THE DEVELOPMENT OF A SELF-DIRECTED LEARNING RESOURCE FOR CORONARY CARE NURSES CARING FOR ADULT PATIENTS WITH CARDIOGENIC SHOCK

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Abstract

Background: Coronary care nurses require specialized nursing skills and knowledge to care for critically ill cardiovascular patients with cardiogenic shock (CS). Informal discussions with an intentional sample of coronary care nurses outlined a need for more education and resources related to the nursing care of adult patients at risk for and who develop CS. **Purpose:** The purpose of the practicum project was to develop a self-directed learning resource for nurses providing direct care to adult patients with CS in the coronary care unit at the Health Sciences Centre, Eastern Health (EH). **Methods:** 1) a literature review, 2) an environmental scan, 3) consultations with nurse educators and nurses, and 4) the development of a self-directed learning resource. **Results:** The literature review findings supported the belief that nurses have knowledge gaps related to CS nursing care and that a self-directed learning resource is an effective educational strategy for nurses. The environmental scan revealed a variety of learning resources related to CS, but a lack of comprehensive learning resources targeting coronary care nurses was also identified. Consultations supported the development of the resource and informed relevant content for inclusion within the resource. The findings were utilized to develop the self-directed learning resource consisting of four modules: 1) an overview of CS, 2) hemodynamic monitoring and the nursing care of a pulmonary artery catheter, 3) vasoactive medications, and 4) the intra-aortic balloon pump. **Conclusion:** The self-directed learning resource was developed in a paper format with an implementation plan to create a computer-based resource available on the Learning Management System at EH. The aim is for coronary care nurses to complete the self-directed learning resource to meet their individualized learning needs related to caring for adult patients at risk for and who develop CS.

Keywords: *coronary care*, *nurses*, *self-directed learning*, *cardiogenic shock*

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Introduction

Nurses specializing in critical care nursing possess the expert knowledge and skills to provide safe, competent care to improve their patient's overall health and wellness. Specialized nursing care is necessary when caring for patients admitted to a critical care unit, such as a cardiac intensive care unit, due to their increased risk for complications and potentially life-threatening illnesses. One of the leading causes of admission to cardiac intensive care units is cardiogenic shock (CS) (Bohula et al., 2019). CS is a complex health complication that causes the heart pump to fail (Ni hici et al., 2020), leading to decreased cardiac output and systemic tissue hypoperfusion (Tehrani et al., 2020). It is essential to recognize that nurses working in areas that require highly specialized nursing practice have unique learning needs specific to the care required for complex and critically ill patients in this setting.

The cardiac intensive care unit at the Health Sciences Centre (HSC) is called the coronary care unit (CCU), and nurses practicing in this unit are referred to as coronary care nurses. These coronary care nurses are integral multidisciplinary team members providing direct care to critically ill cardiovascular patients. With the complexities of CS management and treatments, these coronary care nurses need the knowledge and skills to assess, treat, monitor, and manage CS in coordination with the multidisciplinary team.

Informal discussions with a sample of coronary care nurses outlined a need for more education and resources related to the nursing care of patients with CS. These nurses reported they lacked confidence and a solid knowledge base on the complexities of CS nursing care. Specifically, they reported a need to learn more about caring for patients with CS and three subtopics: nursing care of pulmonary artery (PA) catheter, vasoactive agents, and intra-aortic balloon pump (IABP). This perceived knowledge gap motivated this practicum project, namely, the development of a self-directed learning resource for coronary care nurses caring for adult patients at risk of and who develop CS. The findings of the literature review, environmental scan, and consultations supported the development of a computer-based self-directed learning resource for coronary care nurses of all experience levels. In this report, I will outline the key methods used to inform resource development and summarize the key components of the self-directed learning resource.

Goal and Objectives

The overall goal of the practicum project was to develop a self-directed learning resource on CS for coronary care nurses providing direct care to adult patients with CS in the CCU at the HSC, Eastern Health (EH), St. John's, Newfoundland and Labrador (NL).

The practicum objectives were:

1. To identify existing learning resources and assess their relevance to this proposed self-directed learning resource to inform the content and the best teaching methods.
2. To examine evidence-based cardiovascular and critical care best practices for nursing care related to the treatment and management of CS for inclusion in the resource.
3. To determine if coronary care nurses have a knowledge deficit about CS nursing care and, if so, to identify what are the gaps in their knowledge.
4. To assess the learning needs of coronary care nurses at the HSC in caring for adult patients with CS.
5. To identify and consult with key stakeholders in the critical care program to gather relevant project information and elicit their recommendations for the

pertinent information to be included in the resource.

6. To develop a self-directed learning resource on CS for coronary care nurses providing direct nursing care at the HSC.
7. To demonstrate advanced nursing practice competencies, including research, leadership, education, and consultation and collaboration.

Overview of Methods

Three methods were utilized to meet the practicum objectives: a literature review, an environmental scan, and consultations. First, an extensive literature review was conducted to examine current evidence-based literature related to CS identification, treatment, and management and to determine if the evidence supported the belief that coronary care nurses had knowledge gaps related to the nursing care of adult patients at risk for and who develop CS. The overall conclusion from the literature review was that the findings supported the statement that knowledge gaps related to CS exist among nurses. In addition, the literature review supported the need for an evidence-based educational strategy that could address the knowledge gap identified. A copy of the literature review can be found in Appendix A of this practicum report.

The environmental scan consisted of a review of relevant Canadian cardiovascular websites, Canadian health authority websites, EH policies, and two healthcare manufacturing companies. I also contacted two nurse educators at the New Brunswick (NB) Heart Centre and the University of Ottawa Heart Institute (UOHI) to request their participation. The extensive environmental scan yielded no comprehensive CS learning resource for coronary care nurses. A copy of the environmental scan report can be found in Appendix B.

Lastly, consultations were conducted with key stakeholders, including a sample of coronary care nurses, their nurse educator at the HSC, and a nurse educator located at the UOHI.

The primary consultations were conducted with coronary care nurses at the HSC to determine if the evidence supported a knowledge gap and, if so, to determine their learning needs and receive input into the resource's content. The analysis of the coronary care nurses' questionnaire responses identified their perceived learning needs. In addition, the consultation with nurse educators provided relevant information related to resource development, including suggestions for informational content and teaching and learning strategies. A copy of the consultation report can be found in Appendix C.

The combined findings of the literature review, environmental scan, and consultations were all utilized in the development of the self-directed resource. A copy of the learning resource for CS can be found in Appendix D.

Theoretical Framework: Knowles' Adult Learning Theory

Knowles' (1984) Adult Learning Theory was utilized to guide resource development and to understand how and what motivates coronary care nurses to learn. Knowles' Adult Learning Theory assumes that adults are self-directed and have experiences that enrich their learning (Collin, 2004; Knowles, 1990). Further, it suggests that adult learners want to actively participate in their learning, including taking the initiative to identify their learning needs and set their learning goals (Collins, 2004). Also, Knowles supported the belief that adult learners relate to practical and relevant content (Candela, 2012). The coronary care nurses each have varying life and work experiences that can support their learning; they will benefit from the information and education they can relate to their current nursing practice. Similarly, including teaching and learning strategies that engage the nurses to utilize past experiences will likely improve their learning as they can actively participate in their learning, reflect on their practice, and think critically about the presented topics.

Summary of Literature Review

A comprehensive search of the literature was completed using electronic databases: PubMed, Cumulative Index to Nursing and Allied Health Literature (CINAHL), and the Cochrane Database for Systematic Reviews. Multiple systematic searches were conducted with the assistance of the local librarian from Memorial University. The keywords used in the systematic searches included: critical care, critical care nursing, cardiovascular nursing, coronary care nursing, intensive care units, coronary care units, professional development, continuing nursing education, staff development, staff training, self-directed, nursing knowledge, CS shock, hemodynamics, PA catheters, mechanical circulatory support, IABP, and vasoactive agents. The search was limited to peer-reviewed research articles available in English, and the reference lists of these articles were searched. The comprehensive literature search yielded 90 studies for review and all studies were scanned for relevance, and the abstracts of relevant articles were thoroughly reviewed. A total of ten studies and three systematic review studies were chosen to inform the literature review.

After completing a scan of the literature, the studies included in the review were critically appraised. The quantitative studies (analytic and descriptive) and systematic reviews included were critically appraised using the Public Health Agency of Canada (2014) Critical Appraisal Tool. Qualitative studies were critically appraised using the Joanna Briggs Institute (JBI) Checklist for Qualitative Research (2020), while narrative systematic reviews were appraised using JBI (2017) Critical Appraisal Checklist for Systematic Reviews.

The review of the literature provided evidence to support that coronary care nurses have knowledge gaps related to providing specialized nursing care to critically ill patients requiring care in a critical care nursing unit such as the CCU. Although there was a lack of evidence related to the nursing care of adult CS patients, the search found critical care nurses had knowledge gaps related to hemodynamic monitoring and the use of vasoactive medications. This finding was important as vasoactive medications are important in the management of CS. Three studies in the literature analysis revealed that nurses with three to four years of critical care experience had knowledge gaps related to hemodynamic monitoring (Currey & Botti, 2006; Jeshvaghani et al., 2021; McGhee & Woods, 2001). Currey and Botti (2006) also found in their qualitative observational study that both experienced and inexperienced nurses did not adhere to evidence-based guidelines for obtaining hemodynamic measurements, including errors in patient positioning and skill-based user technique. In addition, an important finding was that when critical care nurses, regardless of experience level, used evidence-based hemodynamic practices, they made more timely and accurate decisions related to patient care (Currey & Botti, 2006). These findings suggested that both experienced and inexperienced critical care nurses may have learning needs related to hemodynamic monitoring. They would benefit from reviewing evidence-based practices to ensure they are correctly implemented into their nursing practice. Therefore, it could be hypothesized that there is a potential for coronary care nurses to improve their practice, skills, decision-making, and hemodynamic monitoring data by gaining additional evidence-based knowledge specific to CS. Another finding reported by the authors was that certain forms of hemodynamic instability appeared more complex for inexperienced nurses (Currey & Botti, 2006). Inexperienced nurses to CCU at the HSC have previously reported a lack of confidence in their decision-making related to hemodynamic monitoring tools. Therefore, this finding and informal consultations also reaffirm the need to increase inexperienced nurses' familiarity and confidence with hemodynamic tools.

The literature findings supported that nurses' management of vasoactive medications in intensive care units lacks a standardized approach (Hunter et al., 2020). A narrative review by Hunter et al. (2020) reported significant variability in practices within hospitals and between nurses on how they prepare, initiate, administer, titrate, and wean vasoactive medication. Additionally, the author stated that critical care nurses are responsible for managing vasoactive medications; therefore, they must be aware of the potential dangers if errors are made. Hunter et al. concluded that ongoing education after orientation is needed for critical care nurses to improve and standardize practices related to vasoactive medication. The findings reaffirm that improving practices and creating a standardized approach to using vasoactive medications improves coronary care nurses' practice.

The next phase of the literature review aimed to determine the most appropriate delivery mode, educational content, and implementation strategies for the proposed resource. The literature search did not reveal any specific studies which utilized a self-directed educational resource for coronary care nurses caring for adult CS patients, but two studies were found that utilized educational strategies targeting critical care nurses (Oldenburg et al., 2019; Sherman et al., 2012). The literature search was then extended to include health educational strategies using self-directed learning resources; this resulted in an additional two studies (K. R. & Jose, 2013; Cox & Van Wynen, 2011) and two systematic reviews (Murad et al., 2010; Thistlethwaite et al., 2012) being included in the review.

The two systematic reviews and the four studies supported a variety of self-directed learning strategies for critical care nurses (Oldenburg et al., 2019; Sherman et al., 2012), nurses working in other areas (Cox & Van Wynen, 2011; K. R. & Jose, 2013) and other healthcare professionals (Murad et al., 2010; Thistlethwaite et al., 2012). Multiple studies reported that participants' knowledge scores improved after receiving education in a computer-based delivery format (Cox & Van Wynen, 2011; Oldenburg et al., 2019; Sherman et al., 2012) and with the inclusion of self-directed learning strategies (K. R. & Jose, 2013; Murad et al., 2010). In addition, two studies comparing traditional lectures with computer-based learning reported similar knowledge scores between the groups, indicating that each delivery mode allowed learners to retain information learnt (Cox & Van Wynen, 2011; Sherman et al., 2012). Another finding identified within the literature was participants' satisfaction with self-directed learning. The authors stated that the satisfaction with self-directed learning was due to the ease of access to information and the flexible format, allowing participants to set their own pace (Murad et al., 2010; Oldenburg et al., 2019; Sherman et al., 2012). Lastly, Murad et al. (2010) reported that when learners were involved in choosing the learning resources' content and delivery mode, they made more significant improvements in their knowledge scores

In summary, the literature review aimed to determine if a knowledge gap existed among coronary care nurses related to CS nursing care and if the evidence supported the development of a critical care nurses' self-directed learning resource for adults at risk for and who develop CS. The findings revealed that there is a lack of literature specific to nurses' learning needs required for providing complex care to patients at risk for and who develop CS. However, the analysis of literature evidence findings supported that coronary care nurses have knowledge gaps related to hemodynamic monitoring and the use of vasoactive medications; two key interventions in the care of CS. The educational studies and narrative reviews supported that a self-directed computer-based resource would be valuable in providing information and education to coronary care nurses practicing at the CCU, HSC. Lastly, the literature review findings related to self-direct learning are consistent with Knowles' Adult Learning Theory. The literature review highlighted the advantages of self-directed learning, which aligns with the key principles of the adult learner theory. Therefore, the learning resource development included creating opportunities for engagement in education and allowing learners to have input. The information and findings obtained from the literature review helped inform the environmental scan and consultation planning process.

Summary of Environmental Scan

The purpose of conducting an environmental scan was to retrieve and analyze existing learning resources to inform the content and delivery mode of the proposed learning resource targeting coronary care nurses caring for adult patients at risk for and who develop CS. The environmental scan did not require ethical approval from the Health Research Ethics Authority (HREA) of NL; however, the HREA Ethics Screening Tool was completed

First, two main coronary care and cardiovascular nursing centres, NB Heart Centre and UOHI, were identified as potential contributors to the environmental scan. Nurse educators voluntarily agreed to participate after being contacted by email. The practicum project was explained, and the confidentiality of correspondence and information shared was guaranteed. In addition to requesting participation from the nurse educators, I examined relevant Canadian health authorities' and cardiovascular organizations' websites, including the Canadian Council of Cardiovascular Nurses, the Canadian Association of Critical Care Nurses, and the Canadian Cardiovascular Society. Other sources for the scan were two healthcare manufacturing companies' websites: Edwards Lifesciences and Getinge Healthcare. Lastly, I scanned EH's current organizational policies for relevant information related to CS.

The environmental scan retrieved CS educational learning resources in various formats: video, PowerPoint, algorithms, guidelines, and self-directed learning resources. Findings included seven self-directed learning resources: four online and three paper formats. Each self-directed resource included information about the three subtopics of the proposed project: hemodynamic monitoring and the nursing care of a PA catheter, vasoactive medications, and the IABPs. However, it was noted that none of the resources were exclusively related to the nursing care of patients at risk for CS and with CS. The contents of each self-directed resource varied and included two hemodynamic resources, two PA catheter resources, two resources related to the IABP, and a guideline document for vasopressors and inotropes use. Most self-directed resources (4/7) were presented online. The three self-directed resources received from the nurse educators contained information related to nursing responsibilities and implications for clinical practice. The self-directed learning resources reviewed had pertinent information that could be adapted for the project's self-directed resource.

The environmental scan findings revealed that a comprehensive self-directed learning resource containing information for coronary care nurses related to identifying patients at risk for CS and the nursing care of patients with CS unavailable for adaptation or use. In the project's next phase, the literature and environmental scan information led to consultations with key stakeholders with the purpose of gaining additional evidence to support the creation of the proposed practicum resource.

Summary of Consultations

Key stakeholders were identified, and a series of consultations occurred to inform the resource development. The primary stakeholders included the end-users of the resource, forty-five coronary care nurses, and their cardiac critical care nurse educator at the HCS. The secondary stakeholders were two nurse educators who had participated in the environmental scan located at the NB Heart Centre and UOHI. The coronary care nurses and nurse educators were each invited to participate via an email request detailing the purpose of the project and the ethical integrity of the consultation process. While this project did not require review by NL's Health Research Review Board, the HREA Ethics Screening Tool was completed. The consultations were completed using two methods: a questionnaire for the coronary care nurses and semi-structured interviews with each nurse educator. These consultations were conducted to identify the priority learning needs related to the nursing care of adult patients at risk for and who develop CS at the HSC, determine the best teaching and learning strategies, elicit the nurse educators' expertise related to the topic, and clarify information received in the environmental scan.

The literature review results and Knowles' (1984) Adult Learning Theory principles informed the development of the questionnaire for coronary care nurses. Using this information to guide the development of a questionnaire meant allowing learners to identify their own needs and provide their input into the resource content. For example, participants were asked to rate their confidence in using a PA catheter and to recommend relevant content based on their learning needs. The questionnaire included yes/no answers, one ordinal scale, and open-ended questions for learners to contribute their responses. Twenty-five coronary care nurses completed and returned the voluntary, anonymous questionnaire. In addition, two nurse educators from the HSC and the UOHI agreed to participate in a semi-structured interview conducted virtually. I developed an interview guide for the discussions, and each completed interview session was approximately 20-35 minutes. I gathered all the information from the consultation methods and analyzed the findings. The questionnaire responses required quantitative analysis for dichotomous answers and ordinal scale questions. Qualitative content analysis was completed for narrative content from the interviews and written responses from the questionnaire. Transcribed interviews and written questionnaire responses were read thoroughly several times to identify common categories. I developed keywords from the literature review and adult learning theory to identify and label common findings (Polit & Beck, 2021).

The results of the consultations revealed that all 25 coronary care nurse participants and the HSC nurse educator believed that a computer-based self-directed learning resource on CS may benefit the nurses at the HSC. Additionally, the nurse participants and the HSC nurse educator reported a CS resource, including the three subtopics: hemodynamic monitoring, vasoactive medications, and IABP, would be relevant to their practice. Some coronary care nurse participants noted that CS and the three subtopics were not recently discussed in annual unit education sessions and that in-depth exposure to these topics was lacking in their critical care orientation. The HSC nurse educator disclosed that there is a lack of self-directed learning resources available to critical care nurses, and often, the focus is mostly on orientation education. From consultations, the coronary care nurses indicated they would utilize a CS learning resource to increase their knowledge and skills and review relevant information as needed.

The consultation findings outlined various learning needs of coronary care nurses and specific suggestions for educational content for inclusion in the resource. The coronary care nurses' recommendations for content to be included were all related to the main topic of CS, such as explaining CS's etiology (5 nurses), identifying at-risk patients (3 nurses), recognizing the early onset of CS related to clinical signs and symptoms (4 nurses), explaining goals of care (2 nurses), and providing information related to supporting patients and families (3 nurses). Other suggestions included information regarding the ability to interpret if treatments were working, outlining blood testing commonly ordered for patients with CS, describing care goals, and reviewing palliative care planning. Regarding hemodynamic monitoring, nurse participants (52%, 13) reported minimal confidence in anticipating appropriate treatment changes based on direct and indirect measurements received from a PA catheter. Ten nurse participants provided feedback on their learning needs related to PA catheters. Two other relevant findings identified were a request for additional knowledge of interpreting hemodynamic parameters and skills to troubleshoot and avoid complications. Nurse participants (88%, 22) agreed their practice could benefit from including vasoactive medications in the learning resource. Twelve nurse participants (48%) commented that reviewing medications used in their practice was always beneficial, and four nurse participants suggested including vasoactive medications indications, dosages, mechanism of action, and contraindications in the learning resource. In addition, thirteen nurse participants (52%) reported they felt they had learning needs related to IABP, while twelve nurse participants (48%) did not. The nurses with perceived learning needs commented that their needs were related to nursing considerations for caring for a patient with an IABP, including indications for use, interpretation of values and waveforms, assessment of the timing of the IABP, and troubleshooting any problems. The HSC educator suggested that including a brief review of cardiac anatomy, hemodynamic principles, pump failure, appropriate CS treatments, and their effects would also be beneficial.

The other findings from the consultation process comprised the advantages of a computer-based learning resource and effective teaching and learning strategies. Both the coronary care nurse participants and nurse educators agreed that a self-directed learning resource would be an appropriate and favourable education strategy as the resource would be easy to access and allow learners to set their own learning pace. Twenty-four coronary care nurse participants (96%) reported that having easy access to learning was important to them as they favoured setting their own learning pace and choosing appropriate educational content to review based on their needs. Each nurse educator also suggested that content be organized into interactive modules so learners can easily navigate and choose specific topics. Another recommendation from the nurse educators and eight coronary care nurse participants (32%) was that the resource should have an interactive design. The interactive design should include images, waveforms, knowledge tests, nursing practice examples, and case studies. The UOHI educator stressed the importance of ensuring that the content is relevant and practical to the nurses who will be the end-users. For instance, they encouraged the creation of case studies based on incidences or clinical patient examples from the local setting while also encouraging using equipment images from the local nursing unit to be incorporated into the resource design. The UOHI nurse educator utilized this method and gained positive feedback. They reported that critical care nurses appreciated being able to relate theoretical content to real-time scenarios and actual tools used in their practice; this was consistent with the adult learning theory guiding resource development.

The consultation process resulted in consistent findings identified by the coronary care nurse participants and the nurse educators. These findings supported the development of the learning resource in a computer-based format for coronary care nurses caring for adult patients at risk for or who develop CS to utilize to improve their knowledge, skills, and practice specific to CS. The findings from the consultation process with the coronary care nurses and nurse educators were used in the development of the self-directing-learning resource.

Summary of the Resource

The findings from the integrative literature review, environmental scan, and consultations were all utilized to inform the development of a self-directed learning resource for coronary care nurses at the CCU, HSC, EH. Based on the findings from all methods, I developed four modules for inclusion in the CS resource. The first module is an introductory module for the self-directed learning resource providing a thorough overview of the main topic: CS. The primary purpose of module one is to provide the learner with a clear understanding of the evidence-based information related to CS nursing care, including the classification of CS stages, the use of diagnostic tools, and the management and treatment strategies. Upon completing module one, the learner is directed to complete the subsequent three modules to receive more detailed information specifically related to the management and treatment concepts presented in the introductory module. These three key topics are: 1) hemodynamic monitoring and the nursing care of a PA catheter, 2) vasoactive medications, and 3) the nursing care considerations of using the IABP, an MCS device. As previously stated, the complete self-directed learning resource can be found in Appendix D of this report.

The first module provides a comprehensive overview of CS. This module defines CS and explains the physiology and pathophysiology concepts of the CS complications, including who is at risk for developing CS and why early detection is important. The module highlights the common causes of CS and the need to differentiate the underlying etiology as these differences impact the clinical presentation and treatment plans. Additionally, the Society for Cardiovascular Angiography Intervention stages of CS (at risk, beginning, classic, deteriorating, and extremis) are described and summarized within a table format (Naidu et al., 2022). The module also explains non-invasive and invasive hemodynamic monitoring and the diagnostic tools used in caring for patients with CS. An overview of the evidence-based treatments for CS and the multidisciplinary approach to providing care to adults with CS is also included. Lastly, given the high mortality rate in CS, a brief overview of nursing considerations for end-of-life care is provided.

The second module outlines the hemodynamic goals of care and the use of hemodynamic monitoring for adult patients at risk for and who develop CS. The module reviews the fundamental concepts of hemodynamics; preload, afterload, contractility, stroke, and cardiac output. In addition to the overview of important information, module two includes a video link so that if learners self-identify that they require more in-depth hemodynamic information, it is accessible to supplement their learning. The indications for using an invasive hemodynamic monitoring tool, the PA catheter, are provided. The module summarizes the nursing care considerations for assisting the cardiologist with inserting the PA catheter, maintaining the PA catheter to avoid complications, and obtaining and interpreting direct and indirect measures obtained from the PA catheter. In addition, the module summarizes the mechanical errors that can lead to inaccurate hemodynamic measurements and data.

The third module reviews the commonly prescribed vasoactive medications for managing and treating CS: norepinephrine, epinephrine, dobutamine, dopamine, milrinone, and vasopressin. The introduction of the module explains the use of inotropic and vasopressor medications in CS, including the recommended first-line vasoconstrictor of choice for CS. Next, the module thoroughly reviews each commonly prescribed medication separately. Each medication section details the drug's method of action, indications for use, and therapy goals. In addition, the standard nursing practice for administering the drug, including initiating, titrating, weaning, and discontinuing, is explained. Each drug section of the module also details the medication's common adverse reactions, precautions, and warnings. Lastly, the nursing surveillance and monitoring tips are included.

The fourth module provides knowledge regarding using MCS devices in adult patients with CS. A summary of the two classifications of MCS devices, durable and temporary, is provided. However, most of the module focuses on the nursing care of the most common temporary MCS utilized at the HCS, the IABP. Information is provided on the fundamental mechanical principle of counterpulsation of an IABP. Components of the intra-aortic balloon and Cardiosave console are described with images to aid the learner in visualizing the equipment used in their nursing practice. A review of the theoretical concepts of the cardiac cycle is provided to assist the learner in interpreting the IABP arterial waveform. This information is critical for the learner to determine the accurate timing of the balloon to the cardiac cycle. The module also reviews common IABP complications and how to limit them. A table summarizing the Cardiosave alarms and nursing actions required is provided. Lastly, nursing care information and documentation practices related to the IAB insertion and removal, IABP use, maintenance, and weaning are thoroughly reviewed.

The learning resource incorporates various teaching and learning strategies that aligned with the adult learning theory and were supported by the findings from the literature review and consultations. The content for each module is presented in a consistent format with a detailed table of contents to allow the learner to easily navigate based on their learning needs. Each module includes an introduction, a list of learning objectives, relevant evidence-based content for the module topic, illustrations, images, links to educational videos or animated jpegs, EH policy information, a reflective exercise, a case study, an interactive exercise, a knowledge check quiz, and a conclusion. Additionally, each module combines informational text with illustrations, waveforms, photographs of equipment, and tables to link theoretical content to their nursing practice. Case studies with answer keys were included to allow the learner to think critically about the nursing practice situation and apply their nursing experience and new knowledge acquired. To allow the learners even more opportunities to reflect critically on their nursing practice experiences, the modules included reflection exercises. Each module contains a knowledge quiz to allow the learner to test their knowledge retention; the format included multiple choice and true-false questions with rationales for the correct and incorrect answers. Furthermore, the resource consists of an abbreviations summary list, a glossary of terms, printable content, and a pretest and posttest.

The resource content and teaching strategies aim to address the identified perceived knowledge gap and meet the learning needs of the coronary care nurses providing direct care to adult patients at risk for and who develop CS. Knowles' Adult Learning Theory (1984) core principles, such as adults are self-directed with valuable life and professional work experiences, were used to guide the resource development. In addition, adult learners commit to learning when it is perceived as important and relevant to their needs (Candela, 2012; Collins, 2004). Coronary care nurses are encouraged to use their nursing practice experience and existing knowledge to assess and make decisions to complete the interactive exercises, reflection exercises, and case studies provided. In addition, the content presented includes a balance of theoretical information, nursing care implications, and skill-based information to ensure that the content is relevant to the nurses' practice. These strategies enable the nurse to use their past nursing experiences and new knowledge gained to complete the exercises and activities, applying critical thinking and decision-making skills. The developed self-directed learning resource is very relevant to coronary care nurses' practice, and the resource is intended to improve the coronary care nurses' knowledge and nursing practice for adult patients at risk for and who develop CS.

Discussion of Advanced Nursing Practice (ANP) Competencies

At the beginning of the practicum project, a key objective was to develop and demonstrate four advanced nursing core competencies: educational, research, leadership, and consultation and collaboration. According to the Canadian Nursing Association (CNA, 2019), advanced practice nurses contribute their specialized nursing knowledge to meet the needs of individuals, families, and communities. The CNA (2019) established six core comprehensive nursing competencies to summarize the skills and attributes of advanced practice nurses demonstrated across all specialized areas. On the completion of this practicum project, I demonstrated skills and attributes specific to the four advanced nursing core competencies.

Educational

An advanced practice nurse is committed to professional growth through new learning and sharing knowledge with other healthcare providers (CNA, 2019). During the initial phase of my project, there were a series of informal discussions with coronary care nurses, forming the basis for the practicum project. I recognized an educational need for coronary care nurses specifically related to the nursing care of adult patients at risk for CS and who develop CS. Using my knowledge and skills, I created a needs assessment questionnaire to determine and assess coronary care nurses' specific learning needs relating to CS. In addition, the CNA (2019) indicated that advanced practice nurses are committed to education and have a role in the planning and coordinating educational initiatives. I demonstrated this skill by disseminating findings from this practicum project through a PowerPoint presentation to Memorial University's Faculty of Nursing faculty and graduate students.

Research

The CNA (2019) summarized that advanced practice nurses conduct, identify, apply, and critically appraise research. Although a research study was not completed, I demonstrated research competencies by successfully developing methods for the literature review, critically appraising and synthesizing literature, analyzing findings, and writing the review. In addition, I utilized my research skills by upholding ethical principles during the completion of the environmental scan and consultations. The environment scan involved a process of exploring, analyzing, and synthesizing retrieved information to assess their relevance and possible adaptation for use. Also, I used my research skills to conduct the consultations, including developing tools for data collection, analyzing quantitative and qualitative data, and synthesizing findings.

Leadership

Advanced practice nurses are leaders and change agents in their areas of practice (CNA, 2019; Registered Nurses' Association of Ontario [RNAO], 2013). Leadership competencies are demonstrated by nurses when they are a driving force for change (RNAO, 2013). I have demonstrated the leadership competency by leading a healthcare improvement initiative that identified a knowledge gap, determined a viable evidenced-based solution, developed an educational resource, and created an implementation plan.

Consultation and Collaboration

Advanced practice nurses must effectively consult and collaborate with others across healthcare sectors and geographical locations (CNA, 2019). I demonstrated the CNA (2019) consultation and collaboration competence by using my skills to consult and collaborate with critical care nurses, their nurse educator, and nurse educators located in other provinces. Engaging and working collaboratively with coronary care nurses, I conducted a learning needs assessment to understand their learning needs and develop a resource specific to CS to meet these identified needs. Additionally, I effectively coordinated, collaborated, and communicated with nurse educators during the environmental scan and consultations to share knowledge and educational resources to enhance the project's development.

Next Steps

The self-directed learning resource will be accessible to coronary care nurses in printed paper and a computer-based format. The two printed copies of the resource will be located in the coronary care unit at the nursing station. In addition, I plan to partner with the Learning Management System, an online learning platform at EH, to create a computer-based digital option (Eastern Health, 2021).

In addition, the implementation phase will require the ongoing engagement of key stakeholders to assist with the uptake of the new learning resource (Harrison & Graham, 2021). This will be important because, as key stakeholders, these individuals can identify potential barriers and facilitators during the implementation phase (Harrison & Graham, 2021). I plan to conduct a formal meeting with key stakeholders, offered in-person or virtual, during the implementation phase to present the practicum project and seek their immediate feedback. During the implementation phase of the resource, it is vital to target potential adopters who will support and influence the uptake of the resource utilization (Harrison & Graham, 2021). Therefore, along with the ongoing engagement of key stakeholders, the aim is to promote and disseminate the self-directed learning resource to coronary care nurses so that they can complete the learning and apply their new knowledge and skills to their nursing practice. Also, I intend to advertise the launch date of the digital resource, well in advance, by communicating the launch through sending an email notice, using our workplace app, and placing posters around the CCU unit. In addition, I plan to present the practicum project at a local NL chapter of the Canadian Association of Critical Care Nurses to share the findings with coronary care nurses and other critical care nurses.

Creating an evaluation plan for the self-directed learning resource will be guided using process-outcome-impact evaluation principles (Centers for Disease Control and Prevention [CDC], n.d.). Process evaluation determines if the intended implementation of the program has occurred (CDC, n.d.). The CDC (n.d.) described process evaluation as the who, what, when and where questions related to evaluation. The process evaluation plan will be conducted by having coronary care nurse participants, upon completing the computer-based learning resource, answer a simple questionnaire comprising of Likert scale questions. The Likert scale questionnaire will include inquiries about the factors associated with accessing the educational resource and the ease of using interactive links. For example, questions will consist of: if the content was easy to navigate, whether the multi-media links operate appropriately, whether the images of local equipment and waveforms were helpful, whether the layout and colour scheme were appealing to the learners, and whether they were satisfied with the layout and colour scheme the computer-based delivery method.

Outcome evaluation provides information about the program’s effect on the target population’s behaviours (CDC, n.d.). Outcome evaluations for this initiative will include assessing coronary care nurses’ knowledge scores and retention. The participants will be invited to take an electronic knowledge test through a software program such as SurveyMonkey, which could be linked to the LEARN platform. The knowledge test will be completed by participants at three intervals: a pretest, an immediate posttest upon completing the resource, and again at three months.

The last component is impact evaluation to determine if the program's overall goal has been achieved (CDC, n.d.). The impact evaluation will determine if the education provided to coronary care nurses results in a practice change or improvements in patient care. Conducting focus group discussions with coronary care nurse participants three months after the education initiative will determine if changes in behaviours have occurred. Preestablished guiding questions will be used to determine if the knowledge attained impacted the nurses' decision-making skills, leading to the application of new knowledge into their nursing practice. For the focus group sessions to be successful, I will need support from the cardiac critical care nurse educator and the coronary care manager. Also, the manager can help reduce barriers to focus group attendance; for example, the manager could offer to schedule additional nursing staff on the day the focus group sessions are being held. Due to the potential bias concerning my role in developing the resource, I will not be involved in facilitating the focus groups.

Conclusion

Nurses practicing in specialized areas require expert knowledge and skills to care for patients experiencing critical and life-threatening illnesses. After informal discussions with coronary care nurses in a specialized coronary care unit, I identified a perceived knowledge gap related to cardiogenic shock nursing care. An integral literature review, environmental scan, and consultations determined that the perceived knowledge gap existed. Upon completing these three methods, the overall objective for the practicum project was to develop a self-directed learning resource for coronary care nurses caring for adult patients at risk for and who develop CS. The results of the literature review findings, environmental scan, and consultation process were consistent. The literature review findings supported the belief that coronary care nurses have learning needs related to CS and that a computer-based self-directed learning resource would be an effective educational strategy to improve their knowledge and practice. The literature review and the environmental scan identified no comprehensive learning resource specifically targeting coronary care nurses related to CS. The consultation process provided the specific learning needs of coronary care nurses, the most effective teaching and learning strategies, and the most appropriate delivery mode for the resource.

In this final report, I have summarized how Knowles' Adult Learning Theory guided all key methods, including the resource development. Also, an overview of the methods used was detailed, along with summaries of the literature review, environmental scan, consultations, and the self-directed learning resource. The complete reports of these summaries and the self-directed learning resource can be found in appendices A, B, C, and D, respectively. In addition, the final report outlined the next phase of the practicum project, which includes the planned implementation and evaluation strategies. Finally, during the completion of this practicum project, I successfully demonstrated advanced nursing competencies, including education, research, leadership, and consultation and collaboration. In conclusion, I have summarized all aspects and key methods of the practicum project that led to achieving the overall objective of creating a self-directed learning resource for coronary care nurses.

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Appendices

Appendix A: Literature Review Report

The Development of a Self-Directed Learning Resource for Coronary Care Nurses Caring for Adult Patients with Cardiogenic Shock: A Review of the Literature

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Literature Review

Critical care nurses possess the specialized knowledge and skills to provide safe, competent care to improve their patient's overall health and wellness. Patients admitted to a critical care unit require increased nursing care due to their potentially life-threatening illness and the complexities of their disease process. One of the leading causes of admission to cardiac intensive care units is cardiogenic shock (CS) (Bohula et al., 2019). CS is a condition that causes the heart pump to fail (Ni hici et al., 2020), leading to decreased cardiac output and systemic tissue hypoperfusion (Tehrani et al., 2020). Early identification of CS is crucial for the implementation of evidence-based treatments to improve patient outcomes (Naidu et al., 2022, Jones et al., 2019; van Diepen et al., 2017). Evidence-based treatments for CS often involve revascularization strategies, mechanical ventilation, invasive hemodynamic monitoring, vasoactive agents, and mechanical circulatory supports (Tehrani et al., 2020; Vincent & De Backer, 2013). Caring for a patient at risk for or in a state of CS requires a multidisciplinary approach, and critical care nurses are vital members of the critical care team (Tehrani et al., 2020). Critical care nurses are continuously at the bedside using their advanced skills to assess, monitor and manage critically ill patients in a highly technical setting (Canadian Association of Critical Care Nurses [CACCN], 2017).

The Health Sciences Centre (HSC), Eastern Health (EH), is comprised of three critical care units: the Coronary Care Unit (CCU), the Medical Surgical Intensive Care Unit (MSICU), and the Cardiovascular Surgery Intensive Care Unit (CVICU). The setting for this project will be the CCU at the HSC, the tertiary cardiac care facility for the province of Newfoundland and Labrador (NL). Individuals are referred from all locations across NL to access specialized cardiovascular care at the CCU. The critical care nurses practicing in the CCU are also referred to as coronary care nurses. These nurses are integral team members in recognizing the risks of CS, its early detection, and then initiating evidence-based management strategies. At the HSC CCU, coronary care nurses reported a need to learn more about caring for patients with CS and three subtopics: nursing care of pulmonary artery (PA) catheter, vasoactive agents, and intra-aortic balloon pump (IABP). The nurses perceived knowledge gap identified from informal consultations was the motivation for my practicum project. With this knowledge, my practicum project goal is to develop a coronary care nurses' self-directed learning resource for the early identification and management of CS.

The purpose of the literature review is to explore nursing literature to determine if the literature supports that critical care nurses generally have a knowledge deficit related to CS. I will examine critical care nurses' knowledge gaps by appraising and synthesizing the available evidence. Additionally, I will summarize the research findings related to educational strategies for critical care nurses continuing education and discuss the advantages and disadvantages of each. The results of the literature analysis revealed a knowledge gap existed among critical care nurses related to the nursing care of CS and that the development of an evidence-informed self-directed learning strategy is appropriate.

Theoretical Framework

The plan for my practicum project is to develop a self-directed learning resource on CS. The learning resource will be available to all critical care nurses of all experience levels and remain accessible as needed. I will explore the possibility of the resource being available through EH's Learning Management System (2021) and a bound paper copy for distribution to the cardiac critical care unit. The learning resource will include strategies to engage the learner and allow for active participation within each section of the resource. I plan to include illustrations, pictures, case studies, short quizzes, and reflective exercises. The development of the self-directed learning resource will be based on a theoretical framework incorporating principles of Knowles' Adult Learning Theory (1984).

Knowles' Adult Learning Theory

The Adult Learning Theory or Theory of Andragogy was developed by Malcolm Knowles (1984) and is based on learner-centred methods. Knowles proposed and believed that adult learning differs from children learning. Knowles' basic assumptions were that adults are self-directed and have experiences that enrich their learning (Collin, 2004; Knowles, 1990). Also, adult learners actively participate in their learning, including taking the initiative to identify their learning needs and set their learning goals (Collins, 2004). Knowles also highlighted that adults are more likely to learn when the content is practical and relevant to them and their learning needs (Billings & Halstead, 2012). The self-directed learning resource will be based on Knowles' Adult Learning Theory principles and supportive evidence presented in this literature review. To align with Knowles' theory, I will need to ensure that the content is relevant and practical to the critical care nurses at the HSC, EH. These critical care nurses each have varying life experiences and work experiences that will support their learning. Therefore, according to Knowles' Adult Learning Theory, they will benefit from the information and learning because it is relevant to their current nursing practice. I plan to use the HSC critical care nurses' feedback from consultations to inform the content of the self-directed learning resource. In keeping with Knowles' Adult Learning Theory, I want to include strategies to make the self-directed learning resources engaging and interactive. I will need to provide opportunities for critical care nurses to actively participate in their learning, reflect on their practice, and think critically about the presented topics. Including case studies may provide an opportunity for critical care nurses to use past experiences and new knowledge to make appropriate patient care decisions. Also, offering reflective exercises after case studies may be helpful.

Literature Review Methods

A comprehensive search of the literature was completed using the following databases: PubMed, CINAHL, and the Cochrane Database for Systematic Reviews. Multiple systematic searches were conducted with the assistance of the local librarian. The search utilized both PubMed and CINAHL controlled vocabulary terms: Medical Subject Headings (MESH), and CINAHL headings, respectively. The key questions guiding this review were: "What are the learning needs of critical care nurses caring for patients in CS? and "What are the best teaching and learning strategies to support critical nurses in becoming confident and proficient in applying advanced nursing knowledge and performing advanced nursing skills related to caring for adults with CS in a critical care unit?" The keywords used in the various systematic searches included: critical care, critical care nursing, cardiovascular nursing, coronary care nursing, intensive care units, coronary care units, professional development, continuing nursing education, staff development, staff training, self-directed, nursing knowledge, CS, hemodynamics, pulmonary artery catheters, mechanical circulatory support, intra-aortic balloon pumping, and vasoactive agents. The search was limited to peer-reviewed research articles available in English. The reference list of appropriate articles was also searched. Grey literature sources identified within the search were scanned for appropriateness and inclusion.

Overall, the various combination of keyword searches yielded over 90 articles. The search findings were scanned for relevance, and the abstracts of relevant articles were reviewed. A total of ten studies and three systematic review studies were chosen to inform the literature review. The details of the studies by Cox and Van Wynen (2011), Oldenburg et al. (2019), K.R and Jose (2013) and Sherman et al. (2012) can be found in the literature summary tables in the Appendix. Also, each author's name will appear in bold text to indicate inclusion in literature summary tables. The research studies included in this integrative review were critically appraised. The quantitative studies (analytic and descriptive) and systematic reviews included were critically appraised using the Public Health Agency of Canada (PHAC) Critical Appraisal Tool (2014). Qualitative studies were critically appraised using the Joanna Briggs Institute (JBI) Checklist for Qualitative Research (2020). Narrative systematic reviews were appraised using JBI (2017) Critical Appraisal Checklist for Systematic Reviews.

Overview of Cardiogenic Shock

The CCU at the HSC provides care to patients who are critically ill or at higher than normal risk for complications after an acute myocardial infarction, life-threatening arrhythmias, heart failure, or those with CS. CS is defined as a cardiac injury that causes a dramatic reduction in an individual's cardiac output, contributing to end-organ hypoperfusion and hypoxia (Tehrani et al., 2020), and the heart is so severely impaired there is a high rate of mortality despite the best treatments (Tehrani et al., 2020; van Diepen et al., 2017). Acute myocardial infarction with left ventricular dysfunction is the most common cause of CS (van Diepen et al., 2017). Mechanical complications of acute myocardial infarction can cause CS, including papillary muscle rupture, ventricular septal defect, and free wall rupture (Elbadawi et al., 2019). In addition, other common causes of CS are a right ventricular failure, arrhythmias, pericardial disease, and valvular or mechanical dysfunctions (van Diepen et al., 2017). The clinical presentation of CS and varied etiologies can make it challenging to diagnose CS. Another challenge for practitioners is the lack of a standardized definition for CS, and the complex multifactorial pathophysiology of CS remains poorly understood (Jones et al., 2019; van Diepen et al., 2017). Researchers indicate that more robust studies are needed but are often difficult to complete (Jones et al., 2019; van Diepen et al., 2017). The troublesome part is if CS is not identified early, there is a delay in appropriate treatments, leading to an overall worsening condition (van Diepen et al., 2017). As a patient decompensates, there is a higher likelihood of increased mortality (Naidu et al., 2022).

Despite recent recommendations for a standardized response to CS, EH has no systematic approach. The American Heart Association (AHA) recently published a scientific statement reinforcing the need for best-practice standards and a regionalized approach to CS (van Diepen et al., 2017). The AHA recommendations stated that healthcare organizations should implement best-practice standards and coordinate multidisciplinary care in tertiary care centers to centralize resources and deliver the medical, surgical, and mechanical therapies needed to improve outcomes and reduce mortality (van Diepen et al., 2017). In addition, evolving literature recommends that patients at risk for CS be identified to ensure signs of CS are detected early, leading to an activation of a rapid team-based approach to reduce hypotension and improve tissue perfusion (Tehrani et al., 2020, 2022; van Diepen et al., 2017). Critical care nurses have identified the lack of a uniform approach to CS care within EH as a barrier to providing adequate care.

Other organizations have initiated a standardized approach for CS. For instance, the New Brunswick (NB) Heart Centre implemented a four-step Code Shock Team approach: identification, review, activation, and team review. Their CCU nurses were integral to this team approach as they screened all patients admitted to CCU every 12 hours for CS using the Society for Cardiovascular Angiography and Interventions (SCAI) shock stage classification (Sarkar et al., 2021). The SCAI recently updated its shock stage classification for acute cardiac injury presentations (Naidu et al., 2022). The shock stage classifications are divided into five letter categories: at risk (Stage A), beginning CS (Stage B), classic CS (Stage C), deteriorating (Stage D), and extremis (Stage E). The descriptors for CS stages include physical examination findings, biochemical markers, and hemodynamics (Naidu et al., 2022). The NB Heart Centre created a shock assessment score containing these descriptors in a one-page tool for nurses to classify patients (Sarkar et al., 2021). The clinical descriptors are more data-driven and practical (Naidu et al., 2022). Also, the classifications create uniform definitions with a more accurate staging of CS shock (Naidu et al., 2022), allowing clinicians to make appropriate treatment decisions. The NB Heart Centre CCU nurses would notify the CCU resident of their findings, who would then communicate the findings to the CCU attending physician. The CCU attending cardiologist then made the decision to activate the Shock Team, which consisted of immediate communication between the CCU attending physician, interventional cardiologist, and cardiac surgeon on call (Sarkar et al., 2021). The NB Heart Centre reported that nurse screening was feasible with ongoing education (Sarkar et al., 2021). The implementation of the approach clearly outlines the goal-based therapies and the role of the physician and nurse. Sarkar et al. (2021) reported that additional research was needed to determine if their systematic SCAI classification screening can facilitate early diagnosis of CS, shock team activation, and improve outcomes in this patient population. However, this approach certainly met the recommendations for a standardized team approach and clearly articulated the nurse's role in the early identification of CS. The established process supports that when critical care nurses are included in the team approach and have opportunities to increase their knowledge related to the staging of shock and CS goal-based therapies, the result is they can successfully stage shock and create opportunities for early identification.

The critical care nurse typically spends the most of their time at the patient's bedside assessing and monitoring for status changes. Action is needed when a patient exhibits CS signs and symptoms such as hypotension or hypoperfusion (Tehrani et al., 2020). Critical care nurses use their knowledge and skills to implement the best available evidence-based management strategies in coordination with the multidisciplinary team. The evidence-based management strategies for CS often include revascularization therapies, mechanical ventilation, invasive hemodynamic monitoring, vasoactive agents, mechanical circulatory supports, and possible discussions regarding heart transplants for patients with biventricular failure (Tehrani et al., 2020; Vincent & De Backer, 2013). Each of these strategies requires critical care nurses to have the knowledge and skills to initiate, maintain, and avoid potential complications. Critical care nurses practicing in CCU informally reported that they often have challenges incorporating invasive hemodynamic monitoring, an evidence-based management strategy, into their practice. For example, they reported having gaps in their knowledge related to understanding the meaning of direct and indirect measurement obtained for a PA catheter; this impacted their confidence in relying on this tool. The development of the self-directed resource will incorporate evidence-based management strategies with attention given to determining the best way to present content and integrate teaching and learning strategies to ensure the self-direct resource is relevant to the nursing role and nursing practice. This approach aligns with Knowles' (1984) Adult Learning Theory which indicates that adult learners benefit most when content is relevant and practical to the learner.

Occurrence and Impacts

With Canada's aging population and the general increase in the severity of illness of hospitalized patients, there is a growing trend of increased admissions to intensive care units

(Geen et al., 2021). The Canadian Institute for Health Information (CIHI, 2016) reported that since 2007-2008, there has been a 12% increase in ICU admissions and in 2013-2014, cardiac illness accounted for about one in three medical ICU patients, with myocardial infarction and arrhythmias accounting for the majority of the illnesses. Despite the many advances in cardiovascular care, CS continues to be a major challenge for healthcare systems worldwide (Goldberg et al., 2016; Osman et al., 2021; Tehrani et al., 2022) and is one of the leading causes of admission to cardiac intensive care units (Bohula et al., 2019).

Incidence rates of CS and lengths of stay of CS patients are all indicators of the burden CS has on the patient and the healthcare system (van Diepen et al., 2017). Osman et al. (2021) conducted a large national study in the United States over a 15-year period (2004 to 2018) to trend the incidence of hospitalizations among patients with acute myocardial infarction CS, non-acute myocardial infarction CS, and mortality rates. Osman et al. reported that hospitalizations attributed to CS increased from 122 per 100 000 hospitalizations to 408 per 100 000 hospitalizations over the study period ($p_{\text{trend}} < 0.001$); this equates to a tripling rate of hospitalizations. These high incidence rates reflect that CS is a problem within healthcare organizations. Given the high incidence of CS, critical care nurses at the CCU need the knowledge and skills to recognize and manage CS in these critically ill patients to improve their health outcomes. Berg et al. (2019) conducted an epidemiology study with 16 centers in Canada and the United States from 2017-2018. Berg et al. reported patients' median lengths of stay in cardiac intensive care units. The median length of stay for patients without shock was 1.9 days (interquartile range [IQR], 1.0–3.6). In contrast, the length of stay was 4.0 days (IQR, 2.5–8.1 days) for acute myocardial infarction with CS, 4.3 days (IQR, 2.1–8.5 days) for CS not related to acute myocardial infarction, and 5.8 days (IQR, 2.9–10.0 days) for mixed shock (p <0.01 for each; Berg et al., 2019). The increased lengths of stay are likely to indicate that patients with CS are more likely to have more complex needs.

Mortality rates related to CS remain high despite advances in cardiovascular treatments (van Diepen et al., 2017). Osman et al. (2021) reported that there was a slow decline in CS in-hospital mortality from 49% to 37% over their 15-year study period (*p* trend < 0.001). Similarly, the Canadian and United States study by Berg et al. (2019) reported that acute myocardial infarction with CS mortality rates were 36% (95% CI, 28%–45%), CS without acute myocardial infarction was 31% (95% CI, 26%–36%), and mixed shock was 39% (95% CI, 31%–48%). The mortality rates of CS are quite high. There is an ongoing need to ensure critical care nurses and the healthcare team recognize the beginning signs of CS to initiate early evidence-based management. Therefore, the goal of the self-directed learning resource is to improve critical care nurses' knowledge and lead to changes in their nursing practice to identify CS and take action to potential to improve patient outcomes, including helping to reduce mortality rates.

Need for Nursing Knowledge and Skills

As noted in this literature review, there is an overall trend of increasing admissions to critical care units, and patients admitted to critical care often have complex needs. It can be assumed that critical care nurses are responsible for providing care to the hospital's most complex and sickest patients. The Canadian Association of Critical Care Nurses (CACCN, 2017) supported this and stated that the critical care nurse is continuously at the bedside using their advanced skills to assess, monitor and manage critically ill patients in a highly technical setting. In addition, within the critical care environment, patients suffer from a wide variety of medical conditions, with complex cases requiring the support of technical equipment to enhance patient monitoring (Huggins, 2004). Caring for critically ill patients requires nurses to have the cognitive, psychomotor and decision-making skills to deliver safe and competent care to critically ill patients (Dunn, 1992), including the knowledge and skill to use the technical equipment to enhance the monitoring of patients. For CS patients, one example of technical equipment and skills required to monitor patients is invasive hemodynamic monitoring, such as the PA catheter. These highly technical tools require critical care nurses to have comprehensive knowledge and be able to interpret data obtained and apply it to anticipate the changes in the treatment of a CS patient.

Critical care nurses have a responsibility to their professional practice to keep their nursing knowledge and skills current with evolving medical advances. Therefore, they must self-identify their learning needs and seek continuing education to improve and refine their nursing practice. The College of Registered Nurses of Newfoundland and Labrador (CRNNL, 2019) promotes knowledge-based practice and encourages nurses not only to recognize but also to practice within their level of competence, seeking support when needed. As new research evolves and advancements in CS treatment and management continue to occur, critical care nurses should be aware of the most up-to-date best-practice recommendations for caring for adult patients at risk for CS and who develop CS to implement within their nursing practice. As mentioned previously, technical skills are a part of critical care nurses' practice, and gaining confidence and accuracy in applying the most up-to-date best-practice evidence to these skills is essential.

Nursing Challenges in Critical Care

The critical care nurses' work experiences and how they learn can impact their preference for how they participate in receiving ongoing continuing education. I explored three qualitative studies related to critical care nurses' learning and working experiences (Farnell & Dawson, 2005; Stewart, 2021) in the technical environment (McGrath, 2008). Each study conducted semi-structured interviews with critical care nurses (Farnell & Dawson, 2005; McGrath, 2008; Stewart, 2021) with various years of experience in critical care, including novice (Farnell & Dawson, 2005), three years of critical care experience (McGrath, 2008), and less than one year in critical care (Stewart, 2021). The older study by Farnell and Dawson (2005) conducted a series of three interviews.

Structured orientation programs are a fundamental aspect of transitioning to work in critical care. The programs typically consist of structured learning and clinical components to support new learning within a new environment. Informal consultations with critical care nurses at the HCS revealed that they valued the foundational knowledge obtained from their orientation program; however, critical care nurses believe they may benefit from ongoing continuing education learning opportunities after orientation. Similarly, Farnell and Dawson (2005) and Stewart (2021) reported that novice critical care nurse participants voiced that a foundational orientation program was essential to their learning (Farnell & Dawson, 2005; Stewart, 2021). In addition, Stewart stated that novice critical care nurse participants reported a great emphasis on structured learning and the rigorous training that occurs. The study's nurse educators' focus group participants also revealed that the orientation policy was inflexible and could not be deviated from because of the number of new hires and new nursing staff (Stewart, 2021). These findings suggested a lack of an individualized approach for learners and indicated a need to incorporate more flexible strategies for novice critical care nurses. As novice critical care nurses may benefit from offering input and having additional learning strategies available in other delivery modes outside the structured programming offered. In addition, these concepts would also align with the

Adult Learning Theory (1984,1990), stating that learning is most lasting when it is self-initiated, and learners proceed at their own pace (Collins, 2004).

As novice critical care nurses gain more clinical experience, they often struggle to adapt to their new environment. In addition, they may identify that they have further learning needs as they obtain more experience in the environment, resulting in a necessity to review and refine the knowledge learned in orientation. Therefore, novice nurses should have opportunities to establish their own learning needs. Farnell & Dawson (2005) and Stewart (2021) reported that critical care nurse participants felt overwhelmed by the information they were expected to learn in the initial few months of entering critical care practice. Some participants voiced difficulty coping and being overwhelmed with the “new machines” (Stewart, 2021). Generally, these novice nurses reported that both their coping and nursing skills improved after six months of practicing in the critical care setting (Farnell & Dawson, 2005; Stewart, 2021). Additionally, another finding noted that as novice critical care nurses gained more clinical experience, they started to identify their own learning needs. For instance, Farnell and Dawson reported that novice nurses understood they required new nursing skills to practice in critical care. As they gained clinical experience, their knowledge and skills improved. However, the participants often had individual deficiencies; they recognized they had not acquired the more profound and comprehensive knowledge to increase specific skills and confidence in providing adequate care to critically ill patients. The authors reported that the lack of confidence was difficult for novice critical care nurses who are providing direct care to critically ill patients. This supports the belief that strategies are needed to ensure they can access learning resources to assist them in gaining confidence.

The critical care setting is highly technical and quite different from a nursing ward, which can pose challenges for critical care nurses. Critical care nurses at the HCS stated they often felt overwhelmed caring for patients with CS due to the added reliance on technology. Similarly, in McGrath's (2008) study, participants who were critical care nurses with three years of critical care experience voiced challenges in caring for patients within a setting heavily dependent on technological equipment. It was also noted that new critical care nurses in Farnell and Dawson (2005) and Stewart (2021) studies reported feeling constantly challenged as they acquired new knowledge and skills related to technology (Farnell & Dawson, 2005; Stewart, 2021). In contrast, the nurses with three years of work experience had learned to embrace and work harmoniously with technology (McGrath, 2008). Critical care nurses at the HCS caring for patients at risk for and who develop CS will need to have the confidence to embrace technology as CS care relies on clinical assessment and technical tools such as invasive hemodynamic monitoring. Therefore, when developing a self-directed learning resource, consideration should be given to incorporating teaching and learning strategies that will help nurses feel confident and at ease using the technology to guide management and treatment plans.

Supportive working relationships can foster a positive environment whereby nurses can ask questions and continue to grow. This was identified and supported as a common theme within the literature. Several authors found supportive working relationships among nursing staff promoted and added to a positive learning environment (Farnell & Dawson, 2005; McGrath, 2008; Stewart, 2021). Sharing knowledge and expertise is necessary as patient outcomes are central to every nursing care action (McGrath, 2008). Farnell and Dawson (2005) and Stewart (2021) reported that experienced nurses had high expectations for novice critical care nurses, which placed additional pressure on the novice critical care nurses. In contrast, McGrath (2008) reported that experienced nurses understood that novice nurses needed time to master functioning skills within the technological environment. The research suggests that experienced nurses have a role in fostering a supportive learning environment for novice nurses within the critical care unit. Developing a self-directed learning resource targeting novice and experienced critical care nurses in CCU at the HSC is meant to increase their knowledge related to CS. Furthermore, it can also create an environment of continuous learning for all, regardless of experience level. To reinforce learning gained from the resource, critical care nurses will need to support each other to help facilitate competency development and mastery of psychomotor skills. A work environment that is respective and supportive of ongoing learning will succeed in implementing best-practice evidence. Identifying the specific knowledge gaps related to CS will be key in developing the self-directed resource; therefore, the following sections of the review will explore critical care nurses' knowledge gaps related to CS.

Hemodynamics: Knowledge Gaps

Invasive cardiac and hemodynamic monitoring is used in the early identification and management of CS in conjunction with a clinical assessment to adequately monitor changes in a patient's status related to the disease process or treatments provided (van Diepen et al., 2017). Exploring the literature pertaining to critical care nurses' hemodynamic learning needs was necessary to determine if there is a knowledge gap. Two cross-sectional studies were conducted in critical care units in large university hospitals in the United States (McGhee & Woods, 2001) and Tehran (Jeshvaghani et al., 2021), and one qualitative study was conducted in Australia (Currey & Botti, 2006) exploring critical care nurses' educational needs related to hemodynamics concepts. The study by McGhee and Wood (2001) specifically assessed arterial pressure monitoring and three content areas: physiology, technical aspects and waveform.

Jeshvaghani et al. (2021) assessed hemodynamic clinical reasoning skills and central venous pressure monitoring.

Critical care nurses utilize hemodynamic monitoring to care for patients at risk for and who develop CS. During informal consultations, the critical care nurses voiced a belief that they lacked knowledge related to aspects of hemodynamic monitoring when caring for patients with CS. Two cross-sectional studies supported this, noting a knowledge deficit related to hemodynamic monitoring for their critical care nurse participants (Jeshvaghani et al., 2021; McGhee & Woods, 2001). Specifically, nurses in the study scored low in relation to dynamic response characteristics and reflected pressure waves (McGhee & Woods, 2001). Although the findings support the informal discussion with critical care nurses at the HSC, it was surprising that the study participants had between three and four years of critical care experience (McGhee & Woods, 2001). The low scores obtained with experienced nurses leave one to consider that perhaps evidence-based knowledge and practices were also lacking in this group of participants, as one would typically expect experienced nurses to have higher knowledge scores. Each author concluded that continuing education programs are needed to address the learning needs of critical care nurses and improve clinical reasoning skills (Jeshvaghani et al., 2021; McGhee & Woods, 2001). Therefore, the findings support my belief that experienced critical care nurses would benefit from a review of their clinical practice knowledge related to CS, specifically on the topic of hemodynamic monitoring.

Critical care nurses are required to use their clinical assessments in combination with invasive and noninvasive monitoring data to make effective decisions about patient care. Currey and Botti (2006) conducted a qualitative observational study exploring nurses' experiences with hemodynamic decision-making after cardiac surgery in three critical care units. The study participants were critical care nurses (*n* = 39), with 17 nurses having less than three years of work experience and 20 nurses with greater than three years of work experience in the cardiac surgical unit. Following cardiac surgery, the researcher observed critical care nurses for two hours and, after observations, conducted semi-structured interviews. The researchers reported high quality hemodynamic decision-making was observed. Nurses in the study who had more experience in the cardiac surgical unit were noted to make high quality decisions more often, and the inexperienced nurses who received support from experienced colleagues were more likely to make high quality decisions. Also, an important finding was that nurses who used evidence-based hemodynamic practices made more timely and accurate decisions (Currey & Botti, 2006). So regardless of experience, if critical care nurses could gain more knowledge about evidence-based practices and care, they would be able to implement this knowledge in their practice, and there is a potential to improve their decision-making skills. These findings support the belief that teaching and learning strategies to promote knowledge of evidence-based practices related to hemodynamic monitoring are needed to improve decision-making.

Another finding reported by the authors was that certain forms of hemodynamic instability appeared more complex for inexperienced nurses (Currey & Botti, 2006). For instance, inexperienced nurses tended to complete more frequent physical assessments, whereas the more experienced nurse used hemodynamic tools more frequently. The authors indicated that inexperienced nurses might be more familiar with the finding from the physical exam than the data received from a hemodynamic tool such as a PA catheter (Currey & Botti, 2006). Similarly, inexperienced nurses in the CCU at the HSC had previously reported a lack of confidence in their decision-making related to hemodynamic monitoring tools. Therefore, these findings suggest that having educational strategies to increase inexperienced nurses' knowledge and understanding of hemodynamic information may benefit nurses. Providing further education could increase their confidence in using hemodynamic data to improve their nursing practice and decision-making.

Research suggests that critical care nurses of all experience levels benefit from additional education. The study by Currey and Botti (2006) supported this statement, as the authors reported that experienced and inexperienced nurses complied poorly with evidence-based guidelines. The gap in adhering to evidence-based guidelines has been linked to improper patient positioning and errors in user techniques during cardiac output measurements (Currey & Botti, 2006). Researchers also reported another common error was improper patient positioning to eliminate hydrostatic pressure during arterial and venous pressure recordings (Currey & Botti, 2006). Positioning and various practice techniques the critical care nurse utilizes are fundamental to obtaining an accurate cardiac output measurement. While the EH policy document related to invasive monitoring clearly outlines these concepts, the findings suggest that critical care nurses may require refinement in their hemodynamic monitoring techniques to ensure accuracy in data.

The three studies identified knowledge and psychomotor learning needs related to hemodynamic monitoring (Currey & Botti, 2006; McGhee & Woods, 2001; Jeshvaghani et al., 2021). When critical care nurses make errors in obtaining hemodynamic measurements, such as cardiac output, there is a potential for harm to the patient as treatment changes often occur based on these assessed values. Therefore, these findings support the need to improve critical care nurses’ knowledge related to evidence-based care of hemodynamic monitoring tools.

Vasoactive Agents: Knowledge Gaps and Variability in Practice

Critical care nurses frequently administer and manage continuous intravenous infusions of inotropes and vasopressor medications in hemodynamically unstable critically ill patients. Additionally, these inotropes and vasopressor medications are regularly used in the care of a patient with CS (Tehrani et al., 2020; van Diepen et al., 2017). Therefore, nurses practicing in a critical care setting responsible for managing these vasoactive medications must be aware of the potential dangers of errors (Hunter et al., 2020).

In my nursing practice, I have noted that there seems to be great variability between each critical care nurse's approach to titrating and weaning vasoactive medications. Given the level of autonomy related to titrating and weaning vasoactive medications, I explored the literature to determine if the findings supported the belief that knowledge and practice deficits exist among critical care nurses. Hunter et al. (2020) conducted a narrative review, including 13 studies on the nurse management of vasoactive medications in intensive care. The narrative review reported a lack of a standardized and recognized approach to managing vasoactive medications in intensive care units. The authors reported significant variability in practices within hospitals and between healthcare providers on how nurses prepare, initiate, administer, titrate and wean vasoactive medications. The authors summarized that four studies on the preparation and initiation of vasoactive infusions concluded that providing education and standardized practices could support nurses' practices and reduce medication errors. Across the studies, there was an inconsistent approach to managing vasoactive medications and a lack of literature related to the topic (Hunter et al., 2020). Despite the lack of evidence on the use of vasoactive drugs, the authors' summary of findings suggested that improvements are needed. Therefore, the results support that critical care nurses need ongoing education to improve practices and that creating a standardized approach to using vasoactive medications in critical care units would greatly benefit them.

Summary of Gaps in Nursing Knowledge and Skills

The literature review revealed that there is an overall lack of literature on the learning needs of critical care nursing practice related to caring for critically ill patients at risk for CS and who develop CS. The available literature found was descriptive, with the majority of studies being cross-sectional or qualitative design. Despite the lack of robust literature, the studies reported common findings. For example, findings indicated that nurses with and without experience in critical care nursing lacked knowledge and had psychomotor skills deficits (Currey & Botti, 2006; Jeshvaghani et al., 2021; McGhee & Woods, 2001). An important finding was that when critical care nurses, regardless of experience level, were knowledgeable and applied evidence-based practice recommendations, their decision-making was rated by researchers as high quality (Currey & Botti, 2006). As mentioned, this significant research finding reinforces the importance of evidence-based nursing practice knowledge and reaffirms the need to ensure that the self-directed resource is based on evidence-based practice. Another finding was that nurses believe that structured orientation programs are a fundamental aspect of learning in critical care (Stewart, 2021; Farnell & Dawson, 2005). Although this is true, the counter-argument is that there is also a need for more continuing education to meet critical care nurses' individual learning needs. The study by Stewart (2021) found critical care nurses desire a more flexible learning approach to meet their individual needs. With this information, educators should consider the critical care nurses' background and learning needs (Farnell & Dawson, 2005) when developing continuing education strategies to refine and review their knowledge and skills to increase their nursing practice performance (Knowles, 1984).

Interventions to Address Knowledge and Skills Gap

In the previous section, I presented evidence to support the knowledge gap related to critical care nurses' care of adult patients at risk of CS and who develop CS. Next, I will explore educational strategies to address this gap. The literature in this area is also limited, but the review of the literature revealed two relevant studies conducted with critical care nurses related to hemodynamics and PA catheter (**Oldenburg** et al., 2019) and critical care pharmacology (**Sherman** et al., 2012).

The studies by Oldenburg et al. (2019) and Sherman et al. (2012) were conducted in large community hospitals in the United States with critical care nurses. Oldenburg et al. participants were critical care nurses (*n* = 15), with the majority having less than two years of nursing experience. Sherman et al. reported that about half of the participants were new graduates, and the experienced nurses had, on average, 6.1 years of nursing experience (*n* = 70). Oldenburg et al. conducted an uncontrolled before-after (UCBA) study to determine if an e-learning module PowerPoint with a poster (comparing noninvasive with invasive hemodynamic monitoring) displayed in the area and a laminated hemodynamics reference card given to nurses would improve nurses' knowledge and self-efficacy. Sherman et al. conducted a randomized control trial (RCT) to compare a 6.5-hour traditional pharmacology lecture versus a self-directed pharmacology learning module with 4.5 hours of content and a 2-hour discussion session on critical care nurses' knowledge scores.

Assessing the teaching and learning strategies used in these two studies was important to determine if there was evidence to support a self-directed learning resource with critical care nurses (Oldenburg et al., 2019; Sherman et al., 2012). Notably, both groups had similar posttest scores; these results suggest that either form of educational delivery was successful in improving the knowledge of critical care nurses related to pharmacology content. Additionally, the UCBA study by Oldenburg et al. (2019) reported improvements in participants' scores from the pretest to the posttest; however, these results did not reach statistical significance. Although the knowledge scores were not statistically significant, scores still improved, which may indicate that the critical care nurses acquired additional knowledge. Also, the critical care nurses in the study by Oldenburg et al. reported an increase in confidence in accurately interpreting hemodynamic data; this is a positive finding. These findings indicate that there is merit in using e-learning and an interactive learning module to improve critical care nurses' knowledge.

When developing and implementing teaching and learning strategies, educators should determine if participants felt the strategy was effective and if there was a high level of satisfaction with its delivery. Oldenberg et al. (2019) and Sherman et al. (2012) used Likert scales to assess critical care nurse satisfaction with each intervention. In the RCT by Sherman et al., the critical care nurses rated the class effectiveness as "excellent:" 97.1% for discussion, 91.4% for the modules, and 87.9% for the lecture; both the control and intervention methods received positive feedback. Similarly, Oldenburg et al. reported that 90% of critical care nurses said the PowerPoint was helpful and practical, and 80% agreed that the education was motivating. Lastly, Sherman et al. included a focus group to obtain feedback on the delivery modes, although the participation rate was low (n =11). These participants voiced some advantages of the lecture, including the ability to discuss and interact with the instructor (Sherman et al., 2012). The nurse participants also favoured the module format as they could set their own pace, had repeated and easy access to information, and thought the format was flexible and interactive (Sherman et al., 2012). These findings are relevant as knowledge scores increased and critical care nurses were satisfied with the learning delivery method in each study. These results show that both an e-module and an interactive module successfully engaged and motivated learners, supporting the proposed project's plan of developing a self-directed learning resource for critical care nurses.

I continued my literature search for studies on self-directed educational strategies for critical care nurses related to CS; however, no studies were available. Therefore, I extended my search to include health educational strategies using a self-directed learning resource.

The proposed project is a self-directed learning resource, and the environmental scan revealed that case-based learning activities are often included in learning resources. Therefore, I explored the success of these strategies to determine if the literature evidence supports this use. Two high-quality systematic reviews of relevance were included as they explored case-based learning (Thistlethwaite et al., 2012) and self-directed learning (Murad et al., 2010) for health professionals. Thistlethwaite et al. (2012) reported that the case-based methods of use varied from small to large groups with a facilitator; other methods included online and computer-based cases and whole class discussions. The authors summarized that teachers and learners enjoy case-based learning, which helps to engage the learner, but the effectiveness of case-based learning was inconclusive. Despite the unclear evidence to support case-based learning, it may be considered a potential method to increase learner engagement for the proposed resource. Murad et al. (2010) compared traditional learner methods to self-directed learning and reported that self-directed learning was moderately more effective in the knowledge domain. Knowledge-based outcomes were most commonly reported in the included studies. The authors also reported that self-directed learning was likely moderately effective in the domain of skills and attitudes. Still, this finding was based on fewer studies and smaller sample sizes. In addition, the authors reported that self-directed learning may be more effective with advanced learners and when learners are involved in identifying their own needs (Murad et al., 2010). The findings reveal that self-directed learning can effectively improve knowledge, skills, and attitudes. These findings indicate that the proposed project's self-directed learning resource is likely an appropriate method to use with critical care nurses at the HSC.

The last two studies for inclusion in the review assessed the effectiveness of self-directed learning strategies (**Cox & Van Wynen**, 2011; **K. R. & Jose,** 2013). A RCT by Cox and Van Wynen (2011) was conducted with nurses to determine the effectiveness of pressure ulcer education on knowledge scores with three groups: a traditional lecture, a self-directed computer-based module, and the control group only took the pretest. The study by K. R. and Jose (2013) included a self-directed module consisting of three modules related to the nursing care of chest tubes, and nurses had seven days to complete the content before taking the pretest. An advanced practice nurse developed Cox and Van Wynen study intervention, and the identical slides were used with both the lecture and self-directed groups. The lecture intervention occurred in six one-hour-long sessions over two weeks, and the self-directed group was given two weeks to review the modules (Cox & Van Wynen, 2011). For both studies, participants' knowledge scores increased (Cox & Van Wynen, 2011; K. R. & Jose, 2013). Cox and Van Wynen reported that knowledge mean scores increased from the pretest to the posttest for both the lecture and computer-based groups. Also, the researchers reported no statistical difference in knowledge score related to pressure ulcer education between the traditional lecture group and the self-directed computer-based group at three months. Notably, knowledge mean scores increased for both groups, suggesting that self-directed computer-based learning was as effective as the traditional lecture. Also, the fact that knowledge scores were similar at three months indicates that each delivery mode allowed the learners to retain the information learned (Cox & Van

Wynen, 2011). K. R. and Jose also reported knowledge scores about chest tubes increased from the pretest to the posttest from 53.51% to 77.6% (p = .0001). Despite the limitations of the K.R. and Jose study, the results of increased knowledge scores also support that self-directed module learning is an effective learning method for nurses.

Given the findings of the literature, I concluded that the evidence presented in this review supports the development of a self-directed learning resource for coronary care nurses practicing at the HSC related to caring for patients at risk for and who develop CS. During an informal discussion with a sample of coronary care nurses at the HCS, they expressed that they lacked both the confidence and a solid knowledge base on the topic of CS. The nurses voiced a need to review and refine their knowledge of three common CS evidence-based management strategies; the three management topics were hemodynamic monitoring, vasoactive medications, and mechanical circulatory support devices. The critical care nurses' self-directed learning resource for adults with CS is meant to add to the existing resources and learning strategies offered at the HSC. The goal is to develop an evidence-based resource that uses effective teaching and learning strategies identified in the literature to address the current knowledge gap among these nurses.

Summary and Conclusion

This integrative literature review aimed to present evidence to support the development of a coronary care nurses' self-directed learning resource for adults with CS. Overall, I have presented evidence supporting the argument that learning gaps exist related to CS nursing care and the three subtopics: hemodynamic monitoring, vasoactive medications, and mechanical circulatory support device, the intra-aortic balloon pump. There was a lack of literature related to critical care nurses learning needs related to mechanical circulatory supports such as IABP. However, key findings included Currey and Botti (2006) reporting that inexperienced and experienced nurses did not completely implement evidence-based practice recommendations related to hemodynamic monitoring into their nursing practice. Simultaneously, other studies reported that nurses had low knowledge scores related to concepts of hemodynamics (Jehvaghani et al., 2021; McGhee & Woods, 2001). The systematic review by Hunter et al. (2020) found inconsistencies in the use of vasoactive medications in critical care settings resulting from a lack of a standardized approach for critical care nurses managing these medications.

Despite the limitations identified in the self-directed learning strategies with the interventional studies summarized, I believe there is merit in utilizing a self-directed learning strategy for the proposed project. The self-directed learning resource provides adult learners with an accessible resource to use at their own pace (Knowles, 1984). In addition, coronary care nurses can choose to complete all the content or only content relevant to their individual learning needs. The evidence supported self-directed learning in various forms, including e-modules and computer-based learning to improve participants' knowledge scores (Cox & Van Wynen, 2011; K.R. & Jose, 2013; Oldenburg et al., 2019; Sherman et al., 2012). Also, the systematic review by Murad et al. (2010) found that self-directed learning was moderately more effective than traditional learning. Hence, with the findings of this literature review and feedback from the consultation process, I will consider utilizing a computer-based learning format for the CS resource.

Developing a coronary care nurses' self-directed learning resource for the early identification and management of CS for the CCU at the HSC will add to the existing learning initiatives at the site. Knowles' Adult Learning Theory (1984) principles will guide the learning resource development. Therefore, as mentioned, I will next consult with coronary care nurses at the HSC to ensure that the content is relevant to their practice and meets their learning needs.

The goal is to develop a beneficial and interactive learning resource that will promote critical care nurses learning while applying their experiences to engage in critical thinking and decision-making.

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Appendix Literature Summary Table

Study/Design	Methods	Key Results	Comments
Authors: Cox & Van Wynen (2011) Title: The effects of various instructional methods on retention of knowledge of pressure ulcers among critical care and medical-surgical nurses Design: RCT Purpose: Determine if there is a difference in knowledge between traditional lectures and computer-based instruction	N: 60 nurses (32 critical care nurses & 28 medical-surgical nurses) Country/ Setting: • 500-bed suburban community teaching hospital, United States Groups: • Lecture (*n*=20): 6 programs, each 1 hour long, presented by an advanced practice nurse (APN) over 2 weeks • Computer-based instruction (*n*=20): self-learning module developed by APN based on identical PowerPoint slides content and objectives from lecture; 2 weeks to complete • Control (*n* =20): setup appointment for pretest, not provided with any learning Data Collection: • Pressure ulcer knowledge tool; 47-item tool, three subscales (valid and reliable) • 50-item knowledge test (pretest, posttest [immediately after intervention], at 3 months, at 6 months) Analysis: • One-way analysis of variance, paired *t*-tests	**Pretest mean knowledge scores:** • No difference between groups before each intervention $F\ (2, 57) = 0.629$, $p = .537$ **Pretest to Posttest mean knowledge scores:** • Lecture: 92.9 (SD 3.3) • Computer-based: 90.3 (SD 4.9) • Control: 77.2 (5.5); $F\ (2, 57) = 35.784$, $p = .000$ **Posttest to 3 months knowledge scores**: • Lecture: 85.1 (SD 7.0) • Computer-based: 84.1 (SD 4.8) • No statistical differences between the lecture group and the computer-based group, $p = .717$ **3-month to 6 months mean posttest knowledge scores**: • No difference between the three groups $F\ (2, 57) = 0.917$, $p = .405$	Strength of Design: **Strong** Quality: **Medium** Issues: • Lack of regression analysis to control for confounding • Potential for misclassification bias Notes: • Either lecture or computer-based intervention improved knowledge scores for up to 3 months

Study/Design	Methods	Key Results	Comments
Authors: K. R. & Jose (2013) Title: Effectiveness of self instructional module on nursing management of patients with chest tube drainage for staff nurses working in a selected hospital of Odisha Design: Uncontrolled before-after Purpose:	N: 30 staff nurses Country/ Setting: • Medical and college hospital in Brahmapur (bed capacity 1000) Self instructional module: • Consists of 3 modules (topics listed for each unit) • Pretest completed and module given for 7-days to complete posttest on day 8 Data Collection: • Knowledge questionnaire; 30 mins to complete Analysis: • t-test, chi-square	**Knowledge Score:** • Pretest mean 53.51% • Posttest mean: 77.6% *p* = .0001	Strength of Design: **Weak** Quality: **Low** • Self-selection • Possible low participation rate, total number of nurses not noted • Limited details of the development of knowledge questionnaire (reliability reported but no other details) • Simple statistics and limited control for confounding • Potential Bias related to data collection; unclear if researchers were trained in data collection Notes: • Modules read by participants for 7 day and then posttest on 8 days.

Study/Design	Methods	Key Results	Comments

Authors:
 	
Oldenburg et al. (2019)
 	
Title:
 	
Pulmonary Artery Catheters (PAC)
 	
Design: Uncontrolled before-after
 	
Purpose:
 	
To determine if an e-learning module would improve knowledge and self-efficacy scores of nurses regarding hemodynamics and PAC monitoring
	N: 15 ICU registered nurses
	• 67% < 2 yrs. of ICU experience
	Country/ Setting:
	• 15 bed community ICU, employing 50 registered nurses, United States
	Intervention:
	• E-learning module PowerPoint; 15 min voice-over lecture
	• Topics: cardiac anatomy; general hemodynamics concepts; PAC indications, complications, setup, insertion, value interpretation, and waveforms; noninvasive cardiac output monitor indications, application and value interpretation; vasoactive pharmacology; and a case study.
	• Two other supplemental education materials:
	  ○ Poster (compared noninvasive with invasive hemodynamic monitoring)
	  ○ Laminated hemodynamic reference card (hemodynamic values and calculations and the effects of vasoactive medications)
	
	Data Collection: (construct validity-reviewed by 10 physician and APNs with critical care experience)
	• Survey: demographics, 5- nursing knowledge questions (obtained from CCRN-American Association of Critical-Care Nurses), 10-self-efficacy questions
	Analysis:
	• Paired *t*-tests, Fisher's exact test, Cohen's *d* test
		Confidence in accurately interpreting hemodynamic data: (scale 0-100)
		• Pre: 57.3 (SD= 15.5) to post: 76.1 (SD=14.2); Statistically significant increase: $t_{14} = -5.80$, $p < .001$; Cohen's $d = 1.26$
		Score on knowledge exam:
		• Pre: 68.0 (SD = 21.1) to post: 78.7 (SD = 19.2), Increased but not statistically significant: $t_{14} = -1.84$; $p = .088$
		Noninvasive cardiac output monitoring deployment:
		• Pre: 0 to post: 4 Increased deployment but not statistically significant: Fisher's exact test $p = .056$
		Satisfaction:
		• 90% of RNs reported helpful and effective
		• 80% education was motivating
		• 60% presentation as enjoyable and suitable to their learning style
			Strength of Design: **Weak**
			
			Quality: **Low**
			
			• Self-selection
			• Low participation rate (30%)
			
			• No control group
			
			• Confounding variables were not controlled for in the analysis.
			
			Notes:
			• 60% of participants had no formal training related to hemodynamics

Study/Design	Methods	Key Results	Comments
Authors: Sherman et al. (2012) Title: Blended versus lecture learning Design: RCT Purpose: Identify learner outcomes and satisfaction with critical care pharmacology blended vs a traditional lecture	N: 70 nurses new to critical care Country/ Setting: • Large community hospital with multiple critical care units, United States Control: • *n* = 33 (1 resigned employment and 1 did not complete posttest) • 6.5-hour traditional lecture, 6.5 hour Intervention: • *n* =35 • 4.5-hour interactive critical care pharmacology learning modules and 2-hour discussion session Data Collection: (content validity and tested for reliability) • Cognitive learning: 46 item posttest • Class effectives evaluations: Likert scale (excellent, good, fair or poor) • Data collection 2-3 weeks after each interventional education complete (participants provided feedback after with focus group, only 11 participated) • Focus group *n*=11 Analysis: • Fisher's exact test, pooled *t*-test, paired *t*-tests	**Average Pretest scores:** • Control 60.9 (SD 17.56), Intervention 62.9 (SD 15.59); *p* = .68 **Average Posttest scores:** • Control: 88.3 (SD 6.79), Intervention 89.7 (SD 5.16); *p* = .34 **Change in Scores:** • Control: 27.4 $\pm$ 18.09; Intervention 27.2 $\pm$ 6.65; *p* =.96 **Demographics:** • No significance differences of posttest score based on nurses' age, gender, education, nursing experience, and computer learning experience **Class Effectiveness:** • "excellent" 97.1% for discussion, 91.4% for the modules 87.9% for the lecture **Focus Group:** • Advantages of modules: self-paced, flexibility, interactive format • Advantages of lecture: Discussion and interaction with instructor	Strength of Design: **Strong** Quality: **Medium** Issues: • Lack of details on process of randomization • Major confounders assessed but no statistical control for confounders Notes: • New graduates 51.5% of the study population • Nurses had an average of 6.1 years of experience.

Appendix B: Environmental Scan Report

The Development of a Self-Directed Learning Resource for Coronary Care Nurses Caring for Adult Patients with Cardiogenic Shock: Environmental Scan Report

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Overview of the Project

Cardiogenic shock (CS) is a complication that can occur after a cardiovascular injury event, most commonly due to myocardial infarction (Tehrani et al., 2020; van Diepen et al., 2017), and it is one of the leading causes of admission to cardiac (coronary) intensive care units (Bohula et al., 2019). Emerging research suggests that the early recognition of CS and a regionalized multidisciplinary approach to care guided by best practice evidence can help to improve patient outcomes (Tehrani et al., 2020; van Diepen et al., 2017). The multidisciplinary team cares for patients at higher risk for complications and those critically ill after an acute myocardial infarction, life-threatening arrhythmias, heart failure, or those with CS (Mokhtar, 2018). Critical care nurses are essential multidisciplinary team members responsible for continuously monitoring, providing complex care, and implementing treatment plans in coordination with the multidisciplinary team (Canadian Association of Critical Care Nurses [CACCN], 2017).

Caring for critically ill cardiovascular patients at risk for CS and who develop CS is complex due to acute hemodynamic instability (van Diepen et al., 2017). I agree that caring for patients at risk for and who develop CS is complex, and from my professional experience, patients with initial classic signs of CS require a fast-paced, team-based approach to become stabilized. Reflecting on my nursing experience in the coronary care setting, I felt that I could have benefited from a learning resource to review and reference as needed to improve my knowledge and skills related to the complexities of CS care. This reflection led to informal discussions with a sample of coronary care nurses about their care of patients at risk for and who develop CS. From these discussions, I learned that the complexities of CS nursing care, including the reliance on highly technical supportive hemodynamic equipment, often lead to their concerns about confidence in providing nursing care. They also reported feeling they had gaps in their knowledge when caring for a patient who developed CS. These informal discussions with a sample of nurses led to the realization that they also felt their nursing practice could benefit from a learning resource related to CS. Specifically, the nurses identified three subtopics primarily focusing on the nursing roles and care of a pulmonary (PA) catheter, the use of vasoactive agents and nursing care of an intra-aortic balloon pump (IABP). The comprehensive literature review revealed that nurses have learning needs related to hemodynamic monitoring (Currey and Botti, 2006; Jeshvaghani et al., 2021; McGhee & Woods, 2001), while standardized use of vasoactive medications are often inconsistent in critical care settings (Hunter et al., 2019). With this information, the plan was to develop a self-directed learning resource for coronary care nurses caring for adult patients at risk for and who develop CS.

During the initial phases of the practicum project, I conducted an environmental scan to gather relevant information to assist in the development of the self-directed learning resource. An environmental scan seeks various forms of information from internal and external environments to inform the organization’s planning and decision-making at the local level (Harrison & Graham, 2021; Hatch & Pearson, 1998). The aim was to scan and analyze available learning resources to inform the proposed learning resource content and delivery mode. As part of this scan, I examined relevant Canadian cardiovascular organizations’ websites and two healthcare manufacturing companies' websites. I also requested resources from other health centers in Canada and reviewed EH’s current policies related to the topic. Overall, the environmental scan was successful in meeting two practicum objectives:

1. To conduct an environmental scan to identify existing learning resources and assess their relevance to this proposed learning resource manual to inform the content and the best teaching methods.

2. To examine evidence-based cardiovascular and critical care best practices for nursing care related to the treatment and management of CS for inclusion in the learning resource.

The environmental scan generated resources and information of relevance to the practicum project. In conjunction with the literature review and consultations, I will use these findings to prepare and create a plan to successfully develop a self-directed learning resource that aims to meet the specific needs of the coronary care nurses at the HSC, EH. I will explore the environment scan objectives, methods, ethical considerations, and results in the following sections.

Objectives for the Environmental Scan

The objectives for the environmental scan were as follows:

1. Identify existing CS related learning resources for CCU nurses on three key topics: PA catheter, vasoactive agents, and IABP available from other health authorities, reputable Canadian or international cardiovascular organizations and associations, and two healthcare companies.
2. To identify what content, delivery mode, and evaluation techniques have been included in the CCU nurses' learning resources related to CS and the three main subtopics identified: PA catheter, vasoactive agents, and an IABP.
3. To identify existing EH policies or protocols related to hemodynamic monitoring supports (PA catheter) and MCS devices, including the IABP.

4. To analyze the findings of the retrieved materials to determine if information can be adapted for use or to assist in the development of resource content or structure.
5. Summarize the key findings of the environmental scan.

Methods

The environmental scan targeted various sources of information: credible Canadian cardiovascular care websites, Canadian health authorities' websites, and healthcare product manufacturing websites. I scanned each website once, and then content deemed relevant to the project was reviewed in detail. In addition, I formally requested participation in the environmental scan by inviting two nurse educators by email to share any relevant resources used in their organizations. Each educator I contacted accepted the invitation to participate. I summarized key details of the extracted data from websites and the information received from educators in a table format, titled Table 1, within the summary of finding section below. Pertinent information organized in the summary table included identifying each resource's educational topic or content, method of delivery, teaching and learning strategies, and evaluation techniques used.

Sources of Information: Websites

As previously stated, I searched credible critical care and cardiovascular care websites, including the Canadian Council of Cardiovascular Nurses (CCCN, 2020), the Canadian Association of Critical Care Nurses (CACCN, 2022), the Canadian Cardiovascular Society, and the Canadian health authorities' websites for relevant nursing educational material related to CS. The CCCN and CACCN are national organizations promoting and advocating for professional education and research in cardiovascular and critical care nursing, respectively. The CCCN and CACCN have additional continuing educational resources for nurses holding a membership login. Membership is open to nurses across Canada for an annual fee, and there is a discounted membership fee to join both organizations. The content searched on the Canadian Cardiovascular Society website and Canadian health authority websites was available in a general search and provided limited educational information, as I did not have a membership or employee access.

Sources of Information: EH Organizational Policies

Included in my search was the EH intranet, which was scanned for relevant policy documents related to the practicum project. The policy documents are downloadable for storage and printing. The intranet is only accessible to the organization's healthcare employees; I had access to this content as an employee.

Sources of Information: Edwards Lifesciences and Getinge Healthcare

The two healthcare product manufacturing websites, Getinge Healthcare Company and Edwards Lifesciences Corporation, were reviewed. Getinge Healthcare Company is the manufacturer of the IABP, and Edwards Lifesciences Corporation is the manufacturer of the Swan-Ganz catheter, commonly known as a PA catheter. Both of these are the products utilized by EH, with CCU nurses using the products in their delivery of care. Educational training content is available to healthcare professionals on each healthcare company's website without a nominal fee; the only requirement is for an individual to establish an online login to access the content. Hence, I created a login and gained access to the content.

Sources of Information: Nurse Educators

I formally requested participation from the nurse educator at New Brunswick (NB) Heart Centre, Saint John, NB, and the University of Ottawa Heart Institute (UOHI), Ottawa, Ontario. Each nurse educator was invited to share resources associated with CS and the three major subtopics. These cardiac critical care settings are tertiary cardiac care centre hospitals for their respective provinces, similar to the CCU in the HSC in EH, Newfoundland and Labrador. I sent a request for participation email to each nurse educator on November 2, 2022, and asked them to respond within one week. See Appendix A for the participation email sent to each nurse educator. The email invitation requested that the nurse educators, if agreeable, participate in sharing resources related to CS and the three subtopics. Also, they were provided with information about the purpose of the environmental scan, a description of my secure data storage management plan, and an explanation of the ethical integrity of the project. I received a same-day email response from the NB Heart Centre nurse educator agreeing to participate. However, after seven business days, I sent a follow-up email reminder to the UOHI nurse educator. At that time, I received an email from the UOHI nurse educator agreeing to participate in the environmental scan.

Data Collection and Management

Data management included storing and reviewing each obtained resource or document. All correspondence was stored electronically in separate files on a password-protected laptop and not redistributed, except for the information shared in confidence with my practicum supervisor for the practicum project. As mentioned, I disclosed my data collection and management plan to each nurse educator in the request for participation email.

All retrieved and received information was thoroughly reviewed for relevance to the practicum project focusing on educational resources for current evidence-based content and best practice information. I compared resources to determine if consistencies existed in the resources related to the content, delivery mode, and teaching and learning strategies. Also, I examined each resource's presentation and format, including the material for illustrations, tables, charts, videos, and animated videos.

Ethical Considerations

This practicum project did not require a review by the Health Research Ethics Authority (HREA) of NL as it was not a research project. The HREA screening tool was completed and can be found in Appendix B. In conjunction with the literature review and consultation plan, the environmental scan plan aimed to promote improvement in coronary care nurses' care of patients with CS within EH. There is no collection of personal information or concerns for data security with the environmental scan. Participation in the environmental scan was voluntary, as persons contacted chose to respond to email requests. All emails were kept confidential and only shared with my practicum supervisor as needed. I informed each participant that any use or adaptation of resources would not be completed unless I obtained permission through a written request. Also, if permission were granted for use, all contents would be referenced appropriately in the completed self-directed learning resource.

Results

The environmental scan results provided various educational resources for review, with seven self-directed learning resources in multiple delivery modes. Examples of the various delivery modes included e-modules, videos, quick reference guides, PowerPoint presentations, handouts, interpretation sheets, algorithms, and policy documents. See Appendix C for the Environmental Scan Summary Table. The following sections will summarize the findings of the environmental scan.

Websites

The scan of the general websites through the searches, including the review of Canadian cardiovascular and Canadian health authority websites, resulted in a limited number of resources for review. The CCCN website, accessible to members only, had a clinical resource titled *Shock* *management;* however, the website link to the resource was not functioning. I emailed the website administrator but did not receive a timely response. After scanning the CACCN website, I could not find any relevant content; however, the CACCN website provided a link to the American Association of Critical Care Nurses for additional educational resources. I followed this link and located a video presentation with slides on managing a critically ill patient in shock, focusing on CS. The content was well organized, with learning objectives and clinical practice examples provided throughout the presentation. The Canadian Cardiovascular Society website had a guideline document outlining the use of MCS devices in CS. The guideline document disclosed the purpose and indicated recommendations for MCS device use. The last resource I located from the website searches was a self-directed learning resource for caring for a patient with a pulmonary artery catheter from Capital District Health, Nova Scotia District Health. The 24-page paper document included learning objectives, theoretical and practical information, a self-test with answers, and various proficiency standard checklists. The resources reviewed from the website searches provided relevant theoretical information.

EH Policies

Three EH organizational nursing policies were retrieved: patient care of IABP, arterial lines and hemodynamics monitoring, and monitoring and assessment of the critically ill. Each document outlined relevant nursing practice standards and guidelines for each policy. The only document to contain figures or illustrations was the arterial monitoring and hemodynamics document, providing figures to correctly show the patient positioning concerning the process of locating the phlebostatic axis, the reference point for hemodynamic cardiac pressure measurements. The review of organizational policies was necessary to ensure that the content developed for the resource meets the requirements of any existing EH organizational policies.

Edwards Lifesciences and Getinge Healthcare

Each healthcare product manufacturing website had relevant educational content for the project. However, it was noted that only Getinge Healthcare Company presented the major topic of CS with educational content delivered by two videos and one PowerPoint presentation. The first Getinge Healthcare Group presentation was titled: *The next stage in cardiogenic shock: Timing is everything* and was presented as a video presentation with PowerPoint slides, including illustrations, charts, and tables. This presentation included learning objectives, background information on CS, treatment plan considerations, the new Society for Cardiovascular Angiography and Interventions classification (SCAI) of CS, and current research data on the use of MCS devices, such as an IABP. The second video presentation included a pdf file handout containing education about classifications of shock using case study examples. Lastly, Getinge Healthcare Company had a 26-slide PowerPoint evaluating the use of IABP as a treatment option in CS. The PowerPoint contained recent medical trials comparing the risk of complications with inotropes versus using MCS devices in CS. The presentation also included learning objectives, charts, tables and clinical research evidence. Despite no deployed evaluation strategies, each educational resource presented the learning content well.

The Edwards Lifesciences Corporation website content was focused on hemodynamics and the use of the Swan-Ganz catheter. One educational resource contained a six-part video presentation on the principles of cardiac hemodynamics. Each video was between 40-60 minutes, contained 20-40 slides, and had good illustrations of hemodynamic principles. The six-part video presentation extensively reviewed cardiac dynamics, including preload, afterload, contractility, right and left heart function, and right ventricular dysfunction in critical illness. In addition, the Edwards Lifesciences Corporation website contained a two-part e-module titled *Swan-Ganz* *catheter e-Learning-Joanne's story*. The e-module had case study applications of clinical use and interpretation of Swan-Ganz hemodynamic data, as well as reflective questions, illustrations, and evaluation of learning in the form of multiple-choice knowledge questions. Other relevant content on this website was a quick reference guide containing normal hemodynamic parameters and laboratory values. In addition, two animated videos depicting the Swan-Ganz placement and bolus thermodilution were retrieved and reviewed.

Getinge Healthcare Company also included educational content on hemodynamics related to the IABP in the form of a PowerPoint, operational guide, video, and two e-Learning programs. They presented in a 43-slide PowerPoint titled *Hemodynamics of counterpulsation,* reviewing the patient population who would benefit from an IABP and practical technical information to help avoid possible complications. In addition, I reviewed an operational quick reference guide for the use of the IABP, including insertion of the IABP and the use of the console called Cardiosave, as well as the theory of counterpulsation and managing errors and alarms. The 20-minute video presentation titled *The IABP numbers game* with user handout contained visual depictions of the IABP console waveforms and used case studies to explain the content. Lastly, the two e-Learning programs were presented on the theory of the IABP and the Cardiosave IABP console. The two e-Learning programs were structured with learning objectives, appropriate theoretical and practical information, a glossary of terms, interactive applications for learners, and knowledge comprehension testing.

Nursing Educators

Each nurse educator provided multiple resources for review. A total of three resources were obtained from the nurse educator at UOHI, including two PowerPoint presentations: shock and IABP in critical care at the UOHI and one self-learning module on hemodynamics. A total of nine resources were obtained from the nurse educator at the NB Heart Centre, which included two self-directed learning resources on the topics of hemodynamics and guidelines for vasopressor and inotropes use. The remaining seven resources were one-page format quick reference guides or algorithms. These one-page documents included a quick reference for vasopressor and inotropes use in a table format; right heart catheterization interpretation sheet, self-test for PA catheter, CS scoring sheet based on the SCAI stages of shock; their organization's code shock algorithm poster; and short-term use of MCS device algorithm.

The delivery modes for the self-directed resources varied. I received a self-directed online module from the UOHI nurse educator and two paper self-directed resource documents from the NB Heart Centre nurse educator. The UOHI online self-directed module presented theoretical and practical knowledge related to hemodynamics in critical care and understanding invasive lines. After reviewing this self-directed module, I felt that a strength of this document was the inclusion of illustrations, waveforms, and photos of the local equipment used within their organization to set up and use invasive lines. Also, the resource referenced the nursing practice policies at the local level; for example, nurses at UOHI do not wedge a PA catheter, but they use the PA diastolic measurement to calculate cardiac output measurements. The nurse educator's two self-directed packages from NB Heart Centre included a hemodynamic monitoring document and a guideline document on vasopressors and inotropes. The NB Heart Centre 52-page hemodynamic monitoring resource included a review of fundamentals of hemodynamics, monitoring, and practical information for nurses, including sections on clinical relevance and application and testing your knowledge. In addition, the resource included an appendix with a glossary of terms, a table with a summary of the meaning of normal and abnormal hemodynamic parameters, used illustrations, waveforms, and links for video content. The other 14-page paper document on inotropes and vasopressors was well organized and provided the what, when, how, and why of infusing and titrating the medications making the guide a very practical resource for nurses. The NB Heart Centre nurse educator also shared a one-page reference guide for vasopressors and inotropes. The document was organized in a table format and was easy to read, with practical information for critical care nurses.

The nurse educators' self-directed resources were relevant to the practicum project. However, I plan to invite the nurse educators to participate in semi-structured interviews during the consultation process in order to understand their use of the self-directed resources and any implementation and evaluation techniques.

Other resources from UOHI included two PowerPoint presentations: shock and the use of IABP in critical care. The 48-slide PowerPoint reviewed shock, pathophysiology, and types of shock, including CS and included learning objectives. The PowerPoint on the IABP use was longer, with 82 slides providing theoretical content and practical application information, including using images and illustrations from the IABP manufacturing company Getinge Group. Neither of the PowerPoints included an evaluation or knowledge check. As stated, the NB Heart Centre nurse educator also provided seven other one-page documents for my review, including quick reference guides and algorithms. Each document was organized in an easy-to-read format with visual depictions. The additional material received from the two nurse educators provided had strengths, including learning objectives and practical clinical examples.

The environmental scan for resources related to CS and the three subtopics was very informative. The information provided a comprehensive review of the resources available to CCU nurses. In general, a learning resource related to the evidence-based management and treatment of CS is not available in one learning resource package for CCU nurses; rather, the content seems to be dispersed throughout multiple resources.

Summary of Findings

The environmental scan resulted in a comprehensive collection of content in various delivery modes. Given the project's plan is to develop a self-directed learning resource, I will summarize the findings specifically related to self-directed resources. I carefully reviewed the seven self-directed resources obtained from the environmental scan for content, delivery mode, and relevance to my practicum project. The content, delivery mode, and teaching and learning strategies are presented in Table 1. The contents of each self-directed resource varied and included two hemodynamic resources, two PA catheter resources, two resources related to the IABP, and a guideline for vasopressors and inotropes use. None of the self-directed resources contained education exclusively applicable to the project's major topic: critical care nurses' care of a patient at risk for CS or who develops CS. Rather the contents of each self-directed learning resource are related to the project's three subtopics: nursing care of a patient with a pulmonary artery catheter, use of vasoactive medications, and nursing care of a patient with an intra-aortic balloon pump. Most self-directed resources (4/7) were presented online, and five included knowledge questions in the form of multiple-choice and true-false questions. The three self-directed resources received from the nurse educators contained information related to nursing responsibilities and implications for clinical practice. There was only one application of a case study; this was the Edwards Lifesciences e-module on Swan-Ganz. The self-directed learning resources reviewed had pertinent information and could be adapted for use in the project's self-directed resource.

Table 1

Self-directed Content and Delivery Mode

	UOHI Hemo-dynamics	NB Heart Centre Hemo-dynamics	NB Heart Centre Vasopressor and Inotropes	Capital Health PA catheter	Edwards Lifesciences e-module Swan Ganz	Getinge Group e-Learning IABP Theory	Getinge Group e-Learning Cardiosave IABP
Paper form		X	X	X			
Online	X				X	X	X
Nursing responsibilities	X	X	X	X			
Illustrations	X	X		X	X	X	X
Video or animated video		X			X	X	X
Equipment Illustration	X	X		X			
Learning Objectives	X					X	X
Glossary of terms		X				X	
Case study application					X		
Interactive						X	X
Knowledge questions		X		X	X	X	X

Other resource presentation formats included were videos, PowerPoint presentations, a one-page reference guideline, and algorithm documents. The major topic of CS was presented most frequently in video and PowerPoint presentation format. Each CS learning resource had similar CS content covering components of the cardiac cycle, hemodynamics, and common treatments to improve cardiovascular function, including invasive monitoring, vasopressors and inotropes, and MCS devices. The Getinge Group Company video presentation described the classification of CS with case study examples. At the same time, the NB Heart Centre nurse educator shared a classification of the CS score sheet based on the SCAI classification of shock, including physical assessment findings, biochemical markers, and hemodynamic parameters used by nurses at their organization. The other relevant content in the form of guideline documents, policies, quick reference guides and algorithms contained relevant information to the project with the potential for adapting the content to be included in the project's resource. The project's next phase is to complete a consultation process with key stakeholders. The obtained information from the literature review and this environmental scan will be used to inform the consultation process. The consultation process aims to gain more insight into the most appropriate content to be included in the self-directed resource to meet the learning needs of coronary care nurses at the HSC.

Conclusion

A comprehensive environmental scan was conducted to determine the availability, use, and application of self-directed learning resources related to caring for adult patients at risk of and who develop CS in Canada. By completing an environmental scan, I analyzed the content, mode of delivery, and evaluation techniques of educational resources and policies for coronary care nurses related to CS. Findings included seven self-directed learning resources, four online and three paper formats. Each self-directed resource was related to the three subtopics of the proposed project. Still, none of the self-directed resources were exclusively associated with the nursing care of a patient at risk for CS or with CS. The environmental scan retrieved CS treatment resources in various formats: video, PowerPoint, algorithms, and guidelines. The environmental scan findings are supported by the literature review and informal consultations regarding an absence of a comprehensive self-directed resource that contains CS and treatment and management modalities within one document for coronary care nurses. Therefore, the environmental scan findings will be used to develop an evidence-informed learning resource that will effectively meet the learning needs of these nurses.

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Appendix A: Email Inquiry

Dear [insert nurse educator name],

I am currently completing my practicum project to fulfill the requirements of the Master of Science in Nursing program at Memorial University of Newfoundland (MUN) and working collaboratively under the guidance of my supervisor, Ms. Erica Hurley. My practicum project is to develop critical care nurses' self-directed learning for adult patients with cardiogenic shock at the Health Sciences Centre, Eastern Health, St. John's, NL. My focus is to support critical care nurses by providing a self-directed learning resource for advanced nursing skills related to caring for patients with cardiogenic shock- specifically, nursing care and management of a pulmonary artery catheter, vasoactive medications, and an intra-aortic balloon pump.

As a part of an environmental scan, I am writing to request participation and willingness to share any educational resources within your organization that targets critical care nurses' education related to cardiogenic shock. Including anything regarding nursing care and managing a pulmonary artery catheter, vasoactive agents, and intra-aortic balloon pump. The purpose of obtaining resources or educational material in both paper and digital forms is to assess and analyze the content to inform the development of my proposed resource. I will not reproduce material or utilize resources without first seeking approval. Also, all information received will be stored electronically in separate files on my password-protected laptop and not redistributed.

I would greatly appreciate your participation in my environmental scan. Please confirm your intention to participate by replying to this email or contacting me by phone by November 8. I can answer any questions or discuss further. Please feel free to reach me by email or phone.

Kind regards,

Susan Neil, BNRN, CCN(C)

susan.neil@mun.ca

Appendix B: Health Research Ethics Authority (HREA) Screening Tool

Student Name: Susan Neil

Title of Practicum Project: The development of a self-directed learning resource for coronary care nurses caring for adult patients with cardiogenic shock.

Date Checklist Completed: September 23, 2022

This project is exempt from Health Research Ethics Board approval because it matches item number 3 from the list below.

1. Research that relies exclusively on publicly available information when the information is legally accessible to the public and appropriately protected by law; or the information is publicly accessible and there is no reasonable expectation of privacy.
2. Research involving naturalistic observation in public places (where it does not involve any intervention staged by the researcher, or direct interaction with the individual or groups; individuals or groups targeted for observation have no reasonable expectation of privacy; and any dissemination of research results does not allow identification of specific individuals).
3. Quality assurance and quality improvement studies, program evaluation activities, performance reviews, and testing within normal educational requirements if there is no research question involved (used exclusively for assessment, management or improvement purposes).
4. Research based on review of published/publicly reported literature.
5. Research exclusively involving secondary use of anonymous information or anonymous human biological materials, so long as the process of data linkage or recording or dissemination of results does not generate identifiable information.
6. Research based solely on the researcher’s personal reflections and self-observation (e.g. auto-ethnography).
7. Case reports.
8. Creative practice activities (where an artist makes or interprets a work or works of art).

For more information, please visit the Health Research Ethics Authority (HREA) at https://rpresources.mun.ca/triage/is-your-project-exempt-from-review/

Appendix C: Environmental Scan Summary Table

Organization Administrator of Learning Resource or Policy	Topic or Title	Learning Resource/ Delivery Mode	Reference or Website Link
Edwards Lifesciences	Normal Hemodynamic Parameters and Laboratory Values	Quick Reference Guide	https://education.edwards.com/normal-hemodynamic-parameters-pocket-card/1167897#swan-ganz
Edwards Lifesciences **Self-directed**	Swan-Ganz catheter e-Learning - Joanne's story	E-module-2 part • Case study application, reflective questions, illustrations, and multi-choice knowledge questions.	https://education.edwards.com/swan-ganztm-elearning-module-joannes-story-1/275043/scorm/38emqgy1miv37#swan-ganz
Edwards Lifesciences	Swan-Ganz catheter placement animation	Animation video • 1min and 13-sec.	https://education.edwards.com/swan-ganz-catheter-placement/148895#swan-ganz
Edwards Lifesciences	Swan-Ganz catheter bolus thermodilution animation	Animation video • 50-second animation Video.	https://education.edwards.com/swan-ganz-catheter-bolus-cardiac-output/148656#swan-ganz
Edwards Lifesciences Barbara McLean, MN, RN, CCRN, CCNS-BC, NP-BC, FCCM	Principles of cardiac dynamics: Six-part hemodynamic Part 1: Overview of cardiac dynamics; Part 2: The Clinical Perspective of Preload;	Video with slides by presenter • 20-40 slides for each series. • 40-60 min for each video. • Technical content with illustrations. • Good illustrations for hemodynamic principles. • Pdf handout of slides.	Part 1: https://education.edwards.com/the-basics-of-stroke-volume-and-cardiac-output-1-of-6/285965# Part 2: https://education.edwards.com/the-clinical-perspective-of-preload-2-of-6/285993#

	Part 3: The Clinical Perspective of Afterload; Part 4: The Clinical Role of Contractility; Part 5: The Right & Left Ventricle Working Together; Part 6: The Role of Right Ventricular Dysfunction in Critical Illness		Part 3: https://education.edwards.com/the-clinical-perspective-of-afterload-3-of-6/296425# Part 4: https://education.edwards.com/the-clinical-role-of-contractility-4-of-6/296435## Part 5: https://education.edwards.com/the-right-left-ventricle-working-together-5-of-6/296440# Part 6: https://education.edwards.com/the-role-of-right-ventricular-dysfunction-in-critical-illness-6-of-6/299818##
Maquet Getinge Group: Intra-aortic balloon pump therapy Clinical reference documents	IAB Insertion / CARDIOSAVE® IABP Operation Quick Reference Guide	Quick Reference Guide • 40-page document. • Technical data: insertion; use of console (Cardiosave); triggering' Theory of Counterpulsation; timing and timing errors; alarms. • Illustrations.	https://mediahubprodstorage.blob.core.windows.net/mediahub-assets/258/63258/original/MCV00007394_-Cardiosave-Quick-Reference-Guide-_QRG_.pdf
Getinge Group: Intra-aortic balloon pump therapy Clinical reference documents	The next stage in cardiogenic shock: Timing is everything presentation	PowerPoint presentation, 22 slides and presenter dialogue • Learning objectives. • Background on CS; treatment plan considerations; new SCAI classification of CS; and	https://getinge.training/iabp-int/documents/

		current data on the use of MCS device. • Illustration, charts, and tables. • Recent clinical research evidence.	
Getinge Group: Clinical reference documents	Intra-aortic balloon pump therapy: Evaluating treatment options in Cardiogenic shock: Complication matters	PowerPoint presentations, 26 slide • Learning objectives • Topics: Timely evaluation of patient response to treatment; risk of complications with inotropes and mechanical circulatory support options. • Presentation of recently medical trials related to IABP vs Impella use. • Illustration, charts, and tables. • Clinical research evidence	https://getinge.training/iabp-int/documents/
Getinge Group: Clinical reference documents	Intra-aortic balloon pump therapy: Hemodynamics of Counterpulsation	PowerPoint Presentation, 43 slides • Physiologic benefits of IABP therapy; patients who may most benefit from IABP; complications; and practical technical components to optimize IABC therapy. • Illustrations, and tables. • Clinical research evidence.	https://getinge.training/iabp-int/documents/
Getinge Group: Getinge Educational Institute customer education portal	Intra-aortic balloon pump: Theory e-Learning program	e-Course, online module, 30 min completion time • Audio presenter.	https://lms.getinge.training/gateway/course/1010001718/view

documents **Self-directed**		• Learning objectives. • Topics: Theory and timing of balloon counterpulsation; factors affecting diastolic augmentation; indications; contraindications; and potential complications. • Glossary of terms. • Comprehensive knowledge test-multiple choice, and true/false, waveform questions. • Pdf version for note taking.	
Getinge Group: Getinge Educational Institute customer education portal documents **Self-directed**	Cardiosave intra-aortic balloon pump e-Learning program	e-Course, online module, 30 min completion time • Audio presenter. • Learning objectives. • Topics: set-up; operation, technical features and troubleshooting of the Cardiosave IABP. • Interactive applications with Cardiosave console function panel. • Comprehensive knowledge test-multiple choice, and true/false.	https://lms.getinge.training/gateway/course/1010001756/view
Getinge Group: Getinge Educational Institute	Cardiogenic Shock: It is Not One-Size-Fits-All	Video presentation with 26-page handout pdf.; 19 mins • Audio presenter.	https://getinge.training/iabp-int/videos/

		• Case studies for classification of cardiogenic shock.	
Getinge Group: Getinge Educational Institute	The IABP Numbers Game	Video presentation with 20-page handout pdf; 10 mins • Audio presenter. • Waveform explanations: augmented pressures vs unassisted. • Case studies.	https://getinge.training/iabp-int/videos/
University of Ottawa Heart Institute (UOHI)	Shock	PowerPoint Presentation • 48 slides. • Learning objectives. • General Shock, Pathophysiology, Types: Hypovolemic, Cardiogenic, Distributive (Anaphylactic and Septic [Neurogenic covered in Neuro section]), Multiple Organ Dysfunction Syndrome (MODS), and Putting it all together.	Koopman, Z. (2022). *Critical care course: Shock*. University of Ottawa Heart Institute. Retrieved from UOHI personal correspondence.
UOHI	Intra-Aortic Balloon: In Critical Care at UOHI	PowerPoint Presentation • 82 slides. • Cardiac cycle, principles of Counterpulsation, inflation/ deflation, indications/ contraindications, timing, complications, weaning, nursing management, removal,	University of Ottawa Heart Institute. (2022). *Intra-aortic balloon: In critical care at University of Ottawa Heart Institute*. Retrieved from UOHI personal correspondence.

		documentation, and Cardiosave console panel.	
UOHI **Self-directed**	Hemodynamic in Critical Care: Understanding Invasive lines	Online self-learning module • Hemodynamics and key concepts; hemodynamic monitoring in critical care at UOHI; non invasive monitoring, invasive monitoring; central lines (triple lumen catheters, Introducers); arterial lines; central venous pressure monitoring; and pulmonary artery pressure monitoring. • Theoretical and practical information. • Illustrations, waveforms, photos for visual of equipment set-up and use.	University of Ottawa Heart Institute. (n.d.). *Hemodynamic in critical care: Understanding invasive lines.* Retrieved from UOHI personal correspondence.
New Brunswick (NB) Heart Centre **Self-directed**	Vasopressors and Inotropes: The Guidelines of WHAT, WHEN, HOW and WHY of Infusing and Titrating	Guideline document for vasopressors and inotropes • 14-page. • Indications; desired effect; contraindications/warnings; administration/mixing: monitoring parameters; dosage; initiation and titrating (up) and weaning (down). • Practical to nurses.	*Vasopressors and inotropes: The guidelines of what, when, how, and why of infusion and titrating*. NB Heart Centre. Retrieved from NB Heart Centre personal correspondence.

NB Heart Centre	Vasopressor and Inotropes Guidelines Drugs: Norepinephrine, epinephrine, dobutamine, dopamine, Primacor (milrinone), vasopressin	Quick guidelines • Table format. • Dosage ranges: Red and green colour-coded (Red dose range: an indicator that the RN or our medical resident must talk directly to the attending doctor to reassess the plan of care for this patient).	New Brunswick Heart Centre. (2021). *Vasopressor and inotropes guidelines*. Retrieved from NB Heart Centre personal correspondence.
NB Heart Centre	Right Heart Catheterization-Interpretation Cheat Sheet	Interpretation Sheet • One page document. • Normal measurements. • Waveform illustrations.	New Brunswick Heart Centre. (n.d.). *Right heart catheterization: Interpretation cheat sheet*. Retrieved from NB Heart Centre: personal correspondence.
NB Heart Centre **Self-directed**	Self-Directed Learning Package on Hemodynamic Monitoring	Self-directed learning package • Paper document, 52 pages. • Topics: Fundamental concepts of hemodynamics and pressure monitoring (ART, CVP, PA); Nursing responsibilities checklist for ART, CVP and/or PA catheter; appendix with definitions; summary of normal hemodynamic parameters and meaning of abnormal parameters (table format). • Clinical relevance and clinical application sections.	New Brunswick Heart Centre. (2018). *Self-directed learning package on hemodynamic monitoring*. (2nd ed.). Retrieved from NB Heart Centre personal correspondence.

		• Test yourself (Test knowledge). • Photographs, illustrations, and waveforms illustrations. • Links for videos related to PA catheter insertion and cardiac output measurement via thermodilution.	
NB Heart Centre	Self-test PA catheter	PA Catheter Learning Package Test • 9-questions; narrative answers required.	NB Heart Centre (n.d.). *Self-test PA catheter*. Retrieved from NB Heart Centre personal correspondence.
NB Heart Centre	Classifications of Shock	One page document • stage A-E of shock (at risk, beginning, classic, deteriorating, extremis).	NB Heart Centre. (n.d.). *Classifications of shock*. Retrieved from NB Heart Centre personal correspondence.
NB Heart Centre	Shock Assessment Scale (SAS) • Using the Society for Cardiovascular Angiography and Interventions (SCAI) shock stage classification for adult patients	Score sheet • One-page table format. • 5-stages of cardiogenic shock are classified by: physical assessment findings, biochemical markers, and hemodynamic parameters.	NB Heart Centre. (n.d). *Shock assessment scale*. Retrieved from NB Heart Centre personal correspondence.

NB Heart Centre	Code Shock Protocol Poster	Algorithm • Flow chart for steps to follow with adult patient meeting criteria for cardiogenic shock. • Colourful depiction.	New Brunswick Heart Centre. (2019). *Code shock protocol*. Retrieved from NB Heart Centre personal correspondence.
NB Heart Centre	Short-term mechanical circulatory support (MCS) algorithm	Algorithm • Isolate Lt failure (IABP), Isolate Rt failure (Nitric oxide), and biventricular failure (ECMO). • Colourful depiction.	New Brunswick Heart Centre. (n.d.) *Short-term mechanical circulatory support (MCS) algorithm*. Retrieved from NB Heart Centre personal correspondence.
EH	Intra-Aortic Balloon (IABP): Patient Care	Policy document, 4 pages • Nursing practice care and care after removal of balloon. • Older document 2009. • New policy drafted but awaiting approval for use.	Eastern Health. (2009). *Intra-aortic balloon pump (IABP): Patient care* (Policy: 214CC - CAR – 220). Eastern Health intranet.
EH	Policy: Monitoring and assessment of the critically ill	Policy document, 5-pages • Nursing practice regarding vital signs, cardiac monitoring, hemodynamic monitoring, arterial sheaths, and neuro signs. • New policy drafted but awaiting approval for use.	Eastern Health. (2012). *Monitoring and assessment of the critically ill*. Policy 214CC – CAR – 030. Eastern Health intranet.
EH	Arterial lines and hemodynamics monitoring: Set-up,	Policy document, 5-pages • Levelling- figures included • Zeroing- figures of waveforms included.	Eastern Health. (2021). *Arterial lines and hemodynamic monitoring* (Policy: 310-ER-CIRC-20). Eastern Health intranet.

	levelling transducer, zeroing		
Capital District Health Nova Scotia Health Authority nursing division **Self-directed**	Learning Module: Care of the Patient with a Pulmonary Artery Catheter (Post entry-level competency)	Learning module • 24-page document. • Learning objectives. • Self-test and answers. • Proficiency Standards Skills Checklist: Care of the Patient with a Pulmonary Artery Catheter; Maintenance of Pulmonary Artery Catheter; Obtaining Pressure Readings; Measurement of Cardiac Output; Mixed Venous Blood Sampling; and Removal of Pulmonary Artery Catheter.	Critical Care and Heart Health Resource Team. (2009). *Learning module care of the patient with a pulmonary artery catheter* (Post entry-level competency). Capital Health District Website search: https://policy.nshealth.ca/Site_Published/DHA9/document_render.aspx?documentRender.IdType=31&documentRender.GenericField=1&documentRender.Id=5756](https://policy.nshealth.ca/Site_Published/DHA9/document_render.aspx?documentRender.IdType=31&documentRender.GenericField=1&documentRender.Id=5756
Canadian Council of Cardiovascular Nurses (CCCN)	Clinical practice: resources: Shock Management		Website link not operating. I emailed administrator but no response received.
Canadian Association of Critical Care Nurses (CACCN)	Education resources and links provided link to the American Association of Critical Care Nurses (See below).	American Association of Critical Care Nurses.	

American Association of Critical Care Nurses Thomas A. VanDruff MS, ACNP-BC Acute Care Nurse Practitioner Georgetown University	Rhythm, rate, volume, drugs, and devices: Management of the critically ill patient in shock.	Recorded video presentation with slides, 1.15 hours • Objectives included. • Content: Proper cardiac function including preload, afterload, and contractility; common treatment modalities to improve cardiovascular function: fluids, vasopressors, inotropes, and antiarrhythmics; describe the use of mechanical devices to support cardiovascular function such as IABP, pacers, and ventricular assist device. • Illustrations and clinical practice examples.	VanDruff, T. A. (2019). *Rhythm, rate, volume, drugs, devices: Management of the critically ill patient in shock.* American Association of Critical-Care Nurses (AACN). https://www.aacn.org/education/ce-activities/nti19360/rhythm-rate-volume-drugs-devices-management-of-the-critically-ill-patient-in-shock
Canadian Cardiovascular Society Guidelines	Mechanical Circulatory Support (MCS)	Guideline document • MCS purpose and recommended indications for use in heart failure, checklist: Assessment of MCS, and practical tips.	Ezekowitz, Justin A. et al. (2017). Comprehensive update of the CCS guidelines for the management of heart failure. *Canadian Journal of Cardiology, 33*, 1342-1433. https://ccs.ca/eguidelines/Content/Topics/HeartFailure/715%20Mechanical%20Circulatory%20Support.htm?Highlight=shock

Appendix C: Consultation Report

The Development of a Self-Directed Learning Resource for Coronary Care Nurses Caring for Adult Patients with Cardiogenic Shock: Consultation Report

Susan Neil

Memorial University of Newfoundland and Labrador

Overview of the Project

The practicum project plan is to develop a coronary care nurses' self-directed learning resource for adult patients at risk of developing cardiogenic shock (CS) and who develop CS. The motivation for the project evolved from a perceived knowledge gap expressed by coronary care nurses practicing at the coronary care unit (CCU), Health Sciences Centre (HSC), Eastern Health (EH). During an informal discussion with a sample of coronary care nurses, they expressed a belief that they lacked confidence and a solid knowledge base on the topic of CS. Furthermore, they stated a need to increase their knowledge of three CS evidence-based management strategies: hemodynamic monitoring, vasoactive medications, and mechanical circulatory support (MCS) device. Specifically, three coronary care nurses stated that they would benefit from additional knowledge on accurately using and interpreting hemodynamic monitoring tools such as the pulmonary artery (PA) catheter. In addition, these coronary care nurses also felt that reviewing commonly used vasoactive medications would benefit their nursing practice. Lastly, they reported that additional knowledge related to the nursing care of an adult patient with MCS, such as an intra-aortic balloon pump (IABP), would support their learning needs.

The theoretical framework for developing the self-directed learning resource is based on Knowles' Adult Learning Theory (1984) principles. Knowles stated that adult learners are often self-directed and should actively participate in the learning process. Adult learners should be able to contribute their perspectives and ideas when educators are developing a learning experience or plan. However, Knowles added that it is essential for the educator to also contribute to the learning plan as learners may be unaware of things they need to know (Collins, 2004).

In this report, I will describe the approach taken to conduct consultations with coronary care nurses and three nurse educators at the HCS, the New Brunswick (NB) Heart Centre, and the University of Ottawa Heart Institute (UOHI). I will summarize and synthesize relevant consultation findings to inform the development of a self-directed learning resource. I invited the coronary care nurses at the HSC to complete a questionnaire and each nurse educator to participate in an interview. The nurse educators at the NB Heart Centre and the UOHI were invited via email to participate in the consultations to gain more information about the use, implementation, and evaluation strategies related to resources obtained from them in the environmental scan. The overall objective of the practicum project was to develop a coronary care nurses' learning resource for caring for adult patients at risk for and who develop CS. The consultation process aimed to meet two key practicum objectives:

1. Identify the learning needs of coronary care nurses related to CS by conducting a learning needs assessment.
2. Identify and consult with key stakeholders in the critical care program to gather relevant project information and elicit their recommendations for the pertinent information to be included in the resource.

By conducting consultations and analyzing the findings, I will devise and generate a plan to successfully develop a self-directed learning resource to meet the specific needs of the coronary care nurses at the CCU, HSC, EH.

Specific Objectives for the Consultations

The specific objectives for the consultations were:

1. To identify coronary care nurses' learning needs related to nursing care of an adult patient with CS.

2. To identify the preferred mode of delivery for the self-directed learning resource related to the nursing care of an adult patient with CS.

The strategies used to meet the objectives were:

1. To develop a coronary care nurses' questionnaire to identify their learning needs.
2. To develop interview guides to utilize during semi-structured interviews with the cardiac critical care nurse educator at the HSC and nurse educators at the NB Heart Centre and UOHI.
3. To develop and outline the data management and analysis plan for the two consultation strategies: questionnaire and interviews.
4. To implement strategies to ensure ethical integrity during the consultation process.
5. To synthesize and analyze the questionnaire responses received from the critical care nurses at the HSC using Microsoft Office, Excel and content analysis.
6. To synthesize the findings from the interviews by using content analysis.
7. To summarize the key finding of the consultation plan in the consultation report.

Methods

Setting and Sample

The settings for the consultation process included critical care nursing practice settings within three Canadian tertiary hospitals in St. John's, Newfoundland and Labrador (NL); Saint John, NB; and Ottawa, Ontario. The sample participants included coronary care nurses and nurse educators.

The primary setting for the consultations was an 11-bed CCU, a cardiac critical care unit located at the HSC, St. John's, EH. The HSC is a university teaching hospital connected to Memorial University's Schools of Medicine, Pharmacy and Nursing. The CCU serves the people of the entire province of NL for specialized cardiovascular care (Eastern Health, 2022). For the primary setting, the participants for the consultations were a sample of coronary care nurses who provide direct nursing care to patients in the CCU and their cardiac critical care nurse educator. The coronary care nurses practicing in the CCU will be the end-users of the self-direct learning resource. The coronary care nurses are a part of the critical care team, which consists of many healthcare professionals, including cardiologists, cardiovascular surgeons, two patient care nursing coordinators, casual registered nurses, perfusionists, physiotherapists, dieticians, occupational health therapists, pharmacists, and social workers. The secondary settings included tertiary university teaching hospitals: the NB Heart Centre and the UOHI. The NB Heart Centre provides cardiovascular care to people in the province of NB and Atlantic Canada (NB Heart Centre, 2022), and the UOHI is Canada's largest heart health centre (UOHI, 2022). The key participants for consultations at each secondary location were the nurse educator of the NB Heart Centre and the nurse educator at the UOHI. These nurse educators also participated in the environmental scan.

The key consultation stakeholders are the coronary care nurses in CCU and the cardiac critical care nurse educator at the HCS, EH. The consultations were necessary to identify the priority learning needs related to the nursing care of adult patients with CS at the HSC. As mentioned, the coronary care nurses practicing in the CCU will be the end-users of the self-directed learning resource, therefore engaging them is vitally important to understand their learning needs and allow their input to inform the resource's contents (Harrison & Graham, 2021; Rowles, 2012;). In addition, the cardiac critical clinical educator at the HSC is responsible for educating nurses in three critical care units at the HSC: the intensive care unit, the cardiovascular intensive care unit, and the CCU. The HSC nurse educator is a key stakeholder who supports and educates critical care nurses. The HSC nurse educator provided her expertise related to the perceived learning needs of the critical care nurses at the HSC and contributed her past experiences with successful and beneficial teaching and learning strategies. Lastly, consulting the nurse educators at the NB Heart Centre and the UOHI provided further information on the key resources received in the environmental scan, specifically clarifying the targeted user of the key resources received and their existing implementation and evaluation practices.

Data Collection

Strategies for data collection included a questionnaire and semi-structured interviews. The targeted group for the questionnaire included full-time, part-time, and casual coronary care nurses practicing in the CCU at the HSC. Two semi-structured interviews were conducted with each nursing educator from the primary and secondary settings.

Questionnaire

I consulted with coronary care nurses by requesting their participation in completing a questionnaire. I used three methods to invite potential participants to increase the chances of receiving favourable response rates (Polit & Beck, 2021): workplace email, communication app, and multiple posters. I drafted a participation letter detailing the purpose of the questionnaire and the key relevant information; this letter was attached to each questionnaire along with an envelope. The questionnaire was made available in paper form for completion and was located at CCU’s main nursing station desk. The completed questionnaires were placed inside the envelope provided and sealed, then stored in the patient care coordinator's locked storage drawer. Each patient care coordinator had been contacted and agreed to assist with securing the questionnaires.

The email invitation and paper participation letter attached to each questionnaire detailed all pertinent information regarding upholding ethical data collection, storage, and analysis standards. Specifically, I informed the participant that their participation was voluntary, and I would assume their informed consent by the nurse agreeing to participate. I did not collect identifying data and requested participants not to place any identifying data on the completed questionnaire or envelope. Participants were informed that they could not withdraw after completing the questionnaire since the received questionnaires would be anonymous. Lastly, I stated that the questionnaire would only be used for the stated purpose of this practicum project and included a summary of my data management and analysis plan. Please see Appendix A for the email invitation and Appendix B for the participation letter.

The questionnaire development was guided by Knowles' (1984) Adult Learning Theory principles, the literature review, and in consultation with the HSC nurse educator. The questionnaire was comprised of seven questions and one ordinal scale question. Questions included dichotomous answers (yes/no) and open-ended questions for learners to contribute their responses. Also, to assess confidence with nursing care of a pulmonary artery (PA) catheter, a tool for hemodynamic monitoring, an ordinal scale was utilized (no experience, minimal confidence, confident, and very confident) to elicit responses. The last question was open-ended, allowing coronary care nurses to elaborate on any additional information they believed was pertinent to the nursing care of an adult with CS. Please see Appendix C for the coronary care nurses' questionnaire.

Interviews

The second strategy for consultations was three semi-structured interviews with the HSC nurse educator of the cardiac critical care program at the HSC, EH; the nurse educator at the NB Heart Centre; and the nurse educator of the cardiac surgical intensive care unit at UOHI. I emailed each educator an invitation asking if they would agree to be involved in the project. Please see Appendix D and Appendix E for the email invitation request for an interview with the cardiac critical care educator at the HSC and the other nurse educators, respectively.

In the email invitation, I summarized the proposed interview details, including the timing and methods of the interview. I explained to the HSC nurse educator that the interview would be conducted in a convenient private location or virtually if preferred. Due to the two other nurse educators' geographical areas, I offered their interview to be completed by phone or virtually and informed them that each interview would be approximately 20-30 minutes. The email invitation also disclosed pertinent details regarding ethical integrity standards. I also explained to all nurse educators that their participation was entirely voluntary, and by agreeing to participate, I assumed their informed consent. In addition, the nurse educators could withdraw at any time up to the completion of the interview. I detailed my plan to ensure anonymity and confidentiality in my data analysis, which included my data management and security plan (Polit & Beck, 2021), as described in detail in the ethical consideration section below.

Following a detailed literature review and environmental scan, I created two interview guides to assist in the facilitation of each discussion: one for the HSC nurse educator and another for the nurse educators at NB Heart Centre and the UOHI. See Appendix F and Appendix G for each interview guide, respectively. Before the interview session, I asked each participant for permission to audio record the interview and to take field notes (Polit & Beck, 2021).

Data Management and Analysis

In the following section, I will outline the data management and analysis plan for the completed questionnaires and interviews. Quantitative analysis was conducted on received questionnaires for dichotomous answers and ordinal scale questions, including using means and frequencies (Polit & Beck, 2021). The data was initially organized in Microsoft Word and then transferred to Microsoft Excel to depict data in a table or chart. Open-ended questions included in the questionnaire and interview data required content analysis (Polit & Beck, 2021). Permission was received from the UOHI and HSC nurse educators to record audio from each interview, so I transcribed the interview verbatim and verified the transcriptions. I carefully read and re-read the interview data and conducted content analysis to extract common findings (Polit & Beck, 2021). Qualitative content analysis was used to break the data into smaller, more manageable units to derive common findings and meanings (Polit & Beck, 2021). I identified prominent findings by analyzing the narrative content and written responses from the questionnaires. The qualitative data was organized in a Microsoft Word table with added rows to manage findings.

Ethical Considerations

Data collection and storage are paramount to ensure the participants' confidentiality and privacy (Polit & Beck, 2021). Participants were informed that their participation in completing the questionnaire or interview was entirely voluntary. I advised participants that implied consent would be inferred by agreeing to complete a questionnaire or an interview. I promoted ethical integrity by ensuring the anonymity of participants. Concerning data collection and security, each completed questionnaire was stored securely in the CCU's patient care coordinator lock storage drawer. Then I transported all completed questionnaires via a secure briefcase to my home office, where the questionnaires were stored in a secure file cabinet. Once the data had been extracted and stored electronically on a password-protected computer, all questionnaires were shredded. Please refer to Appendix H to view the Health Research Ethics Board (HREB) document that indicates ethical approval was not required for the consultation phase of this project.

Results

Of the 45 coronary care nurses invited to participate, 25 completed and returned the questionnaire, representing a 55% return rate. Semi-structured interviews were conducted with the nurse educator at HSC and the nurse educator at UOHI. The NB Heart Centre nurse educator was not available due to other commitments and my practicum project time restraints. I will present the finding of the questionnaire and interview questions, and then I will synthesize the overall findings of the consultations.

Questionnaires

All 25 coronary care nurses who participated indicated they would be willing to complete a computer-based self-directed learning resource related to caring for adult patients with CS. Most nurse participants (24) reported that computer-based learning would be easily accessible and allow them to learn at their own pace. Some terms used in written responses by the nurse participants included: convenient, accessible, flexible, complete at home, my own time, my schedule, and my own pace. In addition, two coronary care nurse participants commented that they favoured computer-based learning. One nurse participant stated self-directed learning best complemented their learning ability. Another nurse participant said that self-directed learning was easier than learning in a large group with learners of various knowledge levels. In addition, five coronary care nurses reported that they would complete the self-directed learning resource because it was assumed to include best-practice evidence information. Lastly, three nurse participants felt a self-directed resource would allow them to review relevant content based on their individual needs.

The informal conversations with a sample of coronary care nurses and extensive literature review related to CS and nursing care supported the inclusion of three subtopics: hemodynamic monitoring tools (PA catheter), vasoactive medications, and MCS (IABP) in the self-directed learning resource. The nurses were asked if these three subtopics should be included in the self-directed learning resource. All 25 coronary care nurse participants agreed the topics were relevant to the project, with 22 nurse participants providing additional information. A commonly reported finding was that nurse participants (18) felt the three topics were relevant to their practice and CS nursing management. Another nurse participant stated that CS and the three subtopics were not recently discussed in unit education, and another nurse participant felt that coverage of these topics was lacking in their critical care orientation. A re-emerging finding was that coronary care nurse participants reported the topics presented in modules or units would allow them to review the contents as needed. In addition, the qualitative findings from this question included specific individual learning needs related to the PA catheter. Eight coronary care nurse participants commented on PA catheter learning needs, specifically troubleshooting equipment, obtaining accurate values, interpreting values, and identifying waveforms. In addition, some nurse participants (5) stated that infrequently exposure to a PA catheter impacts their ability to become proficient with using the tool.

Sixteen coronary care nurse participants answered the third question and suggested topics for inclusion in the self-directed learning resource. The suggestions varied, but all applied to the major topic of CS. Five coronary care nurse participants requested the causes of CS be included. At the same time, other nurse participants (3) asked for information related to who is at risk for CS, and others (4) added clinical assessment signs and symptoms of CS. Three nurse participants suggested content related to helping patients and families with the psychological impacts of CS. Other suggestions included the early identification of CS, common blood work testing and meaning of results, goals of care, and palliative care planning. In addition, some individual coronary care nurse participants suggested content related to the subtopics, including interpreting the cardiac output numbers and reviewing medications used in CS.

The ordinal confidence scale of nursing care of a PA catheter revealed various results. Eleven nurse participants reported they were confident (44%), and eight nurses were minimally confident (32%) in assisting the physician with inserting a PA catheter; please see Figure 1. Concerning obtaining hemodynamic data from a PA catheter, nine nurse participants reported being confident (36%), and eight nurses reported being very confident (32%); please see Figure 2. However, the majority of nurse participants reported only minimal confidence in interpreting the meaning of direct (44%, 11 participants) and indirect (56%, 9 participants) measurements obtained from a PA catheter. Lastly, thirteen or 52 % of nurse participants had minimal confidence in anticipating appropriate changes to treatments based on direct and indirect measurements received from a PA catheter; please see Figure 3.

Figure 1

Assisting physician with insertion of PA catheter

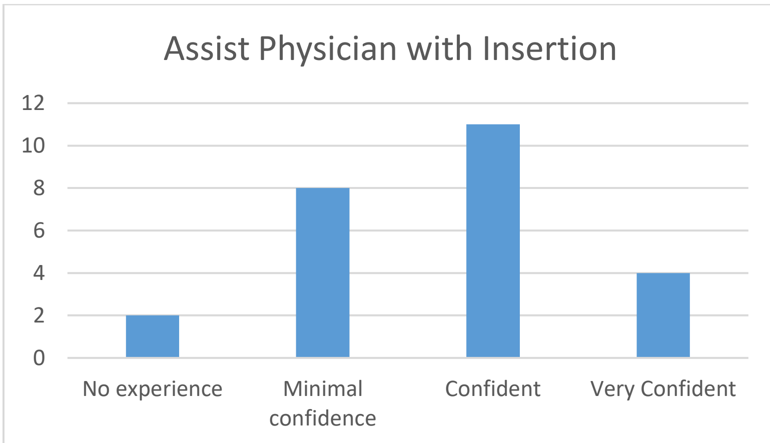


Figure 2

Obtaining correct hemodynamic data from a PA catheter

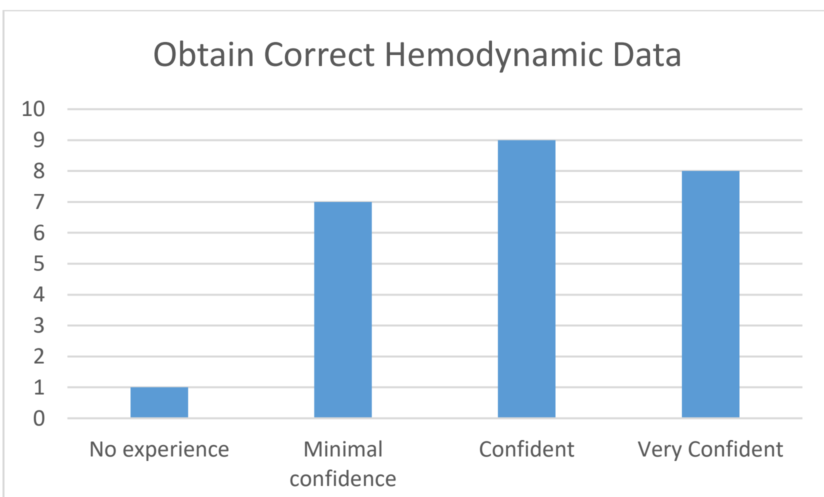
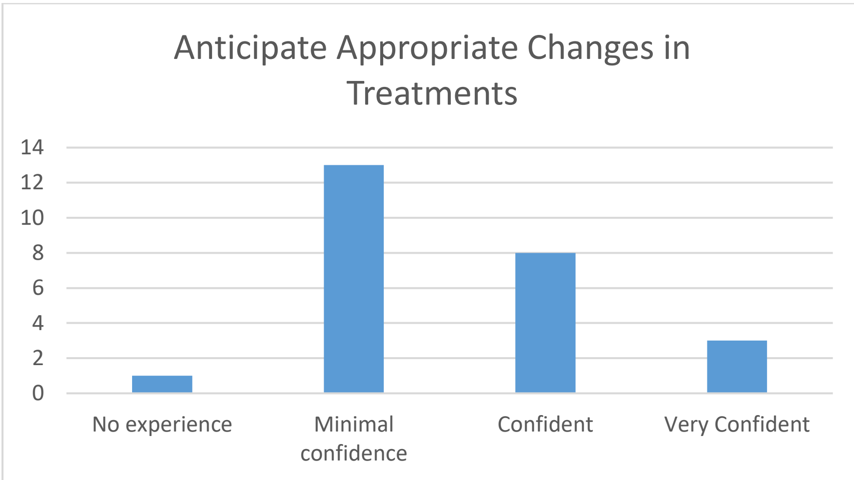


Figure 3

Anticipating appropriate changes in treatments due to indirect and direct measurements



The fifth question requested coronary care nurse participants to provide additional information related to their learning needs associated with interpreting hemodynamic values from a PA catheter. Ten nurse participants contributed responses to this question. These findings revealed that nurse participants had PA catheter learning needs related to knowledge and skills. Four nurse participants requested they wanted to learn more about interpreting the meaning of measurement results and relating these measurements to nursing care. One nurse requested a quick reference guide to outline the normal hemodynamic values and list the anticipated values for a patient in CS. Three nurse participants requested practical information related to avoiding complications and troubleshooting equipment, and the other nurse participant suggested a review of the equipment setup to obtain accurate hemodynamic values. Only one coronary care nurse requested a review of hemodynamic principles to link the PA measurements with concepts such as preload and afterload. One nurse participant commented that the infrequent use of PA catheters made it difficult for new staff to maintain their confidence levels in using the tool. Lastly, one nurse participant reported they had not used a PA catheter in their nursing practice.

Eighty-eight percent of coronary care nurse participants (22) agreed that their practice could benefit from including vasoactive medications in the learning resource. A common finding from 12 nurse respondents who provided additional comments was that a review of medications used in their practice was always beneficial. In addition, six nurse participants agreed that a review related to vasoactive medications for CS is necessary to increase their knowledge. Other nurse participants (4) suggested including vasoactive medications indications, dosages, mechanism of action, and contraindications.

The final question in the questionnaire asked coronary care nurse participants if they had learning needs related to IABP. Thirteen nurse participants (52%) reported they had learning needs related to IABP, while twelve nurse participants (48%) did not. Thirteen of the nurse participants who had learning needs provided additional comments. Generally, the comments were related to nursing considerations for caring for a patient with an IABP, including indications for use, interpretation of values and waveforms, assessment of the timing of the IABP, and troubleshooting any problems. Seven nurse participants stated they wanted information on troubleshooting the IABP alarms and equipment errors and how to identify if there are issues with the placement of the IABP balloon. Also, one nurse suggested they had learning needs related to providing appropriate education to the patient and family about the IABP.

Interviews

The nurse educators from HCS and UOHI agreed to participate in an interview conducted virtually, with the length of each interview being 20-35 minutes long. As mentioned, I utilized two interview guides to facilitate the discussion.

HSC Nurse Educator

Given that the project is a self-directed learning resource for coronary care nurses, the first question posed to the HSC nurse educator was to discuss current continuing education practices within the critical care setting at the HSC. The HCS nurse educator said they conduct an eight-hour education day for each of the three critical care units, in-person or virtual, once a year. The critical care nurse can choose to attend their unit-specific education day, and they are invited to participate in the other two units' education days. Education leave can be granted if the critical care nurse receives approval from their respective managers. The HSC educator noted that virtual learning options since the onset of the COVID-19 pandemic had increased attendance rates. The HCS nurse educator acknowledged a lack of self-directed continuing education resources within EH, targeting critical care nurses and acknowledged that there is no formal process to review the critical care nurses' continuing education needs annually. Additionally, the HSC nurse educator stated that the focus tends to be on providing education during the initial orientation period but also noted that nurses are always welcome to return to an orientation session to review a topic of interest. Furthermore, the HSC nurse educator noted an older critical care nursing specialty competencies checklist from 2007 needs to be updated and utilized more effectively.

The next aspect of the interview disclosed information related to the availability and use of self-directed learning resources for critical care nurses at the HSC. The HSC nurse educator reported that the cardiac critical care program does not currently have self-directed learning resources specific to critical care nurses. The EH Learning Management System (LEARN, 2021), an online platform that staff can access at home or work, provides general e-learning education such as conflict management, fire safety, and workplace safety. However, the LEARN platform is utilized by other programs within EH to include relevant education for nurses. The HSC nurse educator noted that work is progressing on creating an e-learning module on cardiac pacing for the cardiac critical care program, but currently, they refer critical care nurses to manufacturing company websites for resources. Although they acknowledged content may not always apply to the individual nurses' needs. Overall, the HSC nurse educator agreed that there is a need for more self-directed learning resources relevant to critical care nurses.

During the interview, I requested the HSC nurse educator make recommendations for content that they felt should be included in the self-directed learning resource on caring for an adult patient with CS. The recommendations provided included theoretical, skill-based, and nursing care standards. The HSC nurse educator's theoretical suggestions included a brief review of cardiac anatomy, hemodynamic principles, pump failure, appropriate CS treatments, and their effects. In addition, they indicated a need to ensure that the content is relevant to the nurses' practice and includes details about troubleshooting equipment and understanding waveforms and hemodynamic measurements. The HSC nurse educator noted that it is vital to integrate nursing policies and procedures into the resource to ensure critical care nurses complete tasks as established by existing EH standards of care.

The next aspect of the interview explored using a computer-based delivery mode for the self-directed learning resource. The HSC nurse educator reported one advantage of having a computer-based self-directed resource divided into manageable modules is it would allow nurses to select content based on their needs, with nurses also selecting the amount of time they need to spend on their learning. When the HSC nurse educator completes a lecture-based critical care orientation, they have to teach at the lowest learner level and, for example, spend time reviewing cardiac anatomy. They felt this could be completed independently via a self-directed resource so that the in-person time could be used to review skills. The HSC nurse educator felt there was value in establishing the proposed resource as it would be relevant to coronary care nurses' practice.

The HSC nurse educator offered two key recommendations for teaching and learning strategies for the resource. They suggested using case studies and including knowledge checks with immediate feedback. From their experience with teaching and learning, they reported that critical care nurses tended to appreciate the practical application of the theoretical content using case studies. Also, the HSC nurse educator recommended integrating knowledge checks throughout the modules with immediate feedback, but they also stated a knowledge check could also be included at the end of the resource. Their experience with a lecture-based setting was that learners benefitted from a pause moment to reflect and check their knowledge attained.

Lastly, the HSC nurse educator suggested partnering with the LEARN program staff to design interactive modules with appropriate images, waveforms, and videos. The LEARN program has an application proposal process where an EH employee can submit their request for their resource to be implemented into the LEARN online platform. If approval is granted, the EH employee is matched with a LEARN staff member to oversee the implementation of the resource to the internal online learning platform. The HSC nurse educator stated this partnership has great benefits as it ensures the content is adapted appropriately for the computer-based or e-learning platform. Also, the HSC nurse educator reported that implementing the self-directed resource on LEARN would provide access to coronary care nurses and all critical care nurses in EH.

UOHI Nurse Educator

The UOHI nurse educator reported that critical care nurses at their site are required to complete a recertification process annually. The UOHI nurse educator also stated there is a focus on quality and nursing practice reviews related to clinical practice incidences and product malfunctions. They also indicated using an online platform to offer continuing educational content for critical care nurses. Each area chooses to complete content related to their practice on a self-directed e-learning platform with knowledge tests and automatic feedback. The nurse educator stated that they aim to create even more online self-directed courses allowing critical care nurses to review content and test their knowledge. In addition, they remarked that the recent COVID-19 pandemic had increased the site’s transition to more virtual and self-directed learning. The UOHI nurse educator reported a similar account as the HSC nurse educator that attendance rates tended to be higher with virtual options.

In the interview, the following topics explored were the UOHI nurse educator’s experience with self-directed learning, computer-based learning, and case studies. The nurse educator reported having favourable experiences with all three methods and referenced the materials shared in the environmental scan. The UOHI reported that evaluations from the critical care nurses on this hemodynamics resource noted increased knowledge scores and positive nurse satisfaction. Some of the feedback the UOHI nurse educator shared concerning self-directed learning included that critical care nurses appreciate the ability to learn at their own pace and can go back and review concepts. The UOHI reinforced the need to ensure that content is broken down into management units with the integration of nursing practice considerations. The UOHI nurse educator indicated from their experience that critical care nurses relate to case-based studies from the nurses’ actual clinical practice setting. For instance, they have created a case-based study on a nursing practice incidence related to an IABP balloon rupture. The UOHI nurse educator reported creating practical and relevant cases has helped increase the application of theoretical concepts to the nurses' practice. Ultimately, the UOHI nurse educator reinforces that having relative content is important for critical care nurses.

The UOHI nurse educator also agreed that a computer-based self-directed learning resource would benefit critical care nurses. When disclosing some advantages of computer-based learning, they compared computer-based self-directed learning with a traditional lecture. From their perspective, teaching all relevant theoretical content during the lecture requires them to teach to the lowest level of the learners and make for a long session, leaving some learners less likely to be engaged. Alternatively, when the critical care nurse completed the self-direct learning independently at their own pace, this allowed the nurse educator more time to assist in the clinical setting. The UOHI nurse educator indicated they can always answer questions or concerns when critical care nurses complete self-directed learning. This approach allowed the nurse educator to specifically target individual critical care learner needs more than in a group setting and direct more time to clinical support for psychomotor skills in the practice setting.

When discussing recommendations for content, the UOHI educator provided more information on teaching and learning strategies. From the UOHI nurse educator's experience, critical care nurses seem to retain practical applications from clinical practice examples versus only learning theoretical information. Given this information, the nurse educator again reinforced using case-based studies from their organization, including actual hemodynamic parameters, waveforms, and visual images of local equipment. The UOHI nurse educator stated that stock images of equipment are irrelevant to critical care nurses; the nurse educator often took pictures of equipment used in their hospital when developing self-directed resources. Lastly, the UOHI nurse educator suggested including knowledge tests and checks with immediate feedback provided to the learner. In the interview's closing, the UOHI educator stated, "Self-directed learning needs to always be relevant to what you do in your own unit. That is what makes it tangible."

Based on the analysis of the quantitative and qualitative findings from the coronary care nurse participants' questionnaire responses and the qualitative findings of nurse educators' responses from the interviews, two broad qualitative findings emerged: content and delivery modes. In the following sections, I will discuss and analyze these findings. Please see Table 1 below for participants' computer-based content and strategies suggestions.

Table 1

Suggestions for computer-based content and strategies

<table>
<tr><th>Content</th><th>Strategies</th></tr>
<tr><td>

CS

Pathophysiology
Who is at risk
Signs and symptoms

Clinical nursing assessment approach (Systems approach)
Blood chemistry analysis

Treatment and Management

Hemodynamic monitoring

PA catheter
Indications for use
Setup and use
Troubleshooting
Avoid complications
Interpretation of values
Application of values to treatments

Pharmacology and CS

Review of vasoactive medications used in CS
Indications, mechanism of actions, dosages, and

</td><td>

Accessible at anytime
Knowledge testing
Immediate feedback
Use of pictures
Equipment in use in CCU
Include relevant aspects of EH nursing policy and standards of practice
Interactive strategies
Case studies
Relevant and practical to CCU
Reference tools

Quick reference guide
Normal values for PA catheter calculations

</td></tr>
</table>

contraindications ▪ MCS • IABP • Indications for use • Nursing considerations • Troubleshooting • Interpretation of IABP values and waveforms Goals of care ▪ Outcomes ▪ Mortality rates ▪ Palliative care planning • Patient and family psychological needs	

Content

Qualitative and quantitative findings both revealed relevant content for inclusion in the computer-based self-directed learning resource. The quantitative questionnaire findings revealed that all 25 coronary care nurse participants agreed that the resource should include the three subtopics: nursing care of PA catheter, vasoactive agents, and IABP, and 22 nurse participants provided feedback. Most nurse participants (18) stated the three subtopics were relevant to their practice and CS nursing management. Similarly, the HSC nurse educator agreed that including the three subtopics would help nurses meet previously identified learning needs. The UOHI nurse educator did not expressly state theoretical content for inclusion; instead, they focused on teaching and learning strategies.

Within the qualitative data obtained from the questionnaire analysis, coronary care nurse participants expressed specific CS content for the resource. As mentioned, five nurse participants requested information about CS's etiology, while three others wanted to know about identifying at-risk patients. In addition, four nurse participants expressed an interest in learning about the early identification of the onset of CS, including the clinical signs and symptoms. Two nurse participants were also concerned about the goals of care, and one nurse participant wanted to improve their practice of understanding if the treatments provided were working. Other topics suggested by individual nurse participants included information about the blood work commonly ordered for patients with CS, goals of care, and palliative care planning. In addition, a topic that I had not considered as a need for coronary care nurses was the need for information resources to facilitate psychological support for patients and families related to CS; three nurse participants wanted more resources to support the patient and family.

The findings related to hemodynamic monitoring and the PA catheter were derived from the ordinal confidence scale and the qualitative analysis of the questionnaire. Regarding the nurse participant rating of their skills, most participants reported being confident in assisting a physician with inserting a PA catheter (11) and obtaining hemodynamic data from a PA catheter (9). The qualitative analysis identified that four nurse participants wanted more information about their skills in using a PA catheter. For instance, three nurse participants wanted more practical knowledge to avoid complications and troubleshoot equipment. At the same time, one nurse participant wanted to review the equipment setup for obtaining hemodynamic measurements. The knowledge component of the ordinal scale revealed that eleven nurse participants reported only being minimal confident in interpreting the meaning of direct, and nine participants also reported minimal confidence in interpreting indirect measurements obtained from the PA catheter. Furthermore, thirteen or 52% of coronary care nurse participants had minimal confidence in anticipating appropriate changes to treatments based on hemodynamic measurements. These findings were supported by the qualitative analysis of the nurse participants' questionnaires, as four participants stated they wanted to have more knowledge to interpret the meaning of the hemodynamic measurements.

The coronary care nurse participants agreed that the other two subtopics, vasoactive medications and IABP, should be included in the self-directed learning resource. The quantitative analysis of the questionnaire revealed that all 25 nurse participants (100%) expressed an interest in "reviewing" vasoactive medications, and twelve nurse participants provided additional information. The qualitative response findings included that they wanted to review the medications used in CS and the indications, mechanism of action, dosages, and contraindications. Regarding their learning needs related to the IABP, 52% of nurse participants felt they had unmet needs, and thirteen participants (13) provided answers to open-ended questions. For instance, seven nurse participants requested more information to help them troubleshoot IABP alarms and equipment errors, including one nurse who requested to know how to identify if there were issues with the placement of the IABP. Three others asked for more information related to waveform analysis, and one nurse participant wanted to know more about interpreting the IABP numbers. In addition, three nurse participants suggested a review of the IABP would be helpful. These findings supported that nurse participants have learning needs regarding vasoactive medications and the nursing management of the IABP.

Delivery Mode: Computer-based

The overall consensus of the quantitative and qualitative findings was that coronary care nurse participants and two nurse educators agreed that a computer-based delivery mode would benefit critical care nurses. All 25 nurse participants indicated they would be willing to complete a computer-based self-directed learning resource. In addition, 24 nurse participants reported that this mode of delivery would make learning more accessible, and nurses could learn at their own pace. Similarly, both nurse educators agreed that an advantage to self-directed learning was that the learner could set their own pace. In addition, qualitative findings from the nurse participants suggested that three nurses felt a self-directed resource would allow them to review relevant content based on their needs. The nurse educators suggested that content be divided into manageable modules as it would allow the critical care nurses to complete learning as a whole package or only modules based on their learning needs. This structure would also benefit the three nurse participants who stated that self-directed learning resources would allow them to review the relevant content of the resource after providing direct care to a patient.

Both groups of participants disclosed some advantages to self-directed learning versus lecture-based. Each nurse educator reported that lecture-based teaching required educators to teach at the lowest learner level. The UOHI nurse educator reported that an advantage to self-directed learning is that learners can take the time necessary to complete it. Following the self-directed learning, the nurse educator can then be available to answer questions and reinforce content while partnering with the critical care nurses to ensure they can apply their new knowledge into practice. Two coronary care nurse participants commented that they favoured the self-directed learning style. One nurse participant stated that they felt self-directed learning was more manageable than learning in a lecture setting with a large group of other learners, as they often felt intimidated. At the same time, another nurse participant stated that self-directed learning worked better for their individual learning ability.

The qualitative findings analysis disclosed the teaching and learning strategies. The two nurse educators and five coronary care nurse participants reported that the resource would be valuable because it would contain content based on best-practice evidence and standards. Both nurse educators supported using case studies, with the UOHI nurse educator encouraging the creation of case studies based on incidences or clinical patient examples from the local setting. The UOHI nurse educator has had positive feedback from this method, as critical care nurses appreciate being able to relate theoretical content to real-time scenarios. This statement is important as it is associated with Knowles' Adult Learning Theory, which is that critical care nurses are likely to be more engaged in learning that is relevant and practical to them. For example, the UOHI nurse educator included images of equipment used in their setting in a self-directed critical care nurses' hemodynamic learning resource instead of stock images. The UOHI nurse educator found that nurses related to local images and the nurses tended to retain this information better. Both nurse educators mentioned the need to include knowledge tests and checks within the self-directed resource and provide the learner with immediate feedback. Only one nurse participant suggested having knowledge checks with immediate feedback. Although, other nurse participants suggested including images, actual waveforms, troubleshooting examples, and incorporating nursing care practices. In addition, two critical care nurses suggested the inclusion of a quick reference guide may be helpful to their practice. The emphasis on teaching and learning strategies expressed by coronary care nurses and nurse educators

Summary and Implications

In summary, the questionnaire and interview responses from the consultation process had consistent findings, supporting the need to develop a self-directed computer-based learning resource for coronary care nurses caring for adult patients at risk of CS and who develop CS. These findings were comparable with the evidence presented in the literature review conducted for the project. The suggestions for content are all related to the topics identified as evidence-based management and treatment of CS supported by the literature review. Furthermore, the learning needs are consistent with the literature review suggesting coronary care nurses could benefit from more education related to hemodynamic monitoring. For example, the consultations revealed that 52% of coronary care nurse participants are only minimal confident in anticipating appropriate treatment changes based on direct and indirect measurements received from a PA catheter. Also, the literature review reported that the use of vasoactive medication could be inconsistent in critical care, and a more standardized approach is needed. There was strong support for participation in the consultations, with all nurse participants (25) indicating they would complete a self-directed learning resource on CS. The majority of nurse participants (88%) agreed that their nursing practice could benefit from a review of the topic. Another result was that only 52% of nurses reported learning needs related to the IABP.

In addition, the mode of delivery and teaching and learning strategies reported in the consultations are similar to findings from the literature review and environmental scan. All participants agreed that a self-directed learning resource would be an appropriate continuing education strategy. There was a favourable response to having a self-directed resource accessible to learners to set their own learning pace. The nurse educators and some coronary care nurse participants suggested the resource should have an interactive design with images, waveforms, knowledge tests, nursing practice examples or case studies. Also, nurses could use the resource on an as-needed basis to review or obtain evidence-based information.

The consultations, environmental scan and literature review results fully support developing a coronary care nurses' self-directed learning resource for caring for adult patients at risk of and who develop CS. There is a need for continuing education strategies for coronary care nurses within CCU at the HSC. Therefore, I plan to develop a computer-based self-directed learning resource accessible to nurses through EH's (2021) LEARN online platform. The content will be subdivided into four manageable modules: CS overview and three subtopics in managing and treating CS: hemodynamic monitoring and the PA catheter, vasoactive medications, and IABP. Each module will have clear learning objectives and a list of concepts or topics included in that module that will allow the learner to navigate the resource and select contents easily. The modules will consist of appropriate theoretical concepts, evidence-based practice management, and treatment recommendations while integrating nursing practice, policy standards, and clinical applications. The modules will be interactive to enhance the learners' experience by using pretest and posttest, case studies, pause and reflect exercises, practical tips, knowledge checks, video links, images and waveforms to illustrate the content. As recommended by the UOHI nurse educator, I plan to use images of equipment currently used in the CCU so that the images are relevant to the nurses' clinical practice. In addition, I do plan on summarizing some key concepts into quick reference guides in paper format, as this was a strategy noted in the environment scan and requested by a coronary care nurse participant in the consultations. The quick reference document will summarize the topic's contents in a one-page paper for the nurses' ease of use and reference. Two topics for consideration for the quick reference documents are the Society for Cardiovascular Angiography and Interventions staging of CS (Naidu et al. 2022) and PA catheter hemodynamics (normal parameters and waveforms). Overall, I have chosen these fundamental elements for the resource based on the analysis of findings from the literature review, environment scan, consultations and application of Knowles' Adult Learning Theory (1984) principles. The findings support the proposed design of creating a self-directed learning resource guided by best-practice evidence to successfully improve coronary care nurses' knowledge, skills, and practice related to CS.

Conclusion

The project's consultation phase included implementing a strategy that effectively upheld ethical standards in data collection, management, and analysis while meeting the overall aim of the consultations. The project's comprehensive consultation plan aimed to gain key stakeholders' input and contributions to ensure that the resource meets the needs of coronary care nurses practicing in the CCU at the HSC. The analysis of findings from the coronary care nurses' questionnaires and nurse educators' interviews revealed similar findings related to informing the content and delivery mode of the resource. Coronary care nurses' suggested topics for inclusion were CS pathophysiology, hemodynamic principles, assessment, treatment and management, and patient and family concerns. Similarly, the HSC nurse educator recommended the inclusion of cardiac anatomy, hemodynamic principles, pump failure, appropriate CS treatments, and their effects. The coronary care participants also agreed that reviewing the PA catheter, vasoactive medications, and IABP would benefit their nursing practice. Regarding the delivery mode, the coronary care nurse participants and nurse educators supported a computer-based resource due to the ease of access and ability for the learner to set their own pace for learning. The two groups stated the resource should be divided into manageable modules with an interactive design including images, case studies, nursing practice examples, knowledge checks and immediate feedback. The results of the consultations clearly indicate the need for learning information about CS nursing care. I use these findings, the literature review, and environmental scan findings to develop a computer-based self-directed learning resource for coronary care nurses caring for adult patients at risk of and who develop CS.

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Appendix A: Email to CCU Nurses

Dear Coronary Care Nurse,

I am completing my practicum project to meet the requirements for my Master of Science in Nursing (MScN) at Memorial University of Newfoundland and Labrador with the guidance of my supervisor, Ms. Erica Hurley. I have chosen to develop a critical care nurses' self-directed learning resource for adult patients with cardiogenic shock. I would greatly appreciate your input on the learning resource development to ensure that it meets your needs and is valuable to your nursing practice.

I am requesting your participation by completing a questionnaire which will take approximately 15-20 mins of your time to complete. Your participation is entirely voluntary. I will not collect any personally identifying information, and all questionnaires received will be used for the stated purpose, securely stored, and discarded after completing this practicum.

Paper copies of the questionnaire are available at the main desk in CCU. Completed questionnaires can be placed in a sealed envelope provided and locked in the patient care coordinator's storage drawer. I will retrieve the completed questionnaires personally, and all measures to ensure confidentiality will be upheld during the review and analysis.

I appreciate your participation and request the questionnaire be returned by November 27. Please reach me by email, phone, or in person if you have any questions or would like me to address any concerns.

Kind Regards,

Susan Neil, BNRN

Susan.neil@easternhealth.ca

Appendix B: Letter to Attach to Questionnaire for CCU Nurses

Dear CCU nursing staff,

I am completing my practicum project to fulfill the Master of Science in Nurse Program requirements through Memorial University of Newfoundland and Labrador with the guidance of my supervisor, Ms. Erica Hurley. The practicum project aims to develop a critical care nurses' self-directed learning resource for adult patients with cardiogenic shock.

The purpose of this letter is to request your participation in completing a short questionnaire related to your nursing practice and the learning needs of caring for adult patients with cardiogenic shock. This information will guide the development of a resource that meets your needs. Therefore, I would greatly appreciate your contribution to the project by providing your input and ideas by completing the attached questionnaire, which will take approximately 15-20 minutes.

Please note that I will follow all ethical guidelines. Your participation is entirely voluntary, and by agreeing to participate, I will assume your informed consent. I will not collect any identifying data and request that you please not place any identifying information on the questionnaire. Once you complete a questionnaire, you cannot withdraw from the project after submission because there is no identifying data to eliminate your information. All questionnaires received will be used for the stated purpose, securely stored in a locked filing cabinet and password-protected computer, and discarded after completing this practicum.

I kindly ask that questionnaires be completed by November 27, so I can move forward with this project. The completed questionnaire can be placed in a sealed envelope and locked in the patient care coordinator's storage drawer. I will retrieve the completed questionnaires personally, and all measures to ensure confidentiality will be upheld during the review and analysis.

I am available to answer any questions or concerns you may have and can be reached by email, phone, or in person. Thank you in advance for your support and participation.

Kind regards,

Susan Neil, BNRN

Susan.neil@easternhealth.ca

Appendix C: Questionnaire for Critical Care Nurses

1. The literature findings support using computer-based learning for critical care nurses. Would you be willing to complete a computer-based self-directed learning resource related to caring for adult patients with cardiogenic shock? Circle the appropriate answer.

   Yes No

   If yes, please explain why?

2. The literature findings related to cardiogenic shock management support the inclusion of three topics: hemodynamic monitoring tools (pulmonary artery [PA] catheter), vasoactive medications, and mechanical circulatory devices (such as IABP).
   Would you agree that these three topics should be included in the resource?

   Why or why not?

3. Can you suggest any other topics for inclusion?

4. Please select the most appropriate response to describe your nursing care related to the care of a pulmonary artery (PA) catheter, a hemodynamic tool often used for patients with cardiogenic shock.

Skill set	No experience	Minimal confidence	Confident	Very Confident
Assist the physician during the insertion of a PA catheter.				
Ability to correctly obtain hemodynamic data (pulmonary capillary wedge, cardiac output measurement) from PA catheter according to best practice evidence.				
Interpret the meaning of the direct measurements obtained from a PA catheter (central venous pressure, pulmonary capillary wedge pressure, cardiac output, mixed venous oxyhemoglobin saturation)				
Interpret the meaning of indirect measurements obtained from a PA catheter (Systematic vascular resistance, pulmonary vascular resistance, cardiac index, stroke volume index)				
Ability to anticipate appropriate changes in treatments due to direct and indirect measurements received from PA catheter				

5. Please provide any additional information related to your learning needs associated with interpreting hemodynamic values obtained from a pulmonary artery catheter.

6. Would your nursing practice benefit from a review of vasopressor and inotrope medications commonly used in cardiogenic shock? Circle the appropriate answer.

Yes No

If yes, please comment:

7. Do you have learning needs related to the nursing care of a patient with an IABP? Circle the appropriate answer.

Yes No

If yes, please comment:

8. Please add any other information you feel would be important to developing the self-directed learning resource for adult patients with cardiogenic shock.

Appendix D: Email Request to Cardiac Critical Care Nurse Educator, HSC

Dear [insert HSC educator name],

I am completing my practicum project to meet the requirements for my Master of Science in Nursing (MScN) at the Memorial University of Newfoundland and Labrador with the guidance of my supervisor Ms. Erica Hurley. I have chosen to develop a critical care nurses' self-directed learning resource for adult patients with cardiogenic shock. I would greatly appreciate your input on the learning resource development to ensure that it meets the needs of the critical care nursing staff at the Health Sciences Centre, Eastern Health.

I am requesting your participation in an interview. The interview will take approximately 30 minutes and can be held in a private, convenient location of your choice or virtual if preferred. Your participation is entirely voluntary, and I will assume informed consent by your agreement to participate. Upon completion of the interview, you cannot withdraw the information you have provided. I will ensure your anonymity and confidentiality in my data analysis and reports. Additionally, I will securely store all data and notes from the interview in a locked file cabinet and password-protected computer. After completing my analysis, I will properly discard any data collected.

I greatly appreciate your continued support. I would welcome the opportunity for you to share your expertise and knowledge to inform and aid in developing the critical care nurses' self-directed learning resource for adult patients with cardiogenic shock.

Please advise of your interest in participating by November 25, so we can coordinate a convenient time between November 21-28.

Kind regards,

Susan Neil, BNRN

susan.neil@easternhealth.ca

Appendix E: Email Request to other Clinical Educators (NB and Ottawa)

Dear [insert educator's name]

Thank you for your participation in my environmental scan. As you know, I am completing my practicum project to meet the requirements for my Master of Science in Nursing (MScN) at the Memorial University of Newfoundland and Labrador, with the guidance of my supervisor Ms. Erica Hurley. I have chosen to develop a critical care nurses' self-directed learning resource for adult patients with cardiogenic shock. I would greatly appreciate your input on the learning resource development to ensure that it meets the needs of the critical care nursing staff at the Health Sciences Centre, Eastern Health.

I am requesting your participation in an interview. I want to explore your utilization, implementation, and evaluation strategies for the self-directed learning resources you graciously shared. The interview will take approximately 20-30 minutes and can be conducted by phone or virtually if preferred. Your participation is entirely voluntary, and I will assume informed consent by your agreement to participate. Upon completion of the interview, you cannot withdraw the information provided. I will ensure your anonymity and confidentiality in my data analysis and reports. Additionally, I will securely store all data and notes from the interview in a locked file cabinet and password-protected computer. After completing my analysis, I will properly discard any data collected.

I greatly appreciate your continued support. I would welcome the opportunity for you to share your expertise and knowledge. Please advise of your interest in participating by November 25, so we can coordinate a convenient time between November 22-29.

Kind regards,

Susan Neil, BNRN

susan.neil@mun.ca

Appendix F: Interview Guide for Cardiac Critical Care Nurse Educator at HSC

1. What are some current continuing education practices for ongoing education for critical care nurses?

2. Do you have any existing self-directed learning resources in use? If so, can you provide details related to the utilization, implementation, and evaluation of the resources? Delivery modes?

3. Do you believe a self-directed learning resource designed to improve or refine critical care nurses' knowledge related to cardiogenic shock nursing care would be helpful for both experienced and inexperienced critical care nurses?

4. Can you provide any recommendations for the content of the learning resource?

5. The literature supports a computer-based delivery mode for critical care nurses. What would you suggest is the best mode of delivery for the learning resource to meet the continuing education needs of critical care nurses?

6. What teaching and learning strategies would you consider beneficial to include in the learning resource?

7. Do you believe incorporating the self-directed learning resource into the Eastern Health learning management system (LEARN) is feasible?

Appendix G: Interview Guide for NB and UOHI

1. What are some current continuing education practices for critical care nurses at your hospital?

2. My research shows that self-directed learning, computer-based learning, and case studies are effective learning strategies.

    a. What is your experience with self-directed learning?
    b. What is your experience with computer-based learning?
    c. What is your experience with case studies?

3. Do you have any existing self-directed learning resources in use? If so, can you provide details related to the utilization, implementation, and evaluation of the resources?

4. Can you provide details about using your educational resources, specifically self-directed learning resources shared in the environmental scan?

    **NB educator: a. *Self-directed learning package on hemodynamic monitoring*

    b. Vasopressors and *inotropes: The guidelines of what, when, how and why of infusing and titrating?*

    **UOHI educator: a. *Hemodynamics in critical care: Understanding invasive lines*

    a. What are your implementation strategies for the self-directed package?
    b. Have you obtained evaluation data on the self-directed learning packages?

5. Do you believe a self-directed computer-based learning resource designed to improve critical care nurses' knowledge related to cardiogenic shock nursing care would be helpful for both experienced and inexperienced nurses?

6. Can you offer any recommendations for the content of the learning resource?

Appendix H: Health Research Ethics Authority (HREA) Screening Tool

Student Name: Susan Neil

Title of Practicum Project: The development of a self-directed learning resource for coronary care nurses caring for adult patients with cardiogenic shock.

Date Checklist Completed: September 23, 2022

This project is exempt from Health Research Ethics Board approval because it matches item number 3 from the list below.

1. Research that relies exclusively on publicly available information when the information is legally accessible to the public and appropriately protected by law; or the information is publicly accessible and there is no reasonable expectation of privacy.
2. Research involving naturalistic observation in public places (where it does not involve any intervention staged by the researcher, or direct interaction with the individual or groups; individuals or groups targeted for observation have no reasonable expectation of privacy; and any dissemination of research results does not allow identification of specific individuals).
3. Quality assurance and quality improvement studies, program evaluation activities, performance reviews, and testing within normal educational requirements if there is no research question involved (used exclusively for assessment, management or improvement purposes).
4. Research based on review of published/publicly reported literature.
5. Research exclusively involving secondary use of anonymous information or anonymous human biological materials, so long as the process of data linkage or recording or dissemination of results does not generate identifiable information.
6. Research based solely on the researcher's personal reflections and self-observation (e.g. auto-ethnography).
7. Case reports.
8. Creative practice activities (where an artist makes or interprets a work or works of art).

For more information please visit the Health Research Ethics Authority (HREA) at https://rpresources.mun.ca/triage/is-your-project-exempt-from-review/

Appendix D: Self-Directed Learning Resource

The Development of a Self-Directed Learning Resource for Coronary Care Nurses Caring for Adult Patients with Cardiogenic Shock: The Self-Directed Learning Resource

Susan Neil

Memorial University of Newfoundland and Labrador

Self-Directed Learning Resource: Cardiogenic Shock

Overview of Cardiogenic Shock,
Hemodynamic Monitoring and the Nursing Care of a Pulmonary Artery Catheter,
Vasoactive Medications, and
Mechanical Circulatory Device: Intra-Aortic Balloon Pump

Developed by Susan Neil, RN, BN, CCN(C)

Self-directed learning resource developed as a partial requirement for Master of Science in Nursing degree Memorial University of Newfoundland and Labrador

May 2023

Table of Contents

Welcome

Welcome to a computer-based self-directed learning resource on cardiogenic shock and the three subtopics: hemodynamic monitoring and pulmonary artery catheter, vasoactive medications, and mechanical circulatory assist device: the intra-aortic balloon pump. The resource has been developed for coronary care nurses at the coronary care unit (CCU), Health Sciences Centre (HSC), Eastern Health (EH) to contribute to their continuing education on the nursing care of adult patients who are at risk of and who develop cardiogenic shock. Learning needs were identified initially through informal discussions with coronary care nurses. Additionally, a literature review, environmental scan, and consultations with key stakeholders, which included a sample of coronary care nurses and their nurse educator were completed to guide resource development.

This computer-based self-directed learning resource includes four modules:

- cardiogenic shock overview,
- hemodynamics with a focus on using the pulmonary artery catheter and interpretation of hemodynamic values,
- vasoactive medications, and
- the intra-aortic balloon pump.

Please complete Module 1 for foundational knowledge of the nursing care of adult patients at risk for and who develop cardiogenic shock, then complete the remaining three modules or any separate module based on your individual learning needs.

This resource can be used in two ways depending on your needs:

1. A self-learning resource to learn about cardiogenic shock systematically or
2. A quick guide to look up specific cardiogenic shock relevant information for in-the-moment learning.

Each module contains evidence-based information and activities to engage you, the learner, in gaining knowledge and skills needed to care for adult patients who are at risk for and who develop cardiogenic shock, including case studies, interactive activities, reflective exercises, video links, and quizzes.

A table of contents and an abbreviation guide are located at the beginning of each module to assist with using the computer-based self-directed learning resource as a quick guide for in-the-moment learning.

Any terms **bolded** in the computer-based self-directed learning resource can be found in the Glossary located in Appendix A at the end of the resource. In addition, the answer keys to various case studies, interactive activities, and quizzes can be found for each module in Appendices B, C, D, and E. Also, Appendix F will contain any printable content, including quick reference guides.

If you intend on completing all four modules, there is a pre-test for you to complete to test your knowledge. Upon completing all four modules, the same test will be included at the end so you can self-evaluate your learning. The answers to the pre-test can be found in Appendix G.

Enjoy your learning!

Pre-test

To test your existing knowledge, please complete the pre-test before you complete all four modules. After you complete all four modules within the self-directed learning resource, you can take the post-test and compare your answers to assess the knowledge gained from completing this resource. The answers can be found in Appendix G.
Please circle the most appropriate answer for each question.

1. What is the most common cause of cardiogenic shock?

    a. Pericarditis
    b. Dysrhythmia
    c. Pulmonary embolism
    d. Acute myocardial infarction (AMI)

2. Which blood test is used to detect end-organ hypoperfusion in the early stages of cardiogenic shock?

    a. Lactate
    b. Troponin
    c. C-reactive protein (CRP)
    d. B-type natriuretic peptide (BNP)

3. In some cases, the clinical manifestations of cardiogenic shock can vary due to the cause of the shock and its severity.

    True False

4. What is the estimated mortality rate percentage for patients with cardiogenic shock?

    a. 10%
    b. 30%
    c. 20%
    d. 50%

5. What is the normal expected range for cardiac output?

   a. 4-8 L/min
   b. 2-4 L/min
   c. 1-3 L/min
   d. 1-4 L/min

6. You are assessing a patient for cardiogenic shock. What signs and symptoms do you expect to find? Circle all that apply.

   a. Dyspnea
   b. Increased lactate
   c. Warm, flushed skin
   d. Crackles in lung fields
   e. Cool and clammy skin
   f. Strong peripheral pulses
   g. Urinary output > 30 ml/hr
   h. Increased liver function tests
   i. Systolic blood pressure (SBP) < 90 mmHg
   j. Decreased urea (BUN) and decreased creatinine (Cr)

7. What term describes the resistance the ventricles have to pump against?

   a. Preload
   b. Afterload
   c. Cardiac index
   d. Ejection fraction

8. What hemodynamic parameter is an indication of right-sided preload?

   a. Central venous pressure
   b. Systematic vascular resistance
   c. Pulmonary vascular resistance
   d. Pulmonary capillary wedge pressure

9. Of the hemodynamic parameters listed, which parameter is consistent with cardiogenic shock?

    a. Cardiac output of 4 L/min
    b. Cardiac index of 1.8 L/min/m^2
    c. Mean arterial pressure of 70 mmHg
    d. Pulmonary wedge pressure (PWCP) of 6 mmHg

10. In most cases, pulmonary capillary wedge pressure (PCWP) and left ventricular end-diastolic pressure (LVEDP, reported on the cardiac catheterization report) are often used interchangeably to describe left-sided filling pressures or left-sided preload.

    True　　　　False

11. The phlebostatic axis is at the level of the:

    a. Right atrium.
    b. Right ventricle.
    c. Left atrium.
    d. Left ventricle.

12. When measuring atrial and wedge pressure, what is the optimal measuring point on the respiratory cycle?

    a. End inspiration
    b. End expiration
    c. Beginning inspiration
    d. Beginning expiration

13. All of the following are determinants of stroke volume except:

    a. Heart rate.
    b. Preload.
    c. Afterload.
    d. Contractility.

14. The pulmonary artery catheter has other names. Circle all that apply.

    a. SWAN
    b. Sideport
    c. Swan Ganz
    d. Triple lumen

15. What hemodynamic effect will norepinephrine (levophed) have when administered during cardiogenic shock?

    a. Decrease contractility
    b. Decrease cardiac output
    c. Decreased mean arterial pressure
    d. Increase systematic vascular resistance and increase cardiac output

16. The cardiogenic shock patient you are caring for has an intra-aortic balloon pump. The intra-aortic balloon pump inflates during ___________________________ and deflates during ____________________.

    a. Diastole and systole
    b. Inspiration and expiration
    c. Systole and diastole
    d. Expiration and inspiration

17. You notice blood in the extender tubing of the intra-aortic balloon pump; what does this most likely indicate?

    a. Balloon migration
    b. Balloon rupture
    c. Late deflation
    d. Early deflation

18. A patient with an intra-aortic balloon pump has a lethal arrhythmia (ventricular fibrillation or pulseless ventricular tachycardia). It is safe to perform defibrillation, provided clinicians stand clear of the intra-aortic balloon pump catheter and console.

True False

19. Assessing the timing of the intra-aortic balloon pump is crucial to ensure the patient is getting the full benefit of the mechanical assist device. Which timing errors require immediate action to correct.

a. Early inflation and early deflation
b. Early inflation and late deflation
c. Late inflation and late deflation
d. Late inflation and early inflation

20. When reviewing an arterial pressure waveform for an intra-aortic balloon pump, the balloon will inflate just prior to the dicrotic notch.

True False

Thank you for completing the pre-test!

Abbreviations

ACP- advanced care planning ACS- acute coronary syndrome AMI—acute myocardial infarction BP- blood pressure CABG- coronary artery bypass graft CK—creatine kinase CO—cardiac output CI—cardiac index CS—cardiogenic shock CCU- coronary care unit CVP-central venous pressure D5W- dextrose 5% in water HF- heart failure HR- heart rate IABP—intra-aortic balloon pump IV- intravenous LVSWI—left ventricular stroke work index LV—left ventricular MAP—mean arterial blood pressure MI—myocardial infarction NSTEMI- non-ST-elevation myocardial infarction PCI—percutaneous coronary intervention	PCWP—pulmonary capillary wedge pressure PVR- pulmonary vascular resistance RV- right ventricular SCAI- Society of Cardiovascular Angiography and Interventions STEMI—ST-elevation myocardial infarction SVR—systemic vascular resistance VF- ventricular fibrillation VT- ventricular tachycardia

Module 1

Overview of Cardiogenic Shock

Module 1: Overview of Cardiogenic Shock

The purpose of this module is to provide information about cardiogenic shock. This module is intended to be used by registered nurses practicing in a coronary care setting. However, it may also benefit registered nurses practicing in other locations who want to learn more about this topic.

This module contains information, reflection exercises, case studies, documentation tips, tools for practice, and self-tests.

Learning Objectives

Upon completion of this module, you will be able to:

1. Define cardiogenic shock;
2. Describe the most common causes of cardiogenic shock;
3. Describe and identify clinical patient signs and symptoms of cardiogenic shock;
4. Classify the appropriate stages of cardiogenic shock using the Society for Cardiovascular Angiography & Interventions;
5. Recognize the need for the early identification of cardiogenic shock; and
6. Discuss treatment strategies to maintain hemodynamic stability and adequate perfusion.

Cardiogenic Shock

- Cardiogenic shock (CS) is a complex and life-threatening condition caused by severe impairment of myocardial performance where the heart can not pump enough blood to meet the body's demands. [1.2.3]

- CS can occur with a dysfunction of the right ventricular, left ventricular or both, called biventricular failure.[4,5]

- The lack of adequate pumping function results in reduced **cardiac output** (CO), end-organ hypoperfusion, and **hypoxia**.[2,3]

Why do Nurses Need to Know about CS?

- CS is one of the leading causes of admission to cardiac intensive care units.[6]

- Despite advances in cardiovascular care:

    - mortality rates related to CS remain high, estimated at 50%, [7,8,9] and
    - management remains challenging.[2]

- Early recognition and intervention to interrupt the devastating "CS spiral" is critical to survival.[10]

    - “CS spiral” refers to the impact of the reduced cardiac output, which leads to the deterioration of the patient's hemodynamic status and systematic decompensation.[1]

Nurses have a role in identifying patients at risk for CS, recognizing the early signs of CS hemodynamic instability, and coordinating with the multidisciplinary team to implement treatment therapies to improve patient outcomes. Your physical assessment and monitoring of the patient can allow you to recognize and treat signs of CS by collaborating with the healthcare team to initiate appropriate therapies to improve patient outcomes. Your assessment and monitoring should include conducting a thorough physical examination, observing cardiac rhythm, monitoring hemodynamic parameters, monitoring fluid status, and making adjustments to medications and therapies based on the findings from this information. Expertise in this area will better enable you to care for a patient at risk for and who develops CS.

Cause of CS

The most common cause of CS is **acute myocardial infarction** (AMI), resulting in the loss of 40% or more of the functional myocardium. [4,11,12] **ST-elevation** (STEMI) and **non-ST elevation myocardial infarction** (NSTEMI) can damage the myocardium causing CS. Often large anterior STEMI or multiple smaller NSTEMI or NSTEMI with pre-existing ventricular impairment can damage the heart leading to an inability of the heart to maintain CO. [4,1] CS can develop acutely within the first few hours after an AMI or gradually within the first few days of an AMI. [7] Rapid onset, a few hours, is generally noted in anterior MI caused by an occlusion of the left coronary artery.[7]

Other causes for CS include:

- **Heart failure** (HF) and arrhythmic problems
  - When the heart function is impaired, making it harder for the heart to pump oxygenated blood to the body.[13]
- Problems outside the heart include fluid buildup in the chest, internal bleeding, or pulmonary embolism.
- Trauma or injury to the chest can damage the heart, so it no longer pumps blood effectively.
- Mechanical problems that impair the heart's function to fill and eject blood adequately can cause CS, including severe valvular disease, **ventricular septal defect or rupture**, **pericardial tamponade**, and **constrictive pericarditis.** [4,10]

Please see Table 1.1 summarizing the causes of CS categorized into muscular, mechanical, and rhythmic causes.

Table 1.1

Causes of CS [4,10]

Causes of CS		
Muscular	**Mechanical**	**Rhythmic**
Left Ventricular Failure: ▪ AMI ▪ Hypertrophic obstructive cardiomyopathy ▪ **Myocarditis** ▪ Myocardial contusion ▪ Peripartum cardiomyopathy ▪ Post-cardiotomy ▪ Progressive cardiomyopathy ▪ Septic cardiomyopathy ▪ Stress cardiomyopathy (Takotsubo) ▪ Ventricular outflow obstruction ***Right Ventricular Failure:*** ▪ AMI ▪ Myocarditis ▪ Post-cardiotomy ▪ Progressive cardiomyopathy ▪ Pulmonary embolism ▪ Septic cardiomyopathy ▪ Worsening pulmonary hypotension ***Chemotherapeutic, toxic, metabolic:*** ▪ Calcium-channel antagonists ▪ Adrenergic receptor antagonists ▪ Thyroid disorders	▪ Aortic regurgitation- acute bacterial endocarditis ▪ Mechanical valve dysfunction or thrombosis ▪ Mitral regurgitation - myocardial ischemia or infarction ▪ Progressive mitral stenosis ▪ Progressive aortic stenosis ▪ Ventricular septal defect or free wall rupture ***Pericardial Disease:*** ▪ Tamponade ▪ Progressive pericardial constriction	***Tachy-dysrhythmias***: ▪ Atrial fibrillation or flutter ▪ Ventricular tachycardia or fibrillation ***Brady-dysrhythmias***: ▪ Bradycardia or heart block

Pathophysiology

CS shock causes a downward spiral of events within a cycle of cardiac injury leading to cardiac and systematic deterioration, contributing to further cardiac injury and systematic decompensation.[1] Given the various causes of CS and the limited high-quality clinical and research data, many unknowns are still related to CS. [1,14]

CS is a low CO state that occurs when the heart muscle cannot adequately pump blood to the body's organs.[1,2,3]

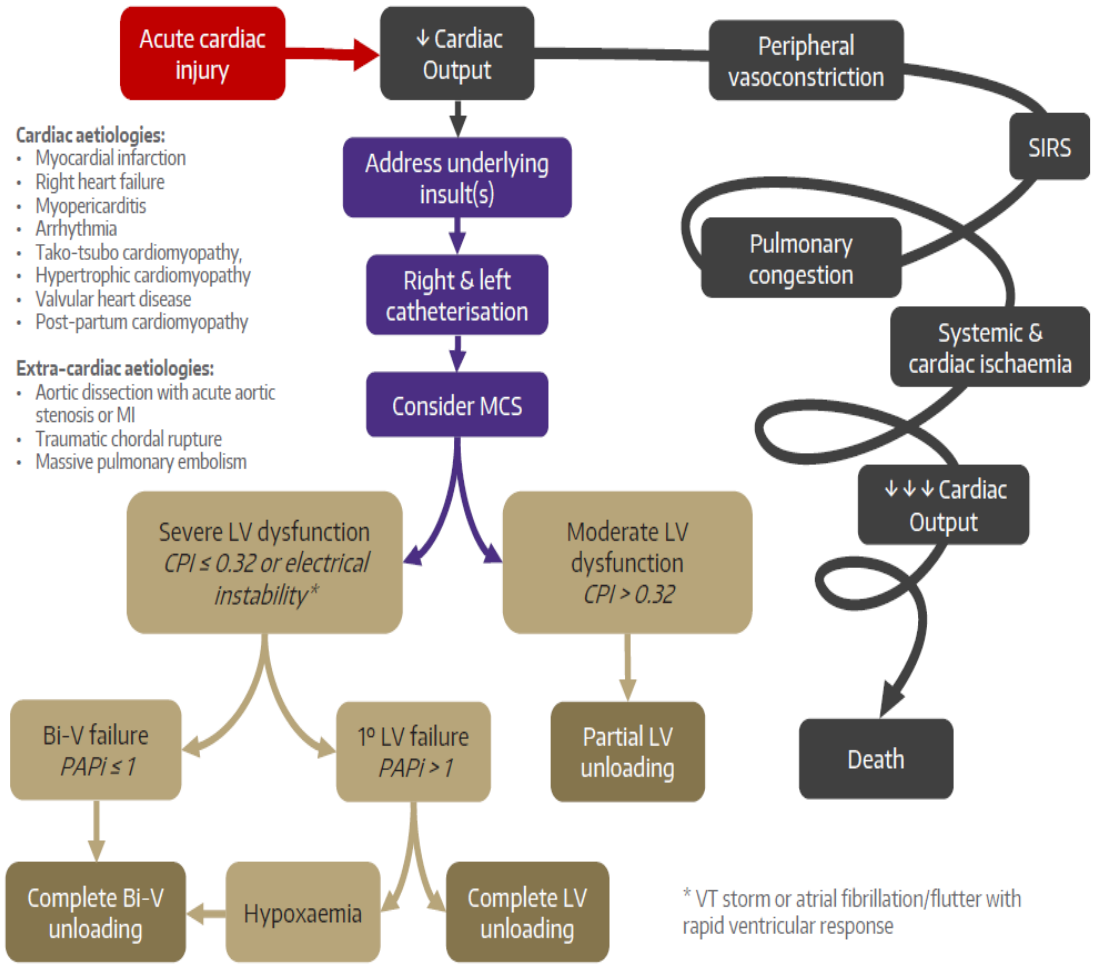
The heart's ventricle impairment in pumping blood forward causes a decrease in stroke volume, which in turn reduces CO and is manifested by:

- hypotension,
- systematic vasoconstriction, and
- cardiac ischemia.[3]

As the CO is decreased, the body attempts to compensate by vasoconstriction, which may initially improve coronary and peripheral perfusion; however, it also increases myocardial afterload and lowers blood pressure worsening myocardial ischemia.[2] In addition, as contractility decreases, the volume in the left ventricle (LV) increases, and the volume starts to back up in the lungs causing pulmonary edema and worsening impaired gas exchange and decreased oxygenation, which further impairs tissue perfusion.[1] See Figure 1.1, depicting the pathology of CS.

Figure 1.1

Pathology of CS



Source. From "Cardiogenic shock: Evolving definitions and future directions in management," by T.L. Jones, T. L. and J. M., 2019, *Open Heart*, *6*(1), p. 2 (https://doi.org/10.1136/openhrt-2018-000960).

Clinical Signs and Symptoms of CS

Clinical presentation of CS may occur rapidly or have a delayed onset with a deteriorating patient condition occurring over days.[15] The clinical manifestations can vary with CS related to the cause of the shock and its severity. Therefore, identifying the underlying cause of CS is crucial in the targeted treatment and management plan.[3]

Patients with CS are often:

- tachycardic,
- hypotensive,
- oliguric,
- cool, clammy skin, and
- have decreased peripheral pulses.[14]

CS presentations are defined as "cold and wet," "dry and cold," and "wet and warm." [2]

"Cold and wet" presentation includes:

- often the most usual or classic presentation,
- cool extremities and pulmonary congestion,
- a reduced cardiac index (CI),
- increased systemic vascular resistance (SVR) and
- increased pulmonary capillary wedge pressure (PCWP).
    - Ex. A patient with an AMI involving >40% of the left ventricle or AMI superimposed on an old MI or a new massive MI. [2]

"Dry and cold" presentation includes:

- euvolemic (a normal volume of fluid),
- a reduced CI,
- increased systemic vascular resistance, and
- normal PCWP.
    - Ex. With this presentation, the patient most likely has a history of previous MI or chronic kidney disease.[2]

"Wet and warm" presentation includes:

- often initially underrecognized by healthcare professionals,
- having systemic inflammatory response syndrome (SIRS) reaction in conjunction with an MI and is associated with a higher incidence of sepsis and mortality,
- reduced CI,
- low-to-normal SVR, and
- an elevated PCWP. [2]

See Table 1.2 for clinical signs and symptoms of CS. See Figure 1.2 for clinical signs and symptoms of HF in CS. See Table 1.3 for the hemodynamic parameters of CS.

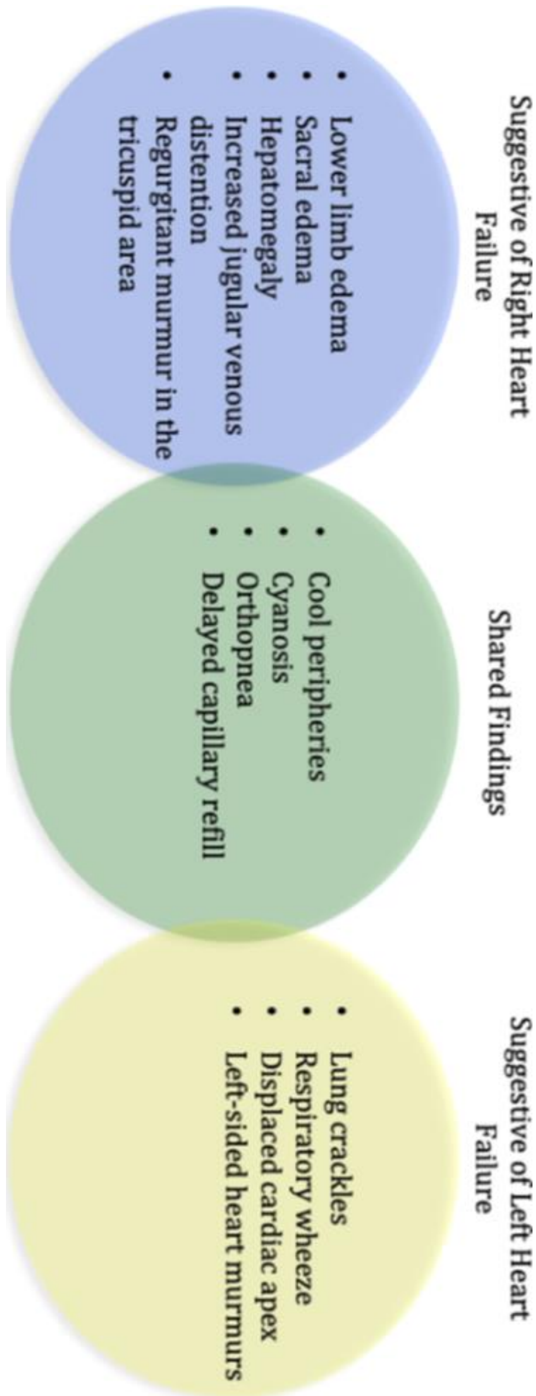
Table 1.2

Clinical Signs and Symptoms of CS [4]

Clinical Signs and Symptoms of CS
• SBP $\leq$ 90mmHg or a BP decrease of 30 mmHg below baseline • Tachycardia, HR > 100 bpm • Dysrhythmias • Altered level of consciousness • Cool, pale skin • Diaphoretic • Thready, weak pulses • Diminished heart sounds • Chest pain • Chest sounds: Crackles • Decreased urinary output, < 30 ml/hr • Reduced CO and **cardiac index** (CI) < 2.2 L/min/m^2 • Increased **central venous pressure** (CVP) • Increased **pulmonary capillary wedge pressure** (PCWP)

Figure 1.2

Clinical Signs and Symptoms of HF in CS



Source. From "Cardiogenic Shock," by C. Vahdatpour, D. Collins, & S. Golberg., 2019, *Journal of the American Heart Association, 8*(8), p. 3 (https://doi.org/10.1161/JAHA.119.011991). Creative Commons Attribution-Noncommercial license.[2]

Table 1.3

Hemodynamic Parameters with CS [16]

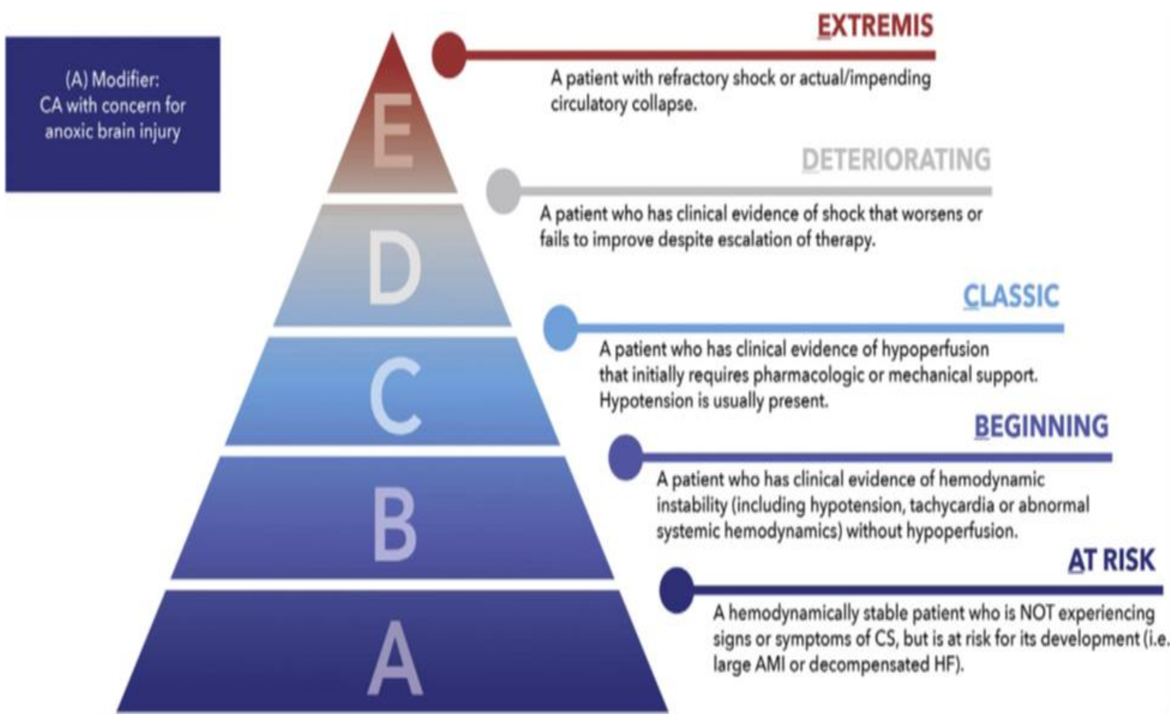
Type of Shock	Mean arterial pressure	Cardiac output	Oxygen delivery	Central venous pressure	Mean Pulmonary arterial pressure	Pulmonary capillary wedge pressure	Systematic vascular resistance
CS	Decreased, no change	Decreased	Decreased	Increased	Increased	Increased	Increased

Stages of CS

The Society of Cardiovascular Angiography and Interventions (SCAI) has established a 5-stage (A-E) classification system for CS (Naidu et al., 2022). The classification applies to acute presentations of cardiovascular injury. The shock stage classifications are divided into five letter categories: at risk (Stage A), beginning CS (Stage B), classic CS (Stage C), deteriorating (Stage D), and extremis (Stage E). See Figure 1.3 for the SCAI Shock classification pyramid.[14]

Figure 1.3

SCAI Classification of CS



Stage A: At risk

- The patient is *not* currently experiencing signs or symptoms of CS.
- The patient is at risk for its development.
  - Large AMI.
  - Prior infarctions and/or acute or acute-on-chronic HF symptoms.

Stage B: Beginning CS

- The patient has clinical evidence of hemodynamic instability (including relative hypotension or tachycardia) with hypoperfusion.

Stage C: Classic

- The patient manifests with hypoperfusion and requires one intervention (pharmacological or mechanical) beyond volume resuscitation.
- The patients typically present with relative hypotension (but hypotension is not required).

Stage D: Deteriorating

- The patient is similar to category C but is getting worse.
- Failure of initial support strategy to restore perfusion as evidenced by worsening hemodynamics or rising lactate.

- Need for more than one vasoactive agent or more than one support device or escalating doses of medication, or need for higher mechanical support settings.

Stage E: Extremis

- Actual or impending circulatory collapse.[14]

The SCAI SHOCK classifications are summarized using descriptors, physical examinations, biochemical markers, and hemodynamics.[14] See Table 1.4 for the physical examination/clinical findings, biochemical markers, and hemodynamic parameters used to classify CS. Also, Table 1.4 can be found in Appendix F for a printable one-page document.

Table 1.4

SCAI Classification of Shock: Physical Exam, Biochemical Markers and Hemodynamics

Stage	Physical examination	Biochemical markers	Hemodynamics
A	• Normal JVP • Strong distal pulses • Normal mentation • Clear lungs	• Normal lactate • Normal renal function (or at baseline)	• Normotensive SBP ≥ 100 mmHg or at baseline
B	• Elevated JVP • Strong distal pulses • Normal mentation • Rales in lung fields	• Normal lactate • Minimal acute renal function impairment • Elevated BNP	• Hypotension SBP < 90 mmHg MAP < 60 mmHg > 30mmHg drop from baseline
C	• Volume overload • Acute alteration in mental status • Cold and clammy • Extensive rales • Ashen, mottled, dusky, or cool extremities • Delayed capillary refill • Urine output < 30 ml/hr	• Lactate ≥ 2 mmol/L • Creatinine increase to 1.5 X baseline or 50 % drop in GFR • Increased LFTs • Elevated BNP	• Tachycardia • HR ≥ 100 bpm • Strongly recommend invasive hemodynamics • CI < 2.2 L/min/m^2 • PCWP > 15 mmHg • Pressors to maintain BP

D	• Any stage of C and worsening (or not improving) • Signs and symptoms of hypoperfusion despite the initial therapy	• Any of stage C and lactate rising and persistently > 2 mmol/L • Deteriorating renal function • Worsening LFTs • Rising BNP	• Any of stage C and requiring escalating dose or increasing number of pressors • Addition of a MCS device to maintain perfusion
E	• Actual or impending circulatory collapse • Typically unconscious • Near pulseless • Cardiac collapse • Multiple defibrillations	• Lactate > 8 mmol/L • CPR • Severe acidosis PH $\leq$ 7.2 Base deficit $\geq$ 10 mEq/L	• Profound hypotension despite maximal hemodynamic support

Legend. BNP, B-type natriuretic peptide; CI, cardiac index; CPR, cardiopulmonary resuscitation; CVP, central venous pressure; GFR, glomerular filtration rate; JVP, jugular venous pressure; LFT, liver function tests; MAP, mean arterial pressure PA, pulmonary artery; PCWP, pulmonary capillary wedge; SBP, systolic blood pressure.

Source. Adapted from "SCAI SHOCK stage classification expert consensus update: A review and incorporation of validation studies," by S. S. Naidu et al. 2022, *Journal of the Society for Cardiovascular Angiography & Interventions, 1(*1), p. 7. (https://doi.org/10.1016/j.jscai.2021.100008). Copyright 2021 by the authors published by Elsevier Inc. on behalf of the SCAI Foundation. CC BY-NC-ND.[14]

Some key considerations to remember about SCAI shock classifications are:

- The classifications are *not* intended for the staging of chronic cardiovascular disease.
- These classifications are intended for the staging of patients presenting acutely.
    - Ex. a large anterior MI or acute-on-chronic HF.
- Not all patients with CS will be the same!
    - Patients may have different physical examinations, hemodynamic parameters, prognosis and treatment methods.[14]
    - Ex. A patient with acute-on-chronic HF

        - They often display a lower SCAI SHOCK stage because they have adaptive and compensatory mechanisms related to their chronic heart failure.[17]

        - A patient with acute-on-chronic HF may provide false reassurance to healthcare professionals; that the patient may seem to be at a lower stage but are on the way to decompensating.

        - Clinicians must work collaboratively and interpret the physical examinations and hemodynamic findings in the context of the full clinical picture; this is very important.

    - Differences are generally situated in stages A and B, but stages C, D, and E are more likely to appear similar and unrelated to the chronicity of the patient.[14]

Nursing Consideration

Given the increased risk of lethal arrhythmias (pulseless VT and VF) in critically ill patients with CS, you should be prepared to intervene as required by the patient's advanced care planning (ACP) directive.

- Standardized cardiac arrest carts are located in all nursing units; familiarize yourself with their location.

- CCU:

    - The cardiac arrest cart for CCU is located across from Room 3.

    - Extra Physio-Control LifePak is located in the storage backroom.

All Eastern Health (EH) employees call 2000 to activate a code blue response if a cardiac arrest occurs.

Case Study 1.1

Read the following case and choose the most appropriate. The answers to these questions can be found in Appendix B: Case Study 1.1: Answer Key.

Mr. Sal is a 67 years old man with a long history, including a coronary artery bypass graft (CABG) 10 years ago, and his normal blood pressure runs 140/70 mmHg. He presents with angina and a positive troponin. His current blood pressure is 94/70 mmHg, and his heart rate is 100 beats per minute (bpm). He is scheduled to undergo diagnostic cardiac catheterization later in the day.

1. Using the SCAI classification of CS, what stage would you classify Mr. Sal?

    a. Stage A
    b. Stage B
    c. Stage C
    d. Stage D
    e. Stage E

Later that day, in the catheterization laboratory, he becomes more tachycardia with his heart rate at 110 bpm and now has a reduced urine output. A pulmonary artery (PA) catheter is inserted, and his cardiac index is 1.8/m2 with a wedge pressure of 29 mmHg.

2. Using the SCAI classification of CS, what stage would you classify Mr. Sal?

    a. Stage A
    b. Stage B
    c. Stage C
    d. Stage D
    e. Stage E

During cardiac catheterization case, a thrombectomy is performed by the cardiac interventionalist. Mr. Sal has ventricular fibrillation, signifying a cardiac arrest, and requires a single 200-joule shock. A low dose inotrope is started, and the intervention is completed successfully. An IABP is placed at the end of the case, and the patient is transferred back to the coronary care unit. Later that night, his urine output declined, and the cardiac index assessment remained below 2 $L/min/m^2$ despite increasing inotropes and IABP 1:1.

3. Using the SCAI classification of CS, what stage would you classify Mr. Sal?

    a. Stage A
    b. Stage B
    c. Stage C
    d. Stage D
    e. Stage E

Source. From "*Cardiogenic shock: It is not one-size-fits-all,"* Getinge Group, 2021, www.getinge.com. Reprinted with permission.[18]

Remember

The SCAI SHOCK classification was established for patients presenting acutely. It is important to remember that the classifications can be used for patients with acute and acute-on-chronic presentations; however, be aware that the patient's physical examinations and hemodynamic findings, prognosis, and response to treatment may differ.[14]

CS Management

CS interventions aim to improve contractility, restore tissue perfusion by reducing myocardial oxygen demand, and preserve the myocardium until blood flow is restored.[10,3] Understanding the etiology of the CS is vital to tailoring interventions to heart failure that is left-sided, right-sided, or biventricular. [3] Also, patients with CS should be treated and managed at specialized tertiary hospitals with the resources to provide expert care to these critically ill patients.[2,3,10]

The key recommended therapies for CS include:

- coronary reperfusion in patients with acute myocardial infarction,
- diagnostic evaluation, including non-invasive and invasive hemodynamic monitoring,
- inotropes and vasopressors,
- ventricular and circulatory support devices as clinically indicated, and
- when recovery is not possible, given the end-organ failure, the focus of care should shift to palliation and comfort the patient and family.[3,19]

Coronary Reperfusion, Revascularization, and Other Therapies

Coronary reperfusion is an evidence-based intervention for a patient with AMI with CS. The recommended strategies for reperfusion include fibrinolytic therapy, **percutaneous cardiac intervention** (PCI), and **CABG**.[3]

Fibrinolytic therapy is recommended when timely invasive revascularization is not possible. This therapy can be considered for patients with STEMI. [3,19] with persistent chest pain for 30 minutes, and if the pain has occurred within the last 6 hours.[20] Fibrinolytic therapy is administered to patients in hospitals outside of St. John’s due to the time delay of transport to the catheterization lab located at the HSC. The fibrinolytic drug used is called Tenecteplase (TNK); the dose is administered based on the patient’s weight. EH has a thrombolytic therapy checklist, part 1 and part 2, for healthcare practitioners to follow[20,] and the physician or nurse practitioner must ensure the patient meets the TNK administration criteria, including confirming there are no absolute contraindications. They also can consult the on-call cardiologist at the HSC for expert opinions.

EH Policy Documents and Forms

Please see Thrombolytic Therapy Checklists Part I and II (Ch 1214) on the EH intranet.[20]

CH-1214
Thrombolytic Therapy

Early revascularization is important in CS after MI. Therefore, patients' timely transfer to the cardiac catheterization lab for PCI is encouraged. Most recent studies and the current recommendation are for the cardiologist interventionist to revascularize the culprit lesion and hemodynamically significant non-culprit stenoses for patients with MI presenting with CS.[3,7] After revascularization, antithrombotic therapy plays an important role in PCI success. Intravenous heparin is most commonly used in patients with CS, as there is limited evidence of antithrombotic therapy in CS patients.[19]

Nursing Consideration and Practice Tips

PCI:

- Fasting is not required.
- Antithrombotic therapy is important for PCI success.
  - Be prepared to provide cath lab nurses with the antithrombotic medication administration times and dosages (ex., Plavix [clopidogrel], Brilintia [Ticagrelor], Lovenox [enoxaparin], Heparin, Fondaparinux, and Aspirin [ASA]).
  - If your patient is mechanically ventilated, you may need to administer antithrombotic medications via an orogastric or nasogastric tube.
  - Patients with PCI will be prescribed dual antiplatelet therapy without interruption after PCI.
  - If patients require continued anticoagulants, the suggestion is to use IV unfractionated heparin, as there is a high incidence of kidney injury and acute liver injury in CS patients.[3]
- Review the PCI post-procedure orders.
  - Follow post-procedure orders for site assessment and care for vital signs, neurovascular checks, activity and ambulation.[21] See Figure 1.4.

Figure 1.4

Site Assessment and Care

Site Assessment and Care

	Sheath Removal	Vital Signs/Site Assessment	Activity/Ambulation
Femoral (Routine ambulation)	by Cath Lab/CCU RN	every 15 min x 4 every 30 min x 2 every1h x 1 ➢ If stable, resume vital signs as per pre-procedure, unless otherwise ordered	➢ Bed rest. Keep extremity straight: x 3 hrs (5F sheath) x 4hrs (6F & 7F sheath) ➢ Head of bed may be elevated up to 45° ➢ Encourage patient to wiggle toes
Femoral (Early ambulation)	by Cath Lab/CCU RN	every 15 min x 4 every 30 min x 2	➢ Bed rest. Keep extremity straight x 1 hour and bed flat ➢ Head of bed may be elevated to 45° at 60 min ➢ Encourage patient to wiggle toes ➢ Ambulate at 90 min ➢ Discharge at 120 min
Note: Electrophysiology patients with **venous access only**, patient may ambulate following **60 minutes** when vital signs are stable.			
Angio-seal ™ (Femoral Use)	N/A	every 15 min x 4 every 30 min x 2 ➢ If stable, resume vital signs as per pre-procedure, unless otherwise ordered	➢ Head of bed may be elevated 30- 45° ➢ Patient may sit up **30 min** post procedure ➢ Patient may ambulate **90 min** post procedure
Radial	by Cardiologist	Every 15 min until band removed ➢ If stable, resume vital signs as per pre-procedure, unless otherwise ordered ➢ Vascular assessment every 15 min while band on and every 15 min x 4 once band removed ➢ Starting at 1 hour post band application, remove 2 mls of air every 15 min x 3, then wait 15 mins and remove band ➢ If bleeding occurs, replace air until bleeding stops and reattempt removal process in 1 hour	➢ Instruct patient to keep hand elevated and immobilized while band in place ➢ Encourage "drumming" of fingers post band removal ➢ Patient may ambulate with band in place, if stable
Brachial	by Cardiologist	every 15 min x 4 every 30 min x 2 every hour ➢ If stable, resume vital signs as per pre-procedure, unless otherwise ordered	➢ Bed rest. Keep extremity straight: x 3 hrs (5F sheath) x 4hrs (6F & 7F sheath) ➢ Encourage patient to wiggle fingers

Ch-0540 20

Source. From "Doctor's Orders Sheet: Post-procedure cardiac catheterization. Site assessment and care," by Neil, personal photo collection.[21]

EH Policy Documents and Forms

Please see the neurovascular assessment flow sheet (Ch 0185) found on the EH intranet.[22]

ch-0185
Neurovascular Assess

For a patient with multiple vessel disease and/or left main disease, the decision for PCI versus CABG revascularization should be made in collaboration between the cardiologist and cardiovascular surgery. Decision-making involves considering the patient history and comorbidities, coronary anatomy, potential treatment-related delays, and patient-informed choices.[3,19]

Clinical Monitoring and Diagnostic Tools

Essential non-invasive and invasive hemodynamic monitoring is recommended. In addition, diagnostic and laboratory evaluations are used to diagnose the severity of the cardiac injury, manage, and evaluate the patient's response to care therapies and interventions provided.[2,3] Table 1.5 outlines the key clinical monitoring and diagnostic tools for use with patients at risk for CS and who exhibit signs of CS.

Table 1.5

Clinical Monitoring and Diagnostic Tools

Monitoring Parameter	Rationale
Non-invasive Monitoring	
• Continuous cardiac monitoring • Continuous pulse oximetry (SpO2) • Respiratory rate (q 1 hourly) • Temperature (q 4 hourly) • Manual blood pressure (q shift) • Mental Status	• Patients with CS have a high incidence of hemodynamic deterioration, arrhythmias, respiratory failure, pulmonary edema, and multiple-system organ failure. • An altered level of consciousness indicates a worsening condition and inadequate perfusion to the central nervous system.[14]

Invasive Monitoring	
Continuous Arterial BP monitoring (ART)	• To monitor MAP and blood pressure to determine response to fluid resuscitation and vasoactive medications.[2,3] • Document every hour on the nursing flowsheet or more frequently as warranted by patients' status • Note. Suppose the patient returns from the cardiac catheterization lab with an arterial sheath. In that case, it must be transduced to pressurized normal saline if it remains in place longer than 4-6 hours. See EH policy titled: *Monitoring and assessment of the critically ill: Adults only.*[23]
Continuous central venous pressure (CVP)	• A central venous line is recommended for administering vasoactive medications. • The central line must be transduced to pressurized normal saline. • Document CVP every 4 hours.[23] • A CVP is a measure of right-sided preload. • A single CVP measurement is an unreliable measure of fluid status; however, the longitudinal trend can provide information on fluid status.[3]
Pulmonary Artery (PA) Catheter *	• It can be beneficial in certain cases of CS, often considered early in the presentation of CS when there is a failed response to initial therapies or uncertainty in the diagnosis. Cardiologists select to use.[2,3,19] • Continuous monitoring of the PA catheter is required at all times.[23] • PA catheter provides indirect and direct measures.

	• All measurements are obtained on insertion and with changes in clinical status.[23] • Obtain and document the CO, systematic vascular resistance (SVR), pulmonary vascular resistance (PVR), and cardiac index (CI) at the beginning of your shift and with changes in the patient's status.[23] • Obtain and document the pulmonary capillary wedge pressure (PCWP) at the beginning of your shift and every four hours.[23] • Every hour, document the pulmonary artery systolic pressure (PAS) and pulmonary artery diastolic pressure (PAD).[23]
Urine output	• Monitor and document every hour.[23] • Indication of renal perfusion.[2,3,19] • **Goal:** at least 0.5 ml/kg/hour.[3]
Diagnostic Tools	
Chest X-ray	• Portable X-ray of the chest. • Cardiologist orders it on admission and with changes in clinical status. • It provides information, including the size of the cardiac muscle and pulmonary congestion. • It confirms the positioning of the endotracheal tube and devices in use, such as temporary pacer wires and mechanical circulatory device.[3]
ECG (Resting 12-lead)	• Used to diagnose a STEMI. • It can provide evidence of other conditions, such as **acute coronary syndrome** (ACS), pulmonary

	embolism, electrolyte imbalances, drug toxicity, and acute myocarditis.[34]
Transthoracic Echocardiogram	• Bedside ultrasound of the heart muscle. • It can help determine if there are mechanical complications. • Provides hemodynamic information, including left ventricular function. • It can assist the cardiology team in determining treatment plans.[3]

PA catheter

The PA catheter remains an important diagnostics and management tool for CS, even though clinical trials have shown no benefit with the routine use of a PA catheter.

The recommendation is the PA catheter be used for patients:

- who are not responsive to initial therapy or,
- in uncertain cases, to facilitate diagnosis. [3]

A PA catheter provides hemodynamic data that can:

- confirm the presence and severity of the CS and
- assist healthcare staff in determining the patient's response to treatment interventions.

The data obtained include the involvement of the right ventricular, pulmonary artery pressures and the pulmonary and systematic resistance of the arterial systems.[3]

Please refer to **Module 2** for a more in-depth exploration of hemodynamics and the nursing care of a pulmonary artery catheter.

EH Policy Documents and Forms

EH nursing policy: *Monitoring and Assessment of the Critically Ill: Adults only (Policy #: 214CC-CAR-030).*[23]

Monitoring and
Assessment of the Cri

Please review the policy to learn the minimum frequency of documenting non-invasive and invasive parameters for a critically ill patient. As clinical status changes, more frequent assessment and documentation are warranted to trend responses to treatment.

Laboratory Tests

As mentioned, laboratory evaluations can provide valuable information to the healthcare team. Biomarker levels and serial measurements can indicate the severity of the cardiac injury and the amount of cardiac necrosis.[3] See Table 1.6 for laboratory tests commonly ordered and used in patients who are at risk for CS and who develop CS.

Table 1.6

Laboratory Tests

Laboratory Tests	
Lactate	• **Elevated** lactate level is a nonspecific test indicating tissue hypoxia.[24] • **Elevated** lactate level (a lack of clearance of lactate) is associated with mortality in CS.[24] • **Timing**: every 1-4 hours.[3,19] • **Sample:** A lactate sample may be obtained from an arterial blood gas from an arterial line or arterial sheath. The Respiratory Therapist (RT) will run the test on the analyzer in critical care. Or a venous sample can be sent to the lab in a gray colour tube stored on ice. [25]

Arterial Blood Gas (ABG)	• Assess arterial oxygenation and ventilation. • Determine metabolic and respiratory acidosis disorders.[3,26] • ABG sample is obtained from an arterial line or arterial sheath, and the RT will run the test on the analyzer in critical care.
Mixed or central venous oxygen saturation	• Provides an oxygenation saturation of blood return to the heart from the superior, inferior vena cava and the coronary sinus.[3] • Normal 60 to 80%.[27] • A sensitive test and a decreasing level will be an early warning sign of inadequate oxygen supply-demand balance.[27] • **Mixed venous oxygen saturation** (SmvO2): obtained from the distal port of a pulmonary artery (PA) catheter. **Central venous oxygen saturation** (ScvO2): obtained from the distal port of CVP.[27] • Determine metabolic and respiratory acidosis disorders.[3,26] • **Low value**: Increased oxygen consumption and decreased oxygen delivery.[28] • **High value**: Decreased tissue oxygen consumption and increased oxygen delivery.[28]
Creatinine level	• Indication of renal function. • **Increasing** serum creatinine level with CS indicates renal hypoperfusion and is associated with poorer outcomes in CS patients.[29,30] • **Sample:** Venous sample sent to the lab in a 'SST' gold colour tube.[25]
Liver function tests	• Monitor for congestive hepatopathy and hypoperfusion. • **Increased** liver function tests (serum aspartate aminotransferase [AST], alanine aminotransferase [ALT], serum bilirubin [BILTO], and lactate dehydrogenase levels [LDH]) can occur with acute ischemia or congestive liver injury in the setting of CS.

	• Levels peak at 24-72 hours and return to baseline in 5-10 days.[3] • **Sample:** Venous sample sent to the lab in a 'SST' gold colour tube.[25]
Complete blood counts (CBC)	• **Timing**: every 12-24 hours; maybe more frequently if the patient is bleeding or at risk for bleeding.[3] • **Sample:** Venous sample sent to the lab in an EDTA (lavender colour) collection tube.[25]
Electrolytes	• **Timing**: every 6-12 hours; adjust timing based on electrolyte imbalances.[3] • **Sample:** Venous sample sent to the lab in an 'SST' gold colour tube.[25]
Coagulation labs (Coags)	• Commonly ordered PTT (partial thromboplastin time) and PT (prothrombin time). • Used to monitor the intrinsic coagulation pathway and for monitoring heparin therapy. Also, mechanical circulatory support devices require antithrombotic monitoring.[3] • **Timing:** every 6 hours for patients of intravenous anticoagulant until therapeutic stable, then daily in the morning. Or every 24 hours if the patient is not on anticoagulants.[3] • **Sample:** A venous sample of a full 3.2% Sodium Citrate tube mixed thoroughly (blue colour tube) and delivered to the lab within 1 hour of collection.[25]
B-type natriuretic peptide (BNP)	• BNP is one of the proteins that help regulate blood flow through the body. Increased levels are present in acute decompensated heart failure. Elevated levels of BNP are associated with increased mortality in CS with an ACS etiology.[31,32] • BNP is not a routinely ordered test at EH, as it has to be sent outside the province for analysis.[25]

Nursing Consideration and Practice Tips

The Newfoundland and Labrador Provincial Laboratory Formulary (PLF) provides an up-to-date and searchable registry of orderable laboratory tests and information.[25] If you cannot find the lab test mnemonic required for Meditech, use the PLF website search tool!

https://www.gov.nl.ca/labformulary/search-provincial-laboratory-formulary/

Vasoactive Agents: Inotropes and Vasopressors

If a patient continues to be hemodynamically unstable after intravenous fluid resuscitation, the next treatment of CS often relies on inotropes and vasodilators. Vasopressors are used to increase **systemic vascular resistance** (SVR) and blood pressure (BP), while inotropes increase cardiac output. However, the cardiologist and nurses are responsible for balancing escalating drug doses as they may have harmful effects.[33] Therefore, mechanical circulatory devices may be necessary.[3] Treatment aims to improve hemodynamic stability and adequate perfusion.[2.3,10]

Generally, vasoactive medications are titrated by nurses based on clinical endpoints or goals established in the physician orders, including:

- Mean arterial pressure (MAP) > 60mmHg.
- Urine output > 0.5ml/kg/hr.
- Cardiac index (CI) > 2.5 L/min/m.[1,3]

Please refer to **Module 3** for more information on the vasoactive medications used in CS.

Mechanical Circulatory Support (MCS) Devices

MCS are ventricular assist devices inserted to optimize the patient's hemodynamic status and provide cardiovascular support.[19] The MCS devices are used for right-sided, left-sided, or biventricular failure. The temporary mechanical circulatory support devices selected for use are based on established recommendations[3,19,] with consideration given to the known effectiveness of the device, the institutional experience and skillset, and device-related complications.[19]

Please refer to **Module 4** for more information on the MCS devices used in CS.

Other Critical Care Measures

- CS patients may often require mechanical ventilation due to worsening hemodynamic state, altered level of consciousness, and **multiorgan system dysfunction** (MODS).
- Glycemic control of a targeted blood glucose level of 8-10 mmol/L is recommended to avoid any episodes of hypoglycemia.
- Prophylaxis of thromboembolism.
- Stress ulcer prophylaxis.[19]

Quiz Activity 1.2

Please answer the following questions by circling the most appropriate answer. The answers can be found in Appendix B of the resource under Quiz Activity 1.2: Answer Key.

1. A 64-year-old male was admitted to the coronary care unit from the emergency room after suffering an AMI. As he arrives at your unit, you observe two vasoactive medications infusing. He has decreased level of consciousness, his colour is ashen and dusky, and his peripheral pulses are very weak and thready. What do you suspect is happening to the patient?

    a. Classic, stage C
    b. Deteriorating, stage D
    c. Extremis, stage E
    d. Not experiencing signs and symptoms of shock

2. What diagnostic lab test would you expect to be ordered to assess for CS?

    a. Lactate
    b. Troponin
    c. Complete blood count (CBC)
    d. Partial prothrombin time (PTT)

3. CS can cause congestive hepatopathy (liver congestion) and hypoperfusion.
    Please circle the answer.

    True   False

4. Which of the following blood work results would suggest worsening CS?

    a. PH 7.4, lactate 1.3 mmol/L, creatinine 50 umol/L
    b. PH 7.36, lactate 1.8 mmol/L, creatinine 42 umol/L
    c. PH 7.4, lactate 7.2 mmol/L, creatinine 220 umol/L
    d. PH 7. 43, lactate 1.0 mmol/L, creatinine 90 umol/L

Approach to CS

The emerging approach to CS care is an emphasis on early recognition and activation of a team-based approach.[10]

The goals of care for CS are:

- to identify and treat the underlying cause,
- improve heart pump effectiveness, and
- improve tissue perfusion.[2,3]

Some organizations have implemented code shock protocol which includes collaboration between multidisciplinary team members to use established pathways of care and code shock protocol.[10,15,34] EH does not currently have an algorithm or pathway for a code shock team-based approach.

The aims of a code shock are:

- an emphasis on rapid identification of a patient's hemodynamics and critical care needs and
- to rapidly deploy appropriate interventions.[10,15,34]

In addition, there is a recommendation to establish regionalized systems of care. The goal of regionalized systems of care emphasizes a patient should be transferred to hospitals with the appropriate resources to care for critically ill patients in CS.[10]

The HSC is the cardiac care hub for the province of Newfoundland and Labrador, with the province's only cardiac catheterization lab. It is necessary to appreciate that hospitals in other areas of Newfoundland and Labrador are not equipped with all the resources needed to provide care for CS. Therefore, healthcare professionals must work together to facilitate the timely transfer of patients with CS to the HSC to receive specialized cardiac care, where the possibility of survival is the greatest.[14]

Code Shock Team Approach

A code shock team approach is not currently implemented in coronary care at the HSC. However, there is still merit in reviewing the code shock team approach because this approach is supported in the literature and may be implemented in the future.

Implementation of a multidisciplinary code shock team approach over 52 months at the Ottawa Heart Institute reported that the initiative was feasible and may be associated with improved long-term survival.[15]

The pathway provides clinical indication criteria to identify CS in the patient that leads to the activation of the code shock; it includes both signs of hypotension and hypoperfusion.[15] See Table 1.7 below for the code shock activation criteria.

Table 1.7

Clinical Indications for Initiation of Code Shock

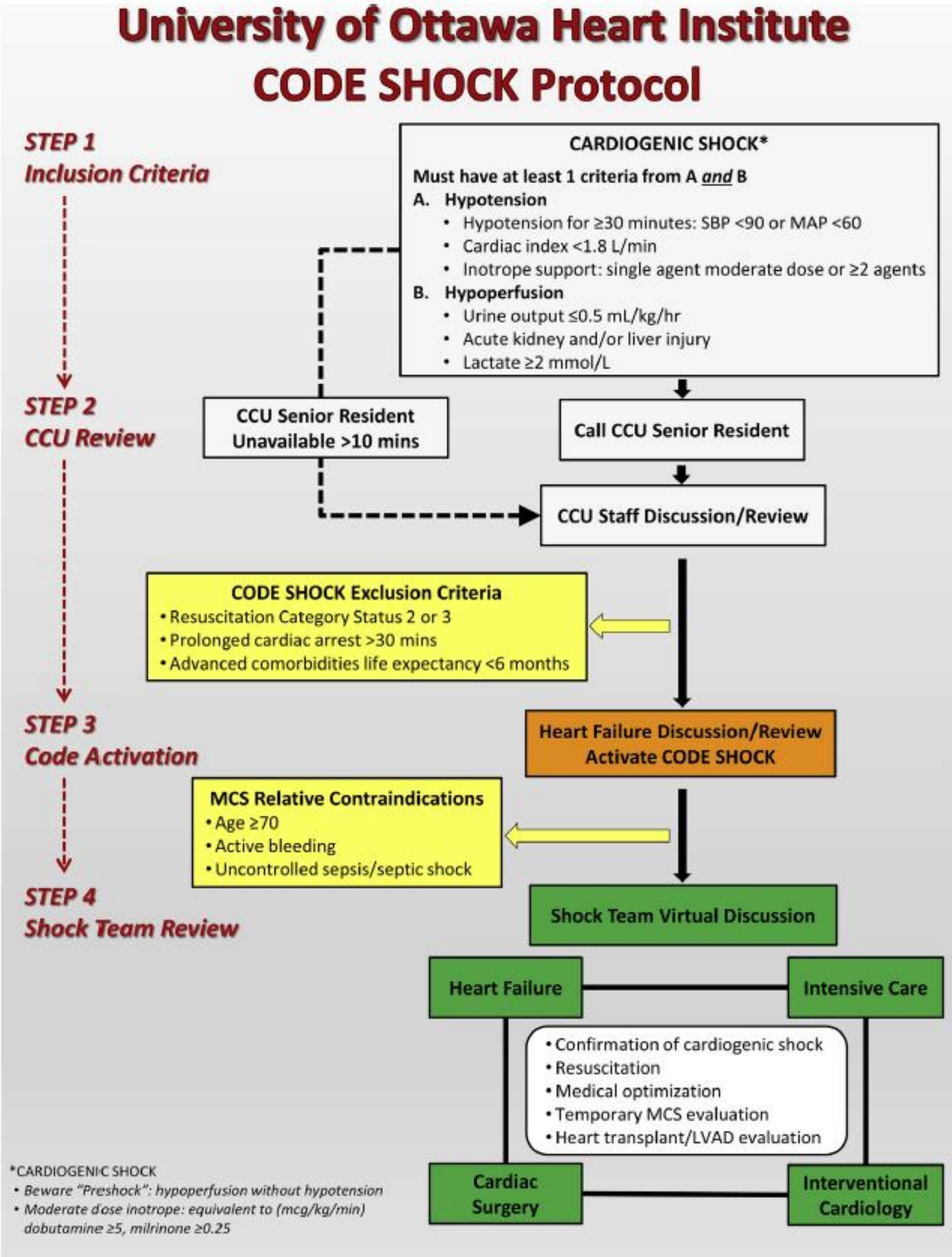
Clinical Indicators for Code Shock Initiation
Must have at least 1 criterion from A <u>and</u> B: **A. Hypotension** • Hypotension for > 30 mins SBP < 90 or MAP < 60 • Cardiac Index < 1.8 L/min • Inotrope/pressor support (1 agent moderate dose or $\geq$ 2 agents) **B. Hypoperfusion** • Urine output < 0.5 ml/kg/hr • Acute kidney or liver injury • Lactate > 2mmol/L

Source. From "Multidisciplinary code shock team in cardiogenic shock: A Canadian centre experience," by F. Lee et al., 2020, *CJC Open, 2(*4), p. 251 (https://doi.org/10.1016/j.cjco.2020.03.009). Copyright 2020 by Elsevier Inc. on behalf of the Canadian Cardiovascular Society. CC BYNC-ND.[15]

Please review Figure 1.5 for the University of Ottawa Heart Institute Code Shock protocol.

Figure 1.5

CS: Code Shock Protocol



Source. From "Multidisciplinary code shock team in cardiogenic shock: A Canadian centre experience," by F. Lee et al., 2020, *CJC Open, 2*(4), p. 251 (https://doi.org/10.1016/j.cjco.2020.03.009). Copyright 2020 by Elsevier Inc. on behalf of the Canadian Cardiovascular Society. CC BYNC-ND.[15]

Similarly, the New Brunswick Heart Centre implemented a nurse-led screening for CS using SCAI SHOCK classifications and a code shock protocol. The NB Heart Centre coronary care unit nurses would notify the coronary care resident, who would then communicate the findings to the coronary care attending physician. The attending cardiologist decided to activate the Shock Team, which consisted of immediate communication between the coronary care attending physician, interventional cardiologist, and cardiac surgeon on call. The NB Heart Centre reported that nurse screening was feasible with ongoing education.[35]. The implementation of the approach clearly outlines the goal-based therapies and the role of the physician and nurse. This initiative highlights the importance of your role as a coronary care nurse.

Reflection Exercise

Think about a patient at risk for CS.

1. What are your assessment findings?
2. Think about the patient's signs and symptoms. What are the characteristics of the different stages of CS?
3. Are you able to classify the stage of CS?
4. What is your justification for the conclusion drawn?

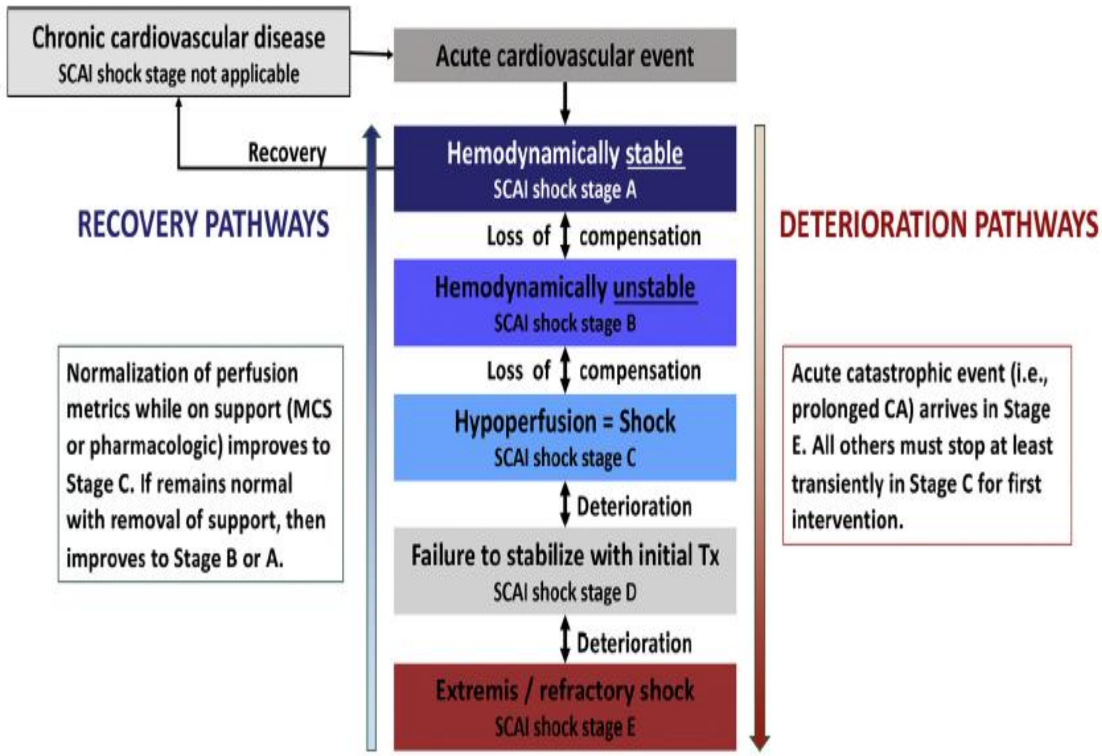
Nursing Role in CS

CS is a complex and potentially life-threatening complication, most commonly from AMI.[2,3] The coronary care nurse is the healthcare provider who typically spends the most time at the patient's bedside assessing and monitoring for status changes. Recognizing who is at risk for CS and the early signs and symptoms of CS is essential to allow for collaboration with the cardiac team leading to the rapid onset of evidence-based interventions to prevent complications and restore tissue perfusion to assist the patient with recovery.[10] You can use your knowledge and skills to implement the best available evidence-based management strategies in coordination with the multidisciplinary team.

CS is a dynamic process, and everyone involved in the patient's care must ensure that advanced supportive therapies can be activated and initiated based on the patient's clinical status.[3,14,15] Patients may respond to treatments, stabilizing and recovering, moving to a lower SCAI stage. Other patients may fail to respond to treatments or suffer an acute catastrophic event such as a cardiac arrest or myocardial rupture and continue to deteriorate, moving to a higher SCAI stage.[14] Please see Figure 1.6 for a depiction of CS's recovery and deterioration pathways.

Figure 1.6

CS is a Dynamic Process



Source. From "SCAI SHOCK stage classification expert consensus update: A review and incorporation of validation studies," by S. S. Naidu et al. 2022, *Journal of the Society for Cardiovascular Angiography & Interventions, 1(*1), p. 9. (https://doi.org/10.1016/j.jscai.2021.100008). Copyright 2021 by the authors published by Elsevier Inc. on behalf of the SCAI Foundation. CC BY-NC-ND.[14]

Reflection Exercise

Treatment for CS involves:

- Timely recognition.
- Team approach.
- Invasive hemodynamic monitoring.
- Minimize inotropes/vasopressors.
- Coronary reperfusion.
- Ventricular support.
- Circulatory support.
- Recovery.[3,19]

End-of-Life Discussions

CS has a high mortality rate, and some patients do not respond to treatment. The acute presentation of CS often does not allow patients, families, and healthcare professionals time to appropriately prepare advanced health directive discussions and goals of care determinants. Also, there is limited evidence available studying the timing of palliative care initiation in the CS patient population. With this in mind, healthcare professionals often note that curative therapies may be blended with palliative care early in the course of care.[3]

Palliative services reduce emotional and physical distress for patients and families.[36] Therefore, despite the limited research on palliative service and the CS patient population, it is recommended that palliative services be offered based on a patient-centred assessment.[3]

All healthcare professionals have a role in discussing the following:

- advanced care decisions,
- patient’s personal goals,
- emotional, practical, and spiritual support,
- symptom control and care, and
- illness understanding and trajectory in preparation for supportive care decision-making.[3]

Healthcare providers, during end-of-life discussions, should openly communicate with patients and families with clear information. Often patients are mechanically ventilated and unable to communicate; therefore, shared decision-making is with the healthcare professionals and the substitute decision-maker. Often decisions are made to withdraw any life-sustaining measures due to the high mortality rates and signs of cardiac demise despite aggressive efforts to improve cardiac function. The recommendation is to use an individualized approach to withdrawing life-sustaining measures and ensure any distressing signs and symptoms are managed promptly.[3,19]

The following are some nursing considerations for the withdrawal of life-sustaining measures:

- Discussing the withdrawal process with the substitute decision-maker and providing information on what to expect.
- If the patient experiences any distress during withdrawal, be prepared to respond promptly.
- It is recommended to place patients in a private room when possible.
- Encourage family members to be at the bedside and assist with care where appropriate.
- Administer pain medications based on signs and symptoms of pain, shortness of breath, and discomfort.
    - Morphine is the often-ordered for pain or dyspnea during the withdrawal process.
- Sedative medications may often be required for acute agitation.
- If possible, extubate to room air and avoid non-invasive mechanical ventilation.
- Remove all monitoring if not providing comfort to the patient.[3]

EH Policy Documents and Forms

Doctor's Order Sheet: Withdrawal of Treatment (Ch-1034 2013/10) [37]

Withdrawal of Treatment.pdf

Please review the Withdrawal of the Treatment doctor's order sheet, found on the EH intranet.

Conclusion

Thank you for completing Module 1! This module provided you with an overview of CS, including the main causes of CS, physical and biochemical markers of CS, diagnostic tools, staging of CS, evidenced-based treatments, and end-of-life care in CS. With this information and knowledge, you should be able to identify patients who are at risk for and who develop CS. Assessing and monitoring for CS signs and symptoms will allow you to intervene and initiate treatments to avoid the potentially catastrophic effects of CS. In addition, it is important to familiarize yourself with the SCAI classification of shock. The SCAI classifications provide a practical and easily applied process to the severity and acuity of the patient's condition. Remember to refer to Appendix F for a printable SCAI chart.

You may proceed to Module 2 to learn more about hemodynamic monitoring and the nursing care of a pulmonary artery catheter.

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Module 2

Hemodynamic Monitoring and the Nursing Care of a Pulmonary Artery Catheter

Module 2: Hemodynamics

The purpose of this module is to review the fundamental principles of hemodynamics and explore the goals of hemodynamic monitoring for adult patients at risk for and who develop cardiogenic shock. The module will focus on the use of a pulmonary artery catheter, a form of invasive monitoring used in patients with cardiogenic shock to diagnose and guide management therapies.

This module can be used by registered nurses practicing in a coronary care setting. It may also be beneficial for registered nurses practicing in other settings who want to learn more about this topic.

Before proceeding, it is recommended that you complete Module 1, as it provides foundational information on cardiogenic shock nursing care.

This module contains information, reflection exercises, case studies, documentation tips, tools for practice, and self-tests.

Learning Objectives

Upon completion of this module, you will be able to:

1. Identify the fundamental concepts of hemodynamic monitoring;
2. Explain the indications for hemodynamic monitoring with a pulmonary artery catheter;
3. Describe and set up the equipment needed for hemodynamic monitoring using a pulmonary catheter;
4. Describe the proper procedure to obtain accurate hemodynamic data from a pulmonary catheter;
5. Describe the direct and indirect measurements obtained from a pulmonary artery catheter and interpret the meaning of the measurements; and
6. Summarize mechanical factors that will lead to inaccurate measurements.

Hemodynamic Monitoring

Hemodynamics is the term used to describe blood flow through the body's circulatory system. Hemodynamic monitoring can be non-invasive and invasive monitoring. Non-invasive hemodynamic monitoring does not involve invasive instruments or catheters inserted into the body. Invasive hemodynamic monitoring is defined as catheters that are placed in central veins or passed through the right chamber of the heart.

Non-invasive forms of hemodynamic monitoring include:

- assessment of skin: colour, temperature, and moisture,
- non-invasive blood pressure monitoring,
- heart rate monitoring, including the quality of the pulse, and
- urinary output.

Invasive forms of hemodynamic monitoring include:

- central venous pressure monitoring from a central venous line,
- arterial blood pressure monitoring from an arterial line, and
- direct and indirect pressure measurements obtained from a pulmonary artery (PA) catheter.[1]

When a patient is in cardiogenic shock (CS), the recommendation is that the patient has access to specialized cardiovascular care in a critical care setting. Invasive hemodynamic monitoring in the form of continuous arterial blood pressure monitoring, central venous pressure, and central venous oxygen saturation are all recommended.[2] Using a PA catheter in selected patients with CS is warranted to guide CS diagnosis and the patient's responses to treatment[2]; however, it does not offer a mortality benefit or reduce the length of intensive care or hospital stay.[3]

Benefits of Invasive Hemodynamic Monitoring

Some of the benefits of invasive hemodynamic monitoring for patients with CS include the following:

- continuous arterial blood pressure monitoring:
    - to monitor response to fluid challenges,
    - to monitor response to vasoactive medications,
    - able to titrate and wean doses based on hemodynamic parameters, and
    - allows for frequent blood sampling, including arterial blood gas (ABG) and lactate levels. [2]
- central venous access and monitoring
    - to administer multiple medication intravenous infusions,
    - monitor the trend of central venous pressure (CVP) over time, and
    - monitor mixed or central venous oxygen saturation.[2]
- PA catheter
    - to obtain measures including cardiac output, cardiac index, PA pressures and right ventricular involvement.[2]

Remember, hemodynamic monitoring of any form is adjunctive to your nursing assessment. Accurate hemodynamic monitoring relies on your care and attention to the accurate setup, levelling and zeroing, and obtaining measurement properly.

There are basic principles of all forms of hemodynamic monitoring, and you can use your current knowledge as you refine your skills and learn more about the PA catheter. The following section will provide a review of the core concepts of hemodynamics.

Learning Video

Please watch the learning video from Edward Lifesciences Clinical Education to review the concepts of cardiac output.

Critical insights: Determinant of Blood Flow (6.47 mins)

https://www.youtube.com/watch?v=Sq0X0bp3K9s

Source. From *"Critical insights: Determinant of blood flow," by B. McIvor, Edward Lifesciences Clinical Education, https://www.youtube.com/watch?v=Sq0X0bp3K9s.*[4]

Cardiac Output

Cardiac output (CO) is the quantity of blood pumped out of the left ventricle over one minute.[1,5] CO is normally 4-8 L/min.[5]

CO = Heart rate x Stroke volume [1,5]

Stroke Volume

Stroke volume (SV) is the volume of blood ejected with each heartbeat.[1] SV is normally 60-100 ml/beat. [5]

SV = CO/HR x 1000

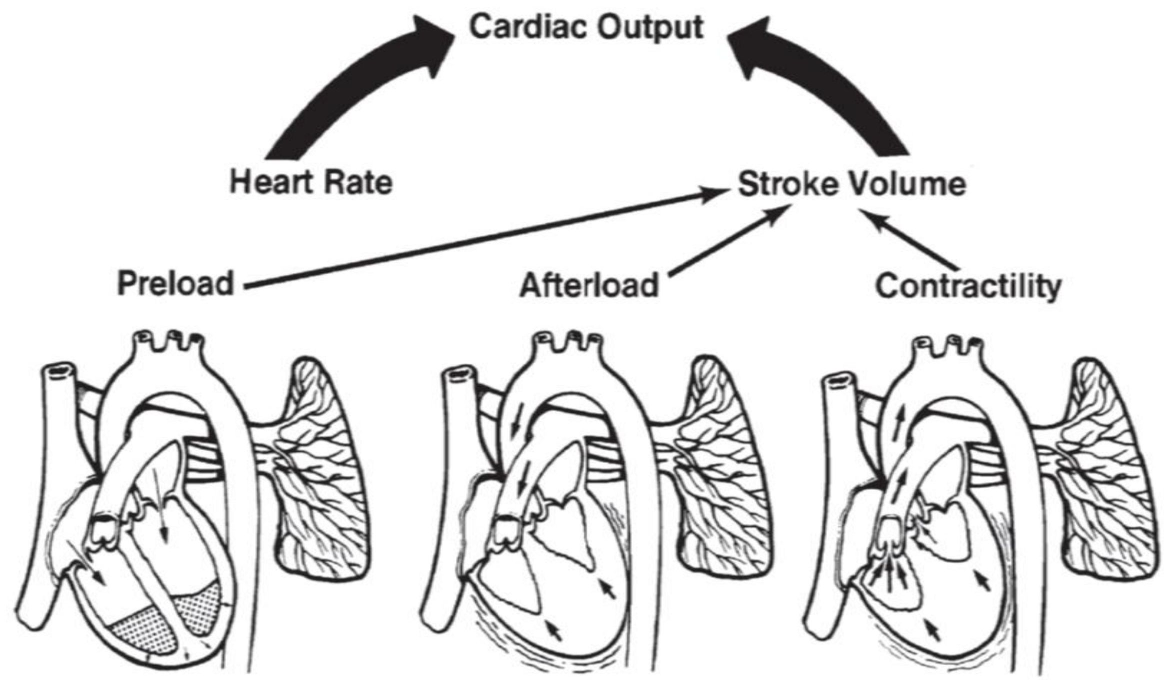
Remember, the preload, afterload, and contractility determine SV.

So, when assessing CO, you need to consider the impact of heart rate and the physiological determinants of SV.[6]

See Figure 2.1 for a depiction of CO.

Figure 2.1

Cardiac Output



Source. From "Anatomy and Physiology," by W. T. McGee, C. Young and J. A. Frazier (Eds.), *Edwards clinical education: Quick guide to cardiopulmonary care* (4th ed., p. 1.13), n.d., Edwards. Copyright by Edwards. Reprinted with permission.[5]

Preload

Preload is the stretch of the myocardial fibre at the end of diastole.[1,6]

Preload can be assessed regarding right heart preload and left heart preload.[5]

- Right heart preload: Right atrial pressure or central venous pressure (CVP).
  - CVP: 2 – 6 mmHg.[5]

- Left heart preload: Pulmonary capillary wedge pressure (PCWP).
  - On a cardiac catheterization report, the wedge is the left ventricular end-diastolic pressure (LVEDP).
  - PCWP: 6-12 mmHg.[5]

- To increase preload:
    - fluid resuscitation and
    - vasopressors.

- To decrease preload:
    - diuretics,
    - vasodilators,
    - positive end-expiratory pressure (PEEP),
    - fluid restriction,
    - and low-sodium diet.[1,6]

Remember

End-Diastole

- is defined as when the right and left ventricles have been passively filled and actively filled (by the atrial kick); they can receive no further volume.[5]

Afterload

Afterload is defined as the force that the right and left ventricles must work against to eject the blood volume.[6]

- Right heart afterload: Pulmonary vascular resistance (PVR)[5]
    - PVR: 100-250 dynes/sec/cm $^{-5}$
- Left heart afterload: Systematic vascular resistance (SVR)[5]
    - SVR: 800-1200 dynes/sec/cm^{-5}
- To increase afterload:
    - dopamine, and
    - norepinephrine (levophed). [2]

- To decrease afterload:
    - milrinone,
    - intra-aortic balloon pump,
    - angiotensin-converting enzyme (ACE) inhibitors,
    - vasodilators,
    - beta-blockers,
    - calcium channel blockers, and
    - morphine.[1,6]

Contractility

Contractility is defined as the heart's contraction force.

- To increase:
    - dobutamine,
    - dopamine,
    - calcium,
    - digoxin,
    - epinephrine,
    - milrinone, and
    - norepinephrine (levophed).
- To decrease:
    - beta-blockers and
    - calcium channel blockers.[1]

Heart Rate

- To increase:
    - atropine,
    - epinephrine, and
    - cardiac pacing.

- To decrease:
    - antiarrhythmics,
    - beta-blockers,
    - calcium channel blockers,
    - cardiac pacing, and
    - digoxin. [1]

Remember

CO = HR x SV

Normal CO = 4-8 L/min[5]

Quiz Activity 2.1

Please answer the following questions by circling the most appropriate answer. The answers can be found in Appendix C of the resource under Quiz Activity 2.1: Answer Key.

1. Cardiac output is defined as the amount of blood pumped out of the heart per minute.

    True False

2. What is the normal cardiac output value?

    a. 4 to 5 L/min
    b. 2 to 3 L/min
    c. 4 to 8 L/min
    d. 1 to 2 L/min

3. A normal cardiac index is 2.5 to 4 L/min[2]

True False

4. What hemodynamic value is reflective of the right-sided heart preload?

   a. PVR
   b. CVP
   c. PCWP
   d. SVR

5. What hemodynamic value is the reflection of the left-sided heart preload?

   a. PVR
   b. CVP
   c. PCWP
   d. SVR

Hemodynamic Pressure Monitoring: PA Catheter

The PA catheter is a flow-directed catheter with a balloon on the distal tip that flows into the correct position until it reaches the pulmonary artery when the cardiologist inflates the balloon. Please note PA catheters are also called SWAN or SWAN GANZ catheters.[5]

A PA catheter is inserted in CS patients to provide more diagnostic information and monitor responses to treatment.[2]

A PA catheter can monitor:

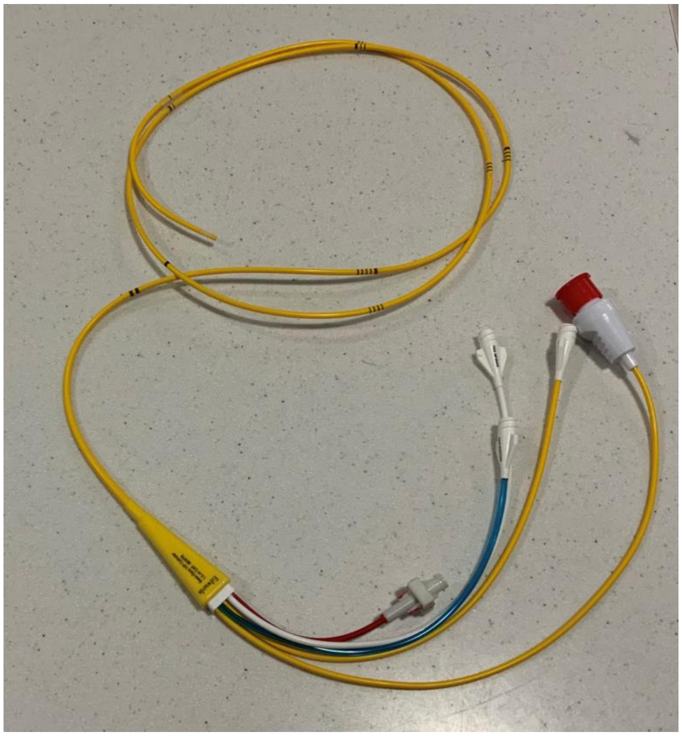
- preload,
- pulmonary pressures, and
- cardiac function indicators such as cardiac output measurement and mixed venous oxygenation. [1,6,7]

The correct interpretation of the numbers obtained from the PA catheter can accurately indicate the systolic function of the right and left heart performance.[7]

Figure 2.2 shows a standard PA catheter used in coronary care.

Figure 2.2

Standard PA Catheter



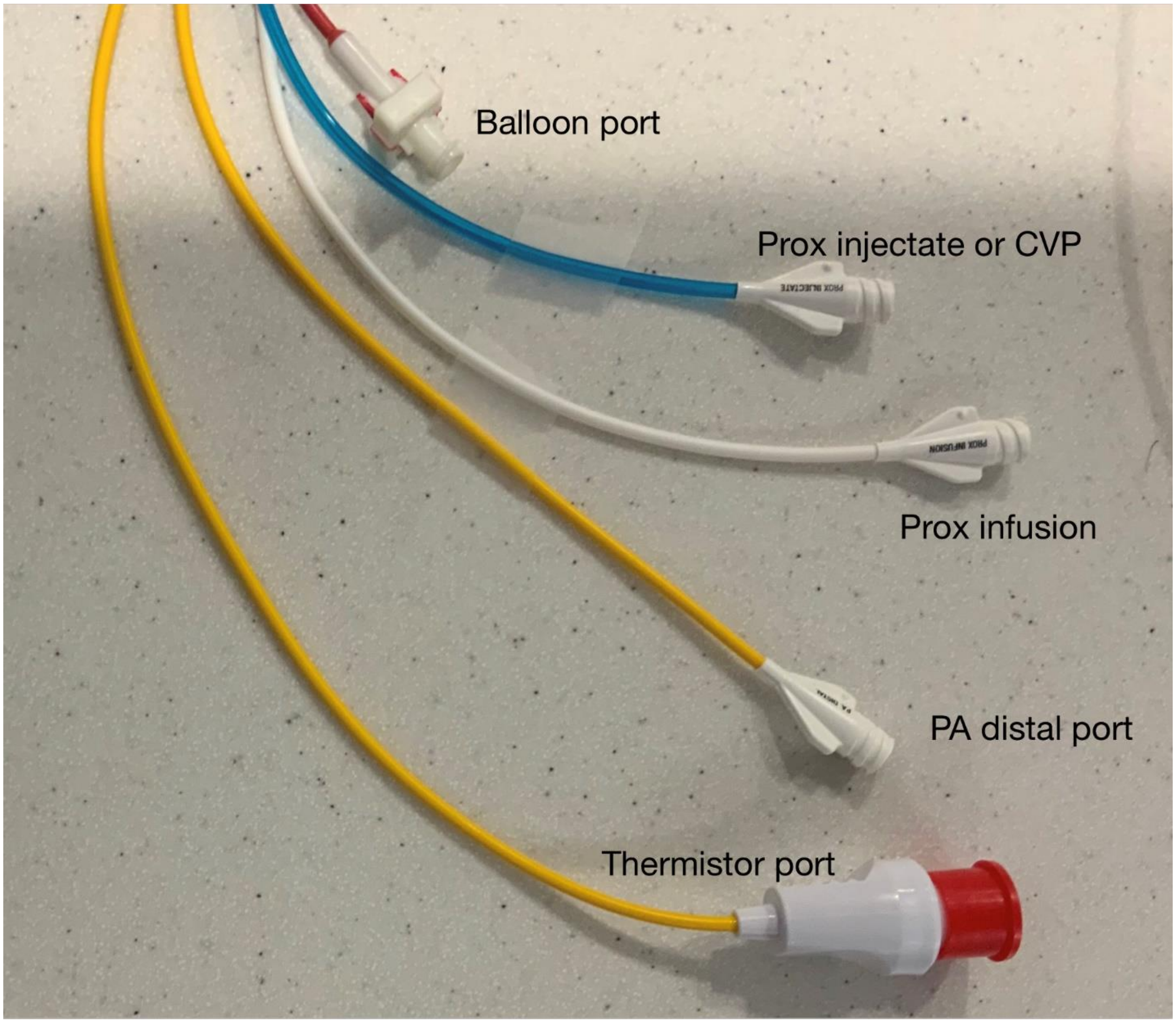
Source. From "PA catheter," by Neil (2023), personal photo collection.[8]

The parts of the PA catheter include (as shown in Figure 2.3):

- *Thermistor* port used to measure blood temperature;
- *PA distal* port used to measure pulmonary pressures;
- *Proximal (Prox.) infusion* port used for continuous infusions;
- *Prox. injectate* infusion port used for instilling fluid for cardiac output measurement, measuring CVP, infusing maintenance fluid and intermittent medication; and
- *Balloon* port with syringe connection port used for balloon inflation.[9,10]

Figure 2.3

PA Catheter: Labelled Ports



Source. From "PA catheter: Labelled ports," by Neil (2023), personal photo collection.[11]

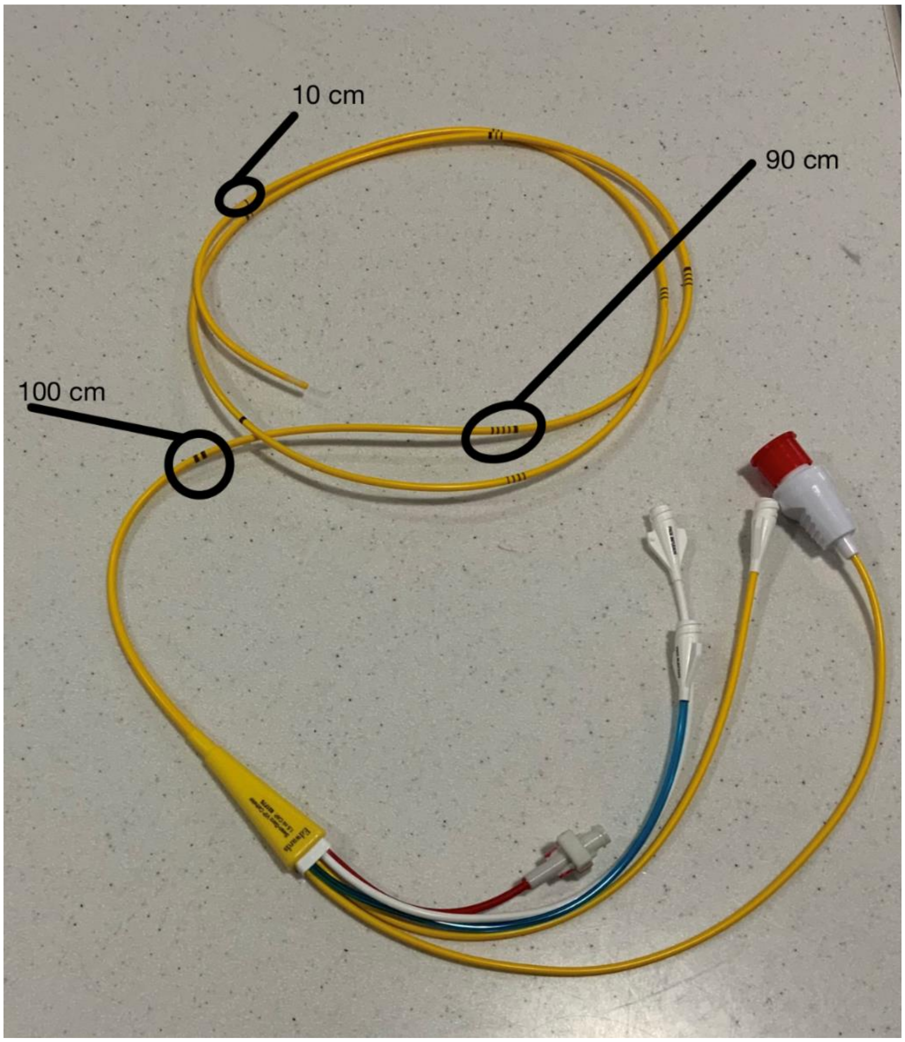
Nursing Practice Tips

Do not administer continuous medication infusions through the prox. injectate port**.**[9,10]

The PA catheter has distance markers on the catheter; the entire length of the catheter is 100 cm. The distance markers are in 10-cm intervals, with a small black line indicating 10 cm and the thick black line marking 50 cm. See Figure 2.4 for a closer assessment of the 10 cm interval markers.[5]

Figure 2.4

PA Catheter: Distance Marking



Source. From " PA catheter: Distance marking," by Neil (2023), personal photo collection.[12]

The most accessed PA catheter insertion sites are via a sideport inserted into the internal jugular and the femoral vein. [1.6] Depending on the insertion site and the patient's height, the insertion distance of the PA catheter will vary.[5]

See Table 2.1 for catheter insertion distance markings.

Table 2. 1

PA Catheter Insertion Distance Markings [5]

Location	Distance to Vena Cava/ Right Atrium Junction	Distance to Pulmonary Artery (PA)
Internal jugular	15 to 20 cm	40 to 55 cm
Subclavian vein	10 to 15 cm	35 to 50 cm
Femoral vein	30 cm	60 cm

Placement Chest X-ray

After the PA catheter is inserted, a chest X-ray is required to confirm the placement of the PA catheter. The distal tip of the PA catheter is radiopaque.[10]

Clinical Application

A sterile sheath will cover the PA catheter, but you should always note the approximate PA catheter's external measurement.

- Use the hub of the sideport (PA catheter inserted through) as a landmark for positioning.
- Now note the 10 cm intervals close to the sideport hub; remember, the catheter is marked in 10 cm intervals.
- Document on your flowsheet the approximate PA cath XX cm to the hub of the sideport.

PA Waveforms

The next section will explore the various PA waveforms that are produced when the PA catheter is inserted into the central vein and passes through the chambers of the heart.

You will need to monitor the pressure waveform during the insertion of the PA catheter.

- The PA catheter must be connected to pressure, and the transducer zeroed and levelled.
- Ensure that all lumens are flushed; you will be required to assist the cardiologist.[9,10]

Assisting with the setup and insertion of the PA catheter will be reviewed later in this module.

PA Catheter Pathway

Right Atrium

- The tip of the PA catheter is in the right atrium, and a CVP trace will be visible.

Right Ventricle

- The balloon is inflated, and the catheter ‘floats’ past the tricuspid valve into the right ventricle.

- An RV trace will be visible.
- It is common for the right ventricle to be irritated and have PVCs or VT, but this will settle as the catheter progresses.

Pulmonary Artery

- The catheter then 'floats' past the pulmonary valve and into the pulmonary artery, and the cardiologist will deflate the balloon.
- A PA trace will be visible.

PCWP

- If the catheter is inflated or termed "wedge the catheter," this advances the balloon into a segment of the pulmonary bed and produces a wedge trace.[9,10,13]

Learning Video

Please watch the learning video Sanz Ganz catheter placement animation video to review the presented concepts.

Swan Ganz catheter placement animation (1.12 mins)

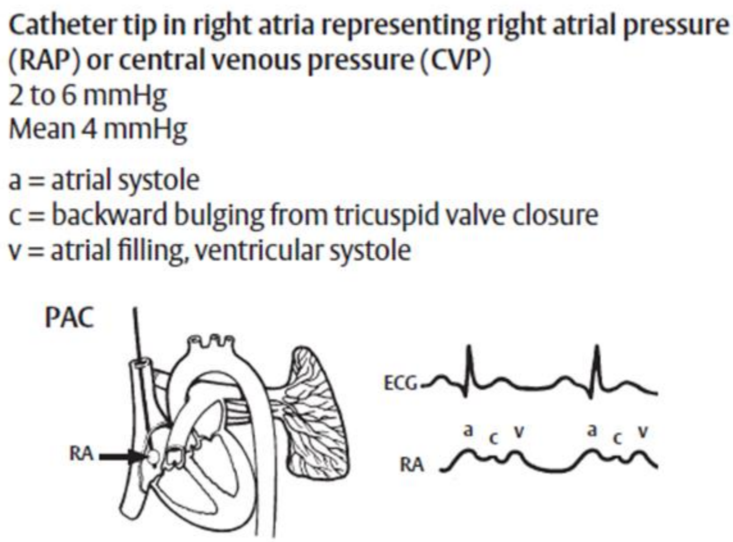
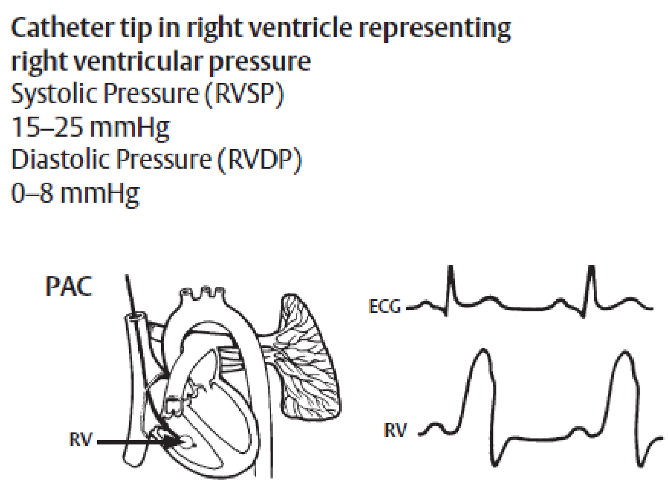
https://www.youtube.com/watch?v=PDMo9zfo0TA

Source. From "Swan Ganz catheter placement animation," by Edward Lifesciences Clinical Education, https://www.youtube.com/watch?v=PDMo9zfo0TA[14]

See Table 2. 2 for the normal PA pressures to be seen when the PA catheter is inserted. When the PA catheter is in place, the pulmonary artery pressures and waveform are continuously monitored.

Table 2.2

PA Pressures and Normal Waveforms

Catheter Tip	*Illustration (ECG trace and Pressure trace)*
Right Atrium • CVP: 2-6 mmHg	
Right Ventricular • RVSP: 15-25 mmHg • RVDP: 0-8 mmHg	

<table>
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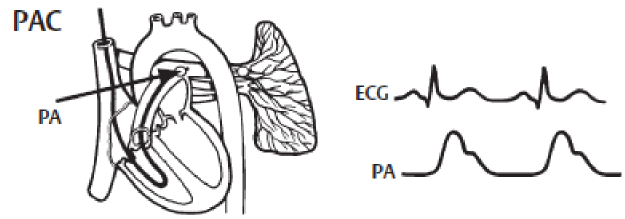
Pulmonary artery

- PAS: 15-25 mmHg
PAD: 8-15 mmHg
- Mean pressure: 10-20 mmHg
- This is the waveform that is continuously displayed and monitored.

</td>
<td>

Catheter tip in pulmonary artery representing pulmonary artery pressure (PAP)
Systolic Pressure (PASP)
15–25 mmHg
Diastolic Pressure (PADP)
8–15 mmHg
Mean Pressure (MPA)
10–20 mmHg



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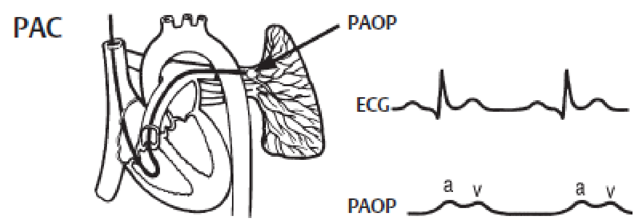
<tr>
<td>

Pulmonary wedge

- PCWP or PAWP: 6-12 mmHg
- When the balloon is inflated and the pulmonary moves to the pulmonary capillary bed, the waveform is seen (a, v).

</td>
<td>

Catheter tip in pulmonary artery representing pulmonary artery occlusion pressure (PAOP) or pulmonary artery wedge pressure (PAWP)
Mean 6–12 mmHg
a = atrial systole
v = atrial filling, ventricle systole

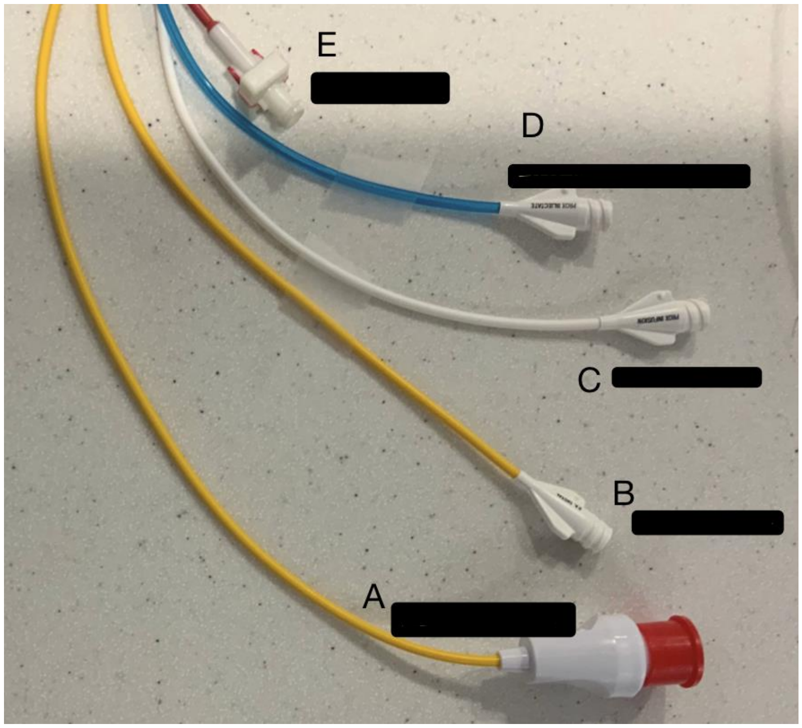


</td>
</tr>
</table>

Source. From “Swan-Ganz catheters: Advanced and standard technology,” by W. T. McGee, C. Young and J. A. Frazier (Eds.), *Edwards clinical education: Quick guide to cardiopulmonary care* (4th ed., p. 6.11-6.12), n.d., Edwards. Copyright by Edwards. Reprinted with permission.[5]

Interactive Activity 2.2

Please label the PA catheter ports and then identify which statement corresponds correctly to each port function. The answers can be found in Appendix C of the resource under Interactive Activity 2.2: Answer Key.



Source. From " PA catheter: Labelled ports," by Neil (2023), personal photo collection.[11]

A____________ ____________	PA distal port	Used to measure pulmonary pressures.
B____________ ____________	Thermistor port	Used to measure blood temperature.
C___________ ____________	Balloon port	Used to instill fluid for cardiac output measurement, measure CVP, for infusing maintenance fluid and/or intermittent medications.
D____________ ____________	Prox. infusion port	Used for continuous infusions.
E____________ ____________	Prox. injectate infusion port	Used for balloon inflation.

Remember

You are required to continuously monitor a PA catheter when it is inserted.

The pressure tracing displayed is the pulmonary artery pressure waveform. Document the PAS, PAD, and mean PA pressure every hour. Obtain and document the PCWP every four hours.[15]

Hemodynamics Measurements

Direct Measurements

- CVP: 2 – 6 mmHg.
- Right-sided intracardiac pressure (RV).
- Pulmonary arterial pressure (PAP).
    - PAS : 15-30 mmHg.
    - PAD: 5-15 mmHg.
    - Mean pulmonary artery pressure: 16mmHg.
- PCWP: 6-12 mmHg.
- CO: 4-8 L/min.
- Mixed venous oxyhemoglobin saturation (Sv02).[5]

Indirect Measurements

- SVR: 800-1200 dynes/sec/cm^{-5}.
- PVR: 100-250 dynes/sec/cm^{-5}.
- CI: 2.5-4 L/min/m^2.
- Stroke volume index (SVI).
- Left ventricular stroke work index (LVSWI).
- Right ventricular stroke work index (RVSWI).
- Oxygen delivery.
- Oxygen uptake.[5]

Nursing Practice Tips

In most cases, the PCWP equals PAD (pulmonary artery diastolic pressure).

- If you have trouble wedging the PA catheter, inform the resident or cardiologist. It is then coronary care practice to use the PAD value for the PCWP (wedge).

Abnormal PA numbers

Certain conditions and disease processes can contribute to *high* PA pressures, including:

- pulmonary hypertension,
- pulmonary embolism,
- positive pressure ventilation,
- constrictive pericarditis,
- cardiac tamponade,
- ventricular septal defect,
- fluid overload, and
- left heart failure.

Certain conditions and disease processes can contribute to *low* PA pressures, including:

- tricuspid valve stenosis,
- pulmonic valve stenosis,
- right ventricular failure,
- hypovolemia, and
- excessive vasodilation.[5]

Nursing Consideration and Practice Tips

Identifying the different pressure waveforms is important to avoid any potential complications.

Right ventricle pressure waveform

- If the catheter migrates back into the right ventricle, it can cause lethal arrhythmias such as ventricular tachycardia.

Wedge pressure waveform

- If the PA catheter migrates too far into the pulmonary artery, it can reduce or obstruct blood flow to the pulmonary artery causing a pulmonary infarct or rupture. [9,10]

Equipment and Setup for PA Catheter Pressure Monitoring

The equipment needed for PA catheter pressure monitoring is the same as that used for all other pressure monitoring lines, such as a CVP or ART line, with a few exemptions.

Please refer to Steps 1 through 6 and the corresponding Table 2.3 for a summary and illustrations of equipment used in coronary care.

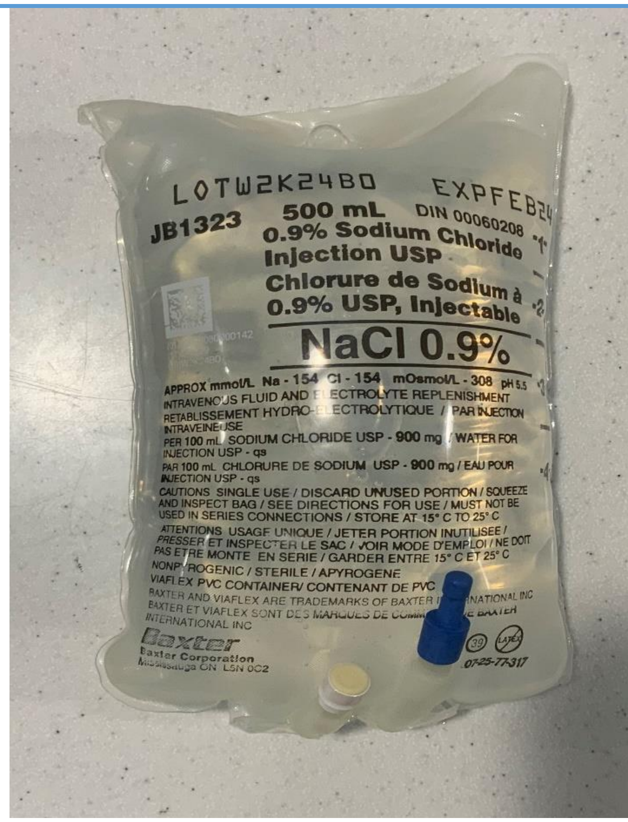
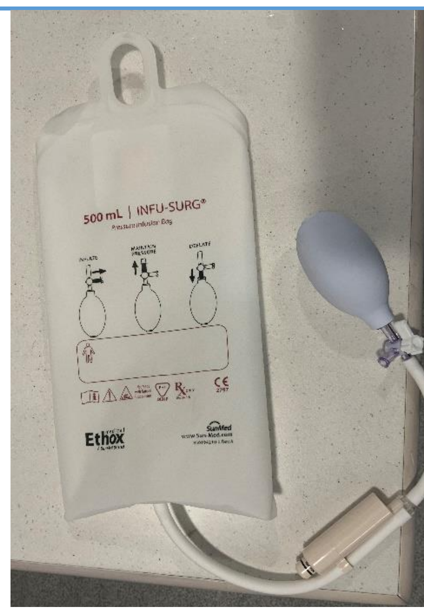
Step 1:

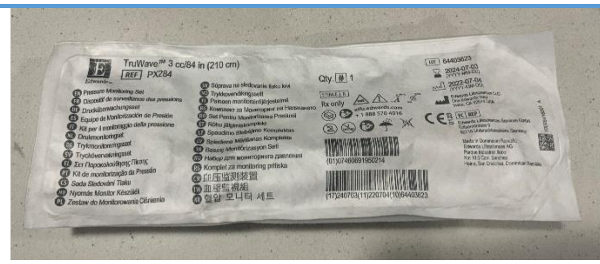
- Prime the pressure monitoring line with 500 ml of normal saline solution with a corresponding 500 ml pressure bag.

- Ensure to flush all stopcocks and change the vented caps to unvented caps. *Rationale*. Prevents blood from bleeding back if the stopcock is turned open in error.

Table 2.3

Summary and Illustrations of Equipment

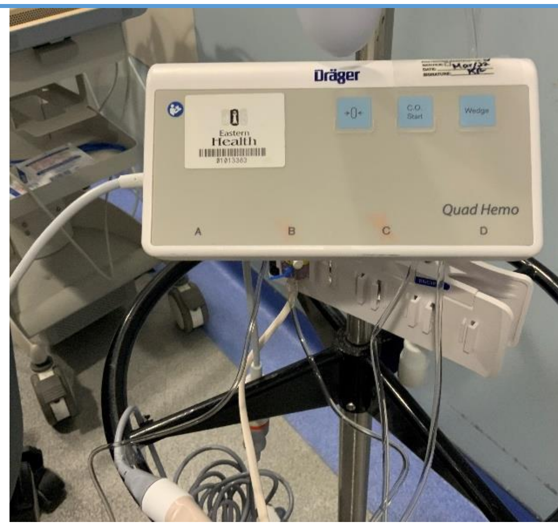
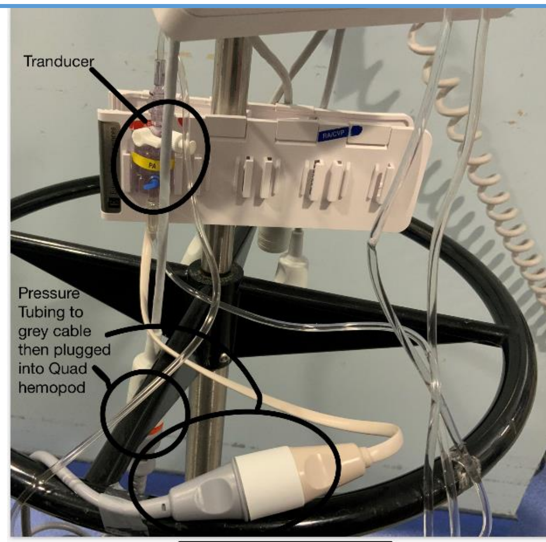
• **500 ml normal saline bag** 1. Change bag q 24 hours; done on nightshift at 0600hrs. 2. Place a white daily label on the bag with your initials, including the time hung. 3. Confirm the correct solution is being used each shift.	
• **Inflatable pressure bag** ○ Maintain pressure of 300 mmHg. ○ Deliver 3-5 ml/hr of fluid to keep the catheter patent. ○ Ensure accurate pressure tracing.	

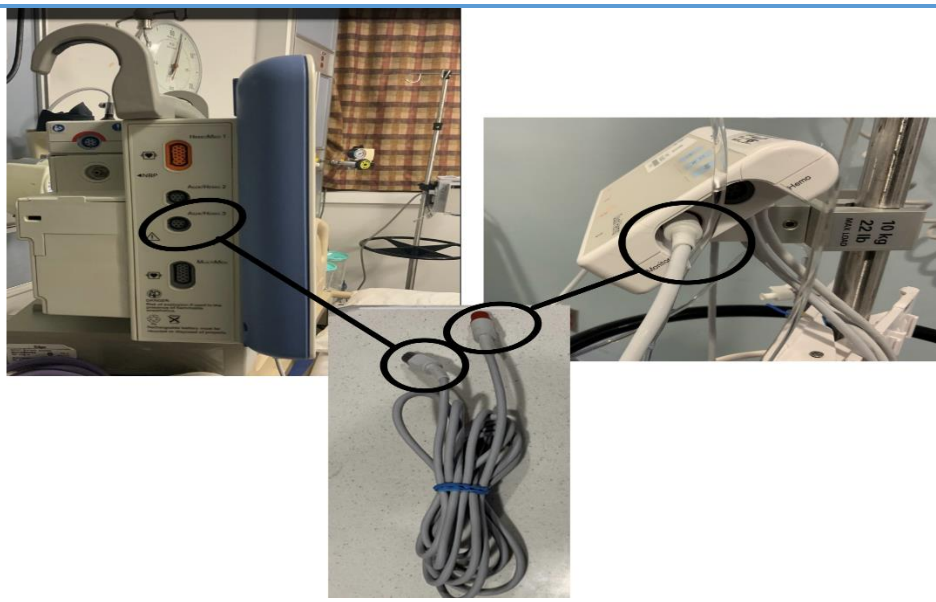
• **Pressure line monitoring tubing** ○ Disposable tubing; changed every 4 days. ○ Ensure all stopcocks have an unvented cap.	

Step 2:

- Hang the pressure bag on the bedside pole.
- Place the transducer on the white clip
- Connect the pressure monitoring tubing to the quad hemopod by using the grey cord with an orange end.
- Connect the quad hemopod to the bedside cardiac monitoring by using the grey cord with a red end.
- Ensure that the end of the pressure monitoring tubing remains capped.

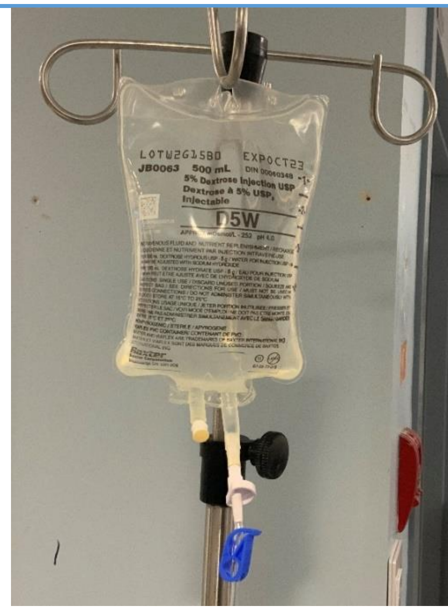
• **Pressure cable** ○ Able to measure one invasive pressure.	

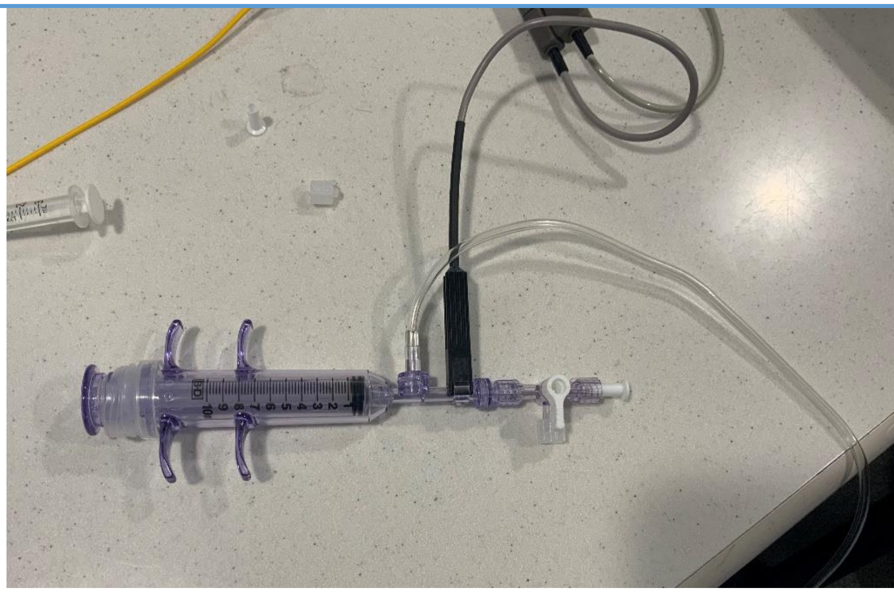
• **Quad Hemo** ○ Able to monitor four pressure via A, B, C, and D. ○ A pressure cable (grey colour with oranges end) connects to the pressure line monitoring kit, and a quad hemopod is connected to the bedside cardiac monitor (grey colour cord with red end).	
• **Clip** to hold disposable transducer located on the pressure monitoring tubing kit.	
• **Cable** to connect quad hemopod to the cardiac monitor.	



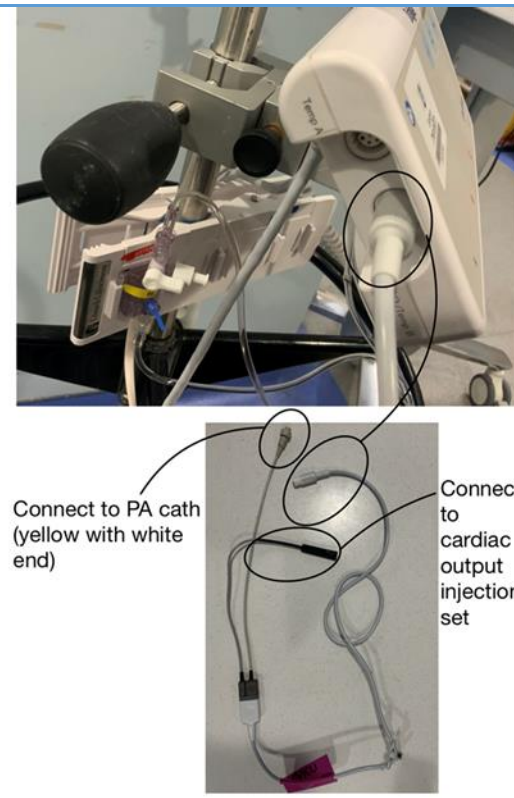
Step 3:

- Next, open the closed cardiac output injection set.
- Spike a 500 ml bag of IV 5% dextrose or 0.9 % N/S solution and prime the closed cardiac output set.
- Obtain the cardiac output cable and connect the black rectangle clip to the closed cardiac output injection set.
- Connect the cardiac output cable to the Quad hemopod.
- Prepare a plain intravenous line of maintenance fluid (ex. N/S or D5W).

• **Closed cardiac output injection set.**	
• **500 ml 5% Dextrose** ○ To be used with the closed cardiac output injection set.	
• **Cardiac output cable** ○ Stored in CVICU. ○ After PA catheter discontinued, please clean and return CO cable to CVICU nursing station for storage.	

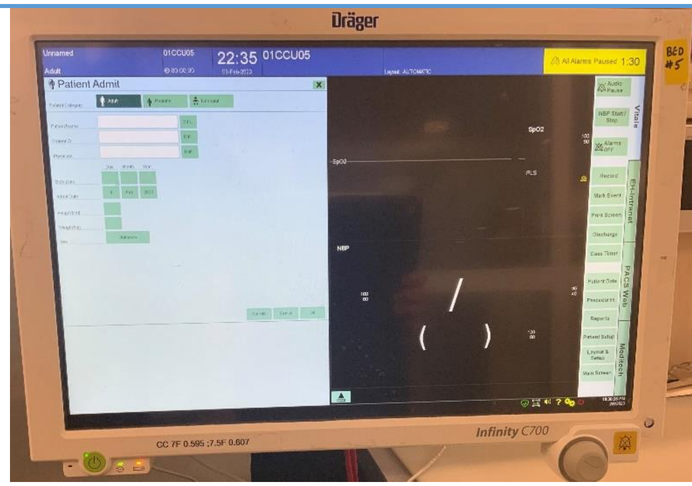
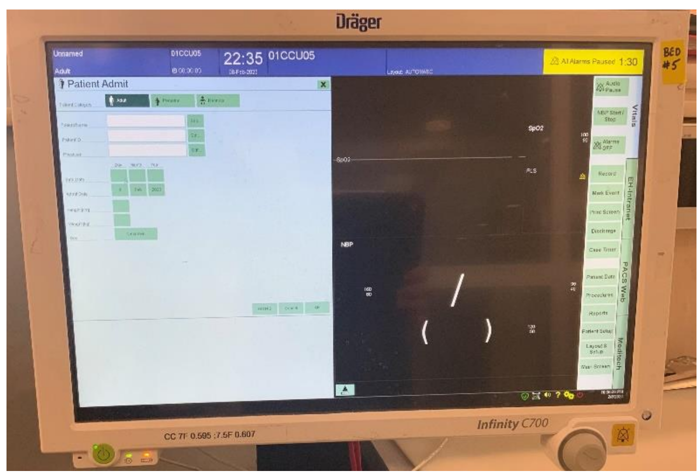


- Connect the cardiac output cable to the Quad hemopod.



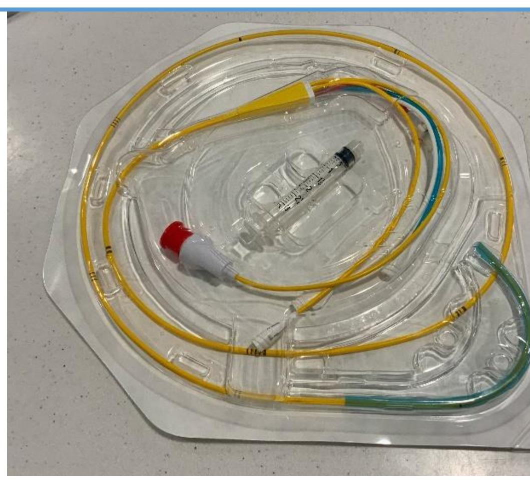
Step 4:

- Confirm the cardiac monitor has the correct information needed to calculate PA catheter measurements.

• Under the patient admit screen enter the patient: ○ Weight, ○ Height, and ○ Sex.	
• Under the monitor parameter screen, choose C.O (cardiac output). • Select the appropriate choices from the drop-down boxes. • The injectate volume is 10 ml. • The *Comp. Constant* is dependent on the PA catheter size. **7F: 0.595** **7.5 F 0.607** • *Reminder*. There is a sticker reminder on each of the Drager Infinity C700 monitors.	

Step 5:

- You are now ready to assist the cardiologist with inserting a PA catheter.
- For insertion, the cardiologist will need to “see” the pressure waveforms from the PA catheter. You will be required to connect the pressure monitoring line to the PA distal. Ensure the cardiac monitor can be seen by the cardiologist.
- You have your pressure monitoring line connected, and the transducer is levelled and zeroed.
- You have an IV maintenance bag ready to facilitate flushing all ports of the PA catheter. All ports of the PA catheter need to be primed. You can place a normal saline lock on the prox. infusion port (white line) after it is primed (solution will exit at the 30 cm mark).
- The cardiologist will test the balloon to ensure it inflates and deflates.
- The cardiologist will insert the percutaneous introducer sheath before inserting the PA catheter (The procedure is the same for any central venous device insertion).
- The PA catheter will be inserted through the sterile sheath.
    - *Rationale*. To keep the exterior of the PA catheter sterile so it can be repositioned as needed.
    - *Remember*. Sterile sheath the screw to the cardiologist and the knob to the nurse.

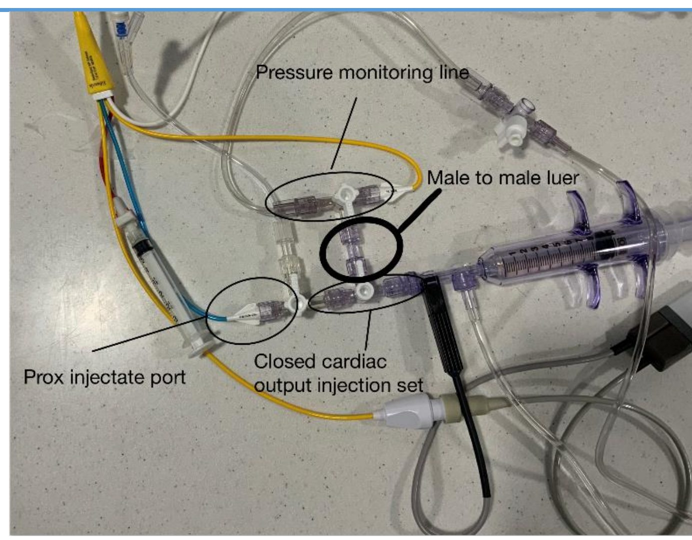
• **Swan-Ganz or PA catheter** in packaging.		

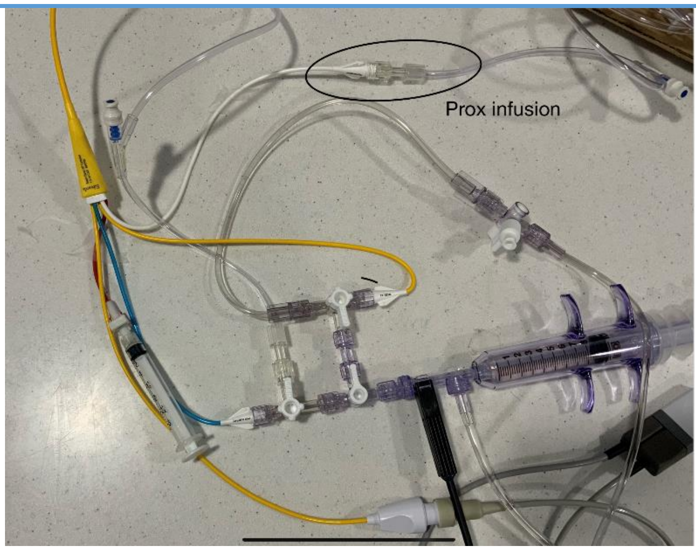
- Supplies for sideport insertion. Arrow percutaneous introducer 8.5 F sheath for use with 7- 7.5 F catheters.
- Sterile full-body drapes.
- Sterile smaller drapes (for coverage of head and neck).
- Chlorohexidine antiseptic cleaning swabs (large).
- # 11 blade, lidocaine plain, 5 ml syringe, 18 G needle and 25 1 ½ " needle.
- Tegaderm ™ CHG (Chlorohexidine pad) dressing.
- Sterile 10 ml normal saline syringes.
- Sterile gloves and gown for cardiologists.
- Other staff: masks and hats; laminated sign: "sterile procedure in progress" to post.

Step 6:

- Now it is time to finish building the "bridge" and connecting all the components.
- Take the pressure monitoring line and the closed cardiac output injection line; use a male-to-male luer to connect the distal pressure monitoring line stopcock and the closed cardiac output injection line.

- Use a male-to-male luer to connect the pressure monitoring line distal stopcock and the closed cardiac output injection line. *Remember*: the pressure monitoring line is already connected to the PA distal for insertion.
- Place an additional stopcock on the end of the closed cardiac output injection set and attach this to the prox. Injectate port. You may connect an intravenous



maintenance fluid at this stopcock. • *Remember*. Do not run continuous IV infusions via the prox. Inject port. *Rationale*. This is the port used to obtain cardiac output, and fluid bolus will occur. • *Remember*. Keep the lines clean and free from any contamination. You need to ensure that all stopcocks are primed with N/S before use.	
• "Yellow tail" with a white end to the cardiac output cable. Carefully make the connection between the two as fragile metal prongs.	
• When the catheter placement is confirmed, you may remove the N/S lock from the prox. infusion and begin intravenous medication infusions.[9,10,13]	

Source. From "PA catheter equipment," by Neil (2023), personal photo collection.[16]

Nursing Consideration

Invasive monitoring provides the most accurate measurement of pressure when the following are completed:

- the accurate levelling of the transducer,
- an appropriately zeroed system,
- all system components are working together, and
- the analysis of system dynamics is acceptable.[6]

Nursing Care of a PA Catheter

All invasive lines need to be zeroed and levelled to ensure accurate measurements are obtained.

- You are required to zero and level the line:
    - when the PA catheter is initially inserted,
    - at the beginning of your shift,
    - and prn.[15]
- You should also complete a dynamic square test at the beginning of your shift to ensure optimal readings are obtained.

Remember these concepts are the same as you have used for arterial (ART line) and CVP monitoring.[17]

Nursing Practice Tips

- Level and zero of PA catheter at the beginning of your shift and with any position changes.
- Document CVP every 4 hours.
- Obtain and document PCWP every 4 hours.
- Obtain and document CO at the beginning of your shift.
- Recheck CO with changes in clinical status, and interventions are provided, such as after fluid bolus resuscitation or the titration of inotropes or vasopressors medications.
- Continuously monitor the PA catheter.
  - Document the PAS, PAD, and mean PA pressure every hour.
  - Monitor for changes in PA waveform trace.
    - Ex. Balloon migration. [9,13]

What is Levelling?

The purpose of levelling is to remove any effects of hydrostatic pressure.[5]

The key point to remember is that the disposable transducer, located on the pressure monitoring tubing, is level to the phlebostatic axis.[17]

- The phlebostatic axis is at the level of the right atrium level. [5]

Clinical Application

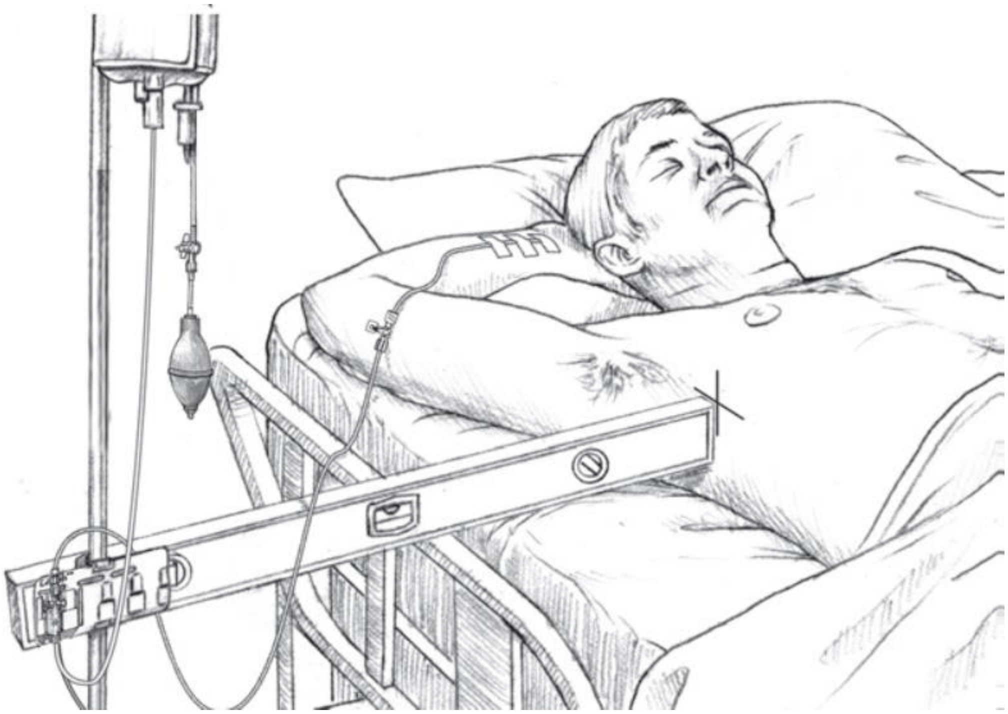
Have you ever seen the disposable transducer taped to the patient's right side when they were transported to coronary care from the emergency department?

Rationale. Taping the transducer to the patient's arm around the level of the right atrium (mid-axillary level) will keep the appropriate level for transport (at the phlebostatic axis).

See Figure 2.5 for an image of the phlebostatic axis.

Figure 2. 5

Phlebostatic Axis



Source. From "Basic Monitoring," by W. T. McGee, C. Young and J. A. Frazier (Eds.), *Edwards clinical education: Quick guide to cardiopulmonary care* (4th ed., p. 2.10), n.d., Edwards. Copyright by Edwards. Reprinted with permission.[5]

Nursing Practice Tips

Phlebostatic axis:

1. Find the angle of Louis (2nd Intercoastal space [ICS]) and count to the 4th ICS space.
2. Trace an imaginary line from the 4th ICS laterally around the chest.
3. Trace the imaginary line from the mid-axillary line.
4. Locate the point on the chest where the 4th ICS and mid-axilla line intersect; this is the right atrium area or the phlebostatic axis.[15]

Improper Levelling

Improper levelling must be avoided and corrected as soon as identified because it can impact the pressure reading, leading to over or under-treating the patient.

- If the transducer is too low, then false high readings.
- If the transducer is too high, there will be false low readings.[5]

Eastern Health (EH) Policy Documents and Forms

Arterial Lines and Hemodynamic Monitoring (Policy: 310-ER-CIRC-20)

Arterial Lines and
Hemodynamic Monitc

Please review the Arterial Lines and Hemodynamic Monitoring Policy on the EH intranet.[15]

Quiz Activity 2.3

Please answer the following questions by circling the most appropriate answer. The answers can be found in Appendix C of the resource under Quiz Activity 2.3: Answer Key.

As you begin your shift, you notice that the pressure line transducer has fallen from the holder. It is dangling below the level of the patient's bedframe.

1. The blood pressure reading displayed on the cardiac monitor is:

   a. Falsely low.
   b. Accurate.
   c. Falsely high.
   d. Inaccurate.

2. What is the anatomical reference point for levelling the pressure monitoring line transducer?

a. Left atrium
b. Right atrium
c. Left ventricle
d. Right ventricle

How to Zero a PA Catheter

The purpose of zeroing is to limit the atmospheric pressure on the pressure monitoring system.[5] You must zero and level the transducer at the beginning of your shift, with changes in the patient's position and prn.[15]

Steps to zero the transducer:

1. Remove the non-vented cap (white cap or blue cap) from the transducer.

2. "Turn the stopcock off to the patient and open to the air."

   - i.e. place the stopcock so it is open between the transducer and air.

3. Press the zero button located on the Quad hemopod or using the cardiac monitor rotary dial select the waveform to be zeroed and next select from menu the zero option.

4. A message prompt on the cardiac monitor will appear as "zeroed."

5. Close the stopcock by turning it to close to the air (atmosphere) and open it to the patient.

6. Replace the non-vented cap.[10,17]

How to Conduct a Square Wave Test

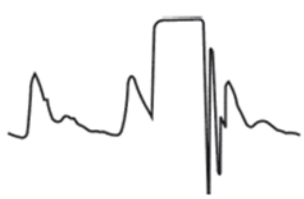
A square wave test ensures that the pressure monitoring system is operating as intended and presents the optimal pressure readings. Complete a square test at the beginning of your shift and anytime you are concerned with a dampened waveform. Refer to Table 2.4 for images and troubleshooting of the square wave test.

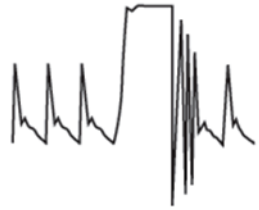
Steps to conduct a square testing:

1. Pull the blue tab on the transducer flush device.
2. Watch the bedside monitor the square wave will be generated.
3. Count oscillations after the square wave.
4. Observe the distance between the oscillations.[5]

Table 2.4

Square Wave Test

Square Wave	Waveform
Optimally damped • 1.5 – 2 oscillations before returning to tracing. • The values obtained are accurate.[5]	**Optimally damped: ACCURATE!** 

Underdamped • 2 oscillations. • Overestimated systolic pressure. • Diastolic pressure pressures may be underestimated. [5] ***Actions to take***: • Ensure there is an appropriate tubing length. • Remove any extra stopcocks. [17]	**Underdamped:** 
Overdamped • < 1.5 oscillations. • Underestimation of systolic pressures. • Diastolic may not be affected.[5] ***Actions to take:*** • Ensure adequate bag pressure (300 mmHg). • Check to ensure no air bubbles in the circuit (If so, clamp line and change set). • Potential indication of a blood clot; see if you can gently aspirate blood. If you cannot, notify MD and plan to remove the arterial line. • Make sure all connections are secure. • Check to ensure no kinks or obstruction of the catheter.[17]	**Overdamped:** 

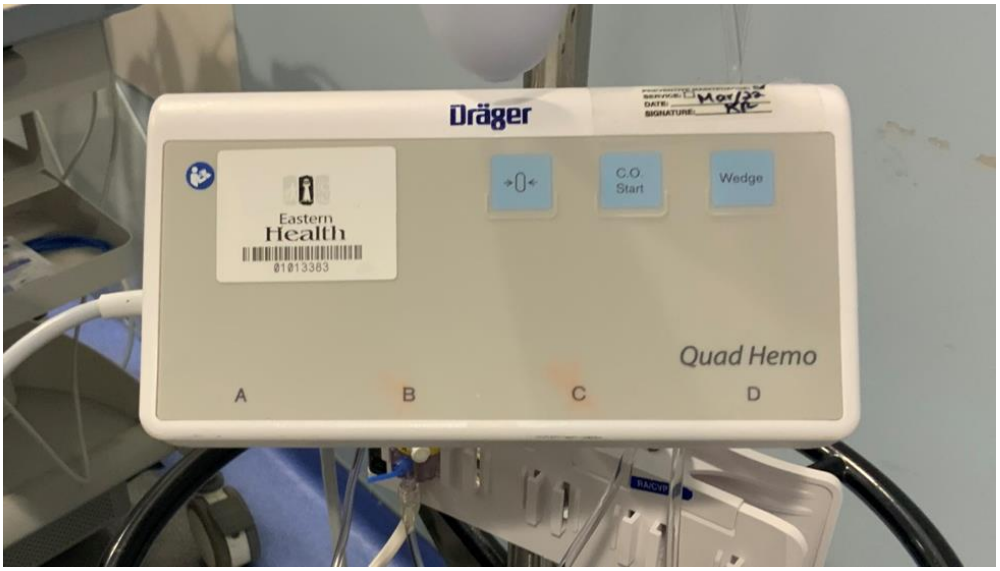
Source. From “Basic Monitoring,” by W. T. McGee, C. Young and J. A. Frazier (Eds.), *Edwards Clinical Education: Quick guide to cardiopulmonary care* (4th ed., p. 2.8), n.d., Edwards. Copyright by Edwards. Reprinted with permission.[5]

How to Wedge a PA Catheter

1. Remove the syringe attached to the PA catheter's red line.
2. Pull the plunge to instill 1.5 ml of air. Reattach the syringe to the connection and ensure that the redline on the white piece is straight (not locked position).
3. Slowly inflate the balloon while observing the PA trace on the bedside cardiac monitor, only instilling enough air to change the PA trace to a wedge trace.
4. Touch the wedge button on the Quad hemopod, as seen in Figure 2.6.
5. Allow the air to come back into the syringe passively, or remove the syringe, and the air will passively exit. Lock the red line to the off position. Confirm that the PA trace is displayed on the bedside cardiac monitor.
6. When the wedge pressure waveform is displayed on the bedside cardiac monitor, use the cursor up and down to capture the centre of the waveform. This is your wedge.[6]

Figure 2.6

Wedge Button on Quad Hemopod

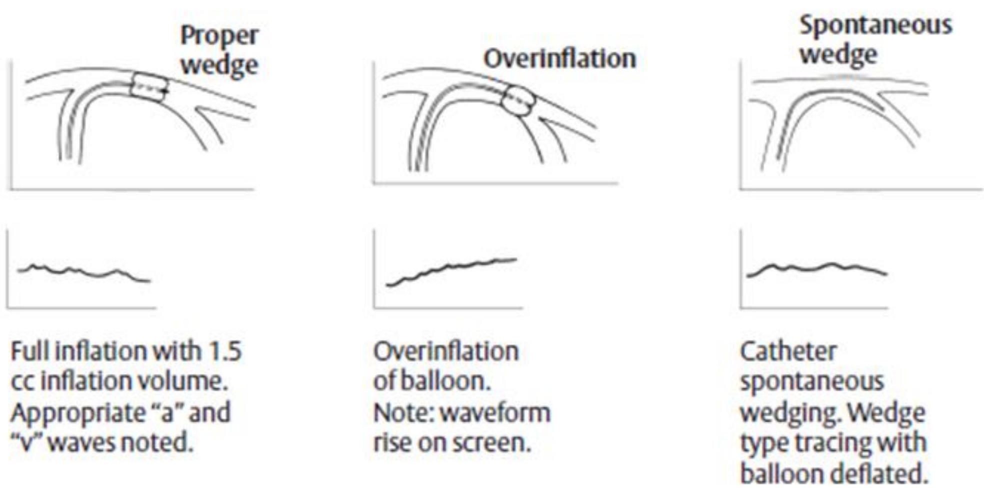


Source. From "Quad hemopod: Wedge button," by Neil (2023), personal photo collection.[18]

Please see Figure 2.7 for wedge waveforms for images of proper wedge waveform, overinflation, and spontaneous wedge.

Figure 2.7

Pulmonary Artery Wedge Waveform



Source. From "Anatomy and Physiology," by W. T. McGee, C. Young and J. A. Frazier (Eds.), *Edwards clinical education: Quick guide to cardiopulmonary care* (4th ed., p. 6.17), n.d., Edwards. Copyright by Edwards. Reprinted with permission.[5]

Nursing Practice Tips

PA catheter:

- Use the syringe that is provided in the PA catheter packaging as it is calibrated for 1.5 ml of air.
- Only instill enough air to change the pulmonary artery trace to a wedge trace; always passively deflate the balloon. Ensure you reattach the syringe to the balloon port in the locked position once the balloon has been passively deflated.
- Do not inflate the balloon if any resistance is met.[9]

Clinical Application

Important to know that there are incidences when PAD and PCWP do not correlate:

- pulmonary HTN,
- mitral stenosis,
- mitral regurgitation,
- severe aortic insufficiency,
- left atrial myxoma,
- decreased ventricular compliance (pericardial disease)
- increased ventricular compliance (dilated cardiomyopathy),
- pulmonary venous obstruction,
- increased end-expiratory pleural pressure (intrinsic or extrinsic PEEP), and
- poor placement in the pulmonary tree.[13,19]

How to Obtain Cardiac Output

Learning Video

Please review the following video of Swan Ganz catheter (PA catheter) bolus thermodilution.

Swan Ganz catheter bolus thermodilution animation (1.12 mins)

https://www.youtube.com/watch?v=Ju0UKTj0IC0

Source. From "Swan Ganz catheter bolus thermodilution animation," by Edward Lifesciences Clinical Education, https://www.youtube.com/watch?v=PDMo9zfo0TA.[20]

The thermodilution CO is the method used to determine CO.

1. Double-check to ensure patient data (height, weight) and the c.c. are correctly entered into the cardiac monitor.

2. Locate the proximal injectate port (blue line) on the PA catheter.

3. The closed cardiac output injection system is along a straight line with the proximal injectate port. Pull 10 ml of fluid into the closed cardiac output injection syringe.

4. Close the stopcocks off so there is a straight path from the syringe to the proximal injectate port.

    - This fluid will go past the temperature measurement black connection on the cardiac output cable, travel into the right ventricular, mix with blood and flow past the PA distal port, where the catheter will detect the temperature change.

5. Press the cardiac output button on the Quad hemopod.

6. Inject the fluid at a steady fast pace at the patient's end of expiration.

7. Watch the cardiac monitor and see the cardiac waveform.

8. When the cardiac monitor screen states "ready," repeat the steps and complete two more 10 ml cardiac output injections.

9. When three cardiac outputs have been obtained, you will get the average and select save the reference.

10. To calculate the hemodynamic parameters and print the information, follow the steps.

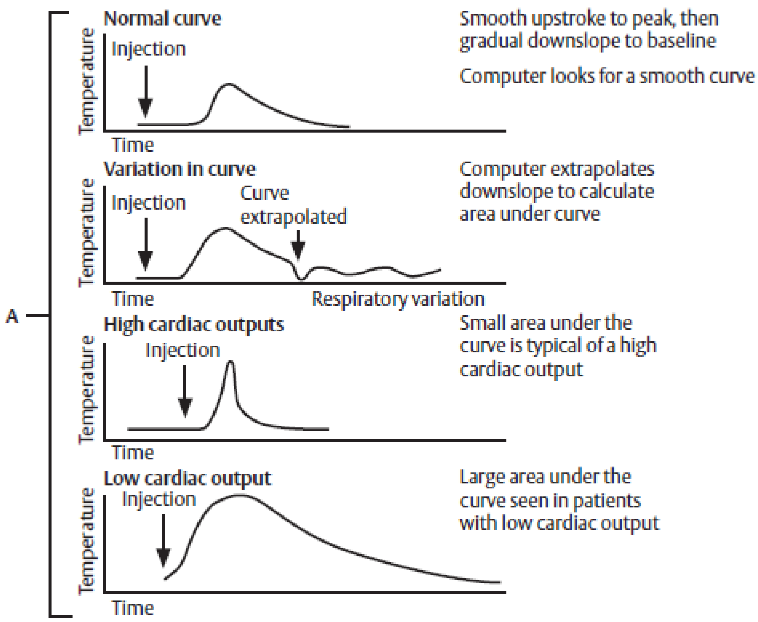
    - Menu-calculations-capture values (if required, add CVP and wedge)- calculate-save reference-print report.

    - The direct and indirect measures will calculate and printed at the nursing station printer.[6]

Please see Figure 2.8 for variations in CO curves, including a normal curve, variation in the curve, high CO, and low CO.

Figure 2.8

Variations in Cardiac Output Curves



Source. From "Advanced and Standard Technology," by W. T. McGee, C. Young and J. A. Frazier (Eds.), *Edwards clinical education: Quick guide to cardiopulmonary care* (4th ed., p. 6.28), n.d., Edwards. Copyright by Edwards. Reprinted with permission.[5]

Nursing Consideration

Potential complications related to an invasive PA catheter include:

- thrombus formation,
- vessel perforation,
- circulatory and neurovascular impairment,
- bleeding, and
- nosocomial anemia. [9]

Conclusion

Congratulations on completing Module 2. This module provided you with an overview of hemodynamics, including the fundamental principles of the determinants of cardiac output: heart rate and stroke volume (preload, afterload, and contractility).

The inclusion of images and video links provided a visual learning opportunity to supplement the intext learning. You should be able to explain the principles of hemodynamics and understand how a change in one determinant will impact the patient's hemodynamic status.

Furthermore, you should be able to describe the components of the PA catheter, including the process of setting up, maintaining, and using the PA catheter. The module included images of hemodynamic equipment and the PA catheter used in your nursing care unit to ensure the content was relevant to your practice. In addition, the PA catheter insertion animation video was provided to allow for visualizations of the anatomical location of the PA catheter.

Your new knowledge will allow you to correctly obtain, interpret, and apply the direct and indirect measures obtained from a PA catheter to your nursing care for a patient at risk for and who develops CS.

You can proceed to Module 3 to learn about vasoactive medications used in CS.

Enjoy the learning!

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Module 3

Vasoactive Medications

Module 3: Vasoactive Medications

The purpose of this module is to review vasoactive medications used in cardiogenic shock. The module will focus on the nursing management of vasoactive medications. The information includes preparing, initiating, administering, titrating, and weaning vasoactive medications. The module will explore the hemodynamic effects of vasoactive medications for a patient at risk for and with cardiogenic shock.

Creating consistent nursing practices for the titrating and weaning of vasoactive medications is recommended based on the best available evidence-based information. It is understood that the titration and weaning of intravenous vasopressor and inotropic medication is not an exact science but depends on the patient's response and the cardiologist's target goals of therapy.

Before proceeding, it is recommended that you complete Module 1, as it provides foundational information on cardiogenic shock nursing care.

This module contains information, reflection exercises, case studies, documentation tips, tools for practice, and self-tests.

Learning Objectives

Upon completion of this module, you will be able to:

1. Explain the indications and contraindications for vasopressor and inotropic medication;

2. Describe the desired and expected effects of vasopressor and inotropic medications;

3. Summarize and choose the appropriate monitoring parameters for each vasoactive medication;

4. Explain the proper technique to administer and mix vasopressor and inotropic medications;

5. Discuss the process of initiating, titrating up, and weaning down medications based on patient hemodynamic response; and

6. Identify the hemodynamic effects such as cardiac output, systematic vascular resistance, and pulmonary vascular resistance related to vasoactive medication usage for patients with cardiogenic shock.

Vasoactive Medications and Cardiogenic Shock

Inotropic agents and vasopressor medications are first-line treatment options for a cardiogenic shock (CS) patient with either acute myocardial infarction or heart failure causes.[1,2,3] They are administered to greater than 90 % of patients with CS.[4]

These medication treatments aim to:

- increase cardiac output, and
- maintain adequate blood pressure.[1,2,3]

Typically, the targeted mean arterial blood pressure for a patient in CS is 65 mmHg[4,] and medication doses are titrated to attain the targeted mean arterial pressure.[1,2,3,4]

An important consideration is that inotropic and vasopressor medications are frequently utilized to increase cardiac output and maintain blood pressure; however, researchers have reported that mortality is higher with increasing doses of inotropic and vasopressor medications used. [4] In addition, there is limited evidence to guide the selection of inotropic agents in patients with CS.[5]

The inotropic and vasopressor medications can:

- increase myocardial oxygen consumption and vasoconstriction, which
- leads to impaired microcirculation and increased afterload.[1,2,3,4]

The recommendation is to administer catecholamines but attempts to avoid unnecessary high doses and wean when hemodynamic status permits weaning.[1,2,4]

- There are higher mortality rates with increasing doses of inotropic and vasopressor medications.
- New evidence supports a greater emphasis on using mechanical circulatory support devices.[1,2,3]

- Refer to **Module 4** for more detail on the use of mechanical circulatory support devices in patients with CS.

Norepinephrine is the first-line vasoconstrictor medication for CS.

- The American Heart Association suggests that norepinephrine may be the vasoconstrictor of choice for CS patients because it is associated with fewer arrhythmias than dopamine.[3]

- The European Society of Cardiology also recommended norepinephrine as the vasoconstrictor of choice when blood pressure is low and tissue perfusion is inadequate. This recommendation is based on a meta-analysis suggesting lower mortality rates with norepinephrine over epinephrine or dopamine.[1]

- There is still further research on the optimal first-line vasoactive medication choice. [3]

CS is complex, with many causing factors; therefore, the cardiologist will select the most appropriate medication based on all the available data, including clinical presentation, assessment, and hemodynamic information.[1,3]

- Remember that the initiation, titration, and weaning of vasoactive medication depends on the individual patient and targeted therapy goals.

- Use your clinical assessment, hemodynamic monitoring measurements, and patient response to medication therapy to guide your practice.

Remember

Norepinephrine is the recommended first-line vasoconstriction for CS.

Norepinephrine (Levophed)

- First-line agent for CS

Method of Action

- Alpha-/Beta- Agonist
  - Stimulates beta-receptors and alpha-receptors.[6]
- *Low doses* activate the beta-1 receptors to increase contractility and augment cardiac output.
- *Higher doses* activate alpha receptors, limiting inotropic effects due to increased vasoconstriction.[7]
- Onset: rapid, and duration: 1-2 minutes (mins).[8]

Indications for CS

- Norepinephrine is the vasoconstrictor of choice when blood pressure is low and there is insufficient tissue perfusion for CS patients.[1]
- Norepinephrine is used to treat acute hypotensive states, cardiac arrest, and shock states.[7,8]
- Before starting norepinephrine infusion, ensure the patient has adequate preload.[8]

Goal of Therapy

- The optimal goal of therapy is not well established, but the recommendation is to titrate to maintain end-organ perfusion.
  - Mean arterial pressure (MAP) > 60mmHg.
  - Urine output > 0.5ml/kg/hr.
  - Cardiac index (CI) > 2.5 L/min/m.[3] (van Diepen et al., 2017)
- Cardiologist will order the target goals of the therapy.[3,8]

Dosing

- Weight-based dosing
    - IV Initial dose: 0.02 mcg/kg/min; titrate based on the clinical goals of therapy.
    - ***Dosage Range*: 0.05 to 0.4 mcg/kg/min**; [3,6,9]
    - ***Usual Dosage Range at HSC: 0.02-0.2 mcg/kg/min***.
        - If the dose reaches 0.2 mcg/kg/min and the targeted therapy goals are not achieved, nurses are required to notify the resident or cardiologist. The physician will complete an assessment of the patient's status, and subsequent titrations above 0.2 mcg/kg/min will then be ordered.

- Cardiologist order should include the following:

    - Starting dose in mcg/kg/min, maximum dose, titration dose, frequency, and desired vital sign effect.

    - ex. Start levophed infusion at 0.02 mcg/kg/min and increase by 0.02 mcg/kg/min q 5 min until SBP > 90 mmHg.[8]

- **Initiation and Titration** (up)
    - Start at the ordered dose and increase rapidly to obtain an adequate BP.
    - Increase by 0.02 mcg/kg/min q 3-5 minutes (since onset is rapid).[6,8]
- **Weaning** (down)
    - Weaning is dependent on BP.
    - Usual rate of weaning is 0.02 mcg/kg/min q15 min.
    - You will see the effects of weaning quickly (within 1-2 mins, as norepinephrine is a very short duration).[8]

Administering and Mixing

- Continuous infusion via an infusion pump.
- Central line is preferred.
- Peripheral line can be used for a short duration (< 72 hours) through a peripheral intravenous (IV) in a large vein at a proximal site (ex., antecubital fossa).

    - Frequent monitoring of IV site for extravasation.

- Dilute vial prior to use:
  - **8 mg in 250 ml** Dextrose 5% in water (D5W) or 0.9 % N/S (peripheral line)
    - Mixed concentration: 32 mcg/ml
  - **16 mg in 250ml** D5W (central line)
    - Mixed concentration: 64 mcg/ml
- Avoid abrupt withdrawal; reduce infusion flow rate slowly.
  - Abrupt stoppage of norepinephrine can cause severe hypotension.[6]

Nursing Consideration and Practice Tips

Do not administer norepinephrine with sodium bicarbonate (in the same intravenous y-connection), as the inactivation of norepinephrine may occur.[6]

Adverse Reactions

- Cardiovascular
  - Bradycardia, cardiac arrhythmia, cardiomyopathy (stress), peripheral vascular insufficiency.
- Central nervous system
  - Anxiety, transient headache.
- Respiratory
  - Dyspnea.
- Peripheral ischemia (< 1 %).[6]

Precautions/Warnings

- Hypersensitivity, allergic-type reactions.
    - Product may contain sodium metabisulfite.
    - Use in caution with asthma and sulphite allergy.
    - Allergic-type reactions, including anaphylactic symptoms and life-threatening asthmatic episodes.
- Extravasation.[6]

Extravasation Management

- If extravasation occurs:
    - Stop infusion immediately and disconnect the IV tubing.
    - Gently aspirate the extravasated solution but do not flush the line.
    - Remove the intravenous cannula.
    - Elevate extremity.
    - Resident or Cardiologist to initiate phentolamine antidote.
        - Obtain a physician's order to initiate antidote.
        - Dilute 5 to 10 mg in 10 to 15 mL NS.
        - With a fine hypodermic needle, administer intradermally into the extravasation site.
        - Should be administered as soon as possible after extravasation; if longer than 12 hours, it may be ineffective.
    - May readminister in 12 hours if the patient remains symptomatic.
    - Apply a dry warm compress. [6,8]

Monitoring

- Continuous cardiac monitoring is indicated.
    - Watch for tachycardia.[6,8]
- If peripheral intravenous infusion, then monitor for skin necrosis from extravasation.
- Continuous arterial line blood pressure monitoring is preferred.
- Non-invasive blood pressure.
    - Titration (up) or weaning (down): every 5- 15 mins.
    - If stabilized: every 30 mins - 1 hour.
- Intravascular volume status.
    - Auscultate heart and lung sounds at least every 2- 4 hours.
- Urine output via foley catheter, every 1 hour.[8]
- Peripheral perfusion: skin integrity, temperature and moisture.[6,8]
- PA catheter in use monitor cardiac output and pulmonary capillary wedge pressure.[6]
- Use your nursing assessment and clinical judgment skills as the patient's condition changes; more frequent assessment may be warranted.[8]

Epinephrine

Method of Action

- Alpha-/beta- agonist[10]
    - Inotropy, chronotropy, dromotrophy, and vasoconstriction.[2]
- Onset: instant, peak: 20 mins, and duration: 20-30 mins.[8]

Indications for CS

- Risks versus benefits of use are considered in use with CS patients because of tachycardia and increased myocardial oxygenation consumption.[1,8]
    - Low doses (bind to beta-receptors): increase heart rate, cardiac contractility and vasodilation.
    - Increased doses (alpha receptors stimulated) increase systematic vascular resistance and blood pressure.[7]
        - May make the heart work harder and constrict the coronary arteries.[8]

Goal of Therapy

- Increase cardiac output and systematic vascular resistance.[3]

Dosing

- Weight-based dosing
    - IV Initial dose: 0.02 mcg/kg/min or higher.
        - Higher dose initiation may be indicated based on the patient's hemodynamic status titrate based on the clinical goals of therapy.
    - ***Usual Dosage Range***: **0.02 to 0.2 mcg/kg/min.**[10]

- Cardiologist order should include the following:
    - Starting dose in mcg/kg/min, maximum dose, titration dose, frequency, and desired vital sign effect.[8]

- **Initiation and Titration** (up)
    - Increase by 0.02 mcg/kg/min q 5 minutes to achieve increased blood pressure and/or heart rate.
    - Depending on patient status, you may increase every 1-2 mins; titration is very dependent on the patient status.[8]

- **Weaning** (down)
  - Weaning should be ordered and include the targeted hemodynamic parameters.[8]
  - Usual rate of weaning is 0.02 mcg/kg/min q15 min- 30mins.
    - Monitor: MAP and cardiac index (if PA catheter in use).[8,10]

Administering and Mixing

- Continuous infusion via an infusion pump.
- Central line is preferred.
- Frequent monitoring of IV site for extravasation.
- Dilute vial prior to use:
  - **8 mg in 250 ml** Dextrose 5% in water (D5W) (peripheral line).
    - Mixed concentration: 32 mcg/ml.
  - **16 mg in 250ml** D5W (central line).
    - Mixed concentration: 64 mcg/ml.
  - Compatible in D5W and N/S.
- Avoid abrupt withdrawal; reduce infusion flow rate slowly.[8,10]

Adverse Reactions

- Cardiac effects
  - May worsen angina.
  - May cause cardiac arrhythmias.
  - Caution in patients with cardiac disease or those receiving drugs that sensitize the myocardium.
- Pulmonary edema
  - May occur due to vasoconstriction and cardiac stimulation.
- Renal effects
  - May reduce urinary output due to renal blood vessel constriction.[10]

Precautions/Warnings

- Risk and benefit of use due to tachycardia and increased myocardial oxygen demand.
- Avoid extravasation.[10]

Extravasation Management

- If extravasation occurs:
    - Stop infusion immediately and disconnect the IV tubing.
    - Gently aspirate the extravasated solution but do not flush the line.
    - Remove the intravenous cannula.
    - Elevate extremity.
    - Resident or Cardiologist to initiate phentolamine antidote.
        - Obtain a physician's order to initiate antidote.
        - Dilute 5 to 10 mg in 10 to 15 mL NS.
        - With a fine hypodermic needle, administer intradermally into the extravasation site.
        - Should be administered as soon as possible after extravasation; if longer than 12 hours, it may be ineffective.
    - May readminister in 12 hours if the patient remains symptomatic.
    - Apply a dry warm compress.[8,10]

Monitoring

- Continuous cardiac monitoring is indicated.
    - Watch for tachycardia.[8,10]
- If peripheral intravenous infusion, then monitor for skin necrosis from extravasation.
- Continuous arterial line blood pressure monitoring is preferred.[8,10]
- Non-invasive blood pressure.
    - Titration (up) or weaning (down): every 5 mins.
    - If stabilized: every 30 mins- 1 hour.

- Intravascular volume status.
    - Auscultate heart and lung sounds at least every 2- 4 hours.
- Monitor urine output via foley catheter every 1 hour.[8]
- Peripheral perfusion: skin integrity, temperature and moisture.[8,10]
- Use your nursing assessment and clinical judgment skills as the patient's condition changes; more frequent assessment may be warranted.[8]

Dopamine

Method of Action

- Dose-dependent alpha, beta and dopamine agonists.[2]
- Second-line drug in most forms of shock.
- Onset: 1-2 min, peak: 10 mins, and duration: length of infusion.[8]

Indications for CS

- Shock states and treatment of hypotension.[3,11]
- *Note*. Norepinephrine is preferred over dopamine when blood pressure is low and tissue perfusion pressure is insufficient in CS patients.[1]
- Dopamine: Hemodynamic effect is dose-dependent[3]; see Table 3.1.

Table 3.1

Dosage Dependent Response[3]

Dosage	Hemodynamic effects
0.5- 2 mcg/kg/min	↑ cardiac output
5-10 mcg/kg/min	↑↑ cardiac output and ↑ systematic vascular resistance
10- 20 mcg/kg/min	↑↑ systematic vascular resistance and ↑cardiac output

Goal of Therapy

- Lower doses observe an increase in urine output.
- Higher doses observe an inotropic and chronotropic effect and increased blood pressure.[3]

Dosing

- Weight-based dosing
  - IV initial dose: 2.5 mcg/kg/min; titrate up based on the clinical goals of therapy.
  - ***Usual Dosage Range*: 0 - 10 mcg/kg/min**.[11]
- Cardiologist order should include the following:
  - Starting dose in mcg/kg/min, maximum dose, titration dose, frequency, and desired vital sign effect.[8]
- **Initiation and Titration** (up)
  - Start at the ordered dose and increase by 2.5 mcg/kg/min until there is an adequate response.[8]
- **Weaning** (down)
  - Usual rate of weaning is 2.5 mcg/kg/min q 10- 30 min, but follow the cardiologist's order.
  - Monitor for low blood pressure, changes in urinary output and decrease in heart rate.
  - May discontinue at the dose of 2.5 mcg/kg/min, provided the patient is stable.[8]

Administering and Mixing

- Continuous infusion via an infusion pump.
- Central line is preferred.
    - May be administered peripherally for a short time until a central line is obtained.
- Premixed infusion bag:
    - **400 mg in 250 ml** Dextrose 5% in water (D5W) (peripheral line).
        - Mixed concentration: 1600 mcg/ml.
    - **800 mg in 250ml** D5W (central line).
        - Mixed concentration: 3200 mcg/ml.[11]

Adverse Reactions

- Cardiovascular
    - Angina, Atrial fibrillation, bradycardia, cardiac conduction disorder, ectopic beats, hypertension, hypotension, palpitation, tachycardia, and ventricular arrhythmias.
- Central nervous system
    - Anxiety and headache.
- Respiratory
    - Dyspnea.
- Dermatologic
    - Peripheral gangrene.
- Gastrointestinal
    - Nausea and vomiting.[11]

Precautions/Warnings

- Correct hypovolemia with fluid resuscitation prior to initiation of infusion.[8]
- Use with caution in ventricular arrhythmias.
- Extravasation into the skin causes necrosis.[11]

Extravasation Management

- If extravasation occurs:
    - Stop infusion immediately and disconnect the IV tubing.
    - Gently aspirate the extravasated solution but do not flush the line.
    - Remove the intravenous cannula.
    - Elevate extremity.
    - Resident or Cardiologist to initiate phentolamine antidote.
        - Obtain a physician's order to initiate an antidote.
        - Dilute 5 to 10 mg in 10 to 15 mL NS.
        - With a fine hypodermic needle, administer intradermally into the extravasation site.
        - May readminister in 12 hours if the patient remains symptomatic.
    - Apply a dry warm compress.[8,11]

Monitoring

- Continuous cardiac monitoring is indicated.
    - Watch for tachycardia.[8,11]
- If peripheral intravenous infusion, then monitor for skin necrosis from extravasation.
- Continuous arterial line blood pressure monitoring is preferred.
- Non-invasive blood pressure.
    - Titration (up) or weaning (down): every 5-15 mins.

  - If stabilized: every 30 mins - 1 hour.[8]
- Intravascular volume status.
  - Auscultate heart and lung sounds at least every 2- 4 hours.
- Monitor urine output via foley catheter every 1 hour.[8]
- Peripheral perfusion: skin integrity, temperature and moisture.[8,11]
- PA catheter in use monitor cardiac output and pulmonary capillary wedge pressure.[11]
- Use your nursing assessment and clinical judgment skills as the patient's condition changes; more frequent assessment may be warranted.[8]

Dobutamine

Method of Action

- Inotropy and mild vasodilation.[2,12]
- Stronger beta-1 adrenergic receptor effects than alpha-receptor.[12]
- Onset: 1-2 mins, Peak: 10 mins, Duration: Length of infusion.[8]

Indications for CS

- Help improve contractility and may be given simultaneously to norepinephrine.[1]
- Inotropic agent is used in CS to increase cardiac output and has no selective effect on renal flow, whereas dopamine does.[8]

Goal of Therapy

- Improves cardiac output and decreases systematic vascular resistance.[12]
- Afterload reduction but may also contribute to hypotension.[2]
  - Use caution if systolic blood pressure < 90 mmHg.[8]
- Augmented cardiac output will increase blood pressure.[13]

Dosing

- Weight-based dosing
    - IV Initial dose: 2 to 5 mcg/kg/minute; titrate based on the goals of therapy.
    - ***Usual Dosage Range*: 2 – 10 mcg/kg/min.**[13]
- Cardiologist order should include the following:
    - Starting dose in mcg/kg/min, maximum dose, titration dose, frequency, and desired vital sign effect.[8]
- **Initiation and Titration** (up)
    - Start at 2.5 mcg/kg/min and increase q 5-15 mins by 2.5 mcg/kg/min to achieve the desired effect.
    - Monitor for tachycardia and hypotension.
    - Tachycardia and hypotension may limit the ability to improve cardiac output.[8]
- **Weaning** (down)
    - Usual rate of weaning is 2.5 mcg/kg/min q 30 mins – 1 hour.
    - Monitor for signs of low cardiac output or pump failure.
        - Signs and symptoms: Increased pulmonary edema, third heart sound, diaphoresis, and increasing shortness of breath.
    - May discontinue at doses of 2.5- 5.0 mcg/kg/min provided the patient is stable.[8]

Administering and Mixing

- **250 mg in 250 ml D5W** (1mg/ml or 1000 mcg/ml).
- **500 in 250 ml D5W** (2 mg/ml or 2000 mcg/ml).[13]
- Administer in a large vein or central line.[8]

Adverse Reactions

- 1 – 10%
  - Cardiovascular:
    - Increased heart rate.
    - Increased systolic blood pressure.
    - Ventricular premature contractions.
    - Angina pectoris.
    - Chest pain.
    - Palpitations.
  - Central nervous system: Headache.
  - Gastrointestinal: Nausea.
  - Respiratory: Dyspnea.[13]

Precautions/Warnings

- Use with caution in hypovolemic states, as a drop in BP will be significant.
- Monitor for arrhythmia.
- May increase ventricular response rate; therefore, ensure ventricular rate is controlled for atrial fibrillation/flutter.
- Monitor for hypotension, as it may occur secondary to vasodilation at higher doses.
- May worsen ventricular ectopy.[13]

Monitoring

- Continuous cardiac monitoring is indicated.
    - Watch for tachycardia.[13]
    - It will cause sinus tachycardia, so monitor for the impact of decreased diastolic time.[8]
- Continuous arterial line blood pressure monitoring is preferred.
- Non-invasive blood pressure.
    - Titration (up) or weaning (down): every 5 - 15 mins.
    - If hemodynamically stabilized: every 30 mins - 1 hour.
- Intravascular volume status.
    - Auscultate heart and lung sounds at least every 2- 4 hours.
- Monitor urine output via foley catheter every 1 hour.[8]
- Peripheral perfusion: skin integrity, temperature and moisture. [8,13]
- Use your nursing assessment and clinical judgment skills as the patient's condition changes; more frequent assessment may be warranted.[8]

Vasopressin

Method of Action

- Stimulates receptors in vascular smooth muscle.[3]
- Catecholamine-sparing drug.[14]
    - Used if patients build up a tolerance to epinephrine, dopamine and norepinephrine.[8]
- Onset: 1-3 min, peak: 5-10 mins, and duration: 10-35 mins.[8]

Indications for CS

- Vasopressin has not been well-studied in the CS setting.[1]
- Recommended for right ventricular (RV) shock, as it raises systematic vascular resistance and has no effect on pulmonary vascular resistance (PVR). [3]

Goal of Therapy

- Increase blood pressure.
- Increase systematic vascular resistance.[3]

Dosing

- ***Usual Dosage Range***: **0.04 units/min.**[14]
- The cardiologist order will order the dose, and it is not our practice at the HSC to titrate vasopressin.

Administering and Mixing

- Continuous infusion via an infusion pump.
- Central line is preferred.
- Frequent monitoring of IV site for extravasation.
- Dilute vial prior to use:
  - **40 units in 100 ml D5W.**
    - Mixed concentration: 0.4 units/ml.[14]

Adverse Reactions

- Tachycardia.
- Decreased blood flow to the extremities.
- Bowel ischemia.[14]

Precautions/Warnings

- Cardiovascular disease
  - May worsen cardiac output.[14]

Extravasation Management

- If extravasation occurs:
    - Stop infusion immediately and disconnect the IV tubing.
    - Gently aspirate the extravasated solution but do not flush the line.
    - Remove the IV cannula.
    - Elevate extremity.
    - Initiate topical nitroglycerin
        - Nitroglycerin topical 2% ointment.
        - Apply a 1-inch strip to the site of ischemia.
        - May repeat every 8 hours as necessary.
    - Apply dry, warm compresses.[14]

Monitoring

- Continuous cardiac monitoring is indicated.
    - Watch for tachycardia.[14]
- If peripheral intravenous infusion, then monitor for skin necrosis from extravasation.[14]
- Continuous arterial line blood pressure monitoring is preferred.
- Intravascular volume status.
    - Auscultate heart and lung sounds at least every 2- 4 hours.
- Monitor urine output via foley catheter every 1 hour.[8]
- Peripheral perfusion: skin integrity, temperature and moisture.[8,14]
- Use your nursing assessment and clinical judgment skills as the patient's condition changes; more frequent assessment may be warranted.[8]

Nursing Consideration and Practice Tips

Intradermal administration of phentolamine (rogitine) should occur as soon as possible after extravasation to avoid skin necrosis.

Used in the treatment of extravasation caused by: norepinephrine, dopamine, dobutamine, and phenylephrine.[8]

Other

Milrinone

Method of Action

- Noradrenergic drugs with inotropic and vasodilatory action.[15]
- Phosphodiesterase-inhibitors.[12]
- Onset: immediate, Peak: 5-15 mins, Duration: 8 hours.[8]

Indications for CS

- Very limited evidence in CS.
- Can improve myocardial contractility and potential for vasodilation effects without increasing oxygen requirements.[1]

Goal of Therapy

- Improvement in cardiac output because of an increase in the strength of contraction.[8]

Dosing

- Weight-based dosing
  - IV loading dose: 50 mcg/kg given over 30 mins.
  - ***Usual Dosage Range*: 0.125 to 0.75 mcg/kg/minute.**[15]
  - Reduced dosing in renal failure.[15]
- Cardiologist order should include the following:
  - Loading dose and starting dose in mcg/kg/min.[8]
- **Initiation and Titration** (up)
  - Start at the ordered dose.
  - Practice in coronary care is not to titrate.
  - May increase the dosage only if a doctor's order is written to titrate.
    - After giving a loading dose over 10-30 mins, start infusion at the ordered dose. General practice is to increase by 0.125 mcg/kg/min until desired effect or until the max dose of 0.75 mcg/kg/min.
    - Ex. 0.125, 0.25, 0.375, 0.5, 0.625, and 0.75 mcg/kg/min.[8]
- **Weaning** (down)
  - Decrease by 0.125 mcg/kg/min q 30 to 60 minutes.
    - Monitor for signs of decreasing cardiac output and heart failure.[8]

Administering and Mixing

- Continuous infusion via an infusion pump.
- Give loading dose over 10- 30 mins.
- Dilute vial prior to use:
  - **50 mg in 250 ml** D5W.
  - Mixed concentration: 200 mcg/ml.[15]

Adverse Reactions

- Cardiovascular: Ventricular arrhythmia (>10%).
- Cardiovascular: Angina, chest pain, hypotension, supraventricular cardiac arrhythmia (1-10%).
- Nervous system: Headache (1-10%).[15]

Precautions/Warnings

- Severe tachycardia, this drug is seldom infused by itself as it is often used in conjunction with dopamine or norepinephrine.[8]
- Arrhythmias.
- Hypotension may occur.[15]

Monitoring

- Continuous cardiac monitoring is indicated.
  - Watch for ventricular arrhythmias and tachycardia.
- If peripheral intravenous infusion, then monitor for skin necrosis from extravasation.
- Continuous arterial line blood pressure monitoring is preferred.[15]
- Non-invasive blood pressure.
  - Titration (up) or weaning (down): every 5-15 mins.
  - If stabilized: every 30 mins - 1 hour.
    - Monitor: Due to the afterload-reducing properties of this drug, a slight drop in BP may occur.[8]
- Intravascular volume status.
  - Auscultate heart and lung sounds at least every 2- 4 hours.
- Monitor urine output via foley catheter every 1 hour.[8]
- Peripheral perfusion: skin integrity, temperature and moisture.[8,15]
- Use your nursing assessment and clinical judgment skills as the patient's condition changes; more frequent assessment may be warranted.[8]

Quiz Activity 3.1

Please answer the following questions by circling the most appropriate answer. The answers can be found in Appendix D of the resource under Quiz Activity 3.1: Answer Key.

1. Positive inotropes strengthen the heart's contractions so that the heart can pump more blood with each beat.

   True   False

2. What is the first-line vasoconstrictor medication currently recommended for CS?

   a. Dopamine
   b. Vasopressin
   c. Epinephrine
   d. Norepinephrine

3. The action of the medication is inotropic when it:

   a. Decreased afterload.
   b. Increases heart rate.
   c. Increases the force of contraction.
   d. Is used to treat heart failure.

4. Norepinephrine and sodium bicarbonate are compatible at the intravenous y-connection.

   True   False

5. What drug is used in the management of extravasation by norepinephrine, dopamine, dobutamine, and phenylephrine?

   a. Benadryl
   b. Protamine
   c. Nitroglycerin
   d. Phentolamine

6. Dobutamine improves cardiac output and is indicated for use in all of the following conditions except:

   a. Septic shock.
   b. Arrhythmias.
   c. Congestive heart failure.
   d. Pulmonary congestion.

Conclusion

Congratulations on completing Module 3. This module provided an overview of vasoactive medications used in CS. The information provided will help you understand the indications for each drug used in CS. The common practices for initiating, titrating, weaning, and discontinuing the medications were also outlined. Remember, there is no evidence to support the practice of weaning and titration of vasoactive medications, and these practices are based on the patient's response and the cardiologist's targeted goals of care.

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Module 4

Mechanical Circulatory Assist Devices:

Intra-Aortic Balloon Pump (IABP)

Module 4: Mechanical Circulatory Assist Device: Intra-aortic Balloon Pump

The purpose of this module is to provide a brief overview of the types of mechanical circulatory assistive devices used in cardiogenic shock, and the primary focus will be to detail the nursing care of an intra-aortic balloon pump. This module can be used by registered nurses practicing in a coronary care setting. It may also benefit registered nurses practicing in other settings who want to learn more about this topic.

Before proceeding, it is recommended that you complete Module 1, as it provides foundational information on cardiogenic shock nursing care.

This module contains information, reflection exercises, case studies, documentation tips, tools for practice, and self-tests.

Learning Objectives

Upon completion of this module, you will be able to:

1. Describe the indications and contraindications for the use of an intra-aortic balloon pump;

2. Explain the fundamental mechanic principles of an intra-aortic balloon pump: counterpulsation;

3. Interpret the intra-aortic balloon pump waveform and determine accurate timing of the balloon;

4. Summarize the potential complications related to the use of an intra-aortic balloon pump;

5. Describe actions required to troubleshoot alarms from consoles;

6. Discuss the process of weaning an intra-aortic balloon pump and required nursing actions when the intra-aortic balloon pump is removed;

7. Explain the nursing care considerations for providing care to a patient with an intra-aortic balloon pump; and

8. Discuss the appropriate documentation practices when caring for a patient with an intra-aortic balloon pump.

Cardiogenic Shock and Mechanical Circulatory Support Devices

An intervention for cardiogenic shock (CS) is using a mechanical circulatory support (MCS) device.[1] MCS devices provide circulatory support by having the ability to provide higher levels of hemodynamic support than can be achieved by using pharmacological therapies.[2]

The MCS device provides the following:

- cardiovascular support without increasing the risk of myocardial ischemia and possibly decreased myocardial oxygen demand, which is often found with increased use of vasoactive therapies.[3]
- maintain vital organ perfusion and unload the failing ventricle.[4]
- help to decrease the intracardiac filling pressures that cause a reduction in pulmonary congestion, myocardial wall stress, and myocardial oxygen consumption.[4]

Two Categories of MCS

The MCS devices are broadly classified into two categories: temporary and durable.[1,2]

- *Temporary MCS* devices are used in CS.
- *Durable MCS* devices are used long-term and are continuous-flow devices.[1]

The primary focus of this Module is the use of temporary MCS as these are utilized in CS. In contrast, durable MCS may be considered when the patient stabilizes if they meet the criteria for a durable MCS as a long-term intervention or as a bridge to a heart transplant.[1,5]

Temporary MCS

The temporary MCS devices selected for use in CS patients are based on established recommendations, including:

- the known effectiveness of the device,
- the institutional experience and skillset, and
- device-related complications.[1,5]

The clinical indications for the use of the devices includes:

- to assist the patient in stabilizing;
- to allow time for the heart pump to recover; or to facilitate an intervention such as revascularization; or
- to provide time to make appropriate plans of care, including the possibility of transplant or to optimize the patient to prepare/bridge to a durable MCS device long term is indicated; or
- if recovery is not possible, palliation will be explored.[1]

The choice of a temporary MCS device is based on the following:

- the cause of CS,
- the clinical signs and symptoms of the patient,
- the type of heart failure (left-sided, right-sided, or biventricular) and
- the institutions' expertise and resources to provide care to the patient.[1,5]

The devices are inserted percutaneous or surgically and are removed when there is adequate improvement in cardiac function or other care decision is made.[1,6]

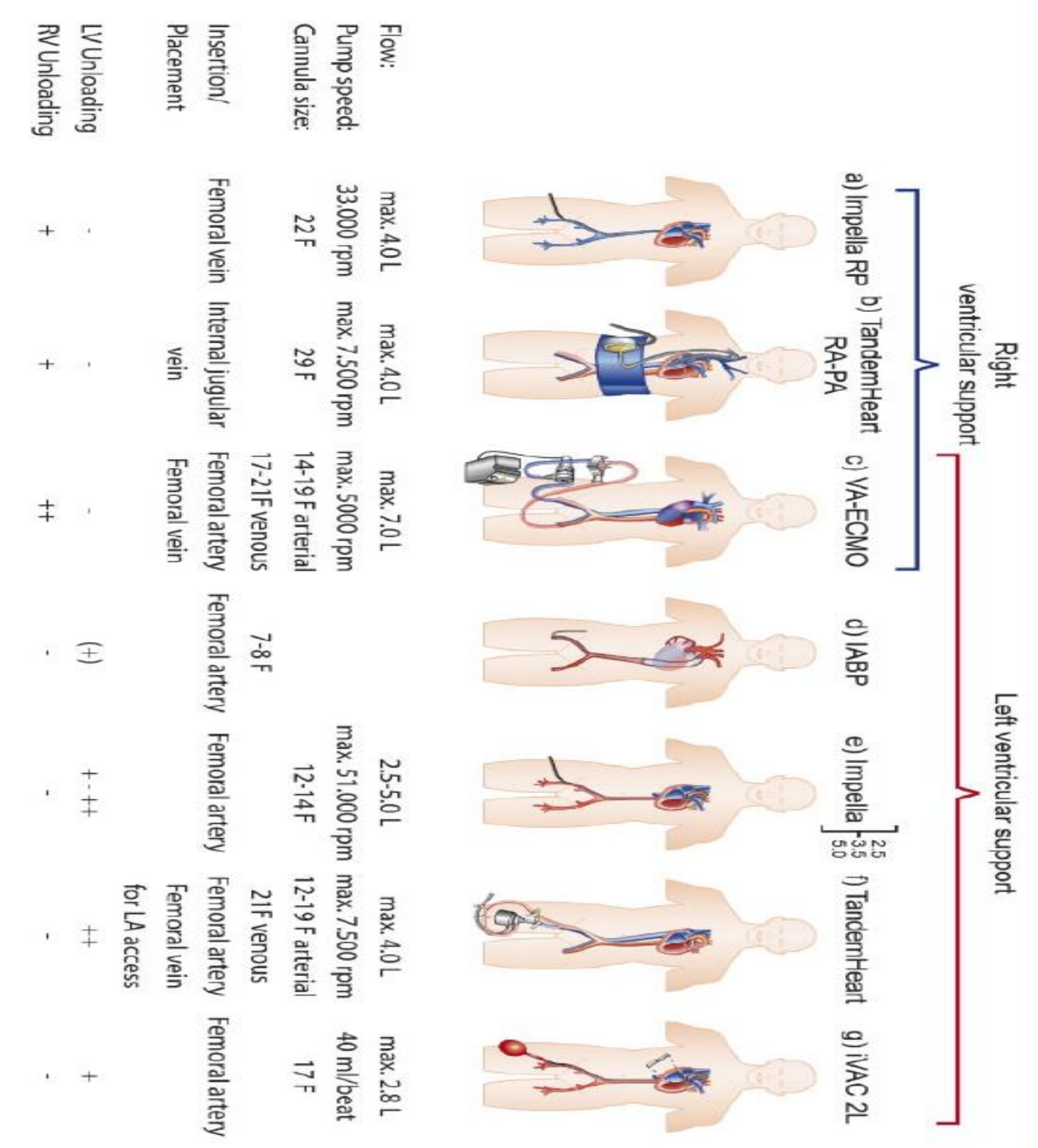
The most commonly used device types include:

- Intra-aortic balloon pump (IABP) (LV Support).
- Percutaneous LV assist devices (pLVAD).
    - LV support- the TandemHeart, and the Impella.
    - RV support Impella RP and Protek Duo.
- Extracorporeal membrane oxygenation (ECMO) (Biventricular failure).[5]

Figure 4.1 displays schematic drawings of current percutaneous MCS devices for a CS with technical features. On the left side of the figure are devices for right ventricular support, and on the right side of the figure are those for left ventricular support.

Figure 4.1

Percutaneous MCS Devices for CS



(a) ImpellaVR RP, (b) TandemHeartTM RA-PA (right atrium—pulmonary artery), (c) VA extracorporeal membrane oxygenation (ECMO), (d) Intra-aortic balloon pump, (e) ImpellaVR, (f) TandemHeartTM, and (g) iVAC 2LVR

Source. From *"*Management of cardiogenic shock complicating myocardial infarction: An update 2019," by H. Thiele, E. M. Ohman, S. de Waha-Thiele, & S. Desch, 2019, *European Heart Journal, 40*(32), pp. 2680 (https://doi.org/10.1093/eurheartj/ehz363). Copyright 2019 by Oxford University Press Journal. Reprinted with permission. [5]

Contraindications for MCS

Contraindications to using a MCS device include:

- anoxic brain injury,
- irreversible end-organ failure,
- prohibitive vascular access, and
- end-stage disease or advance care directive (Do not resuscitate orders).[6]

> ***Remember***
>
> Temporary MCS devices are used:
>
> - to provide time for cardiac contractility to recover, and the device will be removed or
> - to allow time for an evaluation for a durable, long-standing MCS device insertion or heart transplant.[6]

What is an IABP?

The IABP is one of the most commonly used temporary percutaneous left ventricular assist devices in the coronary care unit at the HSC. However, recent research has questioned the mortality benefit of using IABP[7]; but the temporary device is still widely used for CS.[1,6]

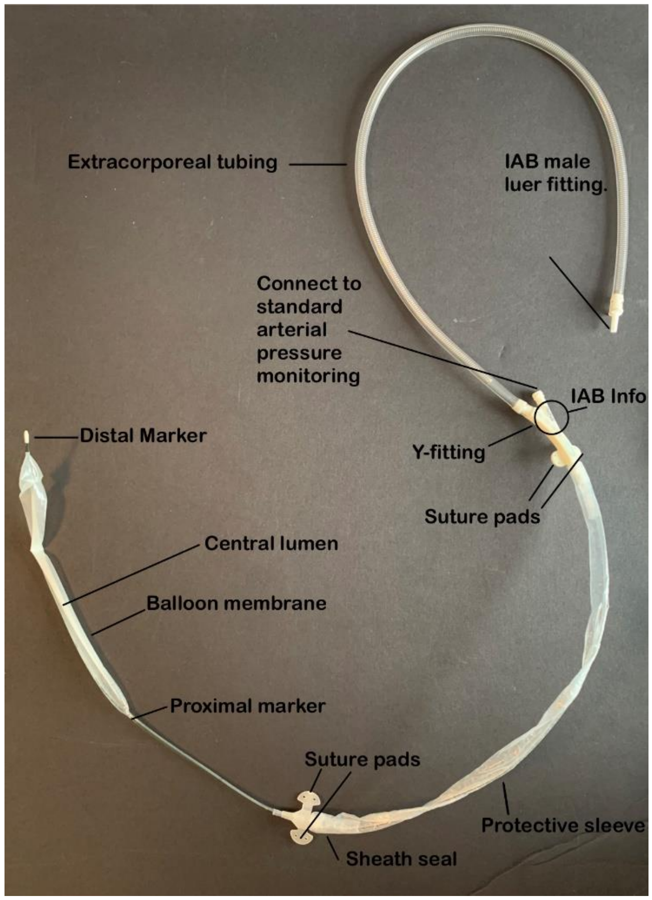
Widespread use is due to the following:

- its availability,
- ease of placement, and
- lower cost than other mechanical support devices.[3,8]

The IABP consists of a double-lumen thin catheter that is advanced over a guidewire through an introducer sheath until it is positioned in descending aorta of your patient, and the catheter has a long balloon on its end. This catheter is connected to a console which controls the balloon inflation and deflation.[9,10] Figure 4.2 demonstrates a type of intra-aortic balloon (IAB) catheter with labelled parts which are described in Table 4.1.

Figure 4.2

Sample IAB Catheter



Source. From "Intra-Aortic Balloon Catheter," by Neil (2023), personal photo collection.[11]

Table 4.1

IAB Catheter Description

IAB catheter components	Purpose
Distal marker	• It is a radiopaque marker. • Positioned 2 cm below the origin of the subclavian artery.

Central lumen	• Designed for guidewire insertion and used for pressure monitoring. • Do not use the central lumen for blood sampling.
Balloon membrane	• Balloon volume should not exceed 90% of the aortic diameter. ○ *Rationale:* to avoid trauma to the aorta. • The sizing of the IAB catheter is based on the patient's height. • Helium is the gas used to inflate the balloon. ○ *Rationale:* *1.* it is a low-density gas which enables rapid inflation and deflation. 2. It is inactive metabolic gas and rapidly dilutes in blood. Important if a balloon leak or rupture occurs.[12]
Proximal marker	• It is a radiopaque marker. • Positioned 2 cm above the renal arteries.
Suture pads	• Catheter secured using sutures; ex. Sutured to upper thigh with IAB inserted in the femoral artery.
Sheath seal and Protective sleeve	• Maintains a sterile catheter.
Y-fitting	• Y-fitting: divides into extracorporeal tubing and connection for standard ART line monitoring set.

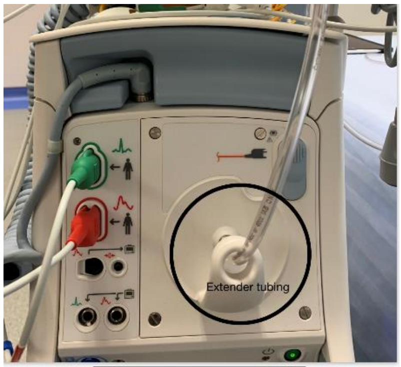
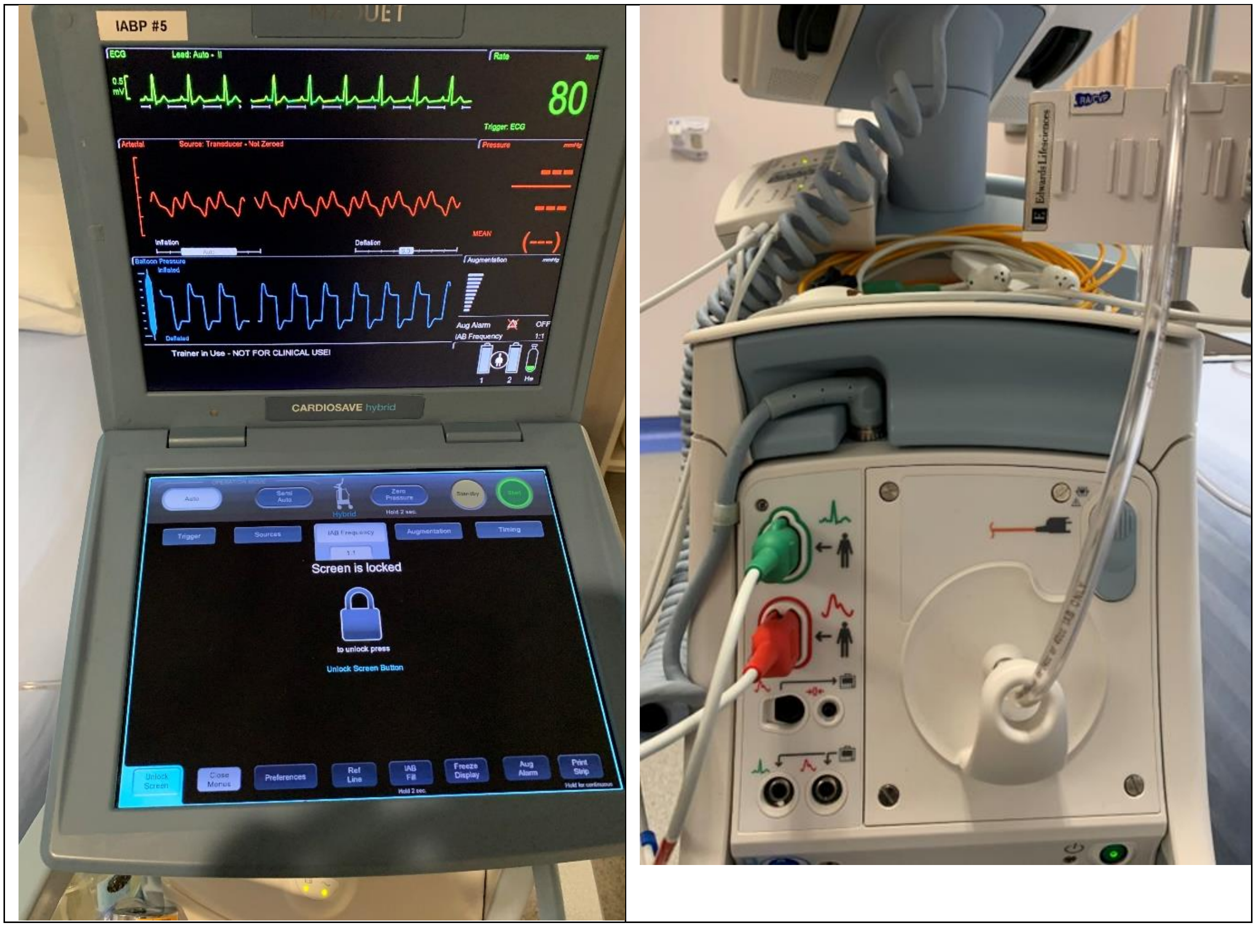
	• Notes: IAB Info: catheter size (F) and balloon size (ml).
Connection to standard Arterial monitoring	• It is connected to a standard ART line monitoring set.
Extracorporeal tubing	• Helium is shuttled into the IAB via this tubing.
IAB male luer fitting	• Attached to female luer and extender tubing, which is then connected to the IABP.[9] (Posterior view of IABP Cardiosave Console). 

Figure 4.3 shows an IABP Cardiosave console commonly used in Eastern Health (EH).

Figure 4.3

Cardiosave Console



Front view and back view of Cardiosave console.

Source. From "Cardiosave Console," by Neil (2023), personal photo collection. [13]

Recommendations for the Use of IABP

The intended use of an IABP is for short-term therapy for patients with reversible left-ventricular failure or an adjunct to other therapies.

The IABP is recommended for CS patients with:

- mechanical complications after an acute myocardial infarction, including aortic stenosis, mitral stenosis, mitral valvuloplasty, mitral insufficiency, ventricular septal defect, and left ventricular aneurysm.[5]
- profound CS when other MCS devices are unavailable, contraindicated, or cannot be inserted.[1]

Learning Video

Please watch a video exploring CS due to myocardial infarction and the use of an intra-aortic balloon pump.

Cardiogenic Shock and Intra-aortic Balloon Pump by Dr. Cal Shipley, M.D. (6 mins)

https://www.youtube.com/watch?v=mADxD7C8jBw

Source. From "Cardiogenic Shock and Intra-aortic Balloon Pump" by C. Shipley, https://www.youtube.com/watch?v=mADxD7C8jBw [14]

Contraindications for an IABP

There are contraindications for the use of IABP in patients.

- Moderate to severe aortic regurgitation
    - The IABP counterpulsation would increase the aortic regurgitation.[15]
- Aneurysms: aortic, thoracic, abdominal
    - Unintended balloon placement in the false lumen may cause an extension of the dissection or even aortic rupture.[15,16]
- Aneurysm abdominal
    - Aortic rupture is a potential complication if the IAB catheter is inserted when an abdominal aneurysm is present.[16]
- Relative contraindications
    - Severe peripheral vascular disease.
    - Severely calcified aorta iliac disease.[9,15]

Benefits of IABP

- The pump operates on the fundamental principle of counterpulsation.[9,10,17,18]
- The gas used for the inflation of the IAB is helium.[9]
- The inflation and deflation of the IAB are timed with the patient's cardiac cycle, which is synchronized with either the electrocardiogram (ECG) or pressure trigger for timing.[10]
    - The IAB inflates at diastole's onset.
    - The IAB deflates just before systole.[9,18]

The following section will review the two components of the cardiac cycle as they relate to the IAB deflation and inflation, as outlined in Table 4.2.

Table 4.2

Cardiac Cycle and IAB

Cardiac Cycle	
Diastole	**Systole**
• **Relaxation** of the atria or ventricles. • Filling of the atria and ventricles. • 2/3 of the cycle. • Coronary arteries are perfused.	• **Contraction** of the atria or ventricles. • Blood is pumped out of the heart and to the rest of the body. • 1/3 of the cardiac cycle.
IAB Inflates	**IAB Deflates**
• **Increase in aortic pressure.** • Displaces blood retrograde to the coronary arteries. • Displaces blood forward peripheral to the rest of the body. • Increases myocardial oxygen supply. • Improved cardiac output. • The IAB inflates at the onset of diastole when the aortic valve closes. 　○ **The dicrotic notch on an arterial waveform represents the closure of the aortic valve.**	• **Decreases the pressure within the aortic root.** • Reducing afterload, which facilitates ventricular emptying. • Reducing myocardial workload.[9,17,18]

IAB Inflation

The IAB inflates at the onset of diastole when the aortic valve closes and the heart muscle is relaxing and filling. This is also when the coronary arteries fill via the **coronary ostium**. When the IAB deflates, it increases the aortic pressure and pushes the blood to the coronary arteries. This action increases the myocardial oxygen supply and improves cardiac output.[9]

IAB Deflation

The IAB deflates during systole when the heart is contracting to cause a decrease in the pressure within the aortic root. This action is like creating a "vacuum" as the blood is expelled from the ventricles [16] There is a decrease in afterload and myocardial workload.[9]

Insertion and Position of the IAB

- The IAB is most commonly inserted in the femoral artery via percutaneous puncture.
    - If the IAB is inserted in the femoral artery, the patient will remain on bed rest with the head of bed less than or equal to 30 degrees, with no hip flexion, and required to keep their leg straight.[19]
- In some incidences, it can also be placed in the left-axillary artery.[20]

When the IAB catheter is appropriately positioned, it is located in the descending aorta. The distal tip marker is located just below the left subclavian artery, and the proximal tip marker of the IAB is just above the renal artery. [3,18,20] Figure 4.4 for the positioning of the IAB in the descending aorta.

Figure 4.4

Positioning of IAB in Descending Aorta

Source. From "*Intra-aortic Balloon Counterpulsation Therapy: Theory of Counterpulsation ELearning Program*," by Getinge Group, 2021, p. 13 (https://lms.getinge.training/gateway/course/1010001718/view). Copyright 2021 by Getinge Group. Reprinted with permission.[18]

Femoral Insertion

Most commonly, at the HSC, the cardiologist inserts the IAB in the femoral artery through a sheath using fluoroscopy in the cardiac catheterization lab. Insertion under fluoroscopy is recommended to position the IAB catheter properly. [9] However, there are some incidences when the cardiologist or cardiac surgeon may insert the IAB at the patient's bedside. The cardiologist or cardiac surgeon and the perfusionist are responsible for the initial setup of the IABP, and the perfusionist is available for ongoing troubleshooting.

Radiopaque Marker

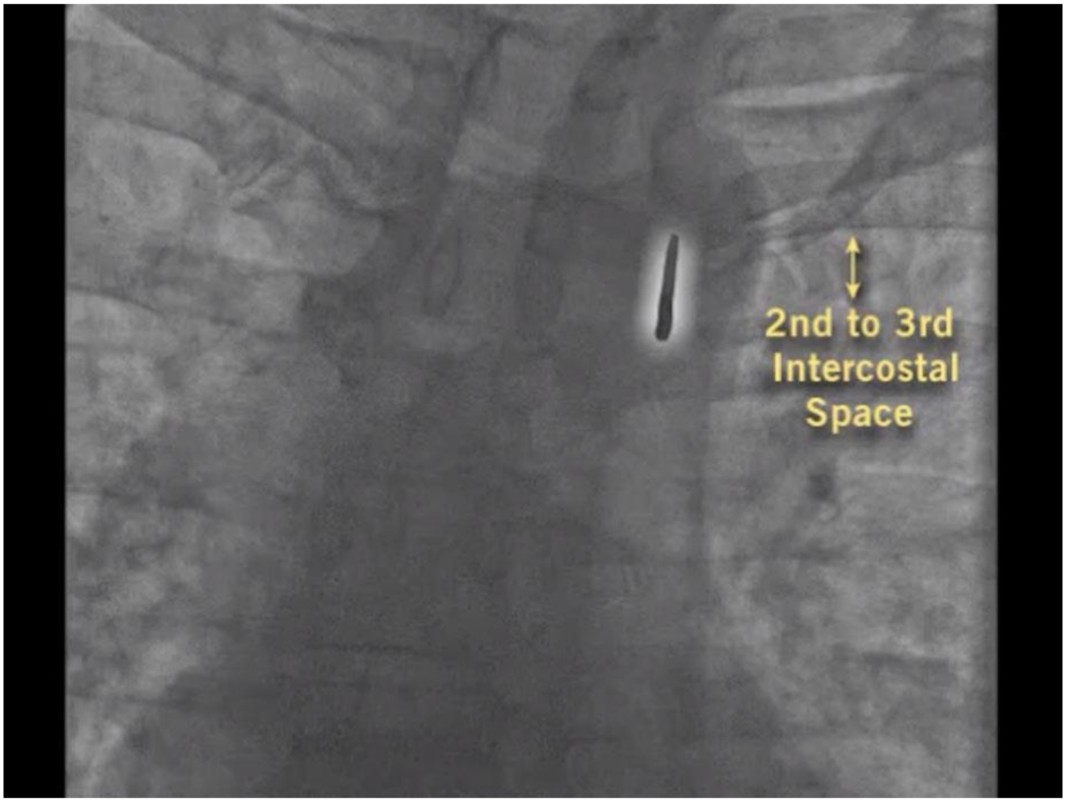
The IAB catheter used at the HSC has a radiopaque marker at the distal tip and proximal tip of the IAB catheter that is visible under fluoroscopy or radiography to confirm placement.
If the cardiologist inserts the IABP at the patient's bedside, then the correct catheter position is verified by obtaining a portable chest X-ray for placement.

- The distal tip of the IAB should be approximately 2 cm from the left subclavian artery at the level of the carina.[3,8]

Figure 4.5 shows the IAB distal marker between the 2nd and 3rd intercostal space.

Figure 4.5

IAB Catheter X-ray Positioning



Source. From "*Intra-aortic Balloon Counterpulsation Therapy: Theory of Counterpulsation ELearning Program*," by Getinge Group, 2021, p. 12 (https://lms.getinge.training/gateway/course/1010001718/view). Copyright 2021 by Getinge Group. Reprinted with permission.[18]

Remember

Key points for correct IAB catheter positioning:

- The EH IABP policy does not include a recommendation for placement X-ray.[19]
- Current practice is to confirm IAB placement by X-ray if not inserted under fluoroscopy; follow the doctor's orders.
- A daily portable chest X-ray is recommended but not listed in the policy; follow the doctor's orders.
- Obtain a doctor's order for Stat portable chest X-ray if you are concerned about the possible migration of IAB.
- X-ray: Proper position is the distal tip should be between the 2nd and 3rd intercostal space.[18]
- *Reminder*: IAB- 2 cm below the origin of the left subclavian artery and 2 cm above the renal arteries. [9,18]

The visibility of the IAB on X-ray is enhanced when the IABP is placed on standby. You should have a cardiologist or cardiac surgeon's approval to place it on standby, as some patients may be hemodynamically unstable to tolerate the IABP on standby.[9]

You should be prepared to assist the cardiologist with the bedside insertion of the IAB. The perfusionist is notified and will also assist with the IAB insertion at the bedside.

- The perfusionist is responsible for retrieving the IAB catheter and Cardiosave console.
- The perfusionist will be present for the insertion and assist with the initial setup and ongoing troubleshooting of the IABP.
- The cardiologist or cardiac surgeon is responsible for obtaining informed consent from the patient or substitute decision maker.
- The nurse will help the patient to a supine position to prepare for the insertion of the IAB catheter, gather the necessary supplies, and assist the cardiologist as needed with insertion.[9]

Learning Video

Please watch a video demonstrating the insertion of an IAB catheter.

Getinge IAB catheter insertion video (16 mins)

https://www.youtube.com/watch?v=WhDOAYs3PW4

Source. From "Getinge IAB catheter insertion video," by Getinge, https://www.youtube.com/watch?v=WhDOAYs3PW4 [21]

IAB Sizing

Various sizes of IAB catheters are available based on the patient's height, and each IAB sizing is indicated on the y-fitting of the IAB.[22] Table 4.3 summarizes the balloon size with the corresponding height.

Table 4.3

IAB Catheter Sizing

Balloon Size	Height
25 ml (7F)	Less than 152 cm (5')
34 ml (7F)	152-163 cm (5'-5'4")
40 ml (7.5F)	163-183 cm (5'4- 6')
50ml (8F)	Greater than 183 cm (6')[22]

Nursing Consideration and Practice Tips

If the patient has the IAB catheter inserted in the cardiac catheterization lab, it is the coronary care unit practice to bring a Hillrom Progressa Bed, a pressure-relief mattress, to the cardiac catheterization lab for the patient's transfer back to coronary care.

Remember, the patient with an IABP will be on bed rest (for the duration of therapy) due to femoral insertion. Promoting pressure reduction with good skincare and turning and repositioning every 2 hours is essential; if hemodynamic stable, do so. Also, don’t forget to relieve pressure from heels.

Equipment for Insertion

- Perfusionist will supply and retrieve the following:
  - IAB catheter.
  - IAB catheter insertion kit.
  - Cardiosave console and helium gas supply.
  - Large transparent dressings.
- Sterile drapes, full body sterile drape, sterile gown and gloves, caps, masks and goggles.
- Skin preparation: Chlorohexidine antiseptic sterile swabs (Large swab-tinted).
- 2% Lidocaine plain, 10 ml syringe, 18 G needle, 25 G 1 ½".
- # 11 blade.
- 0-silk sutures on a cutting needle.
- Stopcocks: 1- two way, 2- three-way.
- Luer lock plug.
- ECG leads.
- Arterial pressure monitoring supplies (art line monitoring kit, 500 ml N/S bag flush solution with 1000 units of heparin, pressure bag) and transducer system on Cardiosave console.[9]
  - At EH, monitoring arterial pressure with an IABP requires using a heparinized normal saline solution to deliver 3-5 ml/hr of heparinized normal saline. This is the current best practice but not listed in the EH IABP policy.[19]

After the insertion and initial setup of the IABP, the perfusionist will review the current Cardiosave console settings:

- IABP frequency,
- monitoring lead,
- trigger mode,
- timing, and
- augmentation alarm set value.

Next, you are required to ensure the IAB catheter dressing is secured, assess the insertion site, and complete the limb neurovascular assessment[19]; then, you can request a portable chest X-ray for placement verification as directed by the cardiologist ordered.

Documentation of the Insertion

Documentation of the insertion should be charted in the nursing progress note on the flowsheet, including:

- Informed consent,
- Universal precautions and sterile technique,
- catheter size and balloon volume (ex. 7F, 25ml),
- site of insertion,
- confirmation of placement completed,
- any difficulties with insertion,
- IABP frequency, and
- response to therapy.[9]

Documentation on the flowsheet, including:

- IAB catheter size, balloon size, and location,
- augmented systolic and diastolic pressure in a red pen (minimum q 1 hr or more with changes to hemodynamic status),
- augmented pressure with a red X and circle (minimum q 1hr or more with changes in hemodynamic status),
- mean pressure red X, and
- frequency of IABP (q 1 hr).[19]

Figure 4.6 shows a sample Cardiosave console screen with the displayed ECG and arterial waveform values supplying a visual of how to document the numbers on the critical care flowsheet. These hemodynamic valves are also used to target the initiation and weaning of vasoactive drugs. In coronary care, the practice is to target an augmentation pressure of 90 mmHg or higher; the cardiologist orders this targeted pressure. Please see Figure 4.7 and Figure 4.8 for the documentation as required for the IABP.

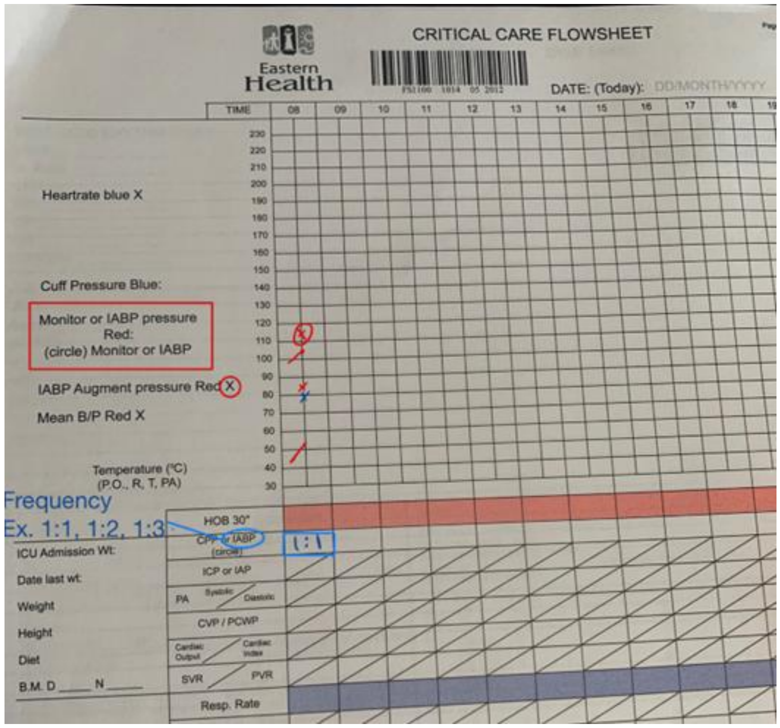
Figure 4.6

Sample Documentation on Flowsheet

Source. From *IAB insertion / CARDIOSAVE® IABP operation quick reference guide* (p. 15), by Maquet Getinge Group, n.d.(https://getinge.training/wp-content/uploads/2021/02/Cardiosave-IAB-Operation-Transport-Quick-Reference-Guide-MCV00020163_REVC.pdf). Copyright by Maquet Getinge Group. Reprinted with permission. [22]

Figure 4.7

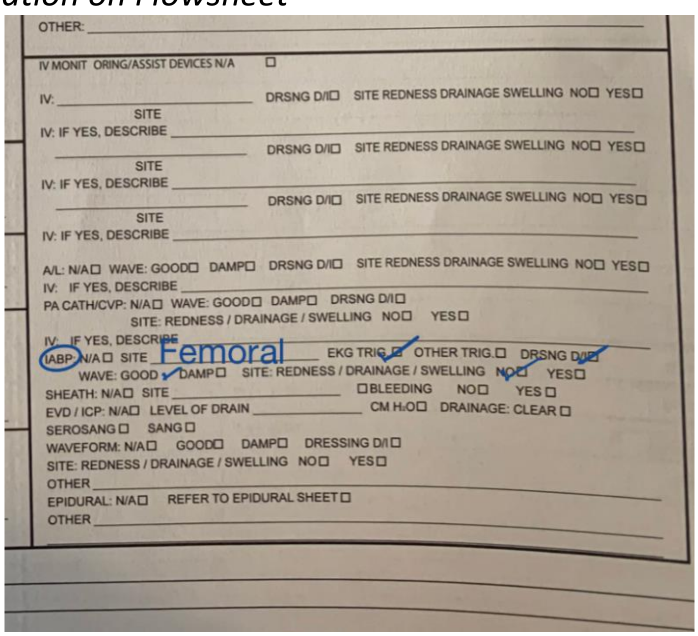
Sample Documentation on Flowsheet



Source. From "Critical care flowsheet: Sample documentation," by Neil (2023), personal photo collection.[23]

Figure 4.8

Sample Documentation on Flowsheet



Source. From "Critical care flowsheet: Sample documentation," by Neil (2023), personal photo collection.[23]

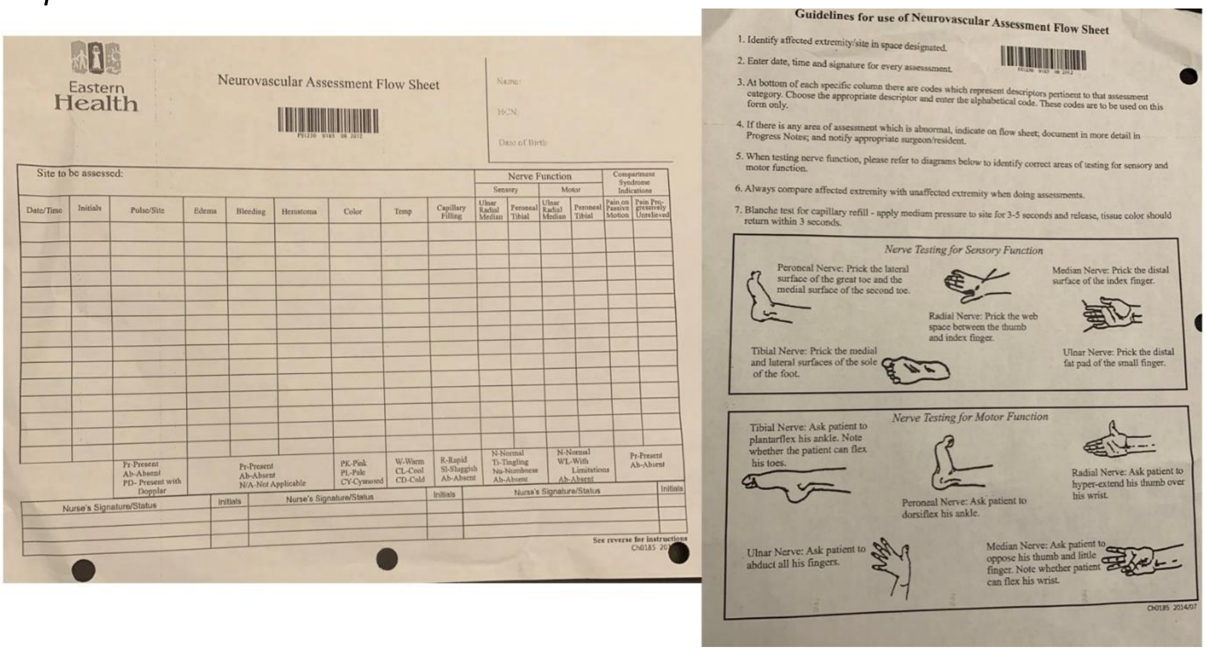
Neurovascular Assessment

Peripheral pulses and neurovascular assessment documentation is completed on the Neurovascular Assessment Flow Sheet for the limb with the IABP.[19]

Please see Figure 4.9 for a sample of a neurovascular assessment flow sheet with a posterior view of the guidelines for the neurovascular assessment.

Figure 4.9

Sample Neurovascular Assessment Flow Sheet



Source. From "Neurovascular Assessment Flow Sheet," by Neil (2023), personal photo collection. [24]

The routine frequency of neurovascular assessment:

- after initial insertion: q 15 mins x 4,
- q 30 mins x 2,
- then q 1 hr.[19]

Nursing Practice Tips

Xray

Meditech mnemonic for portable chest X-ray:

Category: DIPORT; Procedure: CHEP [25]

After requesting the portable chest X-ray in Meditech, you must page the HSC X-ray department at 570-9207.

Perfusionist

The perfusionist can be reached by pager or by calling the HSC switchboard at 7171, and they can page the perfusionist on call for you.

Augmentation

Augmentation on the IABP represents the assisted end-diastolic pressure or augmented diastolic pressure, the highest point on the diastolic waveform.[8] The Cardiosave console will display the augmented diastolic pressure as "Aug."[22]

The augmented pressure, assisted systolic, and diastolic pressures are documented hourly in coronary care.[19]

You can adjust the augmentation alarm by selecting the "Aug. alarm" and using the arrows to increase or decrease the set value for the alarm.[22]

- Set your alarm appropriately based on the target goals of therapy.
    - Ex. If the cardiologist has ordered a goal augment BP of 90 mmHg, then set the alarm to 90 mmHg.

See Figure 4.10 for the Cardiosave console screen with the augmentation alarm displayed.

Figure 4.10

Augmentation Alarm

Source. From "Augmentation alarm on the Cardiosave console," by Neil (2023), personal photo collection.[26]

Nursing Practice Tips

Transporting patient with an IABP:

- The cardiologist should confirm the transport is clinically indicated.
- A Perfusionist staff member must be present.
- Ensure continuous cardiac and hemodynamic monitoring.
- The Cardiosave console can be unplugged for transport and plugged into AC power again at the transport location.

Nursing Assessment and Documentation

Nursing care and assessment of a patient with an IABP and its components are vital to ensure the patient's comfort and avoid any potential complications.

Eastern Health (EH) Policy Document

IABP: Patient Care (Policy: 214CC - CAR – 220)

Intra-Aortic Balloon
Pump (IABP) - Patient

Please review EH Policy: IABP: Patient Care on the EH intranet.

Nursing Care Tips

- Positioning.
    - The head of the bed must be equal to or less than 30 degrees.
    - Ensure the leg with the IABP remains straight and no hip flexion.
    - Turning and repositioning q 2 hours if patient hemodynamically stable to log roll.
    - Don't forget to assess heels and use heel protectors.
    - Progressa pressure relief mattress is preferred due to prolonged bed rest.

- Dressing changes.
    - Clear transparent dressing every seven days.
    - Change more frequently if the dressing becomes loose, damp, or saturated with drainage.

- Timing of the IABP.
    - Assess upon insertion, admission of the patient to coronary care, and at the beginning of each shift and as indicated by changes to waveform configuration.
    - Timing will be explained in the following section.

  - Changes in heart rate and rhythm may require a change in timing.
  - Timing errors: *early inflation* and *late deflation* are detrimental and must be attended to as soon as those errors are detected.

- Level and zero the transducer of IABP.
  - Required at the beginning of your shift and with changes in patient positioning.
  - Level and zero the transducer to the right atrium or phlebostatic axis level.

- Flush the pressure line of the IABP.
  - Place the IABP on standby and flush the pressure line at the beginning of the shift.

- Daily chest X-ray.
  - Follow the cardiologist's order.
  - Used to assess the position of the IAB catheter.

- Anticoagulant: Heparin IV protocol.
  - Follow the intravenous (IV) heparin protocol as ordered.
  - IV heparin is used to avoid the complication of thrombus formation.

- Encourage deep breathing exercises.
  - If the patient is conscious, promote adequate ventilation and lung expansion to prevent the development of lung infections.

- Assist with nutrition and hydration.
  - If the patient is conscious, assist the patient with nutrition, as it may be challenging to eat or drink with the head of the bed no higher than 30 degrees. [9,17]

Assessment required EVERY hour

- Document pressures from the IABP.
    - IABP frequency.
        - Frequency 1:1: Augmented pressure, assisted systolic, assisted diastolic, mean arterial pressure, heart rate.
        - Frequency is 1:2 or 1:3: Augmented pressure, assisted systolic, assisted diastolic, mean arterial pressure, heart rate, unassisted systolic and unassisted diastolic pressure.
- Neurovascular assessment of limb with IABP.
- Urine output.
- Check the IAB catheter and tubing.
    - Assess from the insertion site to the Cardiosave console.
    - Look for any blood or foreign particles.
    - *Rationale*. Assessing for potential signs of balloon rupture.[9]

Nursing Practice Tips

IAB migration

- Place Sp02 (oxygen saturation) probe on the left hand and check the left radial pulse.
    - If you lose the Sp02 trace or the left radial pulse is absent or weaker than the right radial pulse; this may indicate that the IAB has migrated too high (possibly the subclavian artery migration).
- Urinary output
    - If you note a decreasing urinary output; this may indicate that the IAB has migrated too low (possibly obstructing the renal arteries) or worsening hemodynamic status.[9]

Quiz Activity 4.1

Please answer true (T) or false (F) to the following statements by placing an 'X' in the appropriate box. The answers can be found in Appendix E of the resource under Quiz Activity 4.1: Answer Key.

	Statements	T	F
1.	The IABP is a right ventricular support device.		
2.	An IABP is recommended for CS when other MCS devices are unavailable, contraindicated, or cannot be inserted.		
3.	Carbon dioxide is the gas used to inflate the IAB.		
4.	When the IAB catheter is positioned correctly, it is in the descending aorta.		
5.	The IAB catheter has two radiopaque markers for visualization under fluoroscopy and X-ray.		
6.	You must visually inspect the IAB catheter and tubing once a shift.		
7.	If patient transport outside the coronary care unit is required, the perfusionist must be present for the transfer.		
8.	You must complete a neurovascular assessment on the affected limb after the IAB is inserted. The routine frequency of assessment is every 15 mins x 4, then every 30 mins x 2, and then every 1hr for the duration of therapy.		

Major IABP Complications

- **Major limb ischemia**
    - As a loss of pulse or sensation, or abnormal limb temperature or pallor, requiring surgical intervention.
    - Potential causes include:
        - thrombus,
        - mechanical obstruction by the IAB catheter,
        - decreased cardiac output,
        - immobilization,
        - arterial injury,
        - pre-existing peripheral vascular disease, and
        - decreased cardiac output. [27]
    - Signs of diminished perfusion to the limb should be communicated immediately to the cardiology resident for intervention.
- Balloon rupture
    - A rare event related to a damaged balloon inner lumen or a pinhole perforation develops.
    - Cause
        - Malposition of the IAB catheter or from the IAB repeated contact with pre-existing calcium plaque.
    - Assessment indicators
        - Blood in the gas line
        - Unexplained loss of helium. [27,28]
    - Action
        - STOP the IABP by placing it on standby

        - CALL perfusionist and cardiologist
        - Disconnect the catheter extender tubing from the IABP console to allow the balloon to deflate.
        - Clamp extracorporeal tubing between white y-fitting and male connector.
        - Place the patient in Trendelenburg as tolerated to guide any residual helium to travel away from the head vessels.
        - Prepare for the IAB catheter removal.
        - Consider IAB catheter replacement if the patient's condition warrants.
        - If blood is suspected of having entered the pump, take the pump out of service. Biomed will need to evaluate. [28]

- Severe bleeding
    - Observe for signs of bleeding.
    - Thrombocytopenia may occur related to the mechanical destruction of platelets by the pumping action of the balloon.[27]
        - Platelet counts are monitored by a complete blood count (CBC) blood test.[17]

Remember

The IABP should not be dormant for 30 mins; due to the high risk of thrombus formation.
If the IABP is inactive for 30 minutes, the IAB catheter must be removed immediately by the cardiologist or cardiovascular surgeon. [9,22]

Cardiosave Console

The Cardiosave console has a touchscreen operational function. You have to press and hold the unlock button to access the menus located at the top of the touch screen.[22] As mentioned, the perfusionist will establish the initial settings and be available 24 hours daily for troubleshooting. Let's take a look at the Cardiosave console and its functions.

Frequency

The frequency of the IABP refers to the ratio of heartbeats to balloon inflations. You can select the frequency, and the drop-down box will appear with the three options, see Figure 4.11.

Figure 4.11

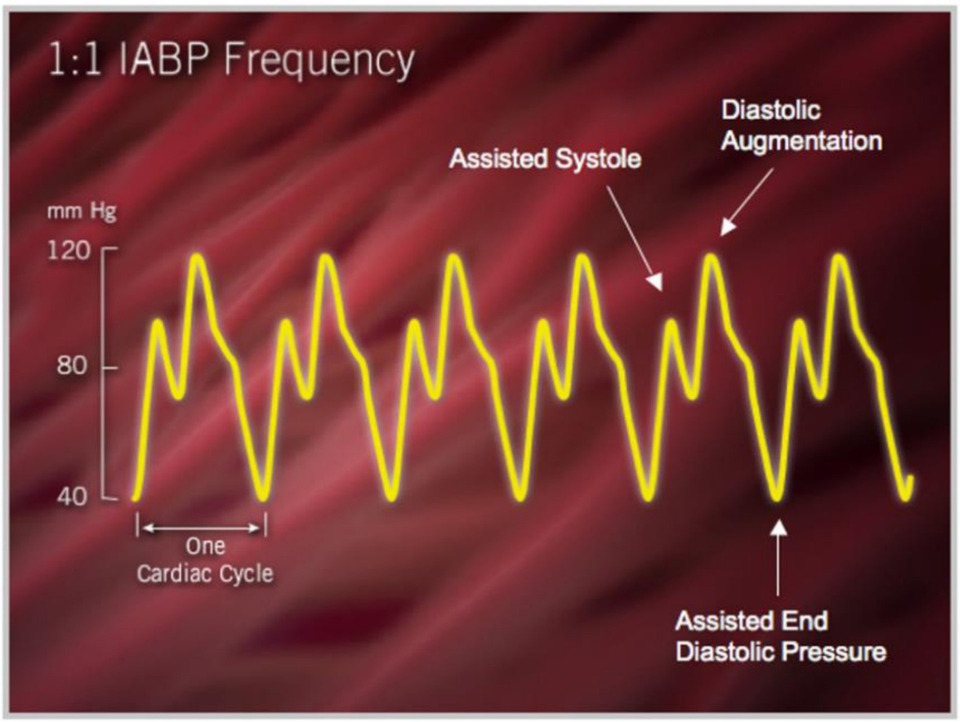
IABP Frequency

Source. From "Cardiosave console: Frequency selection," by Neil (2023), personal photo collection.

There are three options for the IABP frequency: 1:1, 1:2, and 1:3. At the HSC, the most commonly used frequencies are 1:1 and 1:2. Figures 4.12 and 4.13 illustrate the pressure waveform for the IABP 1:1 and 1:2, respectively.

Figure 4.12

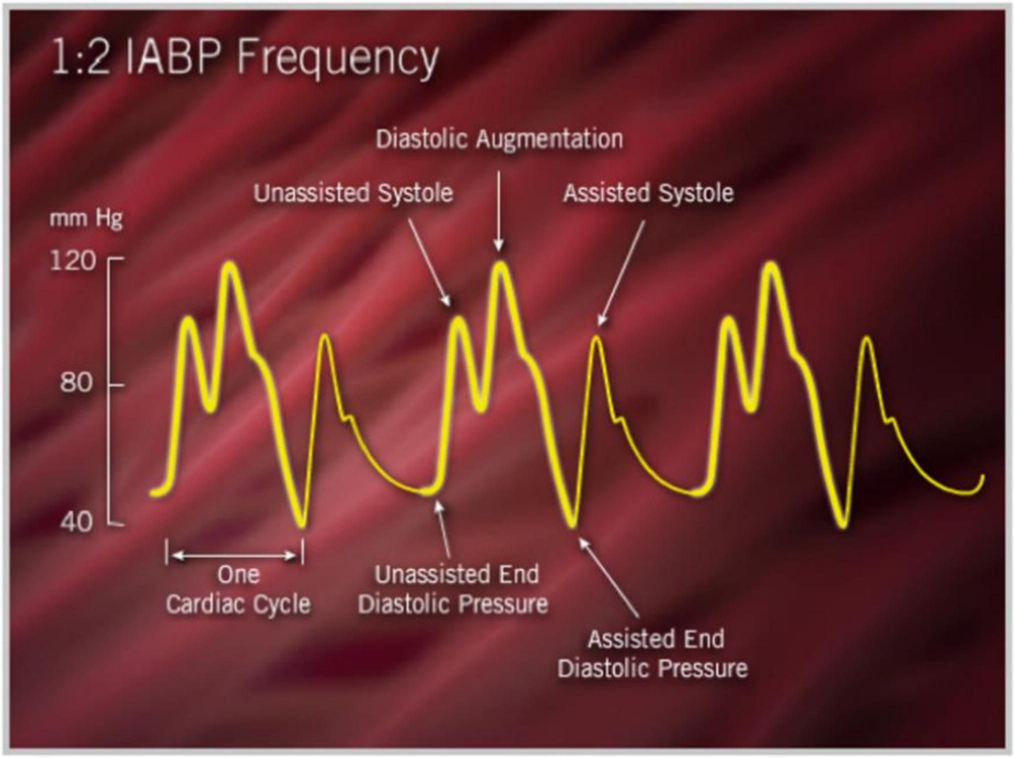
IABP Frequency (1:1) Waveform



Source. From "*Intra-aortic Balloon Counterpulsation Therapy: Theory of Counterpulsation ELearning Program*," by Getinge Group, 2021, p. 18 (https://lms.getinge.training/gateway/course/1010001718/view). Copyright 2021 by Getinge Group. Reprinted with permission. [18]

Figure 4.13

IABP Frequency (1:2) Waveform



Source. From "*Intra-aortic Balloon Counterpulsation Therapy: Theory of Counterpulsation ELearning Program*," by Getinge Group, 2021, p. 18 (https://lms.getinge.training/gateway/course/1010001718/view). Copyright 2021 by Getinge Group. Reprinted with permission.[18]

Clinical Application

The cardiologist orders the ratio of the IABP frequency. Most commonly, the order is a ratio of 1:1 for patients with CS. The goal is to augment every cardiac cycle.

Generally, the cardiologist will order 1:2 when weaning the IABP for removal.[9]

Remember

Systole - IAB deflates

Diastole- IAB inflates[9,17,18]

Trigger

The IABP Cardiosave console needs a source to identify the start of the next cardiac cycle. When the Cardiosave identifies the trigger event, it will deflate the IAB. The perfusionist will set the trigger mode.

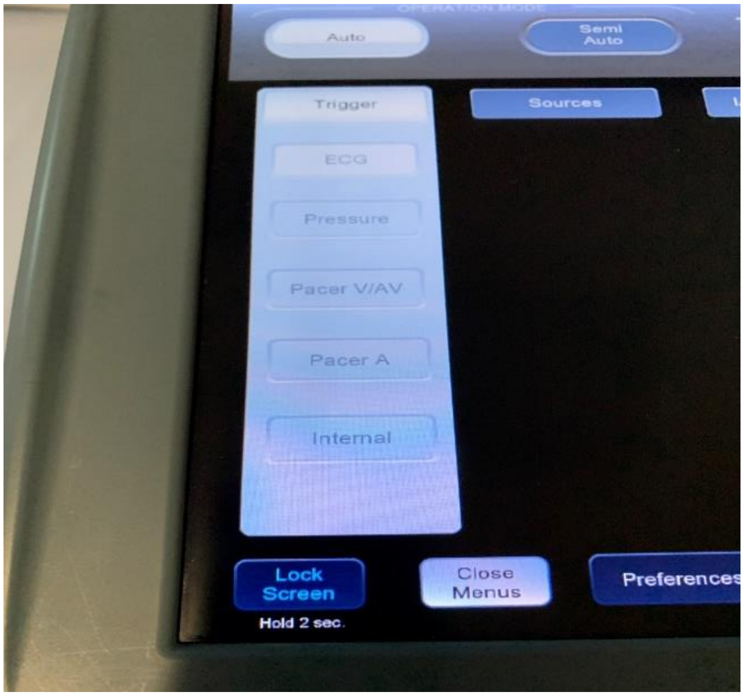
Various trigger modes include:

- electrocardiography (ECG),
- pressure, pacer A/AV,
- Pacer A, and internal.[22]

Figure 4.14 displays the various trigger modes on the Cardiosave Console.

Figure 4.14

Trigger Modes on the Cardiosave Console



Source. From "Trigger modes on the Cardiosave console," by Neil (2023), personal photo collection.[29]

ECG

The preferred trigger mode is ECG because the electrical impulses occur before the mechanical actions of the heart.

- When selecting the correct ECG lead for the trigger, choose the lead that gives the largest R wave and a minimal p and t wave.
- The deflation will occur at the peak of the R wave (systole).
- The IAB inflation is triggered by the middle of the t wave (diastole).
- The ECG leads attached to the Cardiosave console and electrodes should be changed every 24 hours.
- You should remember ECG trigger will likely not be chosen if your patient has arrhythmias or is constantly paced, as the R wave will not be easily detected. [9]

Pressure

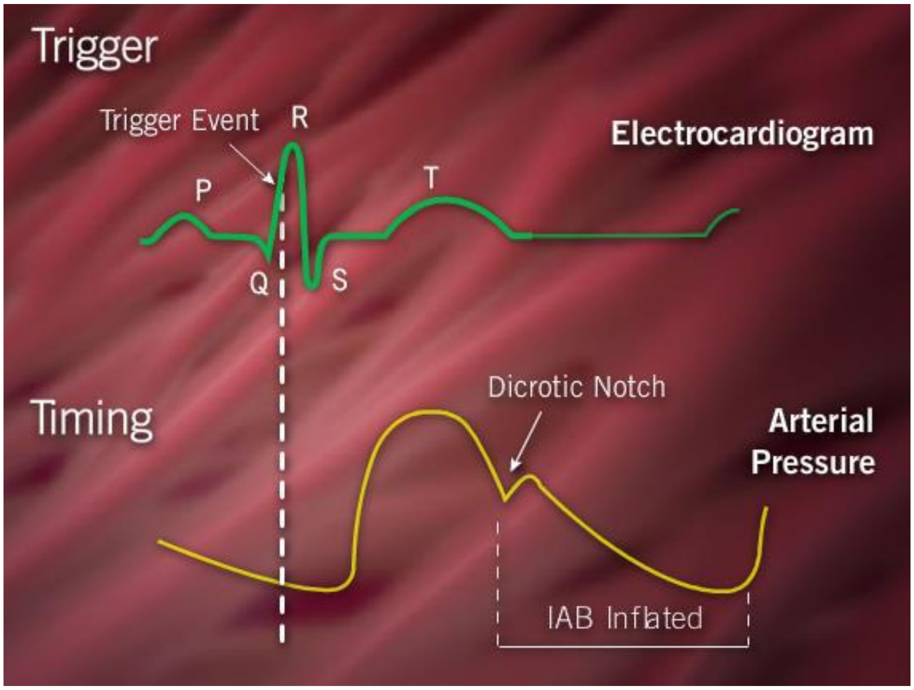
If the R wave is not detectable in the ECG mode, the trigger can be changed to pressure on the Cardiosave console.

- The trigger event for pressure mode is the systole upstroke on the arterial waveform will trigger the IAB deflation.
- The IAB inflation will occur at the dicrotic notch.
- Generally, you will note that the pressure trigger is the "backup" for the ECG trigger.
    - For example, if an ECG lead is disconnected, the Cardiosave console automatically switches to the pressure trigger until the disconnected ECG electrode is reconnected.[22]
- Another important consideration is that a pressure trigger should be selected when a patient suffers a cardiac arrest and requires CPR.
    - This can most easily be done by pulling the ECG cable from the Cardiosave console.
    - Do not turn off the IABP during CPR.
    - The IAB will inflate and deflate in synchrony with chest compressions. If the IAB does not inflate and deflate, it may signal that chest compressions are inadequate.

Review Figure 4.15 as it shows the location of the trigger event (the beginning of the next cardiac cycle, which deflates the IAB) for the ECG and pressure waveforms.

Figure 4.15

ECG and Pressure Trigger Event



Source. From "*Intra-aortic Balloon Counterpulsation Therapy: Theory of Counterpulsation ELearning Program*," by Getinge Group, 2021, p. 15 (https://lms.getinge.training/gateway/course/1010001718/view). Copyright 2021 by Getinge Group. Reprinted with permission. [18]

Pacer V/AV, Pacer A, and Internal

Pacer V/AV and pacer A.

- These trigger modes are only used when the patient's cardiac rhythm is constantly paced (100% paced, all the time).
- Either ventricular paced or atrial ventricular paced rhythms, and there is no reliable R wave.[9,22]

The last trigger mode is internal, an asynchronous mode in which the IAB is set to inflate and deflate at a prescribed rate and is used primarily for cardiopulmonary bypass; very unlikely for this setting to ever be used in coronary care.[9,22]

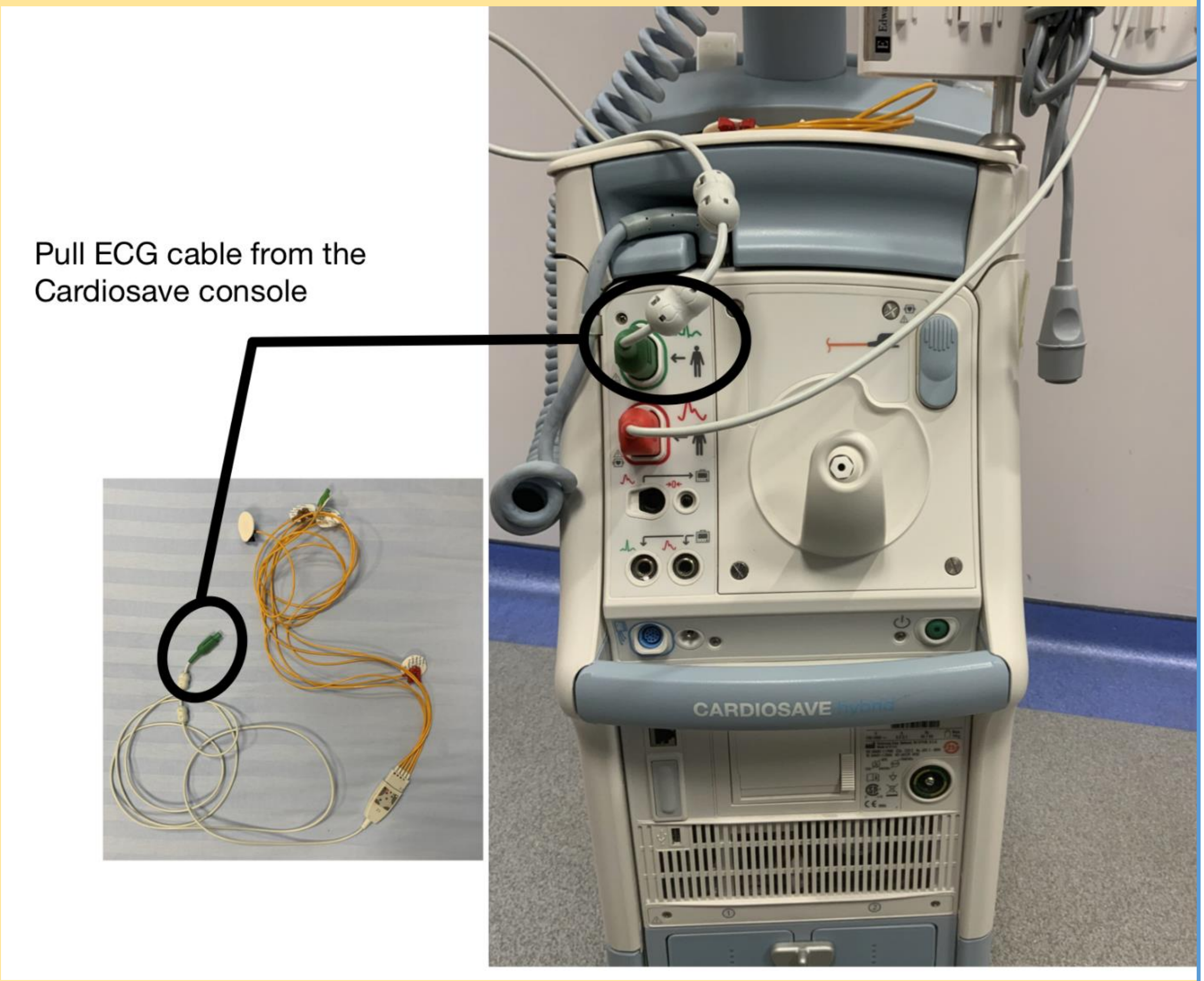
Nursing Practice Tips

Defibrillation

If a patient with IABP requires defibrillation, the IABP can stay in operation, and you can proceed to defibrillation. Be sure not to touch any parts of the IAB catheter or the Cardiosave console during defibrillation to avoid electric shock.

CPR

If the patient with an IABP requires CPR, then the IABP can remain on. The Cardiosave should detect CPR and automatically change to a pressure trigger. However, you can also pull the ECG cable out of the back of the Cardiosave console; this action will automatically switch the trigger to pressure. The chest compressions should generate enough pressure so that the IAB will continue to inflate and deflate and generate an arterial pressure waveform. If the resuscitation is successful, it is very important to assess the timing of the IAB. Also, if you removed the ECG cable remember to plug it back into the Cardiosave console.



Timing of the IABP

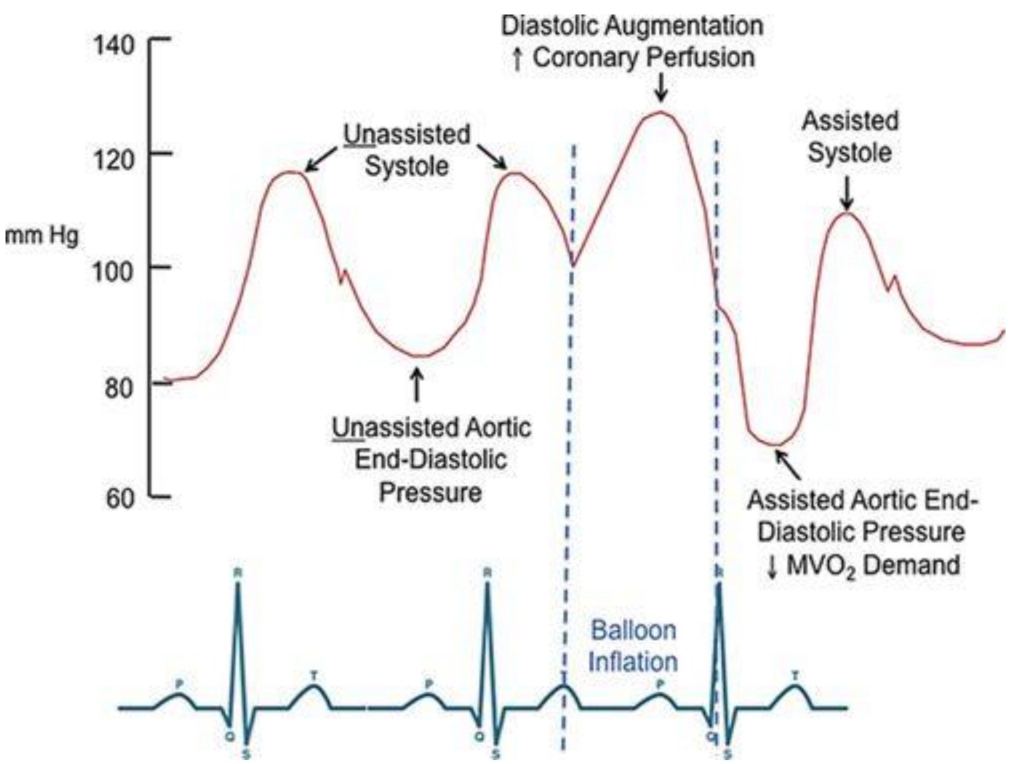
Understanding the principles of counterpulsation and what occurs in a normal cardiac cycle will help you understand the timing of the inflation and deflation of the IAB. Timing is important to ensure the patient gets the full hemodynamic benefit from the IABP. [2] You are responsible for assessing the timing of the IABP at the beginning of your shift and anytime you are concerned about timing errors. [9]

Review Figure 4.16 and examine what is occurring.

- This figure includes both a pressure waveform and an ECG tracing to help you.
- When you are reviewing the timing of the IABP, you must be able to see an unassisted beat (patient) and an assisted beat (balloon).
- The frequency of the IABP is set to 1:2 to assess timing (every 2nd beat will be an assisted beat).[8]

Figure 4.16

Assessment of Timing with Arterial Waveform and ECG



Source. From "Intra-aortic balloon pump for high-risk percutaneous coronary intervention," by T. Patterson, D. Perera, & S. R. Redwood, 2014*, Circulation Cardiovascular interventions, 7*(5), p. 713(*https://doi-org.qe2a-proxy.mun.ca/10.1161/CIRCINTERVENTIONS.114.001258). * [8]

Inflation Timing

The IAB inflates at the onset of diastole when the heart is relaxing; this corresponds with the t wave on the ECG tracing or the dicrotic notch on the arterial waveform. Remember, diastole is when the heart is relaxing and getting ready to repolarize with the closing of the aortic values, which produces the dicrotic notch on the arterial waveform. So, as noted by the first vertical blue dotted line, the IAB inflates on the dicrotic notch, interrupting the normal diastolic phase and creating an augmented or assisted diastole. The augmented diastole (assisted diastole) increases coronary perfusion.[8,9]

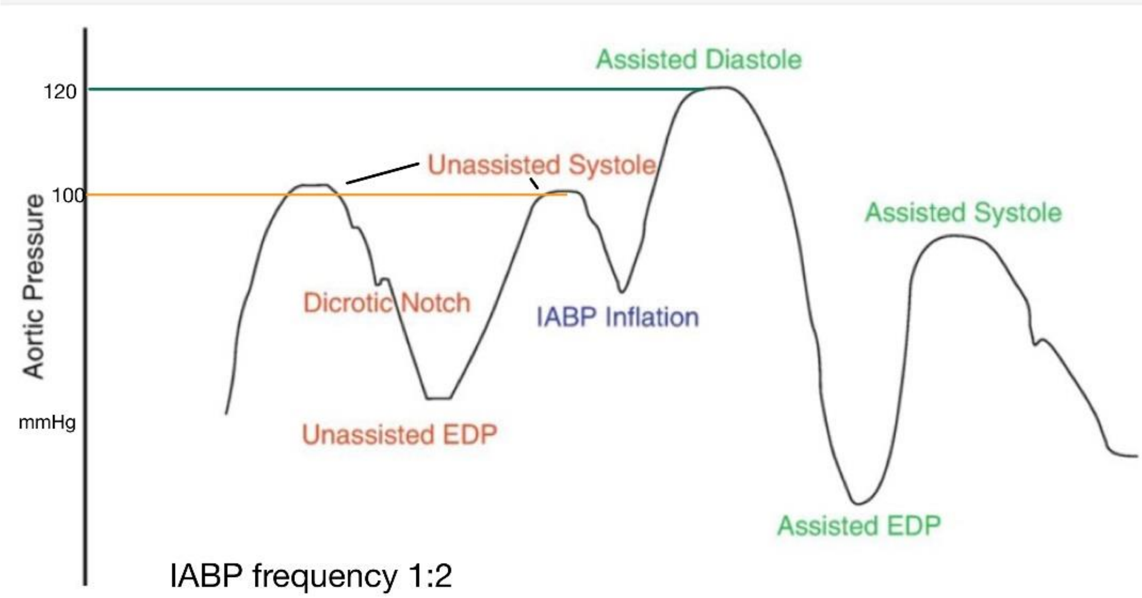
When the IAB inflates properly during diastole just before the dicrotic notch, the response is increased perfusion to the coronary arteries and the displacement of blood in the aorta. The inflated IAB displaces blood into the coronary arteries and the aorta. [9]

Waveform characteristics of good timing, as depicted in Figure 4.17, include:

- the augmented diastole (assisted diastole) should be equal to or higher than the unassisted systole to increase coronary perfusion and
- a "sharp V" shape starting at the dicrotic notch when the "IABP inflation" occurs.[9]

Figure 4.17

Assisted Diastole (augmented diastole) Pressure is Higher Than Unassisted Systole Pressure



Legend. Unassisted EDP: unassisted aortic end-diastolic pressure

Source. Adapted from "Mechanical Circulatory Support in ST-elevation Myocardial Infarction," by N. Lo and E. Magnus Ohman, in T. J. Watson, P.J. Ong, and J.E. Tcheng (Eds.), 2018, *Primary Angioplasty a Practical* Guide, p. 258 (https://doi.org/10.1007/978-981-13-1114-7). Creative Commons Attribution 4.0 International License.[30]

Deflation Timing

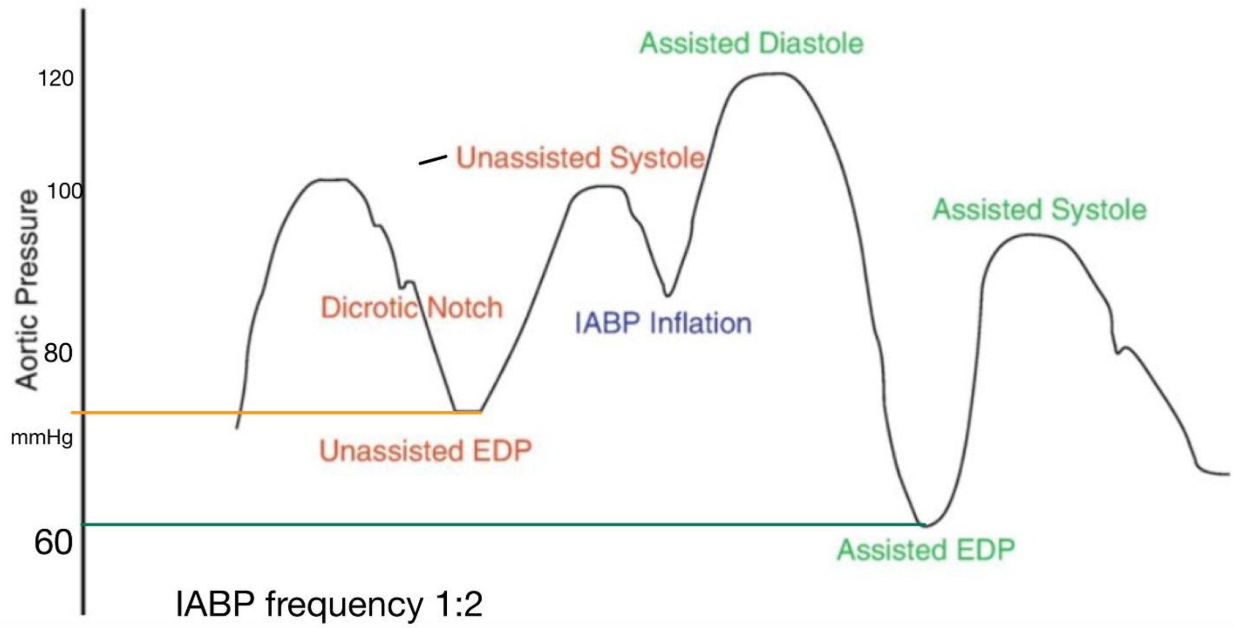
To assess the deflation timing, we can look at the pressure responses, as no specific point can be seen on the arterial waveform for the deflation. Remember, deflation (the IAB collapses) during systole causes the work of the left ventricular to be decreased, leading to decreased afterload and a decrease in the myocardial oxygen demand. With the decreased afterload, you should see an increase in your patient's cardiac output and stroke volume. [17]

Waveform characteristics of good timing, as depicted in Figure 4.18, include:

- the assisted aortic end-diastolic pressure should be lower than the unassisted aortic end-diastolic pressure, and
- the assisted systole should be lower than the unassisted systole.[9]

Figure 4.18

IAB Deflation: Assisted end Aortic Diastolic Pressure is Lower than the Unassisted EaDP



Source. Adapted from "Mechanical Circulatory Support in ST-elevation Myocardial Infarction," by N. Lo and E. Magnus Ohman, in T. J. Watson, P.J. Ong, and J.E. Tcheng (Eds.), 2018, *Primary Angioplasty a Practical* Guide, p. 258 (https://doi.org/10.1007/978-981-13-1114-7). Creative Commons Attribution 4.0 International License.

Nursing Practice Tips

How to Assess the Timing of the IABP?

1. Place the frequency of the IABP to 1:2

2. Print a strip

3. Return the IABP in 1:1

4. Label the strip:

    - Identify the dicrotic notch # 3 (IAB inflation #5)
    - Augmented diastolic pressure #6 (assisted diastole)
    - Unassisted systole (#2)
    - Assisted systole (#8)
    - Unassisted end-diastole aortic pressure (# 4)
    - Assisted end-diastole aortic pressure (#7)

5. Check to confirm that inflation occurs just before the dicrotic notch (#5)

6. Locate the augmented diastolic pressure (assisted diastolic pressure) (#6)

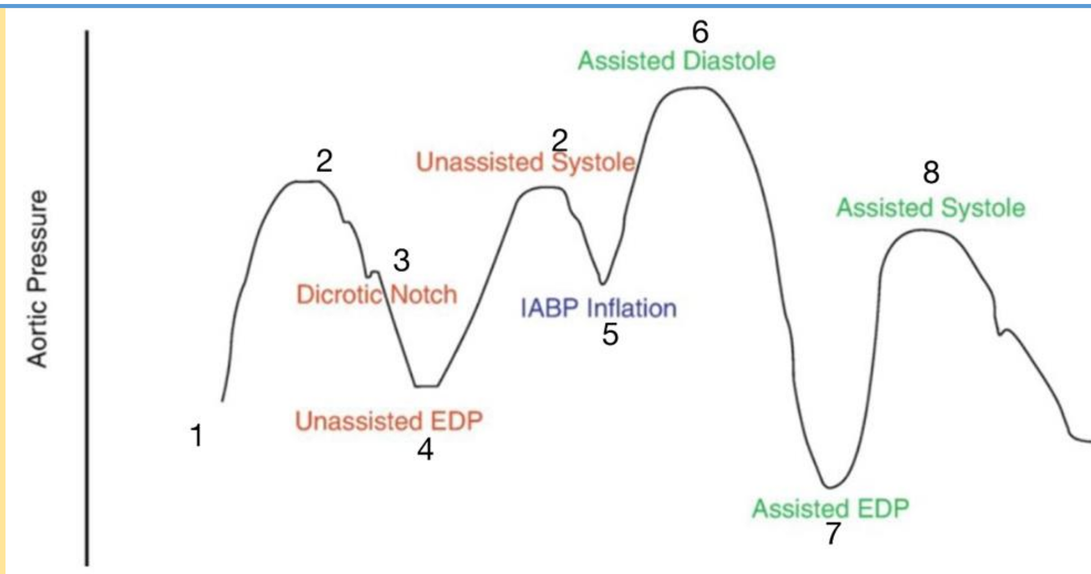
    - Compare the assisted diastole pressure with the unassisted systole
    - **The assisted diastole (augmented pressure, #6) is higher than the unassisted systole (#2)**

7. Compare assisted end-diastolic aortic pressure (#7) with the unassisted end-diastolic aortic pressure (#4)

    - **The assisted end-diastolic aortic pressure (#7) is lower than the unassisted end-diastolic aortic pressure (#4)**

8. Compare assisted systole (#8) with the unassisted systole (#2)

    - **The assisted systole (#8) is lower than the unassisted systole (#2)**



Source. Adapted from "Mechanical Circulatory Support in ST-elevation Myocardial Infarction," by N. Lo and E. Magnus Ohman, in T. J. Watson, P.J. Ong, and J.E. Tcheng (Eds.), 2018, *Primary Angioplasty a Practical* Guide, p. 258 (https://doi.org/10.1007/978-981-13-1114-7). Creative Commons Attribution 4.0 International License. [30]

1. **Aortic valve open (onset of systole)**
2. **Unassisted systole**
3. **Dicrotic notch (closure of the aortic valve)**
4. **Unassisted aortic end-diastolic pressure**
5. **IAB inflation**
6. **Diastolic Augmentation (assisted diastole)**
7. **Assisted aortic end-diastolic pressure**
8. **Assisted systole**

A copy of this content can be found in Appendix F, Printable Content.

Timing Errors: Early Inflation

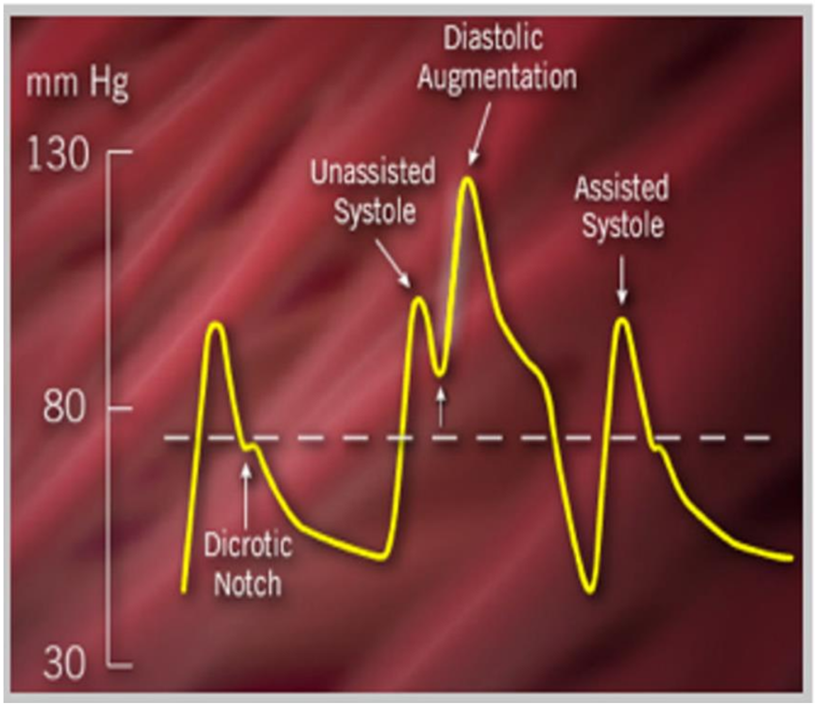
During early inflation, the IAB inflates before the end of systole, before the aortic valve closes. This is problematic as the early closure of the aortic valve means incomplete ejection of blood from the ventricle; this decreases cardiac output. Early inflation causes increased work of the heart, wall stress, afterload, increased oxygen consumption and increased end-diastolic aortic pressure. It can also cause aortic regurgitation. *It is a problem that needs your attention and needs to be fixed.*[9,22]

Waveform characteristics of early inflation, as depicted in Figure 4.19, are:

- the IAB is inflating during systole, before the dicrotic notch (See the white arrows in Figure 4.19), and
- the diastolic augmentation (assisted diastole) is interrupting the systole.[22]

Figure 4.19

Early Inflation



Source. From "*Intra-aortic Balloon Counterpulsation Therapy: Theory of Counterpulsation ELearning Program*," by Getinge Group, 2021, p. 22 (https://lms.getinge.training/gateway/course/1010001718/view). Copyright 2021 by Getinge Group. Reprinted with permission.[18]

Timing Errors: Late Inflation

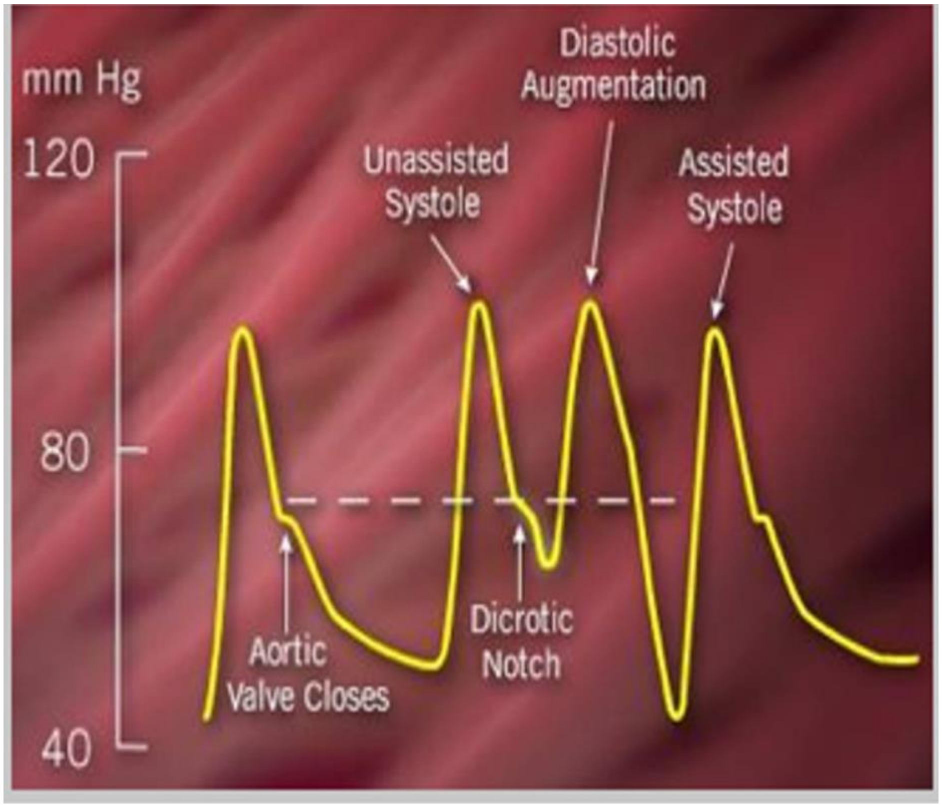
During late inflation, the IAB inflates long after the aortic valve closes. This is problematic as the late inflation means there is less blood available to be displaced to the coronary arteries and the aorta. Late inflation causes a decreased coronary perfusion and decreased mean pressure.

Waveform characteristics of late inflation, as shown in Figure 4.20, are:

- the IAB is inflating after the dicrotic notch,
- the absence of a "sharp V," and
- diastolic augmentation is decreased.
    - Remember: in normal inflation, the diastolic augmentation should be higher than the unassisted systole.[9]

Figure 4.20

Late Inflation



Source. From "*Intra-aortic Balloon Counterpulsation Therapy: Theory of Counterpulsation ELearning Program*," by Getinge Group, 2021, p. 23 (https://lms.getinge.training/gateway/course/1010001718/view). Copyright 2021 by Getinge Group. Reprinted with permission.[18]

Timing Errors: Early Deflation

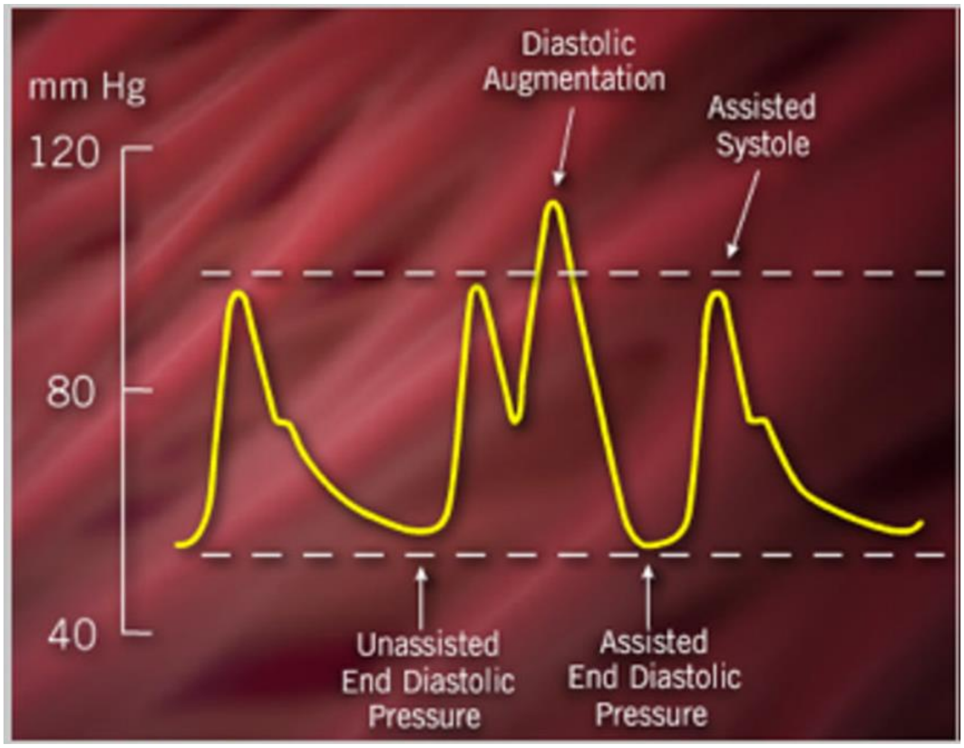
Early deflation is when the IAB deflates during the diastole phase of the cardiac cycle. During early deflation, the afterload is not reduced, which increases the heart's workload and myocardial oxygen consumption. The coronary arteries perfusion may be suboptimal, and retrograde coronary flow may lead to anginal symptoms.

Waveform characteristics of early deflation, as shown in Figure 4.21, are:

- after the diastolic augmentation there is a sharp drop in the waveform,
- the diastolic augmentation is not adequate,
- the assisted end-diastolic aortic pressure is equal to or less than the unassisted end-diastolic aortic pressure, and
- the assisted systole pressure may increase.[9]

Figure 4.21

Early Deflation



Source. From "*Intra-aortic Balloon Counterpulsation Therapy: Theory of Counterpulsation ELearning Program*," by Getinge Group, 2021, p. 23 (https://lms.getinge.training/gateway/course/1010001718/view). Copyright 2021 by Getinge Group. Reprinted with permission.[18]

Timing Errors: Late Deflation

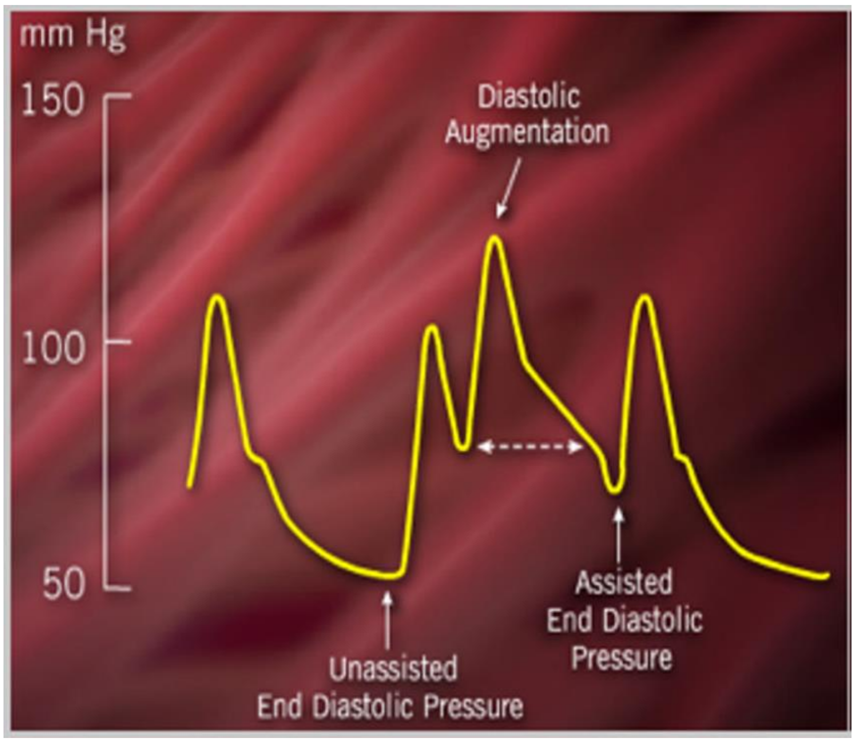
Late deflation means that the IAB deflates after the beginning of the contraction (after the aortic valve has opened). This is a problem as no afterload reduction leads to increased myocardial oxygen consumption due to increased resistance that the left ventricle must pump against. Also, the late deflation of the IAB may obstruct the left ventricular ejection of blood, decreasing cardiac output. *It is a problem that needs your attention and needs to be fixed.*

Waveform characteristics of late deflation, as depicted in Figure 4.22, are:

- the assisted end-diastolic aortic pressure may be equal to or higher than the unassisted diastolic pressure,
- the diastolic augmentation pressure waveform may be widened, and
- the assisted systolic pressure is not assisted; it may be prolonged.[9]

Figure 4.22

Late Deflation



Source. From "*Intra-aortic Balloon Counterpulsation Therapy: Theory of Counterpulsation ELearning Program*," by Getinge Group, 2021, p. 24 (https://lms.getinge.training/gateway/course/1010001718/view). Copyright 2021 by Getinge Group. Reprinted with permission.[18]

Remember

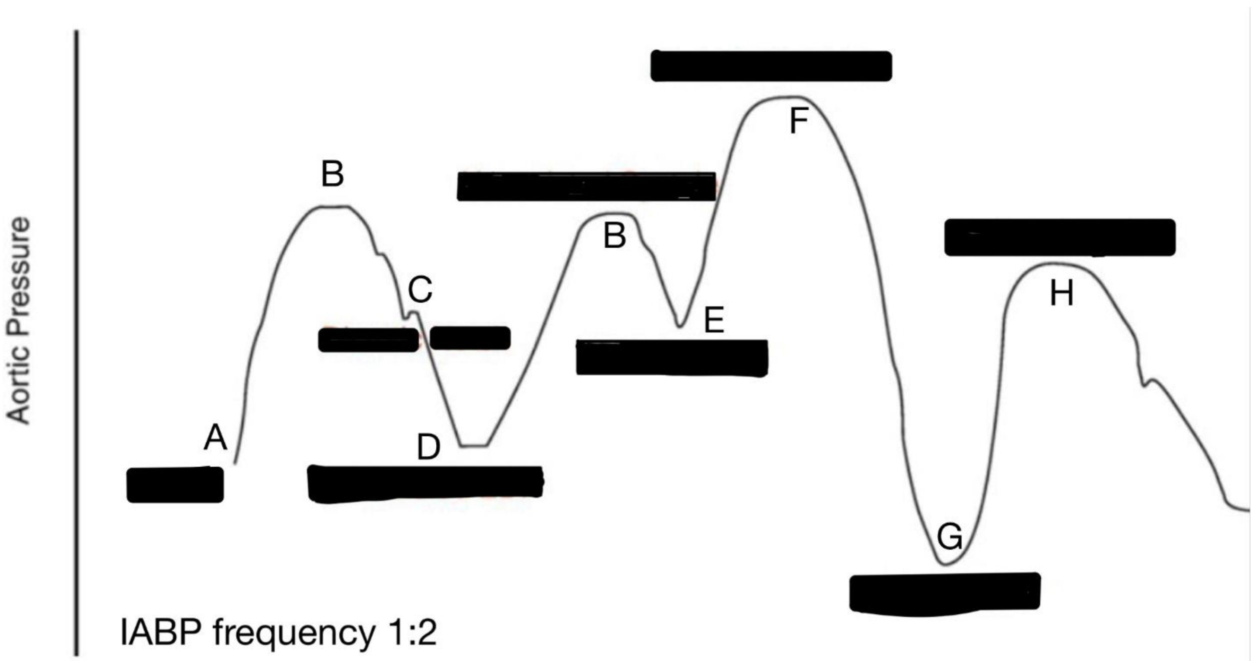
Timing Errors

Remember that early inflation and late deflation are the worst timing errors.

Early inflation *and* ***Late Deflation*** → ***Require immediate intervention***

Interactive Activity 4.2

Please match the correct term with the appropriate letter to identify the main components of the IABP pressure waveform. The answers can be found in Appendix D under Interactive Activity 4.2.



Aortic valve open	Unassisted aortic end-diastolic pressure
Assisted aortic end-diastolic pressure	Dicrotic notch (Aortic valve close)
Assisted systole	IAB inflation
Diastolic augmentation (Assisted diastole)	Unassisted systole

Balloon Pressure Waveform

The IAB waveform is also displayed on the Cardiosave Console. The waveform indicates how well the IAB is inflating and deflating with helium. It is a chair shape. Figure 4.23 illustrates the IAB waveform.

The IAB waveform characteristics are:

- Inflation spike, which is shown as pressure quickly increases to fill the balloon (#3),
- peak inflation artifact (#4) and pressure plateau (#5), and
- then a quick deflation drops in pressure (#6) and a peak deflation pressure below baseline (#7) before it returns to baseline before the next inflation.[9]

Figure 4.23

Balloon Pressure Waveform

Source. From "Cardiosave Console and Balloon pressure waveform," by Neil (2023), personal photo collection.[31]

Troubleshooting and Alarms

The Cardiosave console will make an audible sound when an alarm occurs and an alarm message will be displayed on the screen.

Please see Table 4.4 for the most common alarms and the necessary actions required to resolve the alarm.

Table 4.4

Cardiosave Alarms

Alarm	Action
Augmentation below the limit set	• Check to ensure the alarm limit is set appropriately. • Change in patient's hemodynamic status. Therefore, you will need to attempt to improve hemodynamic status by titrating vasoactive medications, assessing volume status, and collaborating with the cardiologist team.
Autofill failure	• Check the IAB catheter to make sure all connections are secure. • Check the back of the console to ensure the extender tubing for the helium line is not disconnected. • Assess the helium icon on the IABP Cardiosave console to ensure the tank is not empty or closed. Call the perfusionist to access the helium tank.
Unable to update timing	• Cause: Poor waveform. • Check connections and make sure all connections are secure. • Check the transducer line and ensure it is not left open to the air. • Place IABP on standby and flush the transducer line, then press start. • If unable to solve, contact the perfusionist for additional troubleshooting. It may need to be switched to semi-auto and adjust the timing.

	• If the heart rate is less than 30 or greater than 150, you may have to consult the perfusionist to adjust the timing by changing to semi-auto mode and adjust the timing. • *Always consult the perfusionist; they are available 24 hours a day to guide you through these changes*.
IAB disconnected	• The IAB catheter or extender tubing is disconnected. Therefore, reattach the IAB, and remember to press start.
Prolonged time on standby	• Occurs when the pump has been on standby for 10 mins. • Confirm that it is appropriate to resume pumping. Remember, an IAB catheter should not be inactive for 30 mins; the balloon has a high risk of thrombus formation if dormant.
Gas loss in the IAB circuit	• Cause: Helium loss has been detected in the circuit. • Check the IAB catheter from the insertion site along the catheter up the extender tubing to the IABP console. Observe for blood. If blood is seen, then STOP pumping. Contact the cardiologist and prepare for IAB catheter removal. Blood is an indication of potential balloon rupture. Follow the procedure for IAB rupture complication. • If blood is not seen, proceed to ensure that all connections are tight. • Contact the perfusionist for additional guidance and troubleshooting if you cannot solve the problem.[22]

Unexplained **shutdown** of Cardiosave console • Screen abruptly turns off, and a high-pitched alarm is emitted • Before this happens, there may be other alarms that you should pay close attention to: o Autofill failure, autofill failure, gas gain in the IAB circuit, gas loss in the IAB circuit, and IAB catheter restriction.	• Cause: Blood entering into the Cardiosave IABP when therapy is provided with a perforated IAB catheter. • This can threaten the hemodynamic status of the patient as the loss of support from the IABP. • Follow the procedure for IAB rupture.[22,28]

Case Study 4.3

Read the following case study information and circle the most appropriate answer. The answers can be found in Appendix H: Case Study 1.3: Answer Key.

A 64-year-old female is admitted with a large anterior STEMI. She was emergently transferred to the cardiac catheterization lab and underwent PCI of the left anterior descending coronary artery with a drug-eluting stent. Her LVEDP was high on her catheterization report, and a bedside ECHO revealed a reduced ejection fraction of approximately 20%. During the cardiac catheterization, she received Lasix 40 mg, and a norepinephrine infusion was initiated for an SBP less than 90. Before transferring to the coronary care unit, the cardiologist inserts an IAB catheter, and the IABP is in operation when the patient is transferred to the coronary care unit.

1. What are the benefits of IABP therapy?

    a. Increased preload and increased afterload
    b. Decreased preload and decreased afterload
    c. Increased blood flow to coronary arteries and increased afterload
    d. Increased blood flow to coronary arteries, decreased afterload, and improved cardiac output

2. The perfusionist reviews the setting of the IABP and tells you that the frequency of the IAB is set at 1:1. What does that indicate?

    a. The balloon will inflate with every cardiac cycle (heartbeat)
    b. The balloon will inflate with every second cardiac cycle (heartbeat)
    c. The balloon will inflate with every third cardiac cycle (heartbeat)
    d. The balloon will inflate with every fourth cardiac cycle (heartbeat)

3. The perfusion reports that the trigger mode of the IAB is ECG. When the perfusionist chooses the ECG lead, which would be the best choice?

    a. Widest QRS complex
    b. Largest p-wave and t wave
    c. Small R wave, small p-wave, and t-wave
    d. Largest R wave, minimal p wave, and minimal t-wave

4. The IABP augmentation alarm sounds at 100 mmHg. What is the most appropriate action?

    a. Ignore the alarm
    b. Notify the cardiologist
    c. Begin to titrate the dose of norepinephrine
    d. Adjust the augmentation alarm to 90 mmHg and monitor the patient for hemodynamic changes

Next, as you are monitoring the patient, the IABP alarms “Gas loss in IAB circuit,” and you immediately assess your patient and the IABP Cardiosave console. You notice flecks of blood in the IAB catheter. Please answer questions 5, 6, and 7.

5. What is the likely cause of this alarm?

    a. Poor timing
    b. Balloon rupture
    c. Augmentation alarm
    d. Helium tubing disconnected from IABP

6. What is your next action?

    a. Silent the alarm
    b. Assess the timing
    c. Adjust the augmentation alarm
    d. Place the IABP on standby, notify the cardiologist and perfusionist

7. When you communicate the problem to the cardiologist, what do you anticipate will be the plan of care?

    a. Continue IABP therapy
    b. Urgently remove the IAB
    c. Remove the IABP the next morning
    d. Continue IABP therapy but discontinue systematic heparin

Weaning the IABP

Weaning the IABP is started when there is an order from the cardiologist. Generally, for the order to be obtained, the patient's condition has stabilized, and doses of inotropic medications are low.

The IABP can be weaned by decreasing the frequency of the IABP or augmentation.

- It is the practice in coronary care to decrease the frequency of the IABP from 1:1 to 1:2 and monitor the patient's tolerance for *60 mins.*

You should monitor for:

- tachycardia,
- arrhythmias,
- decreased cardiac output, and
- hypotension.[9]

If the patient tolerates the IABP 1:2, then the cardiologist may decide to remove the IABP or reduce the IABP frequency to 1:3 and monitor for another 60 mins. If no problems arise, then they will remove the IAB catheter.

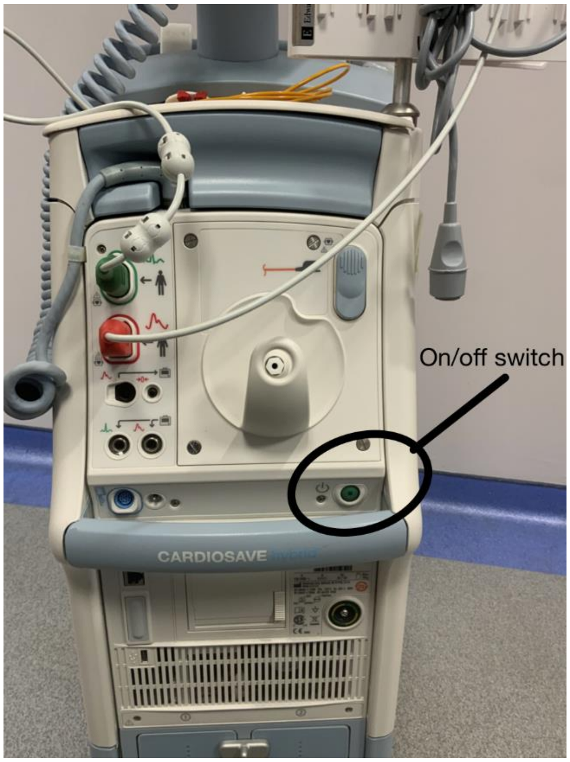
Removal of an IABP

Consideration for removal of an IABP:

- Heparin is held before IABP removal; follow the cardiologist's order, but it is usually held for 2-4 hours before removal.
- Check the morning labs to confirm coagulation and platelet levels; discuss with the cardiologist.
- Prepare the patient for IABP removal.
    - Reposition the patient to supine and move close to the edge of the bed.
    - Consider pain control.
- The Cardiologist will remove the IABP.
- Turn off the console and disconnect the IAB from the console. See Figure 4.24 for the location of the on/off switch (it is on the back of the Cardiosave unit).

Figure 4.24

Cardiosave Console: Power Switch



Source. From "Cardiosave console: Power switch," by Neil (2023), personal photo collection.

- Manual pressure or C-clamp may be used.
  - The cardiologist will remove the IABP catheter with the sheath to avoid the shearing of the balloon and allow blood to bleed back.
  - The cardiologist holds manual pressure, usually held for 15-30 minutes.
  - Alternatively, some cardiologists may prefer to use the C-clamp; therefore, you should position the C-clamp in the bed frame and obtain the disc for use. You must stay with the patient while the C-clamp is in place.
- After the IABP is removed, you are required to monitor the insertion site for signs of bleeding or hematoma formation.
  - Manual pressure and/or the c-clamp are used to maintain hemostasis if bleeding occurs.
- Neurovascular checks are every 15 minutes x 4; every 30 minutes x 2 hours; every 2 hours x 2; then every 4 hours for 24 hours.
- Maintain the affected extremity straight for 4 hours following removal of the IAB catheter.
- Maintain bed rest for 8 hours following removal of the IABP.
- Avoid leg exercises for 24 hours.[9,19]

Patient and Family Considerations

Patient and family education related to the IABP is important to nursing care. CS patients are critically ill, and the treatment involves many life-sustaining supportive devices, including the IABP. It can be a frightening time for the patient and family. Sharing information with the patient and family may help alleviate some of their fears.

Education provided in simple plain language for the patient and family should include the following:

- why the IABP was inserted,
- what the IABP does,
- the potential complications,
- the hourly nursing care, and
- the activity limitations, including bed rest and the affected leg straight.

In addition, if the patient is conscious and coherent, educating them about any abnormal symptoms they should communicate is important.

- Risk of bleeding
    - Signs: sudden wetness at the insertion site, pain in the lower back, and burning discomfort at the insertion site.
- Risk of limb ischemia
    - Signs: tingling, numbness, coldness, pallor and pain in any extremity. [9,17]

Conclusion

Congratulations on completing Module 4!

This module provided an overview of the IABP and the nursing care considerations. You should be able to explain the usage indications and contraindications, fundamental principles of counterpulsation, and the potential complications of the IABP. In addition, images of the Cardiosave console were included to ensure you could visualize the IABP you will use in your practice. Reflect on the many IABP nursing care considerations you have learned as you apply them to your nursing practice. After completing this module, you are ready to complete the required nursing assessments to ensure that the IABP supports your patient’s hemodynamic status. Your nursing care and assessment skills will help avoid complications and detect abnormalities early.

Thank you for taking the time to complete this module or other modules in the resource. This self-directed learning resource will build upon your existing knowledge and strengthen your understanding of the nursing care and treatment of patients at risk for and who develop CS.

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Post-test

Please complete the following post-test once you have completed the modules. At the end of the test, you can refer to Appendix F for the answer key. Please circle the correct answer for each question below.

1. What is the most common cause of cardiogenic shock?

    a. Pericarditis
    b. Dysrhythmia
    c. Pulmonary embolism
    d. Acute myocardial infarction (AMI)

2. Which blood test is used to detect end-organ hypoperfusion in the early stages of cardiogenic shock?

    a. Lactate
    b. Troponin
    c. C-reactive protein (CRP)
    d. B-type natriuretic peptide (BNP)

3. In some cases, the clinical manifestations of cardiogenic shock can vary due to the cause of the shock and its severity.

    True   False

4. What is the estimated mortality rate percentage for patients with cardiogenic shock?

    a. 10%
    b. 30%
    c. 20%
    d. 50%

5. What is the normal expected range for cardiac output?

    a. 4-8 L/min
    b. 2-4 L/min
    c. 1-3 L/min
    d. 1-4 L/min

6. You are assessing a patient for cardiogenic shock. What signs and symptoms do you expect to find? Circle all that apply.

    a. Dyspnea
    b. Increased lactate
    c. Warm, flushed skin
    d. Crackles in lung fields
    e. Cool and clammy skin
    f. Strong peripheral pulses
    g. Urinary output > 30 ml/hr
    h. Increased liver function tests
    i. Systolic blood pressure (SBP) < 90 mmHg
    j. Decreased urea (BUN) and decreased creatinine (Cr)

7. What term describes the resistance the ventricles have to pump against?

    a. Preload
    b. Afterload
    c. Cardiac index
    d. Ejection fraction

8. What hemodynamic parameter is an indication of right-sided preload?

    a. Central venous pressure
    b. Systematic vascular resistance
    c. Pulmonary vascular resistance
    d. Pulmonary capillary wedge pressure

9. Of the hemodynamic parameters listed, which parameter is consistent with cardiogenic shock?

    a. Cardiac output of 4 L/min
    b. Cardiac index of 1.8 L/min/m^2
    c. Mean arterial pressure of 70 mmHg
    d. Pulmonary wedge pressure (PWCP) of 6 mmHg

10. In most cases, pulmonary capillary wedge pressure (PCWP) and left ventricular end-diastolic pressure (LVEDP, reported on the cardiac catheterization report) are often used interchangeably to describe left-sided filling pressures or left-sided preload.

    True False

11. The phlebostatic axis is at the level of the:

    a. Right atrium.
    b. Right ventricle.
    c. Left atrium.
    d. Left ventricle.

12. When measuring atrial and wedge pressure, what is the optimal measuring point on the respiratory cycle?

    a. End inspiration
    b. End expiration
    c. Beginning inspiration
    d. Beginning expiration

13. All of the following are determinants of stroke volume except:

    a. Heart rate.
    b. Preload.
    c. Afterload.
    d. Contractility.

14. The pulmonary artery catheter has other names. Circle all that apply.

    a. SWAN
    b. Sideport
    c. Swan Ganz
    d. Triple lumen

15. What hemodynamic effect will norepinephrine (levophed) have when administered during cardiogenic shock?

    a. Decrease contractility
    b. Decrease cardiac output
    c. Decreased mean arterial pressure
    d. Increase systematic vascular resistance and increase cardiac output

16. The cardiogenic shock patient you are caring for has an intra-aortic balloon pump. The intra-aortic balloon pump inflates during ______________________________and deflates during ________________________.

    a. Diastole and systole
    b. Inspiration and expiration
    c. Systole and diastole
    d. Expiration and inspiration

17. You notice blood in the extender tubing of the intra-aortic balloon pump; what does this most likely indicate?

    a. Balloon migration
    b. Balloon rupture
    c. Late deflation
    d. Early deflation

18. A patient with an intra-aortic balloon pump has a lethal arrhythmia (ventricular fibrillation or pulseless ventricular tachycardia). It is safe to perform defibrillation, provided clinicians stand clear of the intra-aortic balloon pump catheter and console.

    True　　　　　　　　　　　　False

19. Assessing the timing of the intra-aortic balloon pump is crucial to ensure the patient is getting the full benefit of the mechanical assist device. Which timing errors require immediate action to correct.

    a. Early inflation and early deflation
    b. Early inflation and late deflation
    c. Late inflation and late deflation
    d. Late inflation and early inflation

20. When reviewing an arterial pressure waveform for an intra-aortic balloon pump, the balloon will inflate just prior to the dicrotic notch.

    True　　　　　　　　　　　　False

Thank you for completing the post-test!

Appendices

Appendix A: Glossary

Acute Coronary Syndrome (ACS): is a term used to describe a range of atherosclerotic processes, including unstable angina, non-ST-segment elevation MI (NSTEMI), and ST-segment elevation MI (STEMI).[1]

Afterload: the resistance or tension the ventricle must perform to mobilize the volume in the chamber against a resistant circuit.[2]

Cardiac output: the amount of volume ejected per minute (CO= SV x HR).[3]

Cardiogenic Shock: a state of low cardiac output resulting in clinical and biochemical manifestations of end-organ hypoperfusion.[4,5]

Central venous oxygen saturation (ScvO2): is the venous oxygen return obtained from the distal port of CVP.[6]

Contractility: force generated by the myocardium when it contracts (inotropic property).[7]

Coronary artery bypass: a surgical procedure used to treat coronary artery disease. Healthy blood vessels are used as grafts to reroute blood flow around the blocked coronary artery or arteries.[8]

Coronary ostium: opening of coronary arteries at the root of the aorta, superior to the aortic valve.[7]

Heart failure: the cardinal symptoms of heart failure are shortness of breath, ankle swelling, and fatigue. Other signs may include elevated jugular venous pressure, pulmonary crackles, and peripheral edema. HF occurs after a functional or structural abnormality of the heart, leading to elevated intracardiac pressures and inadequate cardiac output at rest and/or during exercise.[9,10,11]

Major Limb ischemia: a loss of pulse or sensation, or abnormal limb temperature or pallor, requiring surgical intervention.[16]

Mixed venous oxygen saturation (SmvO2): obtained from the distal port of a pulmonary artery (PA) catheter. [6]

Myocarditis: is defined as the inflammation of the myocardium, the middle layer, of the heart muscle.[17]

Multiorgan system dysfunction (MODS): is the progressive physiologic failure of two or more organ systems when hemostasis cannot be restored despite interventions.[12]

Papillary muscle dysfunction or rupture: tear or rupture of the muscles or tendons that support the heart valves.[1]

Percutaneous cardiac intervention (PCI): a group of invasive cardiac interventions completed to improve blood flow through the coronary arteries. The diseased coronary arteries are recanalized; the current interventions used are plain old balloon angioplasty (POBA), intracoronary stenting, coronary atherectomy, and thrombectomy. [13]

Pericardial tamponade: pressure on the heart due to a buildup of fluid around it (pericardial tamponade). Classic signs of pericardial tamponade are known as *Beck's triad*: distended neck veins, muffled heart sounds, and hypotension.[14]

Phentolamine: extravasation antidote for norepinephrine, dopamine, dobutamine, and phenylephrine.[15]

Preload: filling the ventricles at end-diastole.[3]

Septal wall tear or rupture: tear or rupture of the wall (septum) between the left and right ventricles.[1]

Stroke volume: the amount of volume of blood ejected per beat.[5]

Systemic vascular resistance (SVR): is defined as the force that the right and left ventricles must work against to eject the blood volume. [18]

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Appendix B: Module 1 Answer Keys

Case Study 1.1: Answer Key

Mr. Sal is a 67 years old man with a long history, including a coronary artery bypass graft (CABG) 10 years ago, and his normal blood pressure runs 140/70 mmHg. He presents with angina and a positive troponin. His current blood pressure is 94/70 mmHg, and his heart rate is 100 beats per minute (bpm). He is scheduled to undergo diagnostic cardiac catheterization later in the day.

1. Using the SCAI classification of CS, what stage would you classify Mr. Sal?

a. Stage A
b. Stage B
c. Stage C
d. Stage D
e. Stage E

***Rationale*.** Mr. Sal presented with a cardiac history of CABG and now has a positive troponin indicating he has suffered an acute myocardial infarction. An acute myocardial infarction is a cause of cardiogenic shock. His current blood pressure has dropped greater than 30 mmHg from his baseline, and his heart rate is 100 bpm. He has clinical evidence of hemodynamic instability without hypoperfusion; therefore, he would be classified as Stage B: beginning cardiogenic shock. See Module 1, pp.166-169.

Later that day, in the catheterization laboratory, he becomes more tachycardia with his heart rate at 110 bpm and now has a reduced urine output. A pulmonary artery (PA) catheter is inserted, and his cardiac index is 1.8/m2 with a wedge pressure of 29 mmHg.

2. Using the SCAI classification of CS, what stage would you classify Mr. Sal?

a. Stage A
b. Stage B
c. Stage C
d. Stage D
e. Stage E

***Rationale*.** Mr. Sal is now tachycardic with a heart rate of 110 bpm, reduced urine output, a reduced cardiac index below 2.2L/min/m2, and a wedge greater than 15 mmHg. Mr. Sal is manifesting signs of hypoperfusion and fluid overload. Mr. Sal would be classified Stage C. He will require interventions. See Module 1, pp. 166-169.

During cardiac catheterization case, a thrombectomy is performed by the cardiac interventionalist. Mr. Sal has ventricular fibrillation, signifying a cardiac arrest, and requires a single 200-joule shock. A low dose inotrope is started, and the intervention is completed successfully. An IABP is placed at the end of the case, and the patient is transferred back to the coronary care unit. Later that night, his urine output declined, and the cardiac index assessment remained below 2 L/min/m2 despite increasing inotropes and IABP 1:1.

3. Using the SCAI classification of CS, what stage would you classify Mr. Sal?

a. Stage A
b. Stage B
c. Stage C
d. Stage D
e. Stage E

***Rationale*.** Mr. Sal is demonstrating signs and symptoms of hypoperfusion despite therapy, as evidenced by his reduced cardiac index and reduced urinary output despite increasing doses of inotropes and IABP 1:1. See Module 1, pp.166-169.

Note. This case presentation is not unusual, as patients often move between the different stages of shock.

Quiz Activity 1.2: Answer Key

1. A 64-year-old male was admitted to the coronary care unit from the emergency room after suffering an acute myocardial infarction. As he arrives at your unit, you observe two vasoactive medications infusing. He has decreased level of consciousness, his colour is ashen and dusky, and his peripheral pulses are very weak and thready.

What do you suspect is happening to the patient?

a. Classic, stage C
b. Deteriorating, stage D
c. Extremis, stage E
d. Not experiencing signs and symptoms of shock

***Rationale*.** The patient meets the criteria for SCAI stage E: Extremis. This patient has decreased level of consciousness, skin is ashen and dusky, and nearing pulseless indicative of impending circulatory collapses. See Module 1, pp.166-169.

2. What diagnostic lab test would you expect to be ordered to assess for cardiogenic shock?

   a. Lactate
   b. Troponin
   c. Complete blood count (CBC)
   d. Partial prothrombin time (PTT)

***Rationale*.** Measures of serum lactate are elevated in cardiogenic shock (Lactate $\geq$ 2 mmol/L). The measurement of serum lactate, elevated levels of which are an indicator of shock. See Module 1, pp.168-169, 180.

3. Cardiogenic shock can cause congestive hepatopathy (liver congestion) and liver hypoperfusion.

   True False

Rationale. Cardiogenic shock results in reduced cardiac output and end-organ hypoperfusion and hypoxia. Often patients will have elevated liver function tests indicating different types of liver dysfunction due to hypoperfusion and venous congestion. See Module 1, pp.181.

4. Which of the following blood work results would suggest worsening cardiogenic shock?

   a. PH 7.4, lactate 1.3 mmol/L, creatinine 50 umol/L
   b. PH 7.36, lactate 1.8 mmol/L, creatinine 42 umol/L
   c. PH 7.4, lactate 7.2 mmol/L, creatinine 220 umol/L
   d. PH 7. 43, lactate 1.0 mmol/L, creatinine 90 umol/L

Rationale. Elevated lactate, signs of renal failure, and a PH moving to acidosis are all signs of cardiogenic shock. This information would likely suggest the SCAI stage D classifications. See Module 1, pp.166-169; 180-182.

Appendix C: Module 2 Answer Keys

Quiz Activity 2.1: Answer Key

1. Cardiac output is defined as the amount of blood pumped out of the heart per minute.

True False

***Rationale*.** Cardiac output is defined as the amount of blood pumped out of the heart per minute. See Module 2, pp. 203.

2. What is the normal cardiac output value?

   a. 4 to 5 L/min
   b. 2 to 3 L/min
   c. 4 to 8 L/min
   d. 1 to 2 L/min

***Rationale*.** Normal cardiac output is 4 to 8L/min. See Module 2, pp. 203.

3. A normal cardiac index is 2.5 to 4 L/min2

True False

***Rationale*.** The cardiac index is an indirect measurement obtained for the pulmonary artery catheter. It is calculated by cardiac output divided by body surface area. It is more accurate than cardiac output as it considers the patient's body size. See Module 2, p.209.

4. What hemodynamic value is reflective of the right-sided heart preload?

    a. PVR
    b. CVP
    c. PCWP
    d. SVR

***Rationale*.** Central venous pressure (CVP) is a direct measurement obtained from the pulmonary artery catheter or central venous access device. It provides the measure for right-sided preload. See Module 2, pp. 204-205; 215.

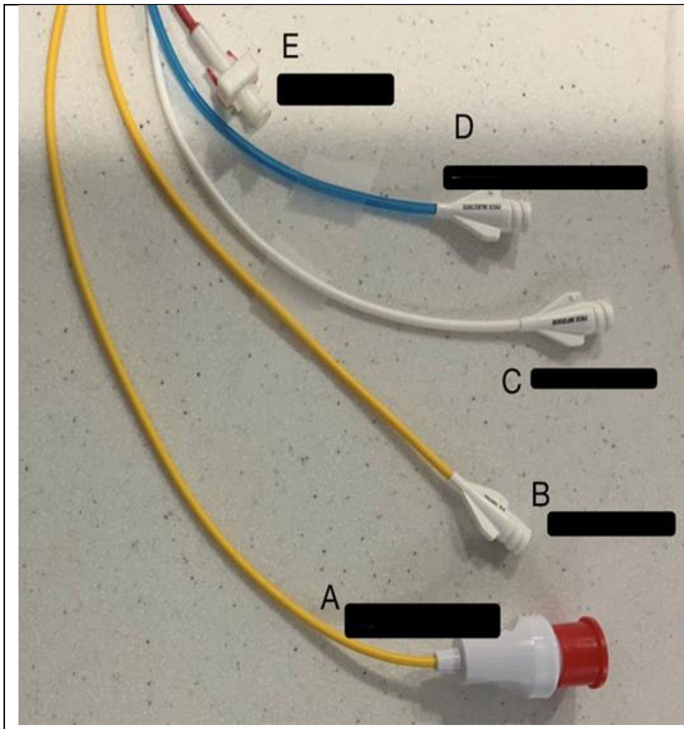
5. What hemodynamic value is a reflection of the left-sided heart preload?

    a. PVR
    b. CVP
    c. PCWP

***Rationale*.** PCWP is pulmonary capillary wedge pressure. The wedge pressure gives the left-sided preload. See Module 2, pp. 204, 216.

Interactive Activity 2.2: Answer Key

Please label the PA catheter ports and each port function.

<table>
<tr>
<td>


</td>
<td>
A
Thermistor port; used to measure blood temperature.

B
PA distal port; measure pulmonary pressures.

C
Prox infusion port; used for continuous infusions.

D
Prox injectate; used to instill fluid for cardiac output measurement, measure CVP, for infusing maintenance fluid and/or intermittent medications.

E
Balloon port; used for balloon inflation.
</td>
</tr>
</table>

Rationale. See Module 2, pp.209-210.

Quiz Activity 2.3: Answer Key

You begin your shift and notice that the pressure line transducer has fallen from the holder and is dangling below the level of the patient's bedframe.

1. The blood pressure reading displayed on the cardiac monitor is:

   a. Falsely low
   b. Accurate.
   c. Falsely high.
   d. Inaccurate.

   Rationale. The blood pressure will be falsely high, potentially leading to vasopressor medications being weaned down when not warranted. See Module 2, pp.234.

2. What is the anatomical reference point for levelling the pressure monitoring line transducer?

e. Left atrium
f. Right atrium
g. Left ventricle
h. Right ventricle

***Rationale*.** When levelling the transducer, the reference point is the level of the right atrium. See Module 2, pp.232-233.

Appendix D: Module 3 Answer Keys

Quiz Activity 3.1: Answer Key

1. Positive inotropes strengthen the heart's contractions so that the heart can pump more blood with each beat.

True	False

Rationale. Inotropic drugs increase the force of contraction. See Module 2, p.198, and Module 3, p. 253.

2. What is the first-line vasoconstrictor medication currently recommended for CS?

   a. Dopamine
   b. Vasopressin
   c. Epinephrine
   d. Norepinephrine

Rationale. Norepinephrine is the first-line vasoconstrictor for CS. See Module 3, p.249; 250-254.

3. The action of the medication is inotropic when it:

   a. Decreased afterload.
   b. Increases heart rate.
   c. Increases the force of contraction.
   d. Is used to treat heart failure.

Rationale. Inotropic drugs increase the force of contraction. Chronotropic drugs increase heart rate. Inotropes increase cardiac contractility, improving cardiac output and improving mean arterial pressure and tissue perfusion. See Module 2, p.206 and Module 3, p.248.

4. Norepinephrine and sodium bicarbonate are compatible at the intravenous y-connection.

    True   False

***Rationale*.** Norepinephrine and sodium bicarbonate are incompatible in the same intravenous y-connection, as the inactivation of norepinephrine may occur. See Module 3, p. 252.

5. What drug is used in the management of extravasation by norepinephrine, dopamine, dobutamine, and phenylephrine?

    a. Benadryl
    b. Protamine
    c. Nitroglycerin
    d. Phentolamine

    Rationale. Phentolamine is injected intradermally to prevent and limit skin necrosis. See Module 3, p. 268.

6. Dobutamine improves cardiac output and is indicated for use in all of the following conditions except:

    a. Septic shock.
    b. Arrhythmias
    c. Congestive heart failure.
    d. Pulmonary congestion.

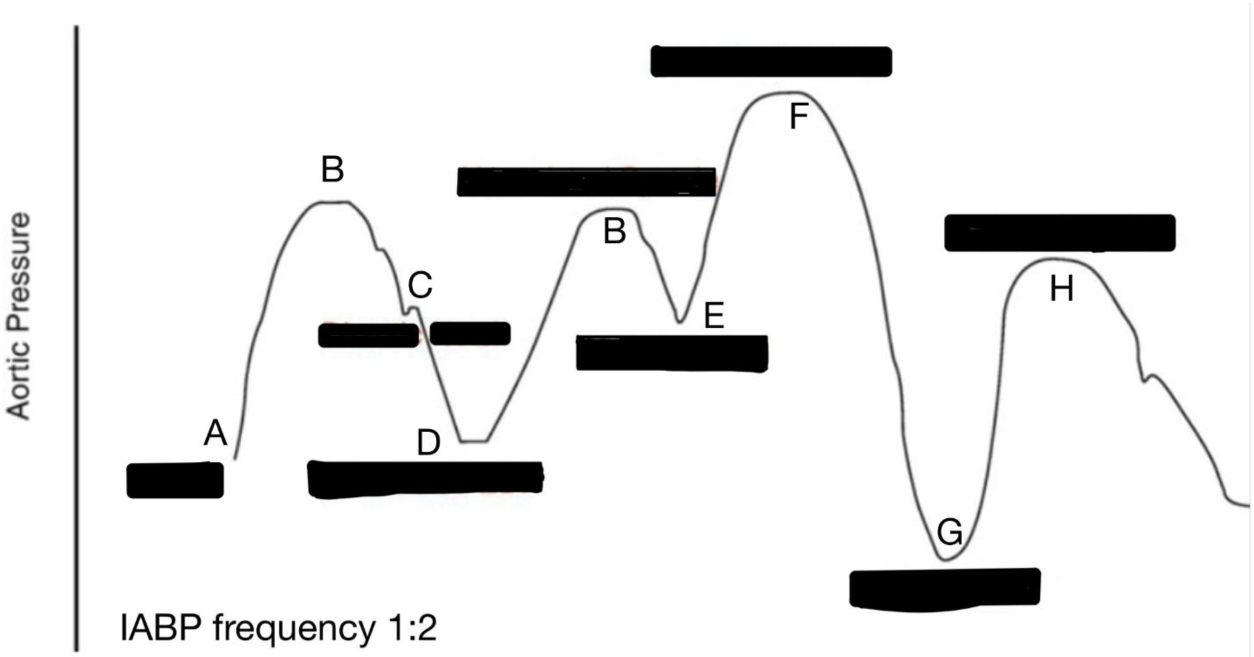
Rationale. Dobutamine is not used to treat arrhythmias and can increase ventricular response rate and risk of arrhythmias and ventricular ectopy. See Module 3, pp.264.

Appendix E: Module 4 Answer Keys

Quiz Activity 4.1: Answer Key

	Statements	T	F
1.	The intra-aortic balloon pump is a right ventricular support device. ***Rationale.*** IABP is a left ventricular assist device. See Module pp. 278, 280.		**X**
2.	An intra-aortic balloon pump is recommended for CS when other MCS devices are unavailable, contraindicated, or cannot be inserted. ***Rationale.*** See Module 4, pp. 280, 285.	**X**	
3.	Carbon dioxide is the gas used to inflate the IAB. ***Rationale.*** Helium is the gas used. See Module 4, p283.		**X**
4.	When the IAB catheter is positioned correctly, it is in the descending aorta. ***Rationale.*** See Module 4, pp. 288-291.	**X**	
5.	The IAB catheter has two radiopaque markers for visualization under fluoroscopy and X-ray. ***Rationale.*** See Module 4, p. 290.	**X**	
6.	You must visually inspect the IAB catheter and tubing once a shift. ***Rationale.*** Visual inspection is required every hour to monitor for signs of IAB rupture. See Module 4, p. 302, 304-305.		**X**
7.	If patient transport outside the coronary care unit is required, the perfusionist must be present for the transfer. ***Rationale.*** See Module 4, p. 299.	**X**	
8.	You must complete a neurovascular assessment on the affected limb after the IAB is inserted. The routine frequency of assessment is every 15 mins x 4, then every 30 mins x 2, and then every 1hr for the duration of therapy. ***Rationale.*** See Module 4, pp. 297, 302.	**X**	

Interactive Activity 4.2: Answer Key



A. Aortic valve open signifies the onset of systole
B. Unassisted systole
C. Dicrotic notch signifies the closure of the aortic valve
D. Unassisted aortic end-diastolic pressure
E. IAB inflation
F. Diastolic Augmentation or Assisted diastole
G. Assisted aortic end-diastolic pressure
H. Assisted systole

Rationale. See Module 4, pp. 314, 316-323.

Case Study 4.3: Answer Key

A 64-year-old female is admitted with a large anterior STEMI. She was emergently transferred to the cardiac catheterization lab and underwent PCI of the left anterior descending coronary artery with a drug-eluting stent. Her LVEDP was high on her catheterization report, and a bedside ECHO revealed a reduced ejection fraction of approximately 20%. During the cardiac catheterization, she received Lasix 40 mg, and a norepinephrine infusion was initiated for an SBP less than 90. Before transferring to the coronary care unit, the cardiologist inserts an IAB catheter and the IABP is in operation when the patient is transferred to the coronary care unit.

1. What are the benefits of IABP therapy?
   a. Increased preload and increased afterload
   b. Decreased preload and decreased afterload
   c. Increased blood flow to coronary arteries and increased afterload
   d. Increased blood flow to coronary arteries, decreased afterload, and improved cardiac output

***Rationale*.** See Module 4, pp.286-287.

2. The perfusionist reviews the setting of the IABP and tells you that the frequency of the IAB is set at 1:1. What does that indicate?

   a. The balloon will inflate with every cardiac cycle (heartbeat)
   b. The balloon will inflate with every second cardiac cycle (heartbeat)
   c. The balloon will inflate with every third cardiac cycle (heartbeat)
   d. The balloon will inflate with every fourth cardiac cycle (heartbeat)

***Rationale*.** See Module 4, pp. 306-308.

3. The perfusion reports that the trigger mode of the IAB is ECG. When the perfusionist chooses the ECG lead, which would be the best choice?

   a. Widest QRS complex
   b. Largest p-wave and t wave
   c. Small R wave, small p-wave, and t wave

d. Largest R wave, minimal p-wave, and minimal t-wave

Rationale**.** See Module 4, p. 310.

4. The IABP augmentation alarm sounds at 100 mmHg. What is the most appropriate action?

    a. Ignore the alarm
    b. Notify the cardiologist
    c. Begin to titrate the dose of norepinephrine
    d. Adjust the augmentation alarm to 90 mmHg and monitor the patient for hemodynamic changes

Rationale**.** See Module 4, p. 299.

Next, as you are monitoring the patient, the IABP alarms "Gas loss in IAB circuit," and you immediately assess your patient and the IABP Cardiosave console. You notice flecks of blood in the IAB catheter. Please answer questions 5, 6, and 7.

5. What is the likely cause of this alarm?

    a. Poor timing
    b. Balloon rupture
    c. Augmentation alarm
    d. Helium tubing disconnected from IABP

Rationale**.** See Module 4, pp. 304-305, 327.

6. What is your next action?

    a. Silent the alarm
    b. Assess the timing
    c. Adjust the augmentation alarm
    d. Place the IABP on standby, notify the cardiologist and perfusionist

Rationale. See Module 4, pp. 304-305, 327.

7. When you communicate the problem to the cardiologist, what do you anticipate will be the plan of care?

    a. Continue IABP therapy
    b. Urgently remove the IAB
    c. Remove the IABP the next morning
    d. Continue IABP therapy but discontinue systematic heparin

Rationale. See Module 4, pp. 304-305.

Appendix F: Printable Content

SCAI Classification of Shock: Physical exam, Biochemical markers and Hemodynamics

Stage	Physical examination	Biochemical markers	Hemodynamics
A	• Normal JVP • Strong distal pulses • Normal mentation • Clear lungs	• Normal lactate • Normal renal function (or at baseline)	• Normotensive SBP $\geq$ 100 mmHg or at baseline
B	• Elevated JVP • Strong distal pulses • Normal mentation • Rales in lung fields	• Normal lactate • Minimal acute renal function impairment • Elevated BNP	• Hypotension SBP < 90 mmHg MAP < 60 mmHg > 30mmHg drop from baseline
C	• Volume overload • Acute alteration in mental status • Cold and clammy • Extensive rales • Ashen, mottled, dusky, or cool extremities • Delayed capillary refill • Urine output < 30 ml/hr	• Lactate $\geq$ 2 mmol/L • Creatinine increase to 1.5 X baseline or 50 % drop in GFR • Increased LFTs • Elevated BNP	• Tachycardia • HR $\geq$ 100 bpm • Strongly recommend invasive hemodynamics • CI < 2.2 L/min/m^2 • PCWP > 15 mmHg • Pressors to maintain BP
D	• Any stage of C and worsening (or not improving) • Signs and symptoms of hypoperfusion despite the initial therapy	• Any of stage C and lactate rising and persistently > 2 mmol/L • Deteriorating renal function • Worsening LFTs • Rising BNP	• Any of stage C and requiring escalating dose or increasing number of pressors • Addition of a MCS device to maintain perfusion
E	• Actual or impending circulatory collapse • Typically unconscious • Near pulseless • Cardiac collapse • Multiple defibrillations	• Lactate > 8 mmol/L • CPR • Severe acidosis PH $\leq$ 7.2 Base deficit $\geq$ 10 mEq/L	• Profound hypotension despite maximal hemodynamic support

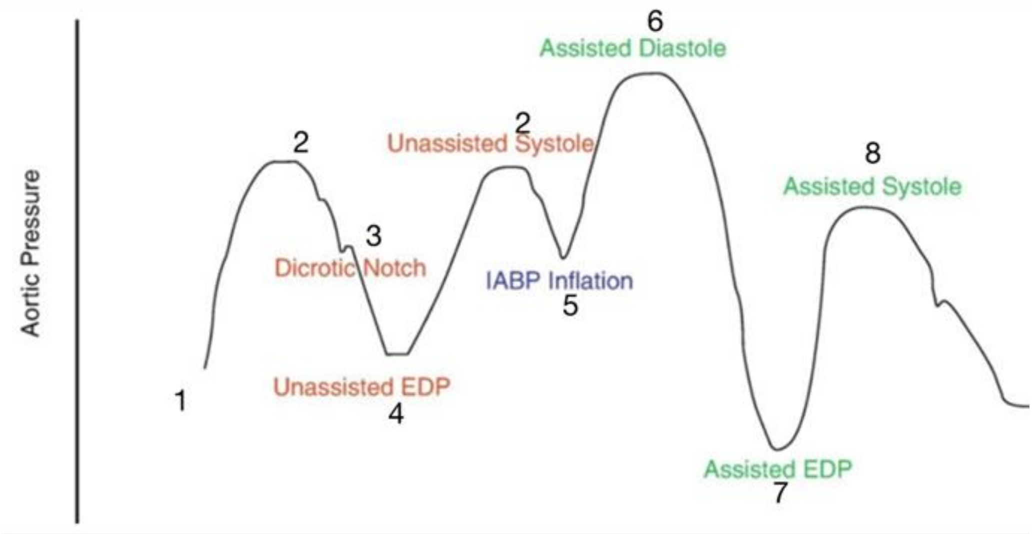
Legend. BNP, B-type natriuretic peptide; CI, cardiac index; CPR, cardiopulmonary resuscitation; CVP, central venous pressure; GFR, glomerular filtration rate; JVP, jugular venous pressure; LFT, liver function tests; MAP, mean arterial pressure PA, pulmonary artery; PCWP, pulmonary capillary wedge; SBP, systolic blood pressure.

Source. Adapted from "SCAI SHOCK stage classification expert consensus update: A review and incorporation of validation studies," by S. S. Naidu et al. 2022, *Journal of the Society for Cardiovascular Angiography & Interventions, 1(*1), p. 7. (https://doi.org/10.1016/j.jscai.2021.100008).

Appendix F: Printable Content

How to Assess the Timing of the IABP?

1. Place the frequency of the IABP to 1:2
2. Print a strip
3. Return the IABP in 1:1
4. Label the strip:
    - Identify the dicrotic notch # 3 (IAB inflation #5)
    - Augmented diastolic pressure #6 (assisted diastole)
    - Unassisted systole (#2)
    - Assisted systole (#8)
    - Unassisted end-diastole aortic pressure (# 4)
    - Assisted end-diastole aortic pressure (#7)
5. Check to confirm that inflation occurs just before the dicrotic notch (#5)
6. Locate the augmented diastolic pressure (assisted diastolic pressure) #6
    - Compare the assisted diastole pressure with the unassisted systole
    - **The assisted diastole (augmented pressure, #6) is higher than the unassisted systole (#2)**
7. Compare assisted end-diastolic aortic pressure (#7) with the unassisted end-diastolic aortic pressure (#4)
    - **The assisted end-diastolic aortic pressure (#7) is lower than the unassisted end-diastolic aortic pressure (#4)**
8. Compare assisted systole (#8) with the unassisted systole (#2)
    - **The assisted systole (#8) is lower than the unassisted systole (#2)**



Source. Adapted from "Mechanical Circulatory Support in ST-elevation Myocardial Infarction," by N. Lo and E. Magnus Ohman, in T. J. Watson, P.J. Ong, and J.E. Tcheng (Eds.), 2018, *Primary Angioplasty a Practical* Guide, p. 258 (https://doi.org/10.1007/978-981-13-1114-7). Creative Commons Attribution 4.0 International License.

Appendix G: Pre-test/Post-test Answer Key

Pre-test and Post-test: Answer Key

1. What is the most common cause of cardiogenic shock?

    a. Pericarditis
    b. Dysrhythmia
    c. Pulmonary embolism
    d. Acute myocardial infarction (AMI)

2. Which blood test is used to detect end-organ hypoperfusion in the early stages of cardiogenic shock?

    a. Lactate
    b. Troponin
    c. C-reactive protein (CRP)
    d. B-type natriuretic peptide (BNP)

3. In some cases, the clinical manifestations of cardiogenic shock can vary due to the cause of the shock and its severity.

    True False

4. What is the estimated mortality rate percentage for patients with cardiogenic shock?

    a. 10%
    b. 30%
    c. 20%
    d. 50%

5. What is the normal expected range for cardiac output?
    a. 4-8 L/min
    b. 2-4 L/min
    c. 1-3 L/min
    d. 1-4 L/min

6. You are assessing a patient for cardiogenic shock. What signs and symptoms do you expect to find? Circle Select all that apply.

    a. Dyspnea
    b. Increased lactate
    c. Warm, flushed skin
    d. Crackles in lung fields
    e. Cool and clammy skin
    f. Strong peripheral pulses
    g. Urinary output > 30 ml/hr
    h. Increased liver function tests
    i. Systolic blood pressure (SBP) < 90 mmHg
    j. Decreased urea (BUN) and decreased creatinine (Cr)

7. What term describes the resistance the ventricles have to pump against?

    a. Preload
    b. Afterload
    c. Cardiac index
    d. Ejection fraction

8. What hemodynamic parameter is an indication of right-sided preload?

    a. Central venous pressure
    b. Systematic vascular resistance
    c. Pulmonary vascular resistance
    d. Pulmonary capillary wedge pressure

9. Of the hemodynamic parameters listed, which parameter is consistent with cardiogenic shock?

   a. Cardiac output of 4 L/min
   b. Cardiac index of 1.8 L/min/m^2
   c. Mean arterial pressure of 70 mmHg
   d. Pulmonary wedge pressure (PWCP) of 6 mmHg

10. In most cases, pulmonary capillary wedge pressure (PCWP) and left ventricular end-diastolic pressure (LVEDP, reported on the cardiac catheterization report) are often used interchangeably to describe left-sided filling pressures or left-sided preload.

    True   False

11. The phlebostatic axis is at the level of the:

    a. Right atrium.
    b. Right ventricle.
    c. Left atrium.
    d. Left ventricle.

12. When measuring atrial and wedge pressure, what is the optimal measuring point on the respiratory cycle?

    a. End inspiration
    b. End expiration
    c. Beginning inspiration
    d. Beginning expiration

13. All of the following are determinants of stroke volume except:

    a. Heart rate.
    b. Preload.
    c. Afterload.
    d. Contractility.

14. The pulmonary artery catheter has other names. Circle all that apply.

    a. SWAN
    b. Sideport
    c. Swan Ganz
    d. Triple lumen

15. What hemodynamic effect will norepinephrine (levophed) have when administered during cardiogenic shock?

    a. Decrease contractility
    b. Decrease cardiac output
    c. Decreased mean arterial pressure
    d. Increase systematic vascular resistance and increase cardiac output

16. The cardiogenic shock patient you are caring for has an intra-aortic balloon pump. The intra-aortic balloon pump inflates during _____________and deflates during ____________.

    a. Diastole and systole
    b. Inspiration and expiration
    c. Systole and diastole
    d. Expiration and inspiration

17. You notice blood in the extender tubing of the intra-aortic balloon pump; what does this most likely indicate?

    a. Balloon migration
    b. Balloon rupture
    c. Late deflation
    d. Early deflation

18. A patient with an intra-aortic balloon pump has a lethal arrhythmia (ventricular fibrillation or pulseless ventricular tachycardia). It is safe to perform defibrillation, provided clinicians stand clear of the intra-aortic balloon pump catheter and console.

True False

19. Assessing the timing of the intra-aortic balloon pump is crucial to ensure the patient is getting the full benefit of the mechanical assist device. Which timing errors require immediate action to correct.

   a. Early inflation and early deflation
   b. Early inflation and late deflation
   c. Late inflation and late deflation
   d. Late inflation and early inflation

20. When reviewing an arterial pressure waveform for an intra-aortic balloon pump, the balloon will inflate just prior to the dicrotic notch.

True False