Development of an Educational Resource for Dialysis Nurses about Pediatric Hemodialysis

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Abstract

Background: Hemodialysis (HD) is a form of renal replacement therapy used for the treatment of kidney disease. In Newfoundland and Labrador (NL), there is a high incidence rate of HD use among the adult population compared to other Canadian provinces; however, the incidence of HD use in the pediatric population is historically rare. The recent rise in multi-organ inflammatory syndrome in children (MIS-C) secondary to COVID-19, combined with the unpredictable weather preventing patient transfer to larger pediatric hospitals elsewhere in Canada, has led to an increased requirement for pediatric HD use in NL. There are no policies or educational resources for nurses specific to pediatric HD in NL.

Purpose: To develop an educational resource for nurses that will improve their knowledge and skills to perform HD on pediatric patients in NL and, ultimately, improve patient and family outcomes.

Methods: I completed an integrative literature review, followed by consultations with local field experts including eight nurses, the clinical educator of the Dialysis Program at Eastern Health, and two nephrologists. I completed an environmental scan with the HD Program Coordinator at a pediatric hospital in Ontario. Based on the information obtained, I developed an education module.

Results: Through literature review, consultations, and environmental scan, I determined the content and delivery method(s) for the educational resource. The content included the lived experience of the patient/family and nurse, nursing care of a pediatric patient and family, vascular access with infection prevention, fluid and volume removal, vital sign ranges, dialysis prescription, machine set-up and programming, and nursing assessment. The most frequently

cited education delivery methods in the literature were lecture, simulation, hard-copy, and online module. The most frequently identified delivery methods through the consultations and environmental scan were online module, simulation, and hard-copy. As such, I chose an online module and a hard copy.

Conclusion: The online module will be available on LEARN, the Eastern Health online education platform, once approved. A hard copy will be available in the dialysis unit at the Health Sciences Centre in Eastern Health. The educational resource with all components will aid in improving nurses' competency to perform pediatric HD, thereby improving patient and family outcomes.

Key Words: pediatric hemodialysis, education, nursing, resource.

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Development of an Educational Resource about Pediatric Hemodialysis: Final Practicum Report

One in ten Canadians is living with kidney disease, an increased incidence of 33% since 2010 (Canadian Institute for Health Information (CIHI), 2020). In 2019, Newfoundland and Labrador (NL) had the highest rate of adult patients starting dialysis as a result of kidney failure with 249 patients per million population (CIHI, 2020). Recently, the incidence rate of kidney failure has increased as a result of the global COVID-19 pandemic, specifically among the pediatric population with multi-organ inflammatory syndrome in children (MIS-C) caused by the virus (Centers for Disease Control and Prevention (CDC), 2020). MIS-C initially presents as a rash, neck pain, and bloodshot eyes which rapidly progresses to the sudden failure of multiple organs including the kidneys (CDC, 2021). The Canadian Pediatric Society (2021) and the CDC (2020) identified MIS-C as a significant cause of morbidity and mortality among the pediatric population in Canada and the United States. Children with MIS-C often do not survive without life-sustaining treatment such as hemodialysis (HD) (CDC, 2020).

Although the incidence of pediatric HD in NL is historically rare (Dr. B. Curtis, personal communication, May 15, 2021), the recent rise in MIS-C, combined with the unpredictable weather preventing patient transfer to larger pediatric hospitals elsewhere in Canada, conceivably presents an increased risk of more pediatric HD in NL. Registered nurses at the Health Science Center (HSC) (an adult tertiary hospital) in St. John's are responsible for dialyzing pediatric patients requiring HD due to its proximity to the Janeway Children's Hospital, the only pediatric hospital in NL. HD is complex and highly technical as it replaces the function of the kidneys, which is the excretion of waste products and regulation of body fluids, electrolytes, and

hormones (Ibrahim et al., 2019). Nurses performing the treatment must be fully knowledgeable and competent in their skills to ensure safe, high-quality patient and family outcomes (Cho, 2020; Rees, 2021). Researchers have demonstrated that the implementation of an education resource significantly improves nurses' knowledge and practice related to pediatric HD (Ahmed et al., 2019; Hassona et al., 2012; Saeed & Al-Mosawi, 2020). Currently, there are no policies or educational resources specific to pediatric HD in NL (Cathy Cake, clinical educator of Dialysis Program Eastern Health, personal communication, June 5, 2021). Further, discussions with the nurses of the HSC dialysis unit revealed a lack of knowledge and skills specific to pediatric HD due to limited educational resources.

The overall goal of this practicum was to develop an educational module for dialysis nurses related to pediatric HD. The objectives for my practicum project were:

1. Explore and identify the key educational need(s) specific to pediatric hemodialysis within the existing adult hemodialysis program in Newfoundland and Labrador.
2. Develop an evidence-based educational resource for the Dialysis Program at Eastern Health specific to pediatric HD in Newfoundland and Labrador.
3. Develop a plan for the implementation and evaluation of my educational resource in practice.
4. Demonstrate the Canadian Nurses Association (2019) advanced practice competencies.

Methods

I completed an integrative literature review, consultations, and environmental scan. The results of these methods led to the determination of the content and educational delivery methods for my educational resource. Content that I found during the literature review included

patient/family and nurses' experience with pediatric HD, central venous catheter (CVC) infection prevention including intraluminal and extraluminal methods, and nursing assessment of the pediatric HD patient including fluid status and dialysis prescription. I also identified several educational methods considered most effective within the literature including lecture, online module, and simulation. During the consultations and environmental scan, I interviewed local and national field experts. Common ideas were identified and used to guide the content of my resource that included caring for a pediatric patient and family, fluid and volume removal, vital sign ranges, vascular access, dialysis prescription, and machine set-up and programming. I also identified common educational delivery methods which included an online module, simulation, and hard copy booklet/binder to be immediately available at the bedside if needed. I chose to combine my consultation and environmental scan results as the common ideas identified in both were very similar, making the environmental scan an extension of the consultations.

Theoretical Framework

Applying educational theories to nursing practice and education provides a way of understanding complex learners and the learning process within the context of assimilating new information at the fast pace of healthcare change (Candela, 2020). I used Kolb's (1984) experiential learning theory as the theoretical framework to guide the development of my educational resource. Only experiential learning can yield the complex, open-ended, skilled knowledge required for learners to recognize the nature of the particular resources and constraints in real life clinical situations (Benner et al., 2010). The learning experience is learner-centered, where learners are encouraged to explore and question by being fully engaged, making decisions, and demonstrating accountability (Candela, 2020).

Kolb's (1984) experiential learning theory is comprised of a four-part learning cycle: concrete experience, reflection, conceptualization, and experimentation. The concrete experience is feeling or doing in which the learner is immersed in the learning experience. Reflection involves the use of a cognitive process where the learner examines their practice. Conceptualization occurs when the learner reflects on what they have learned to understand and apply the concepts. Experimentation involves applying and doing, where the learner directly applies the information learned. This learning cycle is demonstrated in my educational module. The learner has the concrete experience or feeling through active reading and visual stimulation through photographs, graphs, striking font, and colors. Conceptualization and experimentation occur during the scenario portion in which the learner actively applies the new knowledge through decision-making in clinical practice situations and knowledge tests. Reflection occurs after the completion of the module where the learner reflects on their knowledge learned to make decisions in their practice. In the future, I anticipate that the module will continue to be utilized to afford the learner the opportunity to apply the experience of conceptualization, experimentation, and reflection to real life clinical situations in the care of a pediatric patient that requires HD.

Summary of the Literature Review

Methods

I performed a literature search using the following databases: CINAHL, PubMed, Nursing & Allied Health, Google Scholar, Medline, Education Research Complete, Academic Search Complete, and Education Resources Information Center. Search terms included: education, resource, nurs*, pediatric or child or children or adolescent, guideline, hemodialysis

or dialysis, kidney failure, nephrology, experience. Inclusion criteria were: published within the last 20 years and written in the English language as this is my only language. I screened the literature based on the abstract or introductory paragraphs where relevance to the topic was identified and chose sources based on their relevance to the topic of interest. I completed a broad search of global sources and identified literature including published guidelines and research articles. I evaluated research articles for quality of content using the Public Health Agency of Canada Toolkit (2014). All other sources were evaluated by determining the reliability, credibility, and relevance to pediatric HD.

Results

The results of the literature review were valuable in determining the content and delivery method used in my educational resource. The experiences of the child and family during the HD process were common ideas. The experience of being informed that initiating dialysis is essential to maintain life was identified as a devastating, life-altering experience for children diagnosed with kidney failure and their caregivers (Nuel, 2012). El-Gamsay and Eldeeb, (2017), Kilis-Pstrusinska et al. (2013), and Zitzelsberger et al. (2019) found that children on HD experience difficulty in physical and social functioning including physical discomfort and body image issues, and social isolation. Emotional distress among family members was also reported including feelings of guilt, grief, and powerlessness as a result of their child's diagnosis (Cimete 2002; Ong et al., 2021; & Wightman et al., 2019).

The nurse's experience of a child receiving HD was also a common idea throughout the literature. Ibrahim et al. (2019), Kavurmaci et al. (2014), and Shahdadi and Rahnama, (2018) found that nurses' attitudes about the care of children undergoing HD are often negative, due to

feelings of burnout, depression, and anxiety. Excessively long workdays, high workloads, and insufficient resources led to a depletion in the nurses' physical and emotional status. These authors further reported the nurses felt a lack of education relating to the patient's disease affected their quality of care, causing negative attitudes. Additionally, increasing nurses' knowledge and experience with pediatric HD patients is necessary to resolve the challenges in the care of these patients to improve the quality of care provided by nurses and prevent burnout (Ibrahim et al., 2019; Kavurmaci et al., 2014; Shahdadi & Rahnama., 2018).

As a result of the literature review, I identified two essential aspects related to competence in nursing knowledge and skill in pediatric HD: CVC infection prevention and specific areas for nursing assessment of the pediatric patient. CVC infection rates are high among the pediatric HD population (Ashby et al., 2019; Chand et al., 2009; O'Grady et al., 2017; Paglialonga et al., 2016). Strategies to prevent CVC infection included intraluminal antimicrobial locks infused through the CVC at the end of HD and extraluminal site maintenance through dressing changes and physical examination of the CVC site for signs and symptoms of infection (Ashby et al., 2019; Chand et al., 2009; O'Grady et al., 2017).

The nursing assessment included the nurses' ability to recognize the differences between adult and pediatric HD which includes fluid status and dialysis prescription. Fluid status is calculated based on a patient's prescribed target weight, or the patient weight if the kidneys were fully functional and able to remove fluid from the body (Rees, 2021). Rees (2021), Souza et al. (2008), and Fischbach et al. (2005) outline specific recommendations for fluid assessment among pediatric patients including ultrafiltration (fluid removal) calculations to be used by nurses during the assessment of patient fluid status.

Several authors addressed the differences between adult and pediatric HD prescription including the dialyzer, tubing, blood flow rate, and session duration and frequency (Ashby et al., 2019; Fischbach et al., 2005; Rees, 2021; Souza et al., 2008). The dialyzer is a semi-permeable membrane that acts as the artificial kidney to remove fluid and solutes or toxins and is available in different sizes according to the patient's weight and height (Rees, 2021). The tubing, or circuit, used for pediatric HD patients is much smaller than that used for adult patients (Souza et al., 2008). Blood flow determines solute clearance by optimizing diffusion and convection and is typically much lower in pediatric patients compared to adults. Diffusion is the process of molecules moving through the dialyzer or membrane from an area of high concentration to low concentration, whereas convection is the process of pushing the water, toxins, and wastes through the dialyzer by hydrostatic pressure (Ashby et al., 2019). For children, the session duration is similar to that of an adult as it is dependant on the predetermined amount and rate of solute clearance and fluid removal; usually four hours.

The educational delivery methods considered most effective within the literature were lecture, simulation, and online module (Ahmed et al., 2019; Bayoumi & Mahmoud, 2017; Dennison, 2011; Machaly et al., 2020; Ouda et al., 2019; Yousef et al., 2019; Windt, 2016). The literature review also revealed the existence of knowledge gaps as there were no published guidelines, policies, or procedures specific to pediatric HD within Canada, therefore content specific to Canadian guidelines had to be obtained during the consultation and environmental scan. See Appendix A for the literature review report.

Summary of the Consultation and Environmental Scan

Methods

I completed interviews with local and national field experts. Eight nurses voluntarily participated in the consultation interviews, all with varying years of experience in dialysis. Diversity within the sample is important to ensure a rich description of the phenomenon through varied responses and a variety of perspectives (Streubert & Carpender, 2011). I completed two in-person group interviews two days apart to ensure a sufficient number of nurses participated. I also interviewed the clinical educator of the Dialysis Program within Eastern Health in person. The clinical educator was chosen for their expertise in the field of HD and direct involvement in the policy development and education of nurses within the Dialysis Program.

I interviewed two nephrologists within Eastern Health. One had 15 years' experience in pediatric nephrology and the other had over 30 years of experience as an adult nephrologist in NL. I completed an in-person interview to identify their suggestions regarding specific content for an educational resource to improve the nurse's knowledge and understanding of pediatric HD. This was important as it is the nephrologist who writes the dialysis prescription, which is congruent with the information determined through the literature review and consultations and environmental scan.

As per the environmental scan, I consulted with the Pediatric HD Program Coordinator at a large pediatric hospital in Ontario. I also attempted contact with other specialists in pediatric HD in major hospitals across Canada including the Alberta Children's Hospital and Montreal Children's Hospital, however, I was unable to make contact after multiple attempts. The Division of Nephrology at the hospital I consulted is one of the largest Pediatric Nephrology Divisions in

North America and has influence in all other pediatric HD programs in Canada. Therefore, I decided one major national consultation was sufficient for my practicum project.

I used content analysis to examine the interview data. The written data from all interviews were transcribed into Microsoft Word where common ideas were organized. I reviewed all data thoroughly and created a summary of common ideas and categories which were then organized based on responses to interview questions.

Results

I identified several categories resulting from recurring common ideas during data analysis including pediatric HD in NL, nurses' educational needs, educational resource content, delivery method and features, and continuing education.

The potential for an increase in pediatric HD in NL was addressed during all interviews. The nurses, clinical educator, nephrologists, and HD Program Coordinator in Ontario all addressed the potential for increased incidence of pediatric HD in NL in the past/present due to COVID-19 and the possibility that this virus will remain prevalent in populations well into the future. The nurses and the clinical educator of the Dialysis Program identified an increased need for education related to pediatric HD due to the lack of education within the Dialysis Program at Eastern Health. All nurses felt they are expected to perform pediatric HD, however, with the lack of education they did not feel comfortable or confident in their knowledge and skills. They felt they would have patient safety concerns and expressed concerns about potential patient harm and loss of their nursing license.

For the content of the educational resource, common ideas included: caring for a pediatric patient and family, fluid and volume removal, vital sign ranges, vascular access, dialysis

prescription, and machine set-up and programming. The nurses identified a lack of experience caring for pediatric patients and families in general and therefore requested to know more information about the growth and development, communication, and behavior of pediatric patients. The HD Program Coordinator in Ontario confirmed that nurses need to understand concepts such as growth and development for age range, and how to effectively communicate and build trust with pediatric patients and families.

The nurses, nephrologists, and HD Program Coordinator in Ontario identified total blood volume calculations as an important tool for nurses to use during the assessment of a pediatric patient. The nurses, clinical educator, and HD Program Coordinator in Ontario suggested the inclusion of standard vital sign ranges for pediatric patients in the educational resource due to the nurses' lack of pediatric knowledge. All nurses expressed an interest in improving their knowledge of the child's vascular access, including the CVC insertion location, and infection prevention measures compared to adults. The CVC is the primary vascular access in children, whereas adults have a CVC or arteriovenous fistula (surgical connection of an artery and vein, accessed using needles for HD) (Rees, 2021). All participants focused on the dialysis prescription in the interviews with common ideas including dialyzer and tubing size, blood flow, and medication dosages. Specifically, participants wanted to know the differences in prescription of a child compared to an adult.

The most effective educational resource delivery method for the Dialysis Program was identified by the nurses, clinical educator, and HD Program Coordinator in Ontario. Common ideas in the delivery method included an online module, hard-copy binder, and simulation. The

nurses expressed that they wanted an educational resource that was simple in content and interactive with visual stimuli.

Summary of the Educational Resource

The content and delivery method that I used for the educational module were chosen based on the common ideas found in the literature review and consultations and environmental scan. The delivery method I chose is an online module with a printable version. During the development of the module, I realized that the nurses of the Dialysis Unit have little experience in caring for pediatric patients, therefore, I decided to do further consultation with a pediatric nurse educator. Through this necessary consultation, I obtained information specific to the pediatric population including growth and development, nutrition, vital signs ranges, and nursing care. This information was also included in the module.

I divided the module into seven sections that included the following: introduction to pediatrics, nephrological conditions in children, the experience of the patient/family and nurse, vascular access, nursing assessment, machine set-up, and patient scenarios. The resources obtained from the local pediatric clinical educator included textbooks, articles, and relevant websites and were used directly in the introduction to pediatrics section. This section included the topics caring for a pediatric patient which addressed growth and development, principles of working with children, and physiologic measurements in pediatrics that included ranges for vital signs in children.

The remaining sections were formulated based on the information obtained in the integrative literature review and policies/procedures obtained from the HD Program Coordinator in Ontario. The consultations with local field experts including the nurses, dialysis clinical

educator, and nephrologists were used to guide the format of the resource by aiding in the determination of specific content that they deemed most important to be included. For example, I included sections that addressed nursing assessment and vascular access as requested by the nurses. In the manner, the educational resource was developed based on the needs of those who will use the information. As such, I anticipate that this module will be well received. I also used several photographs as visual aids within the module as was requested by the nurses during the consultations. See Appendix C for the educational resource.

Advanced Nursing Practice Competencies

As part of my practicum project, I demonstrated the Canadian Nurses Association (CNA) (2019) advanced nursing practice (ANP) competencies. The ANP competencies are specific knowledge, skills, judgment, and personal attributes based on an appropriate depth, breadth, and range of nursing knowledge, theory, and research that are exhibited by the advanced practice nurse (APN) (CNA, 2019). These competencies include research utilization, leadership, education, consultation and collaboration, direct comprehensive care, and optimizing the health system.

Research utilization involves the APN generating, critiquing, and applying research evidence (CNA, 2019). I demonstrated this competency during my practicum project through synthesis and critical analysis of evidence during the literature review and consultation and environmental scan. I did this by identifying common ideas and categories within the literature and consultation interviews that guided the resource development in content and delivery. Leadership involves the APN being an agent for change through seeking new, effective ways to practice and improve care (CNA, 2019). I demonstrated this competency by identifying a need

for a change in clinical practice at the organizational level through recognizing the lack of nursing knowledge and skills and thus, a need for more education related to pediatric HD.

Education is the commitment to professional growth and learning for all healthcare providers, students, clients, and families (CNA, 2019). I demonstrated this competency through facilitating the future education of fellow nurses by developing an educational resource based on their needs. Also, through the completion of my Master of Nursing degree, I demonstrated continuing education within my nursing career. Consultation and collaboration involve members of the healthcare team and stakeholders at an organizational, provincial, and national level (CNA, 2019). I demonstrated these competencies through collaboration with other healthcare providers at a local and national level including staff nurses, clinical educators, the program coordinator of a major Canadian pediatric hospital, and nephrologists during the consultation and environmental scan. These consultations aided in determining the content and delivery methods to be used to create a resource that will contribute to improved knowledge of pediatric HD among staff nurses.

Direct comprehensive care involves providing comprehensive client-and-family centered care in collaboration with other members of the healthcare team (CNA, 2019). I demonstrated this competency through the methods I used for my project as they allowed me to combine ideas from the literature review and experts in the field to create a resource that will directly improve nursing practice and ultimately, enhance patient and family outcomes. Optimizing the health system involves the effective functioning of health systems through advocacy, promoting innovative client care, and facilitating equitable, client-centered health care (CNA, 2019). I demonstrated this competency by advocating for improved patient care through promoting the

improvement of nursing education and practice and contributing to a system-level change. By incorporating new knowledge through the development of an educational resource, it is expected that nursing competence in pediatric HD will improve. This improvement may lead to benefits including cost savings to healthcare as patients may no longer need transport to larger pediatric hospitals in Canada when requiring HD. Also, patients and families can remain in their home province as currently, pediatric patients requiring HD are forced to move to provinces with dialysis units that have nursing staff educated in pediatric HD.

Implementation and Evaluation

The next steps in my practicum project are implementation and evaluation. A goal is for my educational module to be available on LEARN, the online educational platform for Eastern Health employees. I have started this process through an educational initiative request that was approved by my manager and is currently being reviewed by the learning and development team of the human resources department at Eastern Health. Once approved, the module will be available to all Eastern Health employees. I will also have a hard copy of the module available on the Dialysis unit at the Health Science Center for easy access by the nursing staff. The clinical educator of the Dialysis Program will review and approve the use of my module before it can be placed on the unit. Within the next year, I will condense the information in my module to a hand-held reference guide that will be available for quick access. For example, when the nurse goes to the pediatric intensive care unit to dialyze a patient, the guide will be available for essential information such as ultrafiltration and total blood volume calculations, dialyzer and tubing sizes, and medication dosages. I also plan to function as a resource person for pediatric HD to provide any requested support to nurses. This will include presenting at the yearly education day and

education sessions with the nurses including a simulation exercise of a pediatric HD patient as requested by the nurses in my consultation interview.

As part of the future evaluation of my educational resource, I plan to develop an online survey approximately six months after the implementation of the module. It will be completed by the dialysis nurses to determine the module's effectiveness in improving their knowledge related to pediatric HD. The nurse's evaluation is important to ensure the module meets their learning needs. I plan to work with researchers at Memorial University of Newfoundland to develop effective survey questions. Examples of questions on the survey may include: do you feel your knowledge of pediatric HD has improved after completion of the module, do you feel more comfortable dialyzing a pediatric patient after completing the module versus before, and are there any topics related to pediatric HD that you feel you want to know more about. The responses to the survey will be a guide for future educational initiatives. For example, if the nurses feel they need more information about a specific topic, myself or the Clinical Educator can include this in future education development.

Conclusion

The province of Newfoundland and Labrador has never had a pediatric HD policy or education initiative; however, dialysis nurses are expected to dialyze a pediatric patient when it is required for life sustainment. The education of dialysis nurses related to pediatric HD is imperative, as HD is not limited to the adult population. To this end, I developed an educational module specific to pediatric HD to improve the knowledge and skills of dialysis nurses in Newfoundland and Labrador. The literature review, consultations, and environmental scan were important in determining the content and delivery methods for the educational module. For the

future, the implementation and evaluation of the module will ensure nurses improve and retain their knowledge and skills specific to pediatric HD. Ultimately, this will lead to an improvement in patient and family outcomes.

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Appendix A: Literature Review

The Education of Nurses Performing Pediatric Hemodialysis: A Literature Review

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NURS6660: Practicum 1

The Education of Nurses Performing Pediatric Hemodialysis: A Literature Review

The kidneys are among the most important organs in the body, responsible for the excretion of waste products and regulation of body fluids, electrolytes, and hormones (Ibrahim et al. 2019). When the kidneys become diseased, this compromises the filtering units (the nephrons) and damages their ability to eliminate wastes and excess fluid (Kidney Foundation of Canada, 2021). Kidney disease can range from mild to severe and in some cases, lead to kidney failure (also referred to as end-stage kidney disease). According to the National Kidney Foundation (2021), **kidney failure** is often progressive for greater than three months. However, it is not always progressive as it can occur rapidly, known as **acute kidney injury (AKI).**

Historically, kidney disease has been rare in childhood with incidence rates ranging from 6.9 to 21.8 per million age-related population in the 0–4-year-old age group and 15–19-year-old age group respectively (Canadian Institute for Health Information, 2020). Globally, with the COVID-19 pandemic, an increase in kidney disease has been reported among children attributed to multi-organ inflammatory syndrome (MIS-C). In May of 2020, the Centers for Disease Control and Prevention (CDC; 2020) released a public health advisory along with a case definition for MIS-C among children associated with COVID-19 infection. These children presented with features similar to typical Kawasaki disease or toxic shock syndromes such as rash, neck pain, and bloodshot eyes which progressed to multi-organ failure post-COVID-19 infection (CDC, 2020). According to the Canadian Pediatric Society (2021), the incidence of emergency pediatric hemodialysis (HD) due to AKI secondary to MIS-C has increased across Canada. In the United States, over 4,000 children were diagnosed with MIS-C in 2020, making it

a significant contributor to the morbidity and mortality of critically ill infants and children (CDC, 2020).

Background

Renal replacement therapy (RRT) is used as a treatment for AKI among the pediatric patient population and has three forms: peritoneal dialysis (PD), hemodialysis (HD), and continuous renal replacement therapy (CRRT) (National Kidney Foundation, 2021). Each modality has specific indicators. These typically include the need for ultrafiltration (i.e., fluid removal) for symptomatic volume overload, medication toxicity, and solute removal (i.e., urea, potassium) for uremia or for removal of a toxin (Rees, 2021). As seen in MIS-C, difficulty with ventilation and prone positioning due to fluid volume overload precedents the need for emergency HD (Alabbas et al., 2021). The rapidity of solute generation and its urgency for removal, as in tumor lysis syndrome, hyperammonemia, hyperkalemia, or ingestion of dialyzable toxins, also require HD to sustain life (Rees, 2021), which are conditions that may occur within the pediatric population. PD has been the modality of choice for decades to treat AKI in pediatric patients, however, with the technological development in dialyzer and extracorporeal circuit(s) specific to pediatric size of recent years, the quality of HD treatment offered to pediatric patients has improved considerably (Zitzelsberger et al., 2014). HD is presently considered to be a safe and efficient treatment for pediatric renal impairment (Sousa et al., 2008).

Most Canadian children undergo hospital-based HD with registered nurses performing the treatments (Canadian Institute for Health Information, 2011). The current role of nurses in the management of critically ill patients requiring RRT is fundamental (Ricci et al., 2015). As HD is complex and technical, nurses performing the treatment must be fully knowledgeable and

competent in their skills to ensure enhanced patient and family outcomes (Cho, 2020; Rees, 2021). Competency can be achieved through continuing educational opportunities including participation in educational modules, sessions, and online learning (College of Registered Nurses of Newfoundland and Labrador, 2014). Researchers have demonstrated that the implementation of an education resource significantly improves nurse's knowledge and practice related to pediatric HD (Ahmed et al., 2019; Hassona et al., 2012; Saeed & Al-Mosawi, 2020).

In Newfoundland and Labrador (NL), pediatric HD is only performed by the nurses of the dialysis unit at the Health Science Center (HSC) in St. John's as it is connected to the only pediatric hospital in the province, the Janeway Children's Hospital. In 2019, Newfoundland and Labrador had the highest rate of new patients starting RRT in Canada with 249 patients per million population (The Canadian Institute for Health Information, 2020). However, the occurrence of pediatric HD in the province is rare, approximately one every five years (Dr. B. Curtis, personal communication, May 10, 2021). Like other places in the world such as Italy (Ricci et al., 2015), NL does not have a standardized protocol specific to dialyzing pediatric patients. With the increased incidence of pediatric HD across Canada due to MIS-C, this increase may also occur in NL. This combined with the unpredictable weather preventing patient transfer to larger pediatric hospitals warrants an increased necessity for pediatric HD in NL. There are no policies or educational resources specific to pediatric HD in NL (Cathy Cake, clinical educator of Dialysis Program Eastern Health, personal communication, June 5, 2021). A discussion with the nurses of the HSC dialysis unit revealed a lack of educational resources specific to pediatric HD resulting in a current lack of knowledge.

In this literature review, I will present the results of a comprehensive literature search specific to pediatric HD. I will explore the HD experience of the child, family, and nurse caring for the pediatric HD patient, along with current educational content and delivery methods used to educate nurses about pediatric HD. The results of the literature review will provide background for the development of an educational resource to improve the knowledge and skills of the nurses who are responsible for performing HD on pediatric patients in NL and, ultimately, improve patient and family outcomes.

Methods

I performed a literature search using the following databases: CINAHL, PubMed, Nursing & Allied Health, Google Scholar, Medline, Education Research Complete, Academic Search Complete, and Education Resources Information Center. Search terms included: education, resource, nurs*, pediatric or child or children or adolescent, guideline, hemodialysis or dialysis, kidney failure, nephrology, experience. Inclusion criteria were published within the last 20 years and written in the English language. Literature was screened based on the abstract or introductory paragraphs where relevance to the topic was identified. Sources were chosen based on their relevance to the topic of interest. I completed a broad search of global sources and identified various sources including published guidelines and research articles. All were evaluated for quality of content. Details of all sources can be found in the literature review tables located in Appendix A. As the project development continues, I will narrow the focus to within Canada during the environmental scan and consultation stages.

The Child and Family Experience

The experiences of the child and family during the HD process was a common theme within the literature. The experience of being informed that initiating dialysis is essential to maintain life can be a devastating, life-altering experience for children diagnosed with kidney failure and their caregivers (Nuel, 2012). For weeks, months, or years, these children's lives are disrupted because they must return to the hospital to be dialyzed about three times a week, for three or four hours each visit. For as long as it is necessary, HD constitutes a central feature of their everyday lives, with significant consequences on home, school, and recreational activities (Zitzelsberger et al., 2019).

Abreu et al. (2014), El-Gamsay and Eldeeb, (2017), Kilis-Pstrusinska, et al. (2013), and Zitzelsberger et al. (2019) found that children on HD experience difficulty in physical and social functioning. Children reported physical discomfort and limits in daily activity and were observed to sleep less, have a reduced engagement in physical exercise, and had body image issues. Alterations in their physical appearance, particularly related to vascular access, caused feelings of embarrassment. Socially, children felt isolated and alone with a sense of everyday confinement and constraints having an impact on their lives outside of HD. Children felt that HD limited their social time due to the amount of time taken for preparation, duration, and completion of the treatments.

Family members, particularly parents of the children undergoing HD, have several sources of distress relating to their child being on HD. Emotional distress is a prominent issue for parents whose children undergo HD (Cimete 2002; Ong et al., 2021; & Wightman et al., 2019). Parents experience feelings of guilt, grief, and powerlessness as a result of their child's

diagnosis. They feel grief because of their perceived role as a caregiver in contributing to the disease process, which is compounded by enforcing a strict diet and fluid restrictions on their children. Witnessing their child undergo dialysis and painful medical procedures causes feelings of grief and powerlessness. Emotional effects on the family dynamics also occur as parents feel they are neglecting their other children and/or partners to care for their sick child. As HD required several lengthy hospital visits, parents feel that their time with their other family members is reduced. In particular, if they had other children, they expressed a feeling of uncertainty of how it would affect them in the future (Cimete 2002; Ong et al., 2021; & Wightman et al., 2019). They also experienced strain on their intimate relationships with frequent absences from each other and arguments relating to their child's medical care.

The Nurses' Experience

The dialysis nurse plays a vital role in providing information, care, support, understanding, and therapeutic counseling to the pediatric patient and their family throughout the HD process (Ibrahim, 2019). High-quality nursing care is imperative to contribute to positive patient and family outcomes. Sometimes, however, nursing care lacks the necessary adequacy and safety of patients (Shahdadi & Rahnama, 2018). The many responsibilities of the nurse during the care of the pediatric patient undergoing HD can cause exhaustion, especially with a heavy workload and lack of resources. Providing care for patients with chronic diseases such as end-stage renal disease, working in an environment with complex HD machines demanding attention, and coping with the increased expectations of patients is stressful (Kavurmaci, 2014).

Ibrahim et al. (2019), Kavurmaci et al. (2014), and Shahdadi and Rahnama, (2018) found that nurses' attitudes about the care of children undergoing HD are often negative, due to

feelings of burnout, depression, and anxiety. Excessively long workdays, high workloads, and insufficient resources to accomplish the job led to a depletion in the nurses' physical and emotional resources. These authors further reported the nurses felt a lack of education relating to the patient's disease affected their quality of care, causing negative attitudes. Nurses frequently reported tension between them and the child's parents, including balancing responsibilities and control over the child's care. Nurses reported frustration with parents, especially related to nonadherence and parent's dishonesty in reporting their behaviours which added to their difficulties in managing care and maintaining a positive attitude towards the patients. For example, the emotional and physical damage experienced by the nurses often extended to their family environment, creating negative outcomes in their personal lives, such as relationship strain.

Nursing Needs in Pediatric HD

Increasing nurses' knowledge and experience with pediatric HD patients is necessary to resolve the challenges in the care of these patients to improve the quality of care provided by nurses and prevent burnout (Shahdadi & Rahnama, 2018; Kavurmaci et al., 2014). AKI among pediatric HD patients can be very complex, as seen in MIS-C, causing an increased need for nursing education to improve patient and family outcomes. Keeping nurses updated on new information and procedures relating to HD will aid their ability to adapt to change to ensure best practice and ultimately, enhanced patient and family outcomes (Shahdadi & Rahnama, 2018). Emphasis needs to be placed on the importance of continuous training based on a needs assessment to identify gaps in nursing knowledge and skills for those caring for children undergoing HD (Ibrahim et al., 2019). Periodic training programs and refreshing courses should

be provided to nurses to improve their knowledge, which will reflect in their performance (Bayoumi & Mahmoud, 2018; Yousef et al., 2019). Therefore, well-organized educational resources that enable healthcare providers to become educated and to provide, monitor, and evaluate care are critical (O'Grady et al., 2017).

Educational Content

Although the principles of HD are similar for adults and children, the differences need to be addressed to effectively and safely perform HD and reduce potential complications, thereby improving life expectancy and quality of life for patients (Rees, 2021). Throughout the literature review, I identified two essential aspects for competence in nursing knowledge and skill in pediatric HD: central venous catheter (CVC) infection prevention and specific areas for nursing assessment of the pediatric patient. CVC infection rates are high among the pediatric HD population (Araujo de Souza et al., 2011; Chand et al., 2009; O'Grady et al., 2017; Paglialonga et al., 2016). Nurses must have the knowledge and skill to prevent these infections and ultimately prevent high morbidity and mortality among this population (Chand et al., 2009). Nursing assessment, including patient fluid status and dialysis prescription, was also prevalent within the literature. As pediatric patients are much smaller than adults, a small error in fluid calculations or dialysis prescription programming can be fatal, therefore ensuring nurses are knowledgeable about these parts of the assessment is critical (Cho, 2020).

CVC Infection Prevention

The CVC is the most commonly used vascular access in children in North America with between 78-83% usage in the United States (Araujo de Souza, 2011; Chand et al., 2009; Rees, 2020) and represents the sole initial vascular access for pediatric HD (Cho, 2020). The CVC

places children at high risk for infection because of patient comorbidities such as cardiovascular impairment and malnutrition, and numerous human, environmental, and procedural factors (Ahmed et al., 2019). Catheter-related bloodstream infections (CRBSIs) alone have a reported incidence of 1.1 to 5.5 episodes per 1000 catheter days and are associated with increased morbidity, hospitalization, and death (Miller et al., 2016). As per the United States Renal Data System (2020) sepsis rates associated with CVCs are approximately 80 per 100 patient-years, as compared to only 10 per 100 patient-years for arteriovenous fistula. Comparing adults and children, rates of CRBSI in patients in pediatric intensive care units are higher than those in patients in adult intensive care units (Paglialonga et al. 2004). The Public Health Agency of Canada (2020) reported the number of CRBSI's that occurred in 40 Canadian hospitals between 2008-2018 and pediatric intensive care units (ICU) reported a higher infection rate at 1,450 CRBSI's compared to adult ICUs at 1,331.

The CVC can be colonized with organisms by either of two main routes. The first route is the intraluminal colonization which occurs during repeated handling of the line, the hub, or from administering contaminant solution via the catheter (Ouda et al., 2019). The second route is the extraluminal colonization which originates from the skin at the insertion site and migrates along the external surface of the line.

Intralumenal: Antimicrobial Locks

Both Lok et al. (2020) and O'Grady et al. (2017) address the use of antimicrobial locks to prevent CVC infection. Catheter lock is a technique by which an antimicrobial solution is used to fill a catheter lumen and then allowed to dwell some time while the catheter is idle (i.e., not in use) (O'Grady et al., 2011). This practice is recommended by both Lok et al. (2020) and

O'Grady et al. (2017) in patients with a CVC who are at high risk of infection such as pediatric patients. In their literature review, Lok et al. (2020) found that researchers have demonstrated a substantially lower frequency of catheter-related infection with an antimicrobial lock solution, compared with an anticoagulant lock solution. O'Grady et al. (2017) also found similar results in their meta-analysis as through several randomised controlled trials, researchers determined the rate of CVC infection was significantly lower in the group whose catheters were locked with an antimicrobial solution.

O'Grady et al. (2017) recommend that nurses should be educated regarding evidence-informed procedures for the insertion and maintenance of intravascular catheters, and appropriate infection control measures to prevent intravascular catheter-related infections such as antimicrobial lock solutions. As pediatric HD patients have a high rate of catheter-related infection, nurses need to know and understand all prevention methods. Understanding indications for prophylactic antimicrobial use can provide nurses with the tools for patient advocacy, specifically in their high-risk pediatric HD patients that may benefit from these lock solutions.

Extraluminal: CVC Site Maintenance

External CVC site maintenance includes dressing changes and physical examination of the CVC exit site. Both Lok et al. (2020) and O'Grady et al. (2017) recommend weekly CVC dressing changes with skin preparation of 2% chlorhexidine and sterile transparent or semi-permeable dressing to cover the catheter site. Monitoring of signs and symptoms of bacteremia/septicemia is imperative for early detection and treatment. Inspection of the CVC exit site may reveal *Dacron cuff migration* that places the CVC at risk of infection. *Exit-site infection*

is indicated by the presence of erythema, swelling, tenderness, and purulent drainage around the CVC exit and the part of the tunnel external to the cuff (See Figure 1). Signs of *tunnel infection* are swelling, erythema, fluctuance, and tenderness over the CVC tunnel central or proximal to the cuff. See Appendix B for a glossary of terms. Both Lok et al. (2020) and O'Grady et al. (2017) recommend educating dialysis nurses to ensure proper dressing technique and have the ability to identify physical signs of infection.

Nursing Assessment

Although the principles of HD are similar for adults and children, there are technical aspects of the procedure and complications that are unique to the pediatric population. These differences must be recognized and addressed by nurses to effectively and safely perform pediatric HD, thereby reducing complications (Ashby et al., 2019). These differences are outlined in guidelines for dialyzing pediatric patients by Ashby et al. (2019), Cho, (2020), Fischbach et al. (2005), Rees (2021), and Souza et al. (2008). Details and quality of these guidelines can be found in the literature review summary tables located in Appendix A.

Fluid Status

I found three articles that addressed patient fluid status as an important subject for nurses to understand. All authors agree that there are vast differences between the assessment of fluid removal between pediatric and adult populations (Fischbach et al., 2005; Rees 2021; Souza et al., 2008). Fluid status is calculated based on a patient's prescribed target weight, or the patient weight if the kidneys were fully functional and able to remove fluid from the body (Rees, 2021). Target weight is ordered by the nephrologist; however, nurses are responsible for the assessment of the weight and recommended changes to the prescription based on their assessment. As Ashby

et al. (2019) suggested, target weight assessment in children and adolescents is particularly challenging as it needs frequent adjustment in line with growth or periods of illness. This is particularly true for infants and adolescents during rapid phases of growth. Overestimation of target weight will result in chronic fluid overload leading to hypertension and left ventricular hypertrophy, whereas chronic under-hydration is likely to detrimentally affect residual kidney function and lead to increased symptomatic hypotension both during and immediately post-dialysis.

Rees (2021) and Souza et al. (2008) and Fischbach et al. (2005) outline specific recommendations for fluid assessment among pediatric patients including calculations to be used by nurses during the assessment of patient fluid status. These authors recommend a fluid removal of no more than 5% of the patient's body weight in one session or 0.2ml/kg per hour. Removal of more than recommended will likely result in intradialytic hypotension and hemodynamic instability. All three authors also recommend frequent monitoring of pediatric HD patient's target weight with weekly assessment for those under 40 kilograms and at least monthly for those over 40 kilograms.

Dialysis Prescription

There are significant differences between the pediatric and adult composition and indications for the dialysis prescription which includes the *dialyzer*, tubing, blood flow rate, and session duration and frequency. Nurses must be knowledgeable and competent in the ability to differentiate between the required prescriptions for adult and children. For each patient, a nephrologist develops an individual dialysis prescription to ensure adequate solute clearance and the removal of excess fluid (Rees, 2021).

The type of dialyzer used depends on the patient's residual renal function (Ashby et al., 2019; Cho, 2020; Rees, 2021; Fischbach et al., 2005) The dialyzer acts as the artificial kidney, removing fluid and solutes or toxins. There are two types of dialyzers: low-flux and high-flux. Low flux dialyzers have a moderate permeability, meaning the removal of solutes is moderate. High-flux dialyzers have high permeability, solutes are removed at a high rate. If the patient has a little residual kidney function, a high-flux membrane is recommended as they improve permeability for middle and larger molecules. For pediatric patients, the size of the dialyzer is much smaller compared to adults as the surface area is similar to that of the patient's body and selected according to the patient's size (Cho, 2020; Sousa et al., 2008).

The tubing, or circuit, used for pediatric HD patients is much smaller than that used for adult patients. The selection of tubing for the pediatric patient is dependant on the priming volume. The tubing contains between 100-200mls of the patient's blood at one time while HD is ongoing. It is imperative to ensure the tubing is small enough so that the child is not depleted of blood volume which can cause complications such as hypotension. A child can tolerate a maximum of 10 percent of their total blood volume in the circuit, and a safe volume of the circuit is targeted at eight percent of the total blood volume of the child (Cho, 2020; Fischbach et al., 2005; Rees, 2021; Souza et al., 2008). Tubing available for pediatric patients varies between 20-70 ml with internal diameters from 1.5ml to 3 ml (Souza et al., 2008).

Blood flow is also an important aspect of the dialysis prescription addressed by Fischbach et al. (2005), Rees (2021), and Souza et al. (2008). The blood flow is the speed at which the blood is pumped out of the child and into the circuit (Rees, 2021). Blood flow determines solute clearance by optimizing *diffusion* and *convection*. These authors indicate that

blood flow speed must be adjusted to the size of the child and should not exceed their maximum extracorporeal volume in ml/min (i.e., up to bodyweight x 8 ml/min) to maintain their cardiovascular status. A blood flow rate of 150-200 ml/min or 3-7ml/min per kilogram is recommended. This flow is much smaller than that of an adult, which is typically 300-400ml/min (Rees, 2021).

For children, the session duration is similar to that of an adult as it is dependant on the predetermined amount and rate of solute clearance and fluid removal (Ashby et al., 2019; Fischbach et al., 2005; Rees, 2021; Souza et al., 2008). Sessions typically range from three to four hours, rarely being shorter than four hours. For most infants and children weighing less than 10 kilograms, the need for more than three sessions a week may be required as their diet consists of fluid (milk), hence four to five sessions a week are frequently prescribed to prevent fluid overload. As children are growing, frequent assessment of the adequate number and duration of each session is recommended.

Educational Delivery

As the purpose of this project is to deliver an educational resource, I completed a comprehensive literature search to identify methods of educational content delivery and their subsequent effects on nurse's knowledge and practice. I identified several articles where researchers examined the effect of the implementation of an educational intervention on nurse's knowledge and/or skills related to pediatric HD (Ahmed et al., 2019; Bayoumi & Mahmoud, 2017; Dennison, 2011; Hassona et al., 2012; Machaly et al., 2020; Ouda et al., 2019; Saeed & Al-Mosawi., 2020; Saleh et al., 2018; Yousef et al., 2019; Windt, 2016). Common educational

delivery methods included lecture, active group discussion, demonstration and re-demonstration, simulation, booklet and e-module.

Lecture

The most common educational modality identified was lecture (Bayoumi & Mahmoud, 2017; Hassona et al., 2012; Saeed & Al-Mosawi., 2020; Saleh et al., 2018; Yousef et al., 2019). A lecture is an oral presentation bridging verbal communication with writing and media technologies to provide flexible, adaptable, robust, and contemporary methods to deliver content (Phillips, 2020).

Lecture was implemented as an educational tool related to infection control practices in a pediatric HD unit by Bayoumi and Mahmoud (2018) and Yousef et al. (2020) as they examined handwashing, wearing gloves, gown, mask, use of disinfection, and CVC dressing change technique. They used an interactive lecture with discussion that included content from the CDC guidelines for CVC infection prevention and found significant improvements in nurses' knowledge and practice related to infection control techniques as a result. Saleh et al. (2019) also found improvements in nurses' knowledge and practice in infection control measures along with generalized standards of practice. These included their ability to identify symptoms of fluid overload and electrolyte imbalance, correct dialysis machine programming, CVC care including dressing change, nutrition recommendations for patients, and medication administration competency.

Improvements in knowledge and practice related to catheter care, procedures of disconnecting the patient from the machine, troubleshooting machine alarms, and possible complications during HD such as low blood pressure was observed by Hassona et al. (2012) as a

result of their educational session with lecture. Similarly, Saeed and Al-Mosawi (2020) found an improvement in nurses' general practice knowledge of pediatric HD. Overall, there were significant results observed in all five studies that used lecture as an educational intervention to improve the knowledge and practice of nurses working with pediatric patients undergoing HD.

Simulation

Ahmed et al. (2019), Machaly et al. (2020), and Ouda et al. (2019) used simulation including role-play, demonstration and redemonstration as their primary educational intervention modalities. Role play is a dramatic approach in which individuals assume the roles of others; it increases observational skills, improves decision making, and increases comprehension of complex human behaviours (Phillips, 2020). Demonstration showed learning outcomes through projects, presentations, or learning objects which is revealing the degree to which learners have met the learning objectives. Visibly showing a process often aids in retention, allowing skills to become more understandable as a result (Phillips, 2020).

CVC infection prevention and control was the focus of several education sessions (Ahmed et al., 2019; Ouda et al., 2019). General infection control precautions in the pediatric HD unit included handwashing, wearing gloves, and aseptic technique during the connection and disconnection of the patient to the HD machine. General knowledge of the CVC along with specific knowledge related to hand hygiene, dressing change, and disinfection of hubs and lumens was also included in the sessions. Machaly et al. (2020) focused on general HD procedures including pre, intra, and post dialysis care and intrahemodialytic complications. Content for the simulation sessions was obtained through a need's assessment of the nurses and

research material including guidelines from the CDC for infection control. During the simulation practices of role-play and demonstration, the nurses were observed directly by the researchers.

Simulation resulted in significant improvements in nurse's knowledge and practice in pediatric HD. Ahmed et al. (2019) and Ouda et al. (2019) reported a significant difference in nurses' knowledge and practice scores related to infection control. Similarly, Ahmed et al. (2019) found significance differences between pre and post educational program, regarding knowledge of infection control. Highly significant differences were observed between nurses' practice at pre-program and six months after the program with respect to handwashing, wearing gloves, and medication administration preparation. Ouda et al. (2019) found an improvement in nurses' total practice scores in post intervention as compared with pre-intervention. They also found that there were less catheter-associated infections in post-program intervention.

Machaly et al. (2020) reported an improvement nurses' practice after three weeks of implementing the HD guidelines related to pre and post HD assessment and complications. The guidelines were developed based on recommendations from the National Kidney Foundation, American Nurses Association, and medical journals. The authors used demonstration and redemonstration for elements of practice such as nursing assessment of vital signs, weight measurement, and monitoring machine values. Before the guidelines were implemented, slightly less than two thirds of the nurses had good total knowledge and practice scores based on the pre-intervention survey results. Their total knowledge and practice scores improved significantly after three weeks of implementing the guidelines. Overall, all three studies observed significant differences in nurse's knowledge and practice related to pediatric HD as a result of an educational program utilizing active learning modalities including role-play and demonstration.

Online Module

An online learning module has been used to improve the knowledge of nurses working with pediatric HD patients. Windt (2016) used interactive simulation in their module, which involved the user having the ability to simulate pediatric HD using the HD equipment. Dennison (2011) used similar modalities, using scenarios depicting complications of HD, beginning with frequently noted complications, such as hypotension and muscle cramps, to less frequent but higher acuity complications, including pyrogenic reactions, *dialysis disequilibrium syndrome*, *hemolysis,* and air embolism. An interactive module was created through roll-over fields, which provide added information, audible sounds, or added pictures to enhance the learning process. Roll-over fields are identified by highlighted or underlined areas and pictures. When the browser or mouse moves over that area, further information is displayed to the learner regarding the identified text. Through a staff survey, both of these authors evaluated the nurse's knowledge after the implementation of the module. Windt (2016) found that the majority of the sample agreed or strongly agreed that the content presented in the module improved their level of comfort when managing patients receiving RRT. Most nurses agreed or strongly agreed that the amount and type of information presented was appropriate for their learning needs. Dennison (2011) showed a significant difference between nurses of differing years of dialysis experience after the implementation of the online module. They observed a greater increase in knowledge within the less experienced nurses (<3 years) compared to those with more experience (>3 years).

Implications

I performed a comprehensive search of the literature that revealed several sources specific to the experiences of patients, families, and nurses in pediatric HD. These experiences along with guidelines and educational modalities will be used to improve the knowledge and skills of nurses in pediatric HD through the development of an educational resource. The literature review revealed the existence of knowledge gaps. The guidelines that will be used for the education resource content from CDC and National Kidney Foundation are from credible resources published in the United States and United Kingdom. There were no published guidelines, policies, or procedures specific to pediatric HD within Canada. It is unclear within the published literature which guidelines Canadian pediatric HD programs are following, therefore the development of standards of practice for a newly developed pediatric HD program, such as that in NL, would require several consultations with large fully developed national programs such as those in Toronto and Alberta.

I have found several sources from one country, Egypt. Pediatric HD is very specialized and has traditionally had a limited population base. Individual pediatric nephrology centers have a limited number of patients receiving HD at any given time. Therefore, it is challenging for single centers to recruit sufficient numbers of patients to perform adequately powered clinical studies to evaluate treatment and outcomes in this patient population (Samuel et al., 2010). With the recent increase in pediatric HD due to MIS-C, more research is required within North America to develop a stronger evidence base. Although the sources from countries outside of North America are relevant to this current project content and delivery, to ensure the project is the most suitable and specific to the Dialysis Program within Eastern Health, the consultations

and environmental scan will focus on both local and national sources within Canada. These sources will include local experts in the field and a review of other educational programs within Canada specific to HD such as SickKids in Toronto, the largest pediatric HD program in the country.

Conclusion

The search I performed revealed literature of varying sources from several countries around the world. These sources included guidelines, review articles, quantitative and qualitative research related to pediatric HD. I presented the experience of the patient and family, nurse, and the content and delivery methods to be included in an educational resource to improve nurse's knowledge and skill of pediatric HD. There are gaps within the literature, including a lack of North American resources. I will augment this gap during the development of my educational resource by performing an extensive environmental scan and consultations with field experts locally and nationally. The resource I develop will contribute to improved knowledge and skills specific to pediatric HD among staff nurses and ultimately, enhanced patient and family outcomes.

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Figure 1

Illustration of a Tunneled Catheter Exit-site Infection

Note. Also see exit-site infection definition in Appendix B. From: Miller, L.M., Clark, E., Dipchand, C., Hiermath, C., Kappel, J., Kiaii, M., Lok, C., Luscombe, L., Moist, L., Oliver, M., & MacRae, J. (2016). Hemodialysis tunnelled catheter-related infections. *Canadian Journal of Kidney Health and Disease, 3*, 1-11. http://doi:10.1177/2054358116669129

Appendix A: Literature Summary Table

Legend: Acute Kidney Injury (AKI), Hemodialysis (HD), ESRD (End Stage Renal Disease), V&R (Validity & Reliability)

Study/Design	Methods	Key Results	Comments
Authors: Abreu et al. (2014) Design: Phenomenology Purpose: To identify quality of life impacting attributes related to health of children and adolescents with chronic renal failure, on HD.	N: 42 participants between 8 and 18 years, their parents and caregivers. Data Collection: - Focus groups with the target-population and interviews with specialists. - 14 focus groups were conducted. Two with children, five with adolescents and seven with their respective parents or caregivers. - Conducted between August 2011-March 2013 in two hospitals. - 12 open questions. Participants stimulated to interact, talking and sharing their ideas about the proposed theme. - Thematic and content analysis.	**Main Themes:** - Water and food restrictions. - Limitations imposed by the treatments. - Time dedicated to the treatment. - Change in body image related to the vascular access and growth. - Stigma related to the label of a "sick child" causing limited social interaction. - Lack of self-care due to life restrictions. - Hope of kidney transplantation.	Strength: **Strong** Quality: **High** • Will be used in my educational resource to improve nurses' understanding of the child's perspective of renal failure and HD.
Authors: Ahmed et al. (2019) Design: Uncontrolled before-after Purpose: Evaluate the effect of an educational	N: 36 nurses working in the pediatric dialysis unit Country/setting: Minia, Egypt • Main teaching method simulation (role play, demonstration) • Nurses divided into 9 groups Data Collection: • Pretest/posttest design	**Post Intervention:** Knowledge related to infection control significantly changed: - Infection control: P=0.001 - Hand washing: P=0.001 - General protection measures: P=0.001 - Precaution in dialysis: P=0.005 - Total knowledge: P=0.001 Practice related to infection control significantly changed: - Hand washing: P=0.001	Strength: **Weak** Quality: **Moderate** Issues: No control for major confounders • Useful in the development of my educational

Study/Design	Methods	Key Results	Comments
program of nurses' knowledge and practice regarding infection control measures in a pediatric dialysis unit.	• Data collection from November 2016-April 2017 • Statistical analysis using SPSS-19 • Continuous data compared using t-test • Variables compared using chi-square test **Tool:** Interview questionnaire. Demographic data, nurse's knowledge of infection control (31 closed-ended questions), observational checklist (adopted from CDC to assess infection control practices). Proven reliability and validity. Posttest carried out immediately after intervention and 6 months later.	- Wearing gloves: P=0.001 - Administration of injections: P=0.001 - Dialysis injectable medication administration: P=0.001 - Total nurses' practice about infection control: P=0.001	resource as it will aid in my determination of the educational methodology that I will use.
Authors: Ashby et al. (2019) Design: Guideline Purpose: Provide a guidance on how to look after patients and how to run dialysis units, and provides standards which units should in general aim to achieve.	A guideline published under The Renal Association – a leading professional body for the United Kingdom renal community. Guidelines used to answer the question: "what does good quality hemodialysis look like?". Based on several research articles found from systematic review. Searches were conducted in MEDLINE, PUBMED, Embase, and The Cochrane Library, and supplemented with papers handpicked from the reference lists of review papers. The strengths of the recommendations and the level of supporting evidence coded using the Modified GRADE system.	**Main Topics:** • Planning, initiation & withdrawal of Renal Replacement Therapy • Vascular Access for Hemodialysis • Cardiovascular Disease • Blood Borne Viruses • Assessment of the Potential Kidney Transplant Recipient • Nutrition • Anemia • CKD-Mineral and Bone Disorder • Water Treatment Facilities • Dialysis Water and Dialysis Fluid Quality	Strength: **Strong** Quality: **High** • Useful to guide the topics of pediatric HD that I will use in my educational resource.

Study/Design	Methods	Key Results	Comments
Authors: Bayoumi & Mahmoud (2018) Design: Uncontrolled before-after Purpose: To investigate the effect nurses' knowledge and practice in pediatric HD unit evidence of education program on -based practice (EBP) guidelines related to CVC care.	N: 40 nurses from two HD units of varying education level and years of experience Country/setting: Benha, Egypt • One group of 40 nurses. Measuring knowledge related to CVC care. • Five groups – each group 6-8 nurses • Eight education sessions total. Lecture and group discussion using PowerPoint Data collection: **Tool 1** - Questionnaire with 2 parts: *Part 1*: Six closed-ended questions, including demographics and years of experience. *Part 2*: 25 questions measuring knowledge of CRBSI among pediatric HD patients. Each correct answer was assigned score 1 and wrong answer was assigned score 0. The total score was 25. **Tool 2** - An observational checklist for CVC site performance, including hand washing, wearing mask and goggles, wearing sterile gown, wearing sterile gloves, use of disinfection, and dressing for CVC. Scores assigned if correct or incorrect. • Content validity proven. Chronbach's α equation 0.887. • Data collection conducted from April, 2016 to October 2016	• Improvement in total knowledge of nurses as regards CRBSIs in pediatric HD unit, when compared with that before intervention and immediately after intervention, as well as that before intervention and after 6 months of implementation of teaching guidelines ($P \leq 0.01$)	Strength of Design: **Weak** Quality: **Moderate** Issues: • No control for major confounders • Will be used in my determination of the educational method I will use based on the nurses' responses in the article.

Study/Design	Methods	Key Results	Comments
	• Data evaluation = SPSS computer program Version 20 • Comparison of mean performed using paired-sample t-test and F-test. Correlation among variables tested using Pearson's correlation coefficient.		
Authors: Cho (2020) Design: Review Article Purpose: To discuss HD for the treatment of small children with RRT-requiring conditions, and consider indications, prescriptions, complications, and ethical issues.	• Published under the Korean Society of Pediatric Nephrology • Written by Nephrologist in department of Pediatrics, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, South Korea • Review of research related to guidelines for pediatric HD prescription, complications and ethical issues. • From a physician point of view.	**Guidelines:** 1. Access – CVC sole initial access for children. CVC choice dependent on patient size. 2. Equipment – Blood flow, dialysate flow, and dialyzer size dependent on child's size. 3. Prescription – Extracorporeal blood volume to not exceed 10% of patients size. Blood flow rate of 3-5ml/kg/min recommended. 4. Adequacy - HD dose above which no significant reduction in negative outcomes or improvement in positive outcomes occurs. Measured using Kt/v (urea removal).	Strength/Quality: **Moderate** • Several references are > 30 years old. • Useful because it provides topics relating to pediatric HD that I can use in my educational resource.
Authors: Cimete (2002) Design: Phenomenology Purpose: Describe the common stress factors and coping strategies of parents whose	N: 31 parents of children undergoing HD (toddler to adolescent). 6 fathers and 25 mothers. Country/Setting: Istanbul, Turkey. Two pediatric HD units. Data Collection: • Focus group interviews. • Semi-structured, open-ended questions. • Tape recorded with written notes.	**Common themes:** Financial and bureaucratic problems • Issues with wait times, insurance, financial problems. Appearance and limitations of the child • Growth and development reductions combined with diet and fluid restrictions. • Inability to care for other children. Support systems • Lack of familial support	Strength of Design: **Strong** Rating: **High** • Useful in the development of my educational resource to provide nurses with a

Study/Design	Methods	Key Results	Comments
children had been treated by HD.	• 90 minutes in length. Analysis: • Audiotapes transcribed verbatim. • Content analysis. • Coding based on themes.	• Lack of economic support	better understanding of parent's experiences.
Authors: Dennison (2011) Design: Uncontrolled before-after Purpose: Evaluate the effect of computer assisted learning module on nurses' knowledge of dialysis complications.	N: 60 nurses of varied experience working in one dialysis unit Country/setting: New Jersey, New York • Implementation of an interactive online learning module • Divided into 4 groups based on years of experience in dialysis (1-3 years N=14, 4-9 years N=11, 10-19 years N=19, 20 of more years N=16) Data Collection: • Pretest/posttest to evaluate effectiveness of module • Survey of 10 questions. Proven validity and reliability. • Data were analyzed utilizing PASW Statistics GradPack 17.0 • Evaluation of knowledge test scores: one-way ANOVA.	**Post Intervention:** • Significant mean differences noted on the post-test (F3, 56] = 3.31, P = 0.027 partial 2 of 0.15) • Nurses with three years or less had the greatest overall improvement of 21% compared to those with more than 3 years' experience (9-10%) as they had stronger knowledge base due to previous education. • Difference between pre/post test scores between groups P=0.039	Strength of Design: **Weak** Quality: **Moderate** Issues: • No control for major confounders • Useful because I can use the nurses' responses in determining my own educational resource method.

Study/Design	Methods	Key Results	Comments
Authors: El-Gamsay & Eldeeb (2017) Design: Cross-sectional Purpose: To clarify bio demographic characteristics, common complaints, and physical, and psychosocial status of children with ESRD under regular maintenance HD.	N: 30 children ages 6-16 years with ESRD undergoing HD at a pediatric nephrology unit. Country/Setting: Tanta, Egypt Data Collection: • July 2015-Janurary 2016 • Three structured questionnaires measured the bio demographic data of children and their parents, common complaints before and after the onset of HD. • Assessment sheet of nutritional habits, sleeping patterns, daily physical activities, school achievement, the emotional, behavioral and social aspects of children, and different social relationships. • Proven V&R Analysis: • SPSS version 20 and Microstat-W. Categorical data presented as number and percentages; quantitative data expressed as the mean ± standard deviation.	• 70% of children slept less than 8 h a night. • 75% of the studied children engaged in no physical exercise. For over 50% of the children, the main reasons for not practicing exercise were fear of injury and vascular access. • All children experienced irregular attendance to school; 43.3% had high marks, 36.7% had low marks, and 20% failed to pass exams. • 80% complained of parent's overprotection. • Two-thirds of the studied children were introverted, preferring isolation from other.	Strength: **Weak** Quality: **High** • 46% participants between ages 14-16, limiting generalizability of findings. • Useful in the development of my educational resource because it provides the nurse with improved understanding of the experience of a child on HD.
Authors: Fischbach et al. (2005) Design: Guideline Purpose: Recommendations based on technological	• Written guideline published under The European Pediatric Dialysis Working Group. Established in 1999 by pediatric nephrologists from different European countries with a major interest in dialysis. • Addressed the main factors affecting hemodialysis prescription and management in children including fluid removal,	**Guidelines:** 1. The dialysis unit: • In a pediatric center with nutritional and educational support. 2. Water Quality • Free from microbiological contamination 3. The dialysis machine: • Has ultrafiltration control and option for single and double needle dialysis 4. Blood lines: • Available in infant size and biocompatible	Strength: **Strong** Quality: **High** • Some citations used as support greater than 20 years old.

Study/Design	Methods	Key Results	Comments
developments in pediatric HD.	dialyzer size, blood circuit volume, and vascular access. • Guidelines were initiated and discussed at meetings of the group and refined by e-mail discussion to develop a consensus of opinion, on the basis of cumulative clinical experience and reported studies	5. Principles of blood purification • Small solute clearance from diffusion to convection 6. Extracorporeal blood access and circulation: • Total extracorporeal blood volume should be less than 10% of total patient blood volume • Blood flow rate of 150-200ml/min is sufficient 7. Dialyzer choice: • Synthetic, low-flux, dependent on desired urea and toxin removal 8. The dialysate: • Bicarbonate buffered with low calcium (1.25mmol/L) 9. Dry weight assessment: • Difficult to define in children. No unique method, need for regular assessment. Close collaboration with dietician. 10. Session, prescription and monitoring • Individualized, assessment regularly, psychosocial of patient and family is needed.	• Useful because it provides topics important for nurses to understand when dialyzing a pediatric patient that will be used in my educational resource.
Authors: Hassona et al. (2012) Design: Uncontrolled before-after Purpose: To provide an overview of the effect of an educational program based on	N: 38 nurses working in HD units at Zagazig University Hospital. Country: Egypt • Implementation of an educational program developed from international standards and national guidelines. Data Collection: Knowledge questionnaire: Assessed nurses' knowledge about the care of patients receiving	• Significant gains in the number of nurses who achieved a satisfactory total knowledge score immediately post-intervention and three months after the intervention (P<0.001). • The highest significant gains were in the subcategories related to instructions to the patient in the posttest (91.4%), and hypervolemia in the follow-up test (97.1%). • Gains in number of participants who achieved a satisfactory performance score.	Strength: **Weak** Quality: **Moderate** • No controls for confounders. • Useful in the development of my educational resource to

Study/Design	Methods	Key Results	Comments
clinical practice guidelines to improve the knowledge and performance of nurses in HD setting.	HD. 36 multiple-choice questions grouped under nine categories (clots of the shunt, termination of session, leakage of blood, infection control, dialysis disequilibrium syndrome, hypervolemia, instructions to patients, weight loss, and hemolysis). Observation checklist: Assessed individual nurse performance and had four main sections, each with several subsections. These included a) direct care to the patient undergoing HD that detailed three subsections (pre-dialysis phase, intradialytic phase, and termination phase), b) care for patients with intradialytic problems that detailed five problems (hypotension, muscle cramps, hypertension, dyspnea, and chest pain), c) infection control measures that detailed six subsections (measures related to health care team, patients, dialysis machine and equipment, safe waste management, and unit safety), and d) health education provided to the patient that detailed three subsections (related to vascular access care, diet and fluid restrictions, and general instructions).	The number increased from 0 to 25 in the immediate post-intervention phase. • The highest significant gains were in actions related to care for intradialytic problems in the post-test (96.3%) and in actions related to infection control in the follow-up test (82.9%). • Significant, strong, positive correlation between the number of participants achieving satisfactory knowledge scores and the number of the participants achieving satisfactory performance scores as a total ($r = 0.741$, $P = 0.000$).	determine the educational methodology I will through the responses of nurses.
Authors: Ibrahim et al. (2019) Design: Cross-sectional Purpose: Assess nurses' performance regarding care of	N: A convenience sample of 50 nurses from two HD units located in hospitals Country/setting: Cairo and Ain Shams, Egypt Data Collection: Three tools: 1. Self-administered questionnaire sheet (26 questions about HD knowledge)	• 62% had satisfactory knowledge about CRF and 46% unsatisfactory • 72% of nurses had satisfactory of HD complications • 48% unsatisfactory knowledge of nursing care after HD • 56% had incompetent level of practice regarding care during HD and dry weights	Strength: **Weak** Quality: **High** • Useful in determining the educational method I will use for my resource

Study/Design	Methods	Key Results	Comments
children undergoing HD therapy.	2. Observational checklists (89 steps to rate nurses' practice) 3. Attitude rating scale to assess nurses' performance regarding care of children Data collection over 6 months (March-Aug) Education session 30 min, 3 days per week. - Proven V&R of all tools. Analysis: - SPSS version 20 - Statistical analysis included; percentage (%), square (X2), and Pearson correlation (R)	• 56% of nurses had negative attitude towards caring for children on HD. Only 6% had a positive attitude. • 56% had incompetent level of practice regarding care of child on HD	based on the nurses' responses in the article.
Authors: Kavurmaci et al. (2014) Design: Cross-sectional Purpose: Determine the burnout levels of hemodialysis nurses working in HD units and their relation with some sociodemographic variables.	N: 28 nurses working in 4 HD units. Country/setting: Erzurum, Turkey Data Collection: - Two-part questionnaire – demographics and The Maslach Burnout Inventory (MBI), a self-administered questionnaire, was used to measure burnout in the second part. - Proven V&R Analysis: - SPSS 16.0 program (Chicago, IL) and evaluated with percentage, mean, independent samples t test, one way analysis of variance (ANOVA), correlation, Kruskal–Wallis analysis of variance, and Mann–Whitney U test.	• The MBI score subscales of the nurses provided a mean emotional exhaustion score (EE) of 17.07 ± 8.29, depersonalization (DP) score of 5.89 ± 4.13 and personal accomplishment (PA) score of 20.64 ± 4.10. • Statistically significant difference between DP and PA with gender; marital status and EE; EE and PA with state of having a child; educational status and EE ($P<0.05$). • Nurses working in HD units experience a medium-level burnout in terms of subscales of EE and DP, and a high-level burnout in terms of subscale of PA.	Strength: **Weak** Quality: **High** • Useful because it can be used to improve understanding of the environment in which I will implement my project.

Study/Design	Methods	Key Results	Comments
Authors: Kilis-Pstrusinka et al. (2013) Design: Cross-sectional Purpose: Analyse the health-related quality of life (HRQoL) in Polish children with CKD on HD.	N: 203 children with CKD on HD and their 388 parents/proxies Country/setting: Poland. 12 pediatric nephrology centers. Data Collection: • Chart review for patient demographics • The Pediatric Quality of Life Inventory (PedsQL) 4.0 was used to assess HRQoL • Assesses physical (8 items), emotional (5 items), social (5 items) and school/ nursery school (5/3 items) functioning in adolescents and children • Proven V&R Analysis: • Descriptive statistics • Kolmogorov–Smirnov test for distribution • Mann–Whitney test, the student's t test and the Kruskal– Wallis test were used, to compare the different studied groups. • Chi-squared test or Fisher's exact test was used for comparison between groups • R for Windows, version 2.15.1 and MedCalc for Windows, version 12.3.1.0	• HLQoL scores for all CKD groups were significantly lower in all domains compared with international population norms for healthy children ($p<0.0001$). • Patients treated with dialysis assessed their physical and social functioning lower than patients not receiving dialysis. • Children: 50.54 (40.22-64.13) P=0.001, Parents/care givers: 49.46 (40.22–62.5). P=0.0001	Strength: **Weak** Quality: **Moderate** Issues: • Not all parents completed QOL survey. Some that did complete it may not have been primary caregiver. • Useful because it provides information to improve nurses' understanding of children's experience which will be used in my project.
Authors: Lok et al. (2019) Design: Clinical Practice Guideline for Vascular Access	• Published by the National Kidney Foundation - a national health organization in the United States. • Provides several clinical practice guidelines in nephrology that set the standards of treatment for all aspects of kidney disease.	**Guidelines Specific to Nursing Pediatric Patients:** CVC Infection Prevention: • Use of specific prophylactic antimicrobial locks in patients in need of long-term CVC who are at high risk of CRSBI, especially in	Strength: **Strong** Quality: **High** • Some recommendations

Study/Design	Methods	Key Results	Comments
Purpose: A comprehensive document intended to assist multidisciplinary practitioners care for chronic kidney disease patients and their vascular access.	• Establish quality of care for kidney patients worldwide with research and several publications in national journals such as the American Journal of Kidney Disease. • Accumulation of new evidence related to vascular access of HD patients. • Appraisal of the quality of the evidence was independently conducted by using a Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach, and interpretation and application followed the GRADE Evidence to Decision frameworks. • Each guideline statement is accompanied by rationale/background information, a detailed justification, monitoring and evaluation guidance, implementation considerations, special discussions, and recommendations for future research.	facilities with high rates of CRBSI (eg, >3.5/1,000 days) • Infection surveillance team to monitor, track (in an electronic database), help prevent, and evaluate outcomes of vascular access infections and, in particular, CVC related infections. • Designate only trained individuals who demonstrate competence for the access, use, and maintenance of CVC. • Provision of training, auditing, and feedback for frontline staff with respect to CVC care, connection, and disconnection procedures.	based on low-moderate evidence • Useful as it provides guidelines specific to pediatric central line infection to be used in my educational resource.
Authors: Machaly et al. (2020) Design: Uncontrolled before-after Purpose: Determine the effect of implementing evidence-based nursing guidelines on performance of nurses providing care	N: 36 nurses who provide care to children at two HD units Country/setting: Suez Canal, Egypt - Implementation of guidelines to improve nurses' knowledge and practice in pediatric HD. - Improve overall knowledge of pediatric HD including mechanisms of AKI and nursing assessment skills before, during, and after HD. Data Collection:	- 61.7% of the studied nurses had good total knowledge mean scores before implementing the guidelines and their total knowledge mean scores improved to 88.3% after three weeks of implementing the guidelines. - There was a highly statistically significant difference in total knowledge scores of the studied nurses, where p value=0.000. - 55% of the studied nurses had low total practice mean scores regarding pre, intra and post dialysis nursing care before implementing the guidelines, while the majority (80%) had high total practice mean	Strength: **Weak** Quality: **Moderate** - No control for major confounders. - Post-intervention timeline short. • Useful in determining the

Study/Design	Methods	Key Results	Comments
to children undergoing HD.	- Pretest: Assessment of nurse's knowledge and practice. - Posttest: Assessment of nurse's knowledge and practice 3 weeks guideline post intervention. - Observational checklist to measure practice. - Proven V&R of all tools. Analysis: - SPSS software. Descriptive statistics (mean, range, standard deviation). - Group comparison = chi squared test.	scores three weeks after implementing the guidelines. - There was a highly statistically significant improvement in total practice scores of the studied nurses, where p value=0.000. - 61% of the studied nurses had unsatisfactory total practice mean scores regarding care for children with intra hemodialytic complications before implementing the guidelines, while more than three quarters (78%) of them had satisfactory total practice mean scores after three weeks of implementation of the guidelines. - There was a highly statistically significant improvement in total practice scores of the studied nurses before and after three weeks of implementing the guidelines, where p value=0.000.	educational resource method I will use based on the nurses' responses in the article.
Authors: Mellor et al. (2015) Design: Phenomenology Purpose: Examine ethical issues that non-adherence in pediatric renal failure generate.	N: 11 pediatric and experienced nurses working in a large inner city dialysis unit Country/setting: Birmingham, United Kingdom Data collection: • In-person interviews (27-72 min). Digitally recorded, transcribed verbatim. • Analyzed using content analysis. • No theory to direct analysis – group up approach • Thematic analysis with coding	**Two main themes:** 1. Participant's perceptions and experience of non-adherence • Balancing responsibilities with the child and parents • Adopted a parenting role • Frustration with non-adherence (parent and child) 2. Participants responses to non-adherence • Acting in the minor's best interest • Using persuasion to improve adherence	Strength: **Strong** Quality: **High** Issues: • Using persuasion causing ethical conflict among nurses. • Useful because I plan to include the experience of the

Study/Design	Methods	Key Results	Comments
			nurse caring for pediatric patients in my educational resource.
Authors: O'Grady et al. (2017) Design: CRBSI Prevention Guideline Purpose: Guideline developed for healthcare professionals responsible for surveillance and infection control of intravascular catheters.	Country/setting: United States of America • Published by Centers for Disease Control and Prevention • Prepared by a working group comprising members from professional organizations representing the disciplines of critical care medicine, infectious diseases, healthcare infection control, surgery, anesthesiology, interventional radiology, pulmonary medicine, pediatric medicine, and nursing. • The working group was led several reputable worldwide medical organizations such as Society of Critical Care Medicine (SCCM), Infectious Diseases Society of America (IDSA), Society for Healthcare Epidemiology of America (SHEA), Surgical Infection Society (SIS), American Society of Critical Care Anesthesiologists (ASCCA), Association for Professionals in Infection Control and Epidemiology (APIC), Pediatric Infectious Diseases Society (PIDS), and the Healthcare Infection Control Practices Advisory Committee (HICPAC) of the CDC.	**Key Recommendations in Pediatric Population Specific to Nursing:** • Educate and periodically assess knowledge and practice of healthcare personnel responsible for CVC maintenance • CVC dressing: Use transparent, semi-permeable polyurethane dressings. Cleanse with 2% chlorhexidine. Monitor the site visually when changing the dressing or by palpation through an intact dressing on a regular basis. If patients have tenderness at the insertion site, fever without obvious source, the dressing should be removed to allow thorough examination of the site. • Use prophylactic antimicrobial lock solution in patients with long term catheters who have a history of multiple CRBSI despite optimal maximal adherence to aseptic technique.	Strength: **Strong** Quality: **High** Published by a major operating component of the Department of Health and Human Services in the United States. Supported by high-quality research studies and field experts. • Useful as provided guidelines related to vascular access that will be used in my educational resource.

Study/Design	Methods	Key Results	Comments
Authors: Ong et al. (2021) Design: Systematic Review Purpose: To identify sources of distress among parents caring for children with chronic renal disease undergoing HD	N: 13 papers with the experience of 183 parents met inclusion criteria. Country: Singapore Data Collection: • Six electronic databases searched: PubMed, Embase, PsycINFO, Scopus, Cochrane, Google Scholar Analysis: • Three-step inductive thematic synthesis method used to form descriptive themes and the Critical Appraisal Skill Program (CASP) qualitative checklist to appraise the quality of included articles • Evaluation of studies performed by two authors.	**Five themes:** 1. Disease related distress – diagnosis, treatment, and prognosis stressful for parents. 2. Personal struggles – physical, social, and relationship struggles. 3. Family structure – feeling unable to care for other children or spouse. 4. Lack of resources – lack of formal and informal support. 5. Unrealistic social expectations – stigmatism of caregivers and discrimination of child.	Strength: **Strong** Issues: Most studies setting Western countries – limiting generalizability to other parts of the world. • Useful information that will be used in my educational resource to improve nurses' understanding of the child/parent experience.
Authors: Rees (2021) Design: Guideline/Literature Review Purpose: To review and identify the differences between adult and child HD.	• Guidelines for HD for children are from the Institute of Child Health in London, UK published under Wolters Kluwer. • Recommendations based on current, peer reviewed literature.	• Vascular access – Type and selection including AVF and CVC. • HD equipment – Tubing, dialyzer and machine. Maximum 10% blood volume in extracorporeal circuit. Size of dialyzer dependent on child size. Machine must have: fluid removal system, ability to use low blood flow speeds, ability to use lines of varying blood volumes. • Dialysis prescription – Developed so there is adequate solute and fluid removal. • Provision and assessment of HD – based on a well-functioning vascular access, obtain	Strength/Quality: **High** • Useful because guidelines are directly applicable to topics I will include in my educational resource.

Study/Design	Methods	Key Results	Comments
		optimum weight, adequate clearance, avoid complications during HD including pain and hypotension, psychosocial support. • Complications – Nutrition/growth, mineral and bone disorder, cardiovascular disease, anemia. • Long-term outcome – Mortality (> 30 times higher than children without CKD)	
Authors: Saeed & Al-Mosawi (2020) Design: Uncontrolled before-after Purpose: Assess the effectiveness of health educational program on nurses' knowledge toward HD at Pediatric Teaching Hospitals.	N: 30 nurses working in the Child Welfare Teaching Hospital and the Child's Central Teaching Hospital. Country/setting: Iraq • Educational program to improve nurses' knowledge of pediatric HD using lecture. Pretest/posttest. Data Collection: • Questionnaire: Five domains each one multiple choice questions, the participant chose one answer. The overall sum of questions is 48. Proven V&R. • January 19-22, 2020 Analysis: • Statistical Package of Social Sciences (SPSS)	• Statistically significant difference between relationships pretest and posttest-1 (before and after lecture). When the p-value< 0.05(P=0.000). • Elevation in nurses' knowledge due to effect educational program where the p-value <0.05.	Strength: **Weak** Quality: **High** • Useful to aid in determining which educational methodology I will use for my resource based on the nurses' responses.

Study/Design	Methods	Key Results	Comments
Authors: Saleh et al. (2018) Design: Uncontrolled before-after Purpose: To evaluate the efficacy of education and training interventions on nurse's compliance to standard of nursing care for HD patient.	N: 41 nurses working in the HD unit at El-Menia University Hospital. Country/setting: Egypt • Implemented educational program (lecture) to improve the knowledge and practice of nurses in pediatric HD. • 10 sessions, 45-60 min. Data Collection: • A questionnaire examining knowledge (35 multiple choice questions that were categorized under 5 sub items: clinical manifestation, Dialysis machine, Shunt care, Nutrition and medication lastly infection control. • Observational checklist for performance. 5 main parts: hemodialysis phases, infection control measures, health education, collaboration with health care team, and environment of the unit. • Proven V&R of all tools. • Analysis using SPSS software.	• 68.3% of nurses weren't aware of HD nursing care standards. • More than half of nurses (61.0% - 56.1%) hadn't attended conference during the past 5 years and attended hadn't educational lectures respectively. • There were increasing percent in nurses achieved very good and excellent overall total knowledge and performance in the post-test and the follow-up compared with the pre-test periods, increase in total mean scores for the observations related to overall performance of infection control. there was a strong positive relationship between nurse's knowledge and their performance were dedicated in the post tests at (P< 0.001).	Strength: **Weak** Quality: **High** • No control for confounders. • Useful in determining which educational method I will choose for my resource based on the nurses' responses.
Authors: Shahdadi & Rahnama (2018) Design: Phenomenology Purpose:	N: 9 nurses working in a HD unit. Country: Iran Data Collection: - Semi-structured interviews with open-ended questions.	**Two Main Themes:** 1. *Care Inhibitors* – nursing shortage, financial and family problems, inexperienced nurses, fatigue and mental stresses, heavy work load. Patient emotional sensitivity, difficulty in getting patient's trust. Poor management including inadequate ventilation of the	Strength: **Strong** Quality: **High** • Useful because I will use the

Study/Design	Methods	Key Results	Comments
Describe the living experiences of nurses in HD care.	- 45min to 1 hour over 1-2 sessions in January 2017. - Data saturation achieved. Analysis: - Interviews recorded and hand-written. - Colizzi approach for data analysis (extracting data and organizing into themes). - Study rigor and validity proven.	department, lack of equipment, weak cooperation of head nurse. 2. *Care Facilitators* – nurses experience, emotional relationship between nurse and patient, high education level, and safe environment.	experience of nurses' to better understand the environment in which my educational resource will be implemented.
Authors: Souza et al. (2008) Design: Review Article Purpose: To provide recommendations specific to pediatric HD based on guidelines within the literature.	- Professional opinion of professional university teacher and nurse with 10 years dialysis experience combined with recommendations published by Pediatric Nephrology Journal. - Country: Portugal	**Guidelines:** Vascular Access – CVC most commonly used. Catheter size dependent on child size. Technical Aspects: *Extracorporeal circuit (lines and dialyzer)* – Dialyzer choice recommendations based on child size. High-flow not recommended. *HD Monitor* – Blood flow and dialysate flow. Depends on weight and length of dialysis. Short treatments recommended for first session. Blood flow 150-200ml/min or 5-7 ml/kg. *Infants* – Circuit volume to not exceed more than 10% of child's blood volume to prevent complications such as deoxygenation and hypotension.	Strength/Quality: **Moderate** - Several references outdated (more than 20 years old). Unclear of sources V&R. • Useful because I can use the guidelines in combination with other resource to support the topics that I chose to include in the educational resource.

Study/Design	Methods	Key Results	Comments
Authors: Wightman et al. (2019) Design: Phenomenology Purpose: Describe the experience of parental caregivers of children receiving HD.	N: 35 caregiver-child dyads whose child was receiving hemodialysis. Country/setting: Three pediatric dialysis units in Seattle, Texas, and Wisconsin, USA Data collection & Analysis: • Purposive sampling • Semi structured interviews with caregiver's average 70 minutes • Digitally recorded and transcribed verbatim with field notes • Recruitment ceased at data saturation • Content analysis – themes identified using coding. • Computer software Vivo 11 was used to assist with storage, coding, and searching of data.	**4 major themes:** 1. Caregiver medicalization • Needing to master new medical terms, skills, and routines 2. Emotional adjustment. • Feelings of guilt, grief, stress, feeling like they caused the disease. Eventually acceptance. 3. Pragmatic adaptation • Needing to adjust to the upheaval, responsibilities, and stressors. 4. Social adjustment • Changes in relationships. New relationships with other caregivers and stress on their existing relationships.	Strength: **Strong** Quality: **High** • Useful because the parents' experiences will be used to improve the nurses understanding of pediatric HD.
Authors: Windt (2016) Design: Cross sectional Purpose: Implementation of a structured system and set of resources to support routine education, and the development of two online, interactive	N: 173 nurses working in HD unit with varying years of experience. • Implementation of an online learning module to improve knowledge of pediatric HD among nurses. Data Collection: Survey to measure staff comfort and skills level with HD in pediatric population.	• Over 72% (125 respondents) agreed or strongly agreed that the content presented in the module improved their level of comfort when managing patients receiving RRT. • Twenty-two percent (38 respondents) neither agreed nor disagreed that the module increased their comfort level. • Over 75% (130 respondents) agreed or strongly agreed that the amount and type of information presented was appropriate for their learning needs. • When asked how often modules should be assigned, 43 felt yearly was adequate, 73 thought biannual modules were appropriate,	Strength: **Weak** Quality: **High** • Useful because it will help me to determine which educational methodology to use for my educational resource.

Study/Design	Methods	Key Results	Comments
learning modules to provide additional exposure to RRT throughout the year.		19 wanted three times per year, and 38 felt four modules per year would be best. • There were 30 total comments, both positive and negative. • Some liked the videos; others did not think they were very good. Others liked the information about the warmer. Some remarked that it was a good review and should be given biannually or be available when a patient is on CRRT. Still others felt that more hands-on training was needed.	
Authors: Yousef et al. (2019) Design: Uncontrolled before-after Purpose: Assess the knowledge and practice of nurses following an education intervention regarding the prevention of infection for children under HD.	N: 32 nurses working in the pediatric dialysis unit Country/setting: Assuit, Egypt - Nurses divided into small groups containing 2-4. - Education session (lecture) 1 hour duration with a total of 9 sessions Data collection: **Tool 1**: Questionnaire. Assess current knowledge before education program. 60 questions. Each right answer was given a score of 1 and a wrong answer was given a score of 0. **Tool 2**: Observational checklist sheet. Assess nurses' practice for children under HD. Applied before and 2 months after the implementation of the educational nursing	**Post Intervention:** • Improvements in the nurses' knowledge regarding renal failure (15.53±5.56 vs. 32.27±3.36), HD (16.23±8.05 vs. 29.20±5.76), and infection control measures (48.93 ±16.67 vs. 113.37±10.61) and total knowledge (80.70 ±18.48 vs. 174.83±18.37) after the educational program (P=0.000). • Improvements in the nurses' practice scores regarding hand-washing (P<0.001), changing gloves (P=0.001), wearing mask (P=0.000), skin preparation technique (P=0.000), dealing with blood, body secretions, and fluids (P=0.000), and maintaining clean environment and safe injection practices in addition to the mean total practice score (66.17±8.67 vs.78.00±6.82).	Strength of Design: **Weak** Quality: **Moderate** Issues: • No control for major confounders • Useful to aid in determining the educational methodology I will use based on the nurses responses in the article.

Study/Design	Methods	Key Results	Comments
	program. Each scored 'done correctly' (a score of 1) or 'not done' (a score of 0). • Content validity of study tools = 96%. Reliability estimated using α Cronbach's test for the tools, and its result was R=0.66. • Nurse's knowledge and practices were evaluated before, immediately after, after 2 months of implementation. • Duration = 1 year, lasting from July 2014 to August 2015. • Data were tabulated and statistically analyzed using the computer program SPSS. • Data were expressed as mean, SD, number, and percentage. T-test was used to compare between numeric variables and the $\chi 2$ - test to compare between nonparametric variables. A probability level of 0.05 was adopted.		
Authors: Zitzelsberger et al. (2014) Design: Ethnography Purpose: Describe and interpret children's perceptions	N: 11 children between the ages of 7- and 17-years receiving HD at a pediatric HD unit. Country/setting: Ontario, Canada. Data Collection: - Multiple methods including: structured observations, focused interactions, and guided activities.	**Three themes:** 1. *Time* – everyday rituals and routines. Children felt time was long, taking up too much of their lives. 2. *Space* – everyday confinement and constraints. Children felt they were confined to a machine, limiting their social interactions with other children and lack of privacy.	Strength: **Strong** Quality: **High** • Useful in improving nurses' understanding of the child

Study/Design	Methods	Key Results	Comments
of and responses to the HD unit's temporal, spatial, and technological regimes and relations.	- Conducted during or just prior to the child's treatment. - Collected written notes, mapping, digital photographs, child's drawings and writings. <u>Analysis:</u> - Conceptual framing by thematic analysis - 3 processes: description, analysis, and transformation. - Study rigor & quality proven.	3. *Technology* – everyday life on HD. Children felt anxiety and wonder when their body was incorporated with a machine. Physical boundaries broken between self and machine.	experience on HD to be included in my educational resource.

Appendix B: Glossary of Terms

Convection	Water, toxins, and waste molecules are pushed through a semi permeable membrane, such as a dialyzer, using hydrostatic pressure (Messer et al., 2009).
Cuff Migration	The Dacron cuff migrates or moves out of the catheter exit site therefore the catheter tip to no longer in the correct position and delivery of dialysis through the catheter is no longer possible (British Colombia Renal Agency, 2019).
Dacron cuff	Part of the catheter which is under the skin and helps to keep it in place because the body's own tissue grows and attaches to it. This cuff is situated between the exit site of the catheter and the neck incision (Ash, 2004).
Diffusion	When blood and dialysis fluid with different concentrations of molecules are separated by a semi-permeable membrane, the molecules move through the membrane to the lower concentration (Messer et al., 2009).
Dialysis Disequilibrium	Clinical syndrome of neurologic deterioration that is seen in patients who undergo hemodialysis. Symptoms include restlessness, headache, mental confusion, and coma. It can occur in patients during or immediately after their first treatment (Zepeda-Orozco & Quigley, 2012).
Dialyzer	An artificial filter containing fine fibers that are hollow with microscopic pores, also known as semi-permeable dialysis membrane. Toxins, urea and other small particles can pass through the membrane and are removed from the blood (Fresenius Medical Care, 2021).
Exit-site Infection	Hyperemia, induration, and/or tenderness ≤2 cm from catheter exit site. May be associated with fever and purulent drainage from the exit site (O'Grady et al., 2017).
External to the Cuff	Part of the catheter that is not tunneled under the skin and is fully exposed (O'Grady et al., 2017)
Hemolysis	The destruction of red blood cells which can occur during HD as the result of shear stress when they circulate through the circuit, and are, therefore, at risk for fragmentation. Additionally, blood osmotic changes, dialysate contaminants, or hyperthermia can cause hemolysis during HD (Saha & Allon, 2017).

Appendix B: Consultation and Environmental Scan

Educating Nurses about Pediatric Hemodialysis: Consultation and Environmental Scan

Brittany Woodman

Memorial University of Newfoundland

NURS6660: Practicum 1

Educating Nurses about Pediatric Hemodialysis: Consultation and Environmental Scan

The kidneys are among the most important organs in the body as they perform the life-sustaining task of filtering waste products and excess fluid from the blood for excretion into urine for elimination (National Kidney Foundation, 2021). When the kidneys become diseased, their ability to perform this duty is affected causing waste and fluid buildup, leading to symptoms such as weight loss, loss of appetite, shortness of breath, fatigue, and edema of the extremities (Kidney Foundation of Canada, 2021). These symptoms can lead to life-threatening conditions such as pulmonary edema and cardiac arrest (National Kidney Foundation, 2021). Kidney disease is categorised under two conditions: acute and chronic. Acute kidney injury (AKI) or rapid kidney failure occurs quickly and is often caused by an infection or virus, such as sepsis or COVID-19 (Rees, 2021). Conversely, chronic kidney disease (CKD) is a decline in kidney function for a period of three or more months and the etiology includes lifestyle (diet and exercise), existing chronic conditions such as diabetes and/or hypertension, and hereditary origins such as polycystic kidneys (National Kidney Foundation, 2021).

One in ten Canadians are living with kidney disease, with an increased incidence of 33% since 2010 (Canadian Institute for Health Information, CIHI, 2020). Historically, kidney disease among the pediatric population has been rare, ranging from 6.9 to 21.8 per million in the 0–19-year-old age group, compared to 71,900 per million adults over age 19 (CIHI, 2020). With the global COVID-19 pandemic, renal failure caused by multi-organ inflammatory syndrome (MIS-C) secondary to COVID-19 has risen among the pediatric population (Centers for Disease Control and Prevention, CDC, 2020). MIS-C causes the inflammation of several organs including the heart, lungs, kidneys, brain, skin, eyes, and gastrointestinal system, causing children to present with rare symptoms including rash, neck pain, and bloodshot eyes (CDC,

2020). According to the Canadian Pediatric Society (2021), the incidence of emergency pediatric hemodialysis (HD) due to AKI secondary to MIS-C has increased across Canada. In the United States, over 4,000 children were diagnosed with MIS-C in 2020, making it a significant contributor to the morbidity and mortality of critically ill infants and children (CDC, 2020).

Background

Renal replacement therapy (RRT) is the optimal treatment for kidney disease as it replaces the blood-filtering function of the kidneys (Rees, 2021). There are three methods for RRT: peritoneal dialysis (PD), hemodialysis (HD), and continuous renal replacement therapy (CRRT) (National Kidney Foundation, 2021). Each modality has its indications, including fluid removal, toxin removal, medication toxicity, and solute removal (i.e., urea, potassium) (Rees, 2021). HD is often chosen when rapid fluid and toxin removal is required as indicated in pulmonary edema and metabolic acidosis (Rees, 2021). As seen in MIS-C, difficulty with ventilation and prone positioning due to fluid volume overload warrants the need for HD (Alabbas et al., 2021). The rapidity of solute generation and its urgency for removal, as in tumor lysis syndrome, hyperammonemia, hyperkalemia, or ingestion of dialyzable toxins, also require HD to sustain life (Rees, 2021).

In 2019, Newfoundland and Labrador (NL) had the highest rate of new adult patients starting RRT in Canada with 249 patients per million population (CIHI, 2020). However, the occurrence of pediatric HD in the province is rare, approximately one case every five years (Dr. B. Curtis, personal communication, May 10, 2021). When a pediatric patient requires HD in NL, the dialysis is performed by the registered nurses in the adult dialysis program at the Health Science Center (HSC) in St. John's, which is connected to the only pediatric hospital in the

province, the Janeway Children's Hospital. With the increased incidence of pediatric HD across Canada due to MIS-C, this increase may also occur in NL. This possible increase combined with the unpredictable weather preventing patient transfer to larger pediatric hospitals warrants an increased necessity for pediatric HD in NL. However, even with the potential increase in pediatric HD incidence in NL, there are no policies or educational resources specific to pediatric HD in NL (Cathy Cake, clinical educator of Dialysis Program Eastern Health, personal communication, June 5, 2021).

HD is complex and highly technical, therefore nurses performing the treatment must be fully knowledgeable and competent in their skills to ensure enhanced patient and family outcomes (Cho, 2020; Rees, 2021). Competency can be achieved through continuing educational opportunities including participation in educational modules, sessions, and online learning (College of Registered Nurses of Newfoundland and Labrador, 2014). Researchers have demonstrated that the implementation of an education resource significantly improves nurse's knowledge and practice related to pediatric HD (Ahmed et al., 2019; Hassona et al., 2012; Ibrahim et al., 2019; Saeed & Al-Mosawi, 2020). A discussion with the nurses of the HSC dialysis unit revealed a lack of educational resources specific to pediatric HD, resulting in a current lack of knowledge. The purpose of my practicum project is to create a pediatric HD educational resource to increase nurse's knowledge and understanding of pediatric HD and ultimately, improve patient and family outcomes. As part of my project development, I completed a consultation and environmental scan with local and national experts in the field of HD to identify and explore the specific resource content, as well as the most appropriate educational delivery methods to be utilized.

In this consultation and environmental scan report, I will present the results of interviews that I completed with local and national experts in the field of HD. Locally, I consulted experts including nurses at the HSC dialysis unit, the clinical educator of the Dialysis Program in Eastern Health, and nephrologists within Eastern Health. Consultations with local field experts in HD will ensure the efficacy and uptake of my educational resource through the identification of specific content and educational delivery method(s). Nationally, I contacted the HD Program Coordinator of SickKids in Toronto, Ontario as per my environmental scan. SickKids is the largest pediatric HD program in Canada, therefore, consulting with their field expert was valuable in determining the resources that are available specific to pediatric HD across Canada. I met all objectives of the consultation and environmental scan process, which are outlined in my consultation and environmental scan plans.

Methods

Participants and Data Collection

Eight nurses at the HSC dialysis unit participated in the consultation interviews. Four had greater than ten years of experience and four less than ten years of experience in dialysis. Nurses were chosen based on their varied experience in dialysis for diversity within the sample. Diversity within the sample is important to ensure a rich description of the phenomenon through varied responses and a variety of perspectives (Streubert & Carpender, 2011). I recruited the nurses by approaching them in-person and asking for their voluntary participation in an in-person interview about pediatric HD. I completed two in person group interviews two days apart. I interviewed five nurses in one session and three in another. For convenience and due to the nurses' busy schedules, both interviews took place in the HSC dialysis unit at the end of the shift

where there were no distractions present. I asked the questions from a protocol I had developed for this process (see Appendix A for a list of interview questions), and there were no time constraints placed on the interviews.

I interviewed the clinical educator of the Dialysis Program within Eastern Health. The clinical educator was chosen for their expertise in the field of HD and direct involvement in the policy development and education of nurses within the Dialysis Program. Via telephone, I asked for their voluntary participation in an interview about pediatric HD and conducted the interview in person.

I interviewed two nephrologists within Eastern Health. One was specialized in pediatric nephrology with fifteen years of experience and the other with over 30 years of experience as a nephrologist in NL. I approached them in person and asked for their voluntary participation in an in-person interview to identify their suggestions regarding specific content to be included in an educational resource to improve the nurse's knowledge and understanding of pediatric HD. I interviewed each nephrologist individually in their office.

As per the environmental scan, I consulted with the Pediatric HD Program Coordinator at SickKids in Toronto, ON. I also attempted contact with other specialists in pediatric HD in major hospitals across Canada including the Alberta Children's Hospital and Montreal Children's Hospital, however, I was unable to make contact after multiple attempts. The Division of Nephrology at SickKids is one of the largest Paediatric Nephrology Divisions in North America and has influence in all other pediatric HD programs in Canada (SickKids, 2021), therefore, I decided one major national consultation was sufficient for my practicum project. I emailed the Pediatric HD Program Coordinator at SickKids and asked for their voluntary participation in an

interview to determine the content and delivery of an educational resource for pediatric HD in NL. The interview took place over Microsoft Teams, an online audio/visual meeting software.

I asked questions and wrote detailed notes during and after all interviews. The interviews went as anticipated and no changes were made to the consultation and environmental scan plans. Creating detailed notes afforded the opportunity to organise the data into key topics, which I will discuss below.

Data Management and Analysis

I used content analysis to examine the interview data. The written data from all interviews were transcribed into Microsoft Word where common ideas were organised. I reviewed all data thoroughly and created a summary of common ideas and categories which were then organized based on responses to interview questions. For example, several nurses and the clinical educator of the Dialysis Program at Eastern Health identified an educational binder as their preferred educational method, therefore, I placed it in the category of "resource delivery method" and subcategory "binder". Dialysis prescription was also a common idea within all interviews; therefore, I identified this as a main category, and components such as "fluid removal", "dialyzer", and "medication doses" were subcategories with responses listed below.

Ethical Considerations

I obtained all individual permissions through verbal consent to participate in the interviews. Institutional permissions from SickKids were received to use information from the policies/procedures obtained through consultation with the SickKids HD Program Coordinator. Participant's names were not recorded to ensure confidentiality. I coded participants numerically, for example, Nurse 1, 2, 3, Physician 1, 2, etc. I stored all data on a password-protected computer

including interview responses and policies/guidelines obtained from SickKids and Eastern Health. I conducted the interviews acknowledging my opinions and bias about the subject matter based on my experience as an HD nurse. To clearly articulate my stance, I engaged in frequent peer review with my supervisor. No review was required by HREA as the project meets number three of the HREA screening tool located in Appendix B: "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)".

Results

I identified several categories resulting from common ideas highlighted during data analysis including pediatric HD in NL, nurses' educational needs, educational resource content, educational resource method, educational resource features, and continuing education.

Pediatric HD in NL

During all the interviews that I completed throughout the consultation and environmental scan, the potential for an increase in pediatric HD in NL was addressed. The nurses, clinical educator, nephrologists, and HD Program Coordinator at SickKids all addressed the increased incidence of pediatric HD in NL in the past/present due to COVID-19 and the possibility that it will continue in the future. The HD Program Coordinator at SickKids suggested that NL should develop a pediatric HD program in preparation for the potential increase and to improve patient/family quality of life by allowing them to stay in their home province for treatment. Traditionally, all pediatric HD patients are transferred to larger hospitals in Canada, as NL does not have a pediatric HD program. The nephrologists and clinical educator identified the

possibility of a pediatric HD program in NL in the future to keep patients and families in their home province for treatment. Five nurses suggested that Eastern Health should be more prepared for pediatric HD, even if there is only an occasional case. One nurse felt that because pediatric HD occurs so rarely in NL, it may be a waste of healthcare resources for to have a pediatric HD program within Eastern Health. Two nurses stated they did not know if Eastern Health would benefit from a pediatric HD program.

Nurses Educational Needs

All eight nurses and the clinical educator of the Dialysis Program identified an increased need for education related to pediatric HD due to the lack of education within the Dialysis Program at Eastern Health. All nurses felt they are expected to perform pediatric HD, however, with the lack of education they did not feel comfortable or confident in their knowledge and skills. They felt they would have patient safety concerns and expressed concerns about potential patient harm and loss of their nursing license. The restrictions related to COVID-19 over the past year and a half were recognized as a barrier to education by the nurses and clinical educator. The COVID-19 pandemic caused staff restrictions in movement between dialysis units and the clinical educator office is located at another dialysis unit in St. John's. The historical rare occurrence of pediatric HD in NL was also acknowledged as a reason for lack of education by the nurses and clinical educator, however, the nurses felt that if there is a possibility to dialyze a pediatric patient, they should have received education in the past. The nurses and clinical educator identified MIS-C and the increase across Canada, however, the nurses stated they did not receive any formal education about it and obtained their knowledge through social media and the news.

Educational Resource Content

Everyone I interviewed addressed the content that should be included in the educational resource. I identified several common ideas and categorized them as follows: caring for a pediatric patient and family, fluid and volume removal, vital sign ranges, vascular access, dialysis prescription, and machine set-up and programming. These are not listed in order of number of responses, but listed in this manner based on importance placed among the participants.

Caring for a Pediatric Patient and Family

All nurses voiced that they haven't worked in the pediatric field for a long time, some over five years and others more than 20 years. Due to their lack of experience caring for pediatric patients and families, all nurses stated that they may feel uncomfortable in the pediatric environment. Three nurses expressed that they would like to know more information about the growth and development, communication, and behavior of pediatric patients. Four nurses voiced that they would be unsure what to say to the patients' families who may have many questions about their child on HD. The HD Program Coordinator at SickKids stated that nurses need to understand concepts such as growth and development for age range and building trust with patients and families to make decisions about patient care and communicate to patients and families. I did not consider this before the interviews due to my lack of experience caring for pediatric patients in the Dialysis Program. Going forward with the educational resource development, I will need to consult with the clinical educator(s) at the Janeway Children's Hospital to obtain content related to overall pediatric nursing care.

Fluid and Volume Removal

All participants identified fluid and volume removal as a concept that should be addressed in the educational resource. The nurses, nephrologists, and HD Program Coordinator at SickKids identified total blood volume calculations as an important tool for nurses to use during the assessment of a pediatric patient. Total blood volume is a calculation that determines the amount of total blood that can be safely allowed outside the body in the extracorporeal circuit and is usually 10-15% of the patient's weight (SickKids, 2021). They suggested that samples of total blood volume calculations are included in the resource along with a patient scenario in which the calculations can be applied. The HD Program Coordinator at SickKids, the clinical educator, and one nephrologist suggested nurses should have access to guidelines for the maximum ultrafiltration (fluid removal) per treatment, which is a calculation that the nurse can perform to ensure safe fluid removal during HD. The HD Program Coordinator at SickKids provided materials with patient scenarios including total blood volume and maximum ultrafiltration calculations that they use as an educational tool in their program.

Vital Sign Ranges

The nurses, clinical educator, and HD Program Coordinator at SickKids suggested including a guide with the standard vital sign ranges for pediatric patients in the educational resource. All nurses expressed that as they haven't worked in pediatrics recently, they would need a guide for vital sign ranges including blood pressure, pulse, and temperature per age group as children and adult vital sign ranges are different. For example, the baseline heart rate for a child age 1-3 is 80-130 beats per minute, whereas an adult over age 18 is 60-100 beats per minute (SickKids, 2021). Four nurses specified that they wouldn't be sure if the patient was

hypertensive or hypotensive during HD as children have much lower blood pressures than adults. Three nurses expressed that they would like to know the frequency of vital sign monitoring during treatment with children compared to adults. The HD Program Coordinator at SickKids expressed that in their program, they monitor heart rate and blood pressure at least every half hour and as needed if the patient displays signs of hypotension and infants are monitored on cardiac monitors until they weigh 10kg. The clinical educator in NL and HD Program Coordinator at SickKids suggested a standard table with vital sign ranges per child age group in comparison with adult age groups would be necessary to include in the educational resource for context.

Vascular Access

All nurses expressed an interest in improving their knowledge of the child's vascular access, particularly the central venous catheter (CVC) insertion location, and infection prevention measures compared to adults. One nurse voiced that she dialyzed a pediatric patient several years ago in an emergency and due to the child's weight (around 10kg), a CVC was inserted into both legs through the femoral veins, which is not done with adult patients. The nurses expressed that they would like to know if that is standard practice for pediatric patients. Five nurses questioned if the dressing change frequency is the same with children as adults (once per week), which dressing type is recommended for the CVC, and if the CVC lock solution is the same as used for adults (sodium citrate). The HD Program Coordinator at SickKids and clinical educator both suggested that the educational resource should include an overview of what to expect with the child's vascular access, including common insertion locations and infection prevention measures including CVC dressing type, change frequency, and lock solution. The HD Program Coordinator at SickKids provided their policies for CVC maintenance for reference.

Dialysis Prescription

The dialysis prescription was addressed by all participants in the interviews. The HD Program Coordinator at SickKids provided a copy of their HD order sets used by the nephrologists to order HD. The order sets are a guide that includes all areas of the HD prescription such as fluid removal, medication dosages, blood flow, vital sign monitoring, and urea clearance. Common ideas identified during the interviews included dialyzer and tubing size, blood flow, and medication dosages. The nurses and clinical educator suggested including a guide in my educational resource with the dialyzer and tubing sizes along with the priming volumes (amount of saline in system pre-HD) as these are part of the total blood volume calculation. They suggested that including a list of dialyzer sizes for the patient weight and indicators for the size would be beneficial. Two nurses expressed that they would like to know why one dialyzer is chosen over another. For example, choosing an FX600 versus an FX50, two dialyzer types used specifically for pediatric HD that provide very different toxin clearances. Both nephrologists also stated it would be beneficial to include a list of dialyzer sizes in the educational resource with their priming volumes and urea clearance (volume of blood cleared of urea per minute) (Rees, 2021). The HD Program Coordinator at SickKids provided a table with a list of pediatric dialyzer sizes, priming volumes, and urea clearances.

Blood flow was addressed by all participants. Blood flow is the speed at which the blood moves through the extracorporeal tubing and dialyzer and is measured in milliliters (ml) per minute (Rees, 2021). Typically, a blood flow of around 300ml/min is recommended for adult patients, whereas a child can be as low as 24ml/min based on their weight (SickKids, 2021) Blood flow needs to be optimized to ensure the patient is receiving adequate urea clearance (Rees, 2021). All nurses expressed an interest in increased knowledge of the blood flow rates for

pediatric patients compared to adults. Three nurses voiced that they wouldn't want to run the machine at a higher blood flow rate than the child could tolerate, therefore they suggested the educational resource include suggested blood flow rates based on the child's weight. This was also suggested by the clinical educator in NL and HD Program Coordinator at SickKids. The HD Program Coordinator at SickKids provided a guideline for blood flow that they use as a resource for the nurses within their program. The nephrologists also suggested blood flow rates be included in the educational recourse based on patient weight as they use the guideline from SickKids during their ordering process.

All nurses expressed an interest in learning common dialysis medication dosages based on pediatric dosing. All HD pediatric medications are dosed based on patient weight (SickKids, 2021). The nurses and nephrologists specifically suggested heparin and potassium dosing to be included in the educational resource as they are the most commonly used dialysis medications and are considered high-alert, meaning these medications have a high risk of causing patient harm when used in error. The HD Program Coordinator at SickKids provided a guideline for heparin and potassium dosing based on patient weight which they use to prevent medication error and patient harm.

Machine Set-up and Programming

The nurses, Clinical Educator, and Program Coordinator at SickKids all suggested the educational resource include a step-by-step guideline for how to set up and program the dialysis machine for a pediatric patient. The Clinical Educator and Program Coordinator at SickKids voiced that there are significant differences between the adult and pediatric software, therefore, the nurses need to be familiar with these differences before dialyzing a pediatric patient. These

differences include blood flow settings, vital sign limits, and dialysate flow (electrolyte solution used to remove waste during HD) (Rees, 2021) settings. The pediatric software will not allow the nurse to program beyond the recommended settings. For example, the nurse cannot program a blood flow of 300mls/min for a pediatric patient as the machine setting in pediatric mode is a maximum of 250mls/min. Six nurses and the HD Program Coordinator at SickKids suggested a simulated review session every six months in which the machine set-up and programming is demonstrated as part of continuing competence.

Educational Resource Methods

I addressed possible educational resource delivery methods during the interviews with the nurses, clinical educator, and HD Program Coordinator at SickKids. Common ideas included an online module, hard-copy binder, and simulation.

Online Module

The nurses and clinical educator identified online module as a method used most frequently in the Dialysis Program for nursing education. They recognized online module as convenient and effective in improving their knowledge about the subject, however, the nurses felt they need something tangible that they can use at the bedside along with a module. The HD Program Coordinator at SickKids identified an online module as a method used within their program for the education of nurses, however, it is used in combination with other methods including lecture, hard-copy booklet/binder, and simulation. They use online module during initial orientation to reinforce the material taught in lecture and simulation exercises, and then yearly as continuing competence in pediatric HD. All expressed that a combination of methods was most effective for the education of nurses at SickKids due to the complexity of pediatric HD

and differing learning preferences, such as those that require more hands-on experience for the retainment of material.

Simulation

The nurses, clinical educator in NL, and HD Program Coordinator at SickKids all identified simulation as an effective nursing education method. All identified simulation exercises as very effective in the past for teaching hands-on material such as machine set-up, programming, and troubleshooting alarms. The nurses expressed their interest in a simulation exercise that includes a machine set-up with pediatric extracorporeal dialysis lines, dialyzer, heparin calculations, blood volume/fluid calculations, and machine programming. Five nurses expressed an interest in a high-fidelity simulation in which a patient scenario is presented and they can perform the skills learned in a lecture, module, or binder. Two nurses voiced that they have never participated in a simulation exercise before, therefore did not know if it was an effective educational method for them. One nurse voiced feeling indifferent with simulation as a previous experience was ineffective for their learning. The HD Program Coordinator at SickKids stated they use simulation as part of their nursing education during orientation of new nurses to their program and yearly continuing competence. It is used for educational exercises such as machine set-up and programming and high-fidelity patient scenarios in which knowledge and skill are tested related to complications during HD. They found this effective in keeping the nurses' skills refreshed and thereby keeping their confidence in performing pediatric HD.

Booklet/Binder

A hard-copy booklet/binder was identified as an appropriate educational method by the nurses, clinical educator, and HD Program Coordinator at SickKids. All nurses and the clinical

educator in NL specified that they desired a booklet/binder for use at the patient bedside, particularly when the nurses have to go to the Pediatric Intensive Care Unit as it is a long distance from the dialysis unit and away from HD resources. They identified a booklet/binder as easily accessible and a resource they felt would be used most frequently. All nurses voiced that a binder would be effective for them as a guide to ensure they were setting up and programming the machine correctly. Three nurses specified that they would use a binder that had the correct dosing of medications for children, particularly frequently used medications including heparin and antibiotics, such as vancomycin. The HD Program Coordinator at SickKids stated they have a hard-copy booklet/binder as a resource for the nurses as it is easily accessible and is effective for use in the Pediatric Intensive Care Units as a guide at the patient bedside, principally for blood volume calculation guides and medication dosage and administration instructions.

Education Resource Features

Features of the educational resource that would entice the nurses to use it were addressed with the nurses, clinical educator, and HD Program Coordinator at SickKids. The main features identified included: simple explanations of content, interactivity/visuals, and applicability to practice.

Simplicity of Content

All participants that I asked about educational resource features stated that the presentation of the content should be simple, with no complex language that is not required for explanation. The clinical educator and HD Program Coordination at SickKids suggested presenting basic nursing concepts first, including how to care for a pediatric patient and family, nutrition requirements for children, and common nephrological diseases in pediatrics as these

topics give a foundation for the HD information. All nurses voiced that due to their lack of education about pediatric HD, they would like the resource to start at basic concepts such as caring for a pediatric patient including behavioral/cognitive expectations, standard ranges for pediatric vital signs, and growth and development stages for the child's age. The nurses, clinical educator, and HD Program Coordinator at SickKids all suggested that once the basic concepts are presented, more in-depth information related to the specific HD components such as prescription would be better understood.

Resource Interactivity/Visuals

The nurses, nurse educator, and HD Program Coordinator at SickKids voiced that the resource should have a component of interactivity to aid in interest and retention of the information being presented. Three nurses voiced that they enjoy online modules that have an interactive component, such as matching concepts. For example, one nurse suggested matching the vital sign ranges for the different age groups. Another nurse suggested a simulation exercise to compliment the online module where a group of nurses set up the machine and go through a patient scenario. The use of pictures as visual aids in the resource was identified by the nurses, clinical educator, and HD Program Coordinator at SickKids as an effective feature to include. They all suggested that visual aids such as pictures or a video of the machine set-up, programming, dialyzer sizes, and vascular access would be an effective tool to help improve understanding of the material.

Applicability to Practice

The nurses and clinical educator identified the importance of the resource to apply to the current practice in NL. The clinical educator as well as the nephrologists expressed that NL does

not have the same resources or equipment that other provinces have for HD such as a variety of dialyzer sizes and HD machines, therefore, the educational resource needs to apply to the resources/equipment that are available in NL. Two nurses voiced that they have attended presentations about pediatric HD in the past and the content was too complex, for example, details about dry weights that they felt only nephrologists would use. One nurse expressed attending a presentation that included nurses administering high-alert medications during HD such as mannitol that are not performed in NL and felt concerned that they would be expected to do the same. All nurses felt that they wanted clarification as to what they can or cannot do, particularly for medication administration, during HD of a pediatric patient compared to the adult population. The HD Program Coordinator at SickKids provided their policies for machine set-up and programming that are directly applicable to the dialysis machines used in NL.

Continuing Competence

All nurses, the clinical educator in NL, and the HD Program Coordinator at SickKids identified the importance of continuing nursing competence of pediatric HD through educational methods. All nurses expressed that they would like a minimal yearly educational session about pediatric HD to ensure they keep their knowledge and skills updated. The clinical educator also mentioned a yearly pediatric HD session, however, was unsure whether they could complete it due to other workload demands. This is an area for future review, i.e., who would/could maintain ongoing education related to pediatric HD and is something I plan to address as I consider implementation once the resource has been completed. The HD Program Coordinator stated that their program places emphasis on continuing competence among the nurses, with education sessions completed every six months.

Implications

The consultation and environmental scans provided valuable information for the content and delivery of a pediatric HD educational resource for dialysis nurses. In combination with the findings of my literature review, all information will be used as a guide in the development of the specific content and delivery method of the educational resource. As per the environmental scan, SickKids has a well-established pediatric HD program. The HD Program Coordinator there provided valuable information and resources that are accurate and practical including policies and procedures specific to pediatric HD prescription, vascular access, and HD machine set-up and programming. These resources will be used as a reference for the content I will include in the development of my educational resource.

As the educational resource will be used by the nurses of the dialysis unit, their educational needs regarding the content and delivery of the resource will be used as a guide during the development. The clinical educator of the Dialysis Program provided valuable information that will be used to guide content and delivery method during the development of my educational resource. The nurse educator voiced uncertainly in their ability to use my educational resource for continuing competence in the future therefore, I will determine who will do this if I am unable to. The nephrologists provided content that will be included in the resource, specifically dialysis prescription differences in children and adults. Prior to beginning the development of my resource, I plan to contact the clinical educator(s) at the Janeway Children's Hospital to obtain information about pediatric growth and development, communication, and nutritional needs to provide content for my educational resource. Based on the result of this contact, I may also include guidance in the resource of how to access this information, for example, a hyperlink to an online module.

Conclusion

A pediatric HD program has never existed in NL. AKI secondary to MIS-C and COVID-19 has risen among the pediatric population globally. This, combined with the unpredictable weather preventing patient transfer to larger hospitals, precedents a need to prepare the dialysis nurses of NL for pediatric HD. The information I have obtained from my literature review and consultation and environmental scan will be used in determining the content for and delivery method of my educational resource. My educational resource will be used by the nurses of the HSC dialysis unit as a guide in improving their knowledge and skills of pediatric HD and ultimately, patient and family outcomes.

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Appendix A: List of Interview Questions

Dialysis Unit Nurses:

1. Do you feel that there is a need for enhanced education related to pediatric HD within the Dialysis program currently? Please explain.
2. If you were asked to dialyze a pediatric patient now, would you feel comfortable in your knowledge and skill to do so? What makes you feel comfortable/uncomfortable?
3. Which topics specific to pediatric HD that you would like to learn more about to improve your knowledge and skills?
4. What education methods do you prefer to help improve your knowledge and understanding of a topic such a pediatric HD? Please explain.
5. If an educational resource was developed and implemented within the Dialysis Program about pediatric HD, what would entice you to use it?
6. Do you feel pediatric HD is an area of education that you would need continued education about? For example, a yearly refresher course. Please explain.

Clinical Educator, Dialysis Program, Eastern Health

1. Do you feel there is currently a gap in nursing education related to pediatric HD within the Dialysis program? Please explain.
2. Which topics specific to pediatric HD should be included in an educational resource for the dialysis unit nurses?
3. What educational methods do you feel are best for improving the knowledge and skills of dialysis unit nurses? Why do you feel this method(s) is/are best over another? Please explain.
4. Do you think pediatric HD is an area of education that would require continuing education? For example, a yearly refresher course. Please explain.

5. Do you have any resources related to pediatric HD content and/or delivery to improve the knowledge and understanding of pediatric HD among nurses?
6. Have you consulted with any other pediatric HD programs across Canada to determine their policies and/or procedures? If so, do you have any resources?

Nephrologists:

1. Why do you feel there has been a lack of pediatric HD in Newfoundland and Labrador compared to other provinces in Canada?
2. Why hasn't Newfoundland and Labrador had the resources for pediatric HD before now?
3. If you were to order HD for a pediatric patient versus an adult patient, what would be the main differences?
4. What areas or topics do you feel are most important for an educational resource in order to dialyze a pediatric patient?
5. Do you know any pediatric hospitals within Canada that specialize in pediatric HD?
6. Have you consulted with any other nephrologists within pediatric HD programs across Canada? If so, did they specify what guidelines or areas are important in dialyzing pediatric patients?

Pediatric Dialysis Program Coordinator, SickKids and other Pediatric Hospitals within Canada

1. What content should be included in an educational resource to ensure competence among nurses performing pediatric HD? For example, dialysis prescription. Please explain.
2. What educational strategies do you use within your Pediatric Dialysis Program to improve the knowledge and skills of the nurses? Do you prefer one method over another? Please explain.

3. How have the nurses responded to the educational resources you have implemented regarding pediatric HD? For example, do they use it?
4. Do you use these educational methods as part of continuing education for nurses in the dialysis unit? If yes, in which ways?

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

Student Name: Brittany Woodman

Title of Practicum Project: An Education Resource for Pediatric Hemodialysis in Newfoundland and Labrador

Date Checklist Completed: May 15, 2021

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: The Education Module

Pediatric Hemodialysis (HD): An Education Module for Registered Nurses

Brittany Woodman

Memorial University of Newfoundland

NURS6661: Practicum II

Source. Image from "Pediatric hemodialysis" by © Fresenius Medical Care. *Used with Permission.*

PEDIATRIC HEMODIALYSIS

AN EDUCATION MODULE FOR REGISTERED NURSES

Developed by Brittany Woodman BN, RN

December 2021

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Convection	Water, toxins, and waste molecules are pushed through a semi permeable membrane, such as a dialyzer, using hydrostatic pressure (Messer et al., 2009).
Cuff Migration	The Dacron cuff migrates or moves out of the catheter exit site therefore the catheter tip to no longer in the correct position and delivery of dialysis through the catheter is no longer possible (British Colombia Renal Agency, 2019).
Dacron cuff	Part of the catheter which is under the skin and helps to keep it in place because the body's own tissue grows and attaches to it. This cuff is situated between the exit site of the catheter and the neck incision (Ash, 2004).
Diffusion	When blood and dialysis fluid with different concentrations of molecules are separated by a semi-permeable membrane, the molecules move through the membrane to the lower concentration (Messer et al., 2009).
Dialysate	A mixture of water, electrolytes, and sodium that passes through the dialyzer surrounding the membrane during HD. It removes waste products and balances electrolytes in the blood (Fresenius Medical Care, 2021).
Dialysis Disequilibrium	Clinical syndrome of neurologic deterioration that is seen in patients who undergo hemodialysis. Symptoms include restlessness, headache, mental confusion, and coma. It can occur in patients during or immediately after their first treatment (Zepeda-Orozco & Quigley, 2012).
Dialyzer	An artificial filter containing fine fibers that are hollow with microscopic pores, also known as semi-permeable dialysis membrane. Toxins, urea and other small particles can pass through the membrane and are removed from the blood (Fresenius Medical Care, 2021).
Exit-site Infection	Hyperemia, induration, and/or tenderness ≤2 cm from catheter exit site. May be associated with fever and purulent drainage from the exit site (O'Grady et al., 2017).
External to the Cuff	Part of the catheter that is not tunneled under the skin and is fully exposed (O'Grady et al., 2017).
Hemolysis	The destruction of red blood cells which can occur during HD as the result of shear stress when they circulate through the circuit, and are, therefore, at risk for fragmentation. Additionally, blood osmotic changes, dialysate contaminants, or hyperthermia can cause hemolysis during HD (Saha & Allon, 2017).

INTRODUCTION

Historically, kidney disease among the pediatric population has been rare, ranging from 6.9 to 21.8 per million in the 0–19-year-old age group, compared to 71,900 per million adults over age 19 (Canadian Institute for Health Information (CIHI), 2020). With the global COVID-19 pandemic, renal failure caused by multi-system inflammatory syndrome in children (MIS-C) secondary to COVID-19 has risen among the pediatric population (Centers for Disease Control and Prevention (CDC), 2020). MIS-C causes the inflammation of several organs including the heart, lungs, kidneys, brain, skin, eyes, and gastrointestinal system, causing children to present with rare symptoms including rash, neck pain, and bloodshot eyes (CDC, 2020). According to the Canadian Pediatric Society (2021), the incidence of emergency pediatric hemodialysis (HD) due to AKI secondary to MIS-C has increased across Canada. In the United States, over 4,000 children were diagnosed with MIS-C in 2020, making it a significant contributor to the morbidity and mortality of critically ill infants and children (CDC, 2020).

In 2019, Newfoundland and Labrador (NL) had the highest rate of new adult patients starting renal replacement therapy in Canada with 249 patients per million population (CIHI, 2020). However, the occurrence of pediatric HD in the province is rare, approximately one case every five years (Dr. B. Curtis, personal communication, May 10, 2021). When a pediatric patient requires HD in NL, the registered nurses in the adult dialysis program at the Health Science Center (HSC) in St. John's are required to dialyze them as it is connected to the only pediatric hospital in the province, the Janeway Children's Hospital. Currently, there is no pediatric-specific HD policy in Newfoundland and Labrador. With the increased incidence of pediatric HD across Canada due to MIS-C, this increase may also occur in NL. This possible increase, combined with the unpredictable weather preventing patient transfer to larger pediatric hospitals, warrants an increased necessity for pediatric HD in NL. This module will provide information to increase knowledge and understanding of pediatric HD and ultimately, improve patient and family outcomes.

LEARNING OBJECTIVES

After completing this self-directed education module, the Registered Nurse will be able to:

1. Recognise the stages of growth and development in children from birth to adolescence.
2. Demonstrate understanding of the principles of working with children in the healthcare setting.
3. Identify the role of nutrition in child growth, development, and obesity.
4. Identify the parameters and recommended means of measurement of vital signs in children.
5. Describe common nephrological conditions that may occur among children.
6. Discuss the patient, family, and nurse experience of a child receiving hemodialysis.
7. Demonstrate understanding of vascular access in children with central venous catheter (CVC) locations, sizes, and maintenance.
8. Identify the signs and symptoms of CVC infection and prevention methods.
9. Discuss nursing assessment of the child on HD including fluid, dialysis prescription, and medications.
10. Identify differences in HD machine set up between children and adults.

SECTION ONE: INTRODUCTION TO PEDIATRICS

PART ONE: CARING FOR A PEDIATRIC PATIENT

GROWTH AND DEVELOPMENT

Figure 1.0

Growth and Development of Children

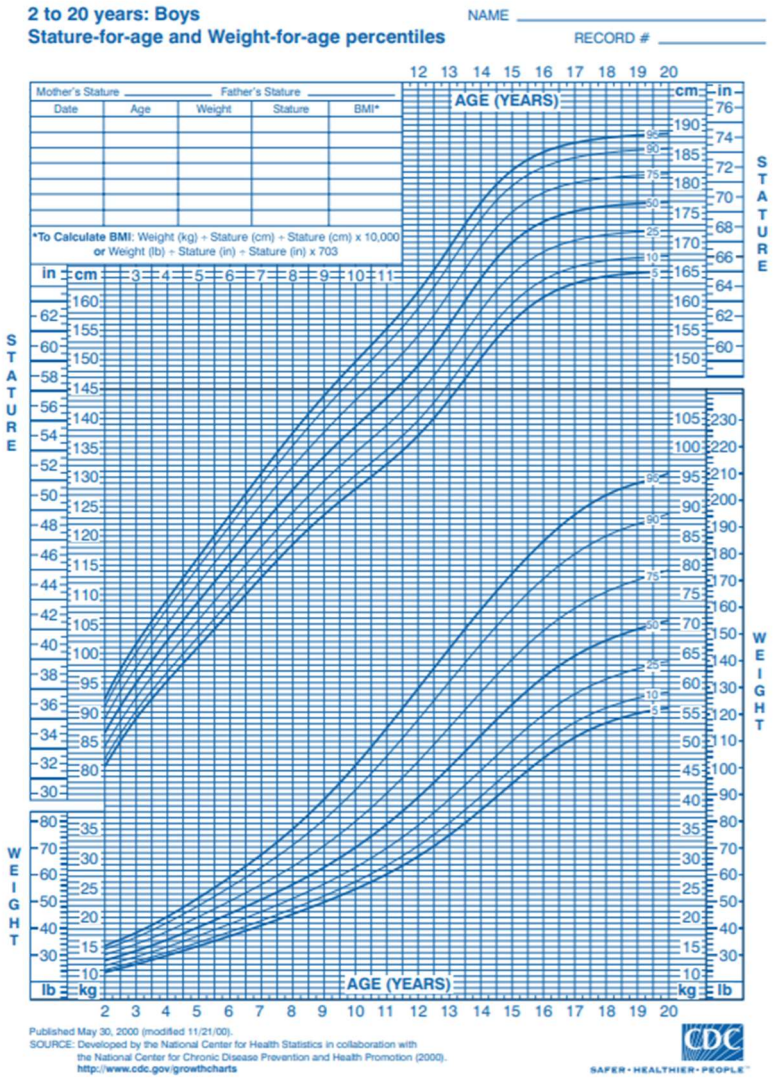
Source. From avant-gardemusicstudio web site, by Unknown Author, Microsoft Bing, Creative Commons Attribution -ShareAlike 2.0 Generic

Knowledge of normal growth and development and the ability to assess the child's developmental level are crucial to working effectively with children and parents in any healthcare setting (Mullen & Pate, 2018). Measurement of physical growth in children is a key element in evaluating their health status. Physical growth parameters include: weight, height, arm circumference, and head circumference (Hockenberry & Wilson, 2018). Values for these growth parameters are plotted on percentile charts. The child's measurements in percentiles are compared with the general population (CDC, 2021).

The most commonly used growth charts are those compiled by the World Health Organization (WHO) and the CDC. They can be found here: https://www.cdc.gov/growthcharts/index.htm

Figure 1.1

Growth and Development Chart



Source. Growth Chart, Boy's age 2-20. Retrieved from: https://www.cdc.gov/growthcharts/clinical_charts.htm#Set1

Children whose growth may be questionable include:

1. Children whose height and weight percentiles are widely disparate (e.g., height in the 10th percentile and weight in the 90th percentile)
2. Children who fail to follow the expected growth velocity in height and weight, especially during the rapid growth periods of infancy and adolescence.
3. Children who show a sudden increase, decrease, or no change in a previously steady growth pattern (Hockenberry & Wilson, 2018).

Table 1.0

Growth and Development during Infancy

AGE (MO)	MOTOR, SENSORY, VOCALIZATION, AND SOCIALIZATION
1-2	Can turn head from side to side and lift 45 degrees when prone. Grasp reflex strong but fades at age 2. Visually searches to locate sounds. Vocalizes, distinct from crying. Demonstrates social smile in response to stimuli.
2-4	Balances head well in sitting position. Rolls from back to side. Inspects and plays with hands. Follows objects to periphery. Locates sound by turning head side to side. Laughs aloud. Drooling begins. Considerable interest in surroundings. Enjoys social interaction.
4-6	Can turn over from abdomen to back. Teething begins, may chew and bite. Grasps objects voluntarily. Begins to imitate sounds. Recognises parents. Frequent mood swings. Briefly searches for dropped object.
6-8	Sits, leaning forward on both hands. Transfers objects from one hand to another. Can fixate on small objects. Produces vowel sounds. Increasing fear of strangers. Fretful when parent disappears.
8-10	Sits steadily unsupported. Pulls self to standing position and hold onto furniture. Uses thumb and index finger in pincer grasp. Responds to simple verbal commands. Localises sounds. Says “dada” “mama” with meaning.
10-12	Birth weight tripled and length increased by 50%. Walks with one hand held. May attempt first step alone. Says three to five words. Searches for objects.

Hockenberry & Wilson, 2018

Table 1.1

Growth and Development of the Toddler

AGE (MO)	MOTOR, SENSORY, LANGUAGE, AND SOCIALIZATION
15	Walks without help since 13 mo. Casts objects to floor. Able to identify geometric forms. Says 4-6 words, including names. Tolerates some parental separation.
18	Runs clumsily; falls often. Builds tower of cubes. Says ten or more words. Great imitator. Beginning awareness of ownership.
24	Goes up and down stairs alone. Turns pages of a book. Accommodation well developed. Has vocabulary of approximately 300 words. Increased independence from parent.
30	Jumps with both feet. Good hand-finger coordination. Gives first and last name. Separates easily from parent. In play, helps put things away.

Hockenberry & Wilson, 2018

Table 1.2

Growth and Development of the Preschooler

AGE (YR)	MOTOR, LANGUAGE, SOCIALZATION, COGNITION, RELATIONSHIPS
3	Jumps off bottom of step. Rides bicycle. Builds tower of 9-10 cubes. Imitates drawing. Has vocabulary of 900 words. Uses sentences of three or four words. Dresses self with help. Increased attention span. Feeds self. Is in preconception phase. Beginning understanding of time and space. Attempts to please parents. Aware of family relationships.
4	Skips and hops on one foot. Can lace shoes, may tie bow. Has vocabulary of 1500 words. Uses sentences of four or five words. Questioning is at peak. Very independent. Tends to be selfish and impatient. Play is associative. In phase of intuitive thought. Understands time better. Takes aggression or frustration out on parents or siblings. Do's and don'ts become important.
5	Skips and hops on alternate feet. Ties shoelaces. Has vocabulary of 2100 words. Uses sentences of six to eight words. Names four or more colors. Less rebellious. Independent but trustworthy. Eager to do things right and try to please. Begins to question parents thinking by comparing to other adults. Uses time-oriented words. Gets along well with parents. Strongly identifies with parent of same sex.

Hockenberry & Wilson, 2018

Table 1.3

Growth and Development of the School-aged Child

AGE (YR)	MOTOR, MENTAL, ADAPTIVE, PERSONAL-SOCIAL
6	Loses first tooth. Gradual increase in dexterity. Very active. Develops concepts of numbers. Defines common objects such as fork in terms of their use. Uses knife to spread butter/jam on bread. Takes bath without supervision. Reads from memory. Can share and cooperate better. Often engages in rough play.
7	Repeats performances to master them. Notices certain items missing from pictures. Reads clock/watch correctly. Brushes and combs hair. Likes to help and have a choice. Takes part in group play.
8-9	Increased smoothness and speed of fine motor control. Dresses self completely. Gives similarities and differences between two things. Knows days of week and months. Describes common objects in detail. Helps with routine household tasks such as sweeping. Looks after own needs at table. Easy to get along with at home. More sociable and better behaved.
10-12	Female pubescent changes begin. Writes brief stories. Washes and dries own hair. Raises pets. Loves friends. Enjoys conversation. Like family. Demonstrates affection.

Hockenberry & Wilson, 2018

Table 1.4

Growth and Development during Adolescence

AGE (YR)	GROWTH, COGNITION, IDENTITY, RELATIONSHIPS, SEXUALITY
11-14	Secondary sex characteristics appear. Explores newfound ability for limited abstract thought. Comparison of "normality" with peers. Preoccupied with rapid body changes. Trying out various roles. Conformity to group norms. Desire to remain dependant on parents while trying to detach. Close, idealized friendships with members of same sex. Self exploration and evaluation of sexuality. Limited dating, usually group. Wide mood swings.
15-17	Secondary sex characteristics well advanced. Developing capacity for abstract thinking. Modifies body image. Self centered. Idealistic. Major conflicts over independence and control. Emotional detachment from parents. Strong need for identity to affirm self image. Fear of rejection by peers. Identification of sexual attractions. Feeling of "being in love". Feelings of inadequacy common; difficulty asking for help.
18-20	Physically mature. Established abstract thought. Able to view problems comprehensively. Body image and gender role definition nearly secured. Mature sexual identity. Social roles defined. Emotional and physical separation from parents complete. Relationships characterized by giving and sharing. Forms stable relationships and attachment to others. May publicly identify sexual identity. More constancy of emotion.

Hockenberry & Wilson, 2018

Figure 1.2

Working with Children

Source. From "Project Hope nurse, Diane Speranza listens to a child's heartbeat while taking her vital signs", by the United States Navy, 2006, Wikimedia Commons, Creative Commons Attribution- ShareAlike 2.0 Generic

1. *Introduce Yourself to the Child and Family*. Include the child in conversation even if the child does not seem to be responding. Children may not respond verbally but will listen to everything that is said and decide how much comfort or danger the situation holds for them. Assure the child that it is all right to talk or not to talk.

2. *Honesty Is Vital to Establishing a Trusting Relationship with Children*. Be honest with the child if the procedure will hurt. To deny that something will hurt and then do something that causes the child pain could destroy the possibility of establishing a trusting, cooperative relationship with that child. Admit that you do not know the answer if the child asks a question you cannot answer. Promise to try to find the answer.

3. *Make Eye Contact and Address the Child by Name*. The child may not return eye contact, but can still be listening intently.

4. *Stoop or Bend to Communicate at the Child's Eye Level When Possible.* Show that you're giving the child your full attention which helps the child to feel safe and in control.

5. *Allow the Child to See Your Hands and Any Instruments You Will Use.* If possible, allow the child to touch and examine the instruments because this will tap into his or her

curiosity. Most children are cooperative if they know you are not planning a painful procedure.

6. *Allow the Child to Make Choices Whenever Possible, But Avoid Giving the Child Artificial Choices.* For example, do not ask permission to measure the child's blood pressure unless you are prepared to respect his or her choice if the child refuses. Simply state what you need to do in a gentle but matter-of fact manner and do it. Examples of realistic choices include desired Popsicle flavor and choice of video game to play.

7. *Allow the Parents to Participate in the Child's Care Whenever Possible.* Some procedures can be accomplished with the child sitting on a parent's lap or in a position of comfort, such as a hug. This allows the child to feel safe.

8. *Use a Calm, Soothing Voice.* Get the child's attention in a non-threatening tone to ensure they listen to what you are saying. This helps them to understand and respond in a positive way.

9. *Encourage the Family to Bring the Child's Favorite Articles from Home.* Gives the child a sense of safety through familiarity. Can also aid as a visual stimulus during examination to distract the child. For example, when giving a vaccination.

Mullen & Pate, 2018

Figure 1.3

Child Nutrition

Source. From "Convince Kids to Eat" by Scripps, 2012, Microsoft Bing, Creative Commons Attribution- Share Alike 2.0 Generic

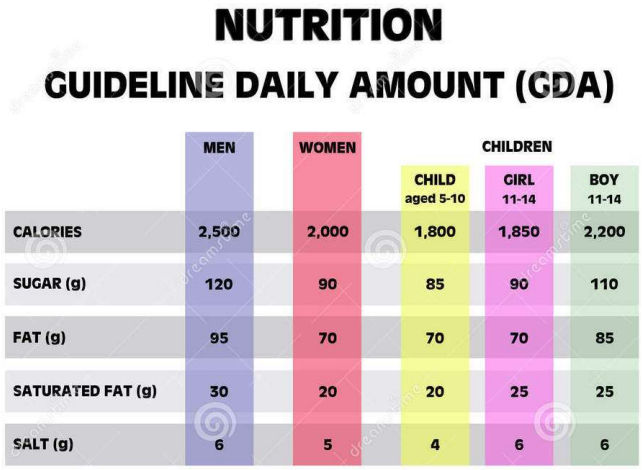
Knowledge of the child's dietary intake is an essential component of a nutritional assessment. The dietary reference intakes (DRIs) are a set of four nutrient based reference values that provide quantitative estimates of nutrient intake for use in assessing and planning dietary intake. These include:

- Estimated average requirement – Nutrient intake required to meet the requirement of half the healthy individuals for a specific age group.
- Recommended dietary allowance – Average daily dietary intake sufficient to meet the nutrient requirement of nearly all individuals for the age group.
- Adequate intake – Recommended intake level based on estimates of nutrient intake by healthy groups of individuals.
- Tolerable upper intake level – Highest average intake level likely to post no risk to adverse health effects (Government of Canada 2021; Hockenberry & Wilson, 2018)

Healthy eating in childhood and adolescence is important for proper growth and development and to prevent various health conditions (CDC, 2021a). The Government of Canada (2021) recommends that parents choose healthy food options such as fruit and vegetables and replace sugary drinks with water. Also, limit the number of highly processed foods offered and prepare meals with little to no added sodium, sugar, and saturated fat.

Figure 1.4

Guidelines for Intake



Source. From "Nutrition Guideline Amounts" by mrgscience, 2018, Microsoft Bing, Creative Commons Attribution-ShareAlike 2.0 Generic.

CLINICAL EXAMINATION OF NUTRITION

Figure 1.5

Examination of Nutrition

Source. From "Nursing Assessment", by Wikipedia, 2021, Wikimedia Commons, Creative Commons Attribution-ShareAlike 2.0 Generic

A significant amount of information regarding nutritional deficiencies comes from a clinical examination, especially from examining the skin, hair, teeth, gums, lips, tongue, and eyes. Signs of nutritional deficiencies in children may include:

- o < 5 or > 95 percentiles for growth
- o Poor weight pain and absence or delay of growth
- o Skin hard and scaling, poor turgor, pruritis
- o Hair stringy, dull, dry, thin. Alopecia.
- o Softening of cranial bones, delayed fusion of sutures, headache.
- o Enlarged thyroid.
- o Eyes burn, itch, photophobia.
- o Hearing loss.
- o Irritation and cracks at nasal angle.
- o Fissures and inflammation of mouth corners.
- o Teeth browning, defective enamel.
- o Depressed rib cage, sharp protrusion of sternum.
- o Heart palpitations, rapid pulse. Increased/decreased blood pressure.
- o Abdomen distended, flabby. Constipation or diarrhea.
- o Muscle weakness, pain, cramps.
- o Joint swelling and pain.
- o Irritable, lethargic, apathetic, listless.
- o Diminished or absent tendon reflexes.

Hockenberry & Wilson, 2018

CHILDHOOD OBESITY

Obesity in children is defined as a body mass index at or greater than the 95th percentile for youth of the same age (Hockenberry & Wilson, 2018). Obesity rates among children and youth in Canada have nearly tripled in the last 30 years (Government of Canada, 2021).

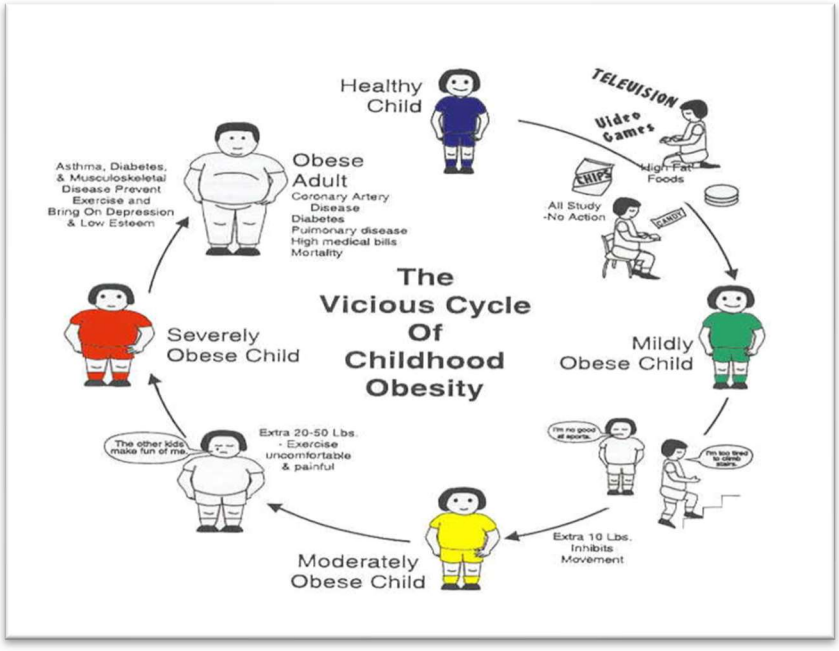
HEALTH PROBLEMS FOR OBESE CHILDREN

- High blood pressure
- Type 2 diabetes
- Sleep apnea and other beathing problems
- Bone and joint problems

RISK FACTORS

Figure 1.6

Risk Factors for Childhood Obesity



Source. From "Childhood Obesity" by Unknown Author, blogspot web site, 2011, Microsoft Bing, Creative Commons- ShareAlike 2.0 Generic

PART TWO: PHYSIOLOGIC MEASUREMENTS IN PEDIATRICS

Key elements in evaluating physical status of vital functions include temperature, pulse, respiration, and blood pressure (Hockenberry & Wilson, 2018).

TEMPERATURE

Table 1.5

Temperature Ranges in Children

CHILD (< 18 YR)	ADULT (> 18 YR)
36.6°C – 37.2°C	36.1°C – 37.2°C

Temperature can be measured at several body sites in children via oral, rectal, axillary, ear canal, tympanic membrane, temporal artery, or skin. Children 3 months to one year have a higher baseline temperature at around 37.5°C. (Hockenberry & Wilson, 2018).

Table 1.6

Recommended Temperature Screening Routes in Infants and Children

Birth to 2 years	Axillary Rectal (most accurate)
2 to 5 years	Axillary Tympanic Oral Rectal (most accurate)
Over 5 years	Oral Axillary Tympanic

Hockenberry & Wilson, 2018

HEART RATE

Pulse can be taken radially in children older than 2 years of age. In infants and young children, the apical pulse (heard through stethoscope) is more reliable. Count the pulse for one full minute in infants and young children due to possible irregularities in rhythm (Hockenberry & Wilson, 2018).

Table 1.7

Heart Rate Ranges in Children

AGE RANGE	HEART RATE (BEATS PER MIN)
NEWBORN	100-180
1 WEEK-5 MONTHS	100-200
6-12 MONTHS	80-150
1-3 YEARS	80-130
3-5 YEARS	80-120
6-10 YEARS	70-100
11-14 YEARS	60-105
15 YEARS OR OLDER	60-100

CDC, 2021; Hockenberry & Wilson, 2018

RESPIRATION

Count the respiratory rate in children in the same manner as the adult patient. However, in infants observe abdominal movements, since respirations are primarily diaphragmatic. Count for one full minute for accuracy as may be irregular (Hockenberry & Wilson, 2018).

Table 1.8

Respiratory Rates for Children

AGE	RATE (BREATHS/MIN)		
Newborn	35	5-6 years	21
1 to 11 months	30	7-8 years	20
2 years	25	9-12 years	19
3-4 years	23	13-18 years	16-18

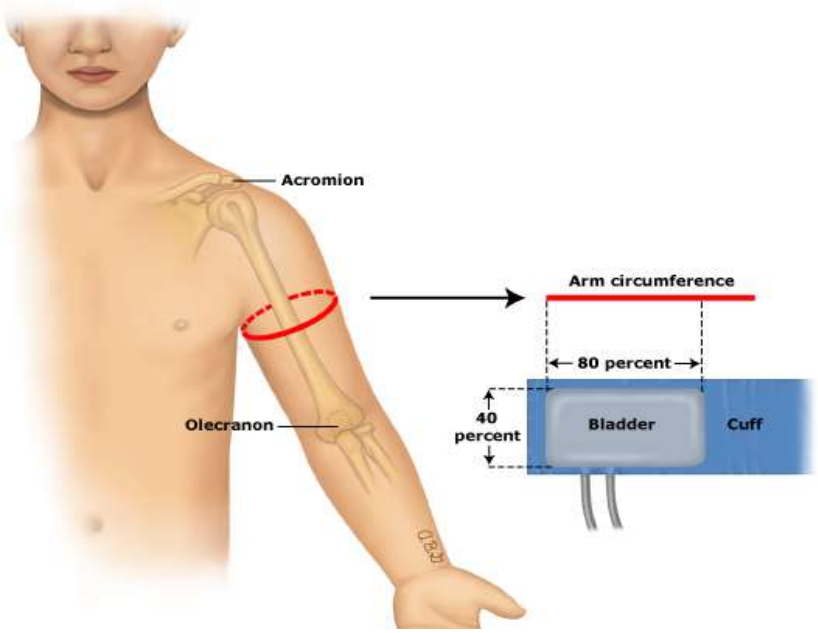
CDC 2021; Hockenberry & Wilson, 2018

BLOOD PRESSURE

The most important factor in accurately measuring blood pressure (BP) is the use of an appropriately sized cuff. A technique to establish an appropriate cuff size is to choose a cuff with a bladder width that is approximately 40% of the arm circumference midway between the olecranon and the acromion (Hockenberry & Wilson, 2018).

Figure 1.7

Blood Pressure Cuff Measurement in Pediatrics



Cuffs that are too narrow or too wide affect the accuracy of BP measurements. If it is too small, the reading is falsely high. Too large, the reading is falsely low (CDC, 2021; Hockenberry & Wilson, 2018).

Source. Image from https://ykhoa.org/d/image.htm?imageKey=PEDS/73414

Table 1.9

BP Values and Mean Arterial Pressures in Pediatrics

AGE	**MEAN**	**90TH PERCENTILE**	**95TH PERCENTILE**
Newborn (1-3 days)	65/41 (50)	75-49 (59)	78/52 (62)
1month-2 years	95/58 (72)	106/68 (83)	110/71 (86)
2-5 years	101/57 (74)	112/56 (82)	115/68 (85)
6-12	112/57 (78)	117/60 (85)	118/62 (87)
12-18	120/70 (80)	115/68 (78)	125/73 (82)

Hockenberry & Wilson, 2018

BLOOD TESTS OF RENAL FUNCTION

Table 1.10

Laboratory Values of Renal Function in Pediatrics

TEST	*NORMAL RANGE (mmol/L)*	*DEVIATIONS*	*SIGNIFICANCE*
Blood Urea Nitrogen (BUN)	Newborn: 1.1-4.3 Infant, child: 1.8-6.4 Thereafter: 2.5-6.4	Elevated	Renal disease – acute or chronic (the higher the BUN the more severe the disease).
Uric Acid	Child: 0.12-0.32	Increased	Severe renal disease
Creatinine	Infant: 18-35 Child: 27-62 Adolescent: 44-88	Increased	Severe renal impairment

Hockenberry & Wilson, 2018

COMMON LABORATORY TESTS (ELECTROLYTES)

Table 1.11

Common Laboratory Tests in Pediatrics 1

TEST	AGE	NORMAL RANGE (MMOL/L)
POTASSIUM	Newborn Thereafter	3.0-6.0 3.5-5.0
CALCIUM	Newborn Child Thereafter	2.25-2.73 2.20-2.70 2.10-2.55
BICARBONATE	All Ages	Arterial: 21-28 Venous: 22-29

COMMON LABORATORY VALUES (HEMATOLOGY)

Table 1.12

Common Laboratory Tests in Pediatrics 2

TEST	AGE	NORMAL RANGE
HEMOGLOBIN	2 month – 6 yr	1.40-2.17 mmol/L
	6-12 yr	1.78-2.40 mmol/L
	12-18 yr Male:	2.02-2.48 mmol/L
	Female:	1.86-2.48 mmol/L
HEMATOCRIT	2 month – 6 yr	0.28-0.42 vol fraction
	6-12 yr	0.35-0.45 vol fraction
	12-18 yr Male:	0.37-0.49 vol fraction
	Female:	0.36-0.46 vol fraction

Hockenberry & Wilson, 2018

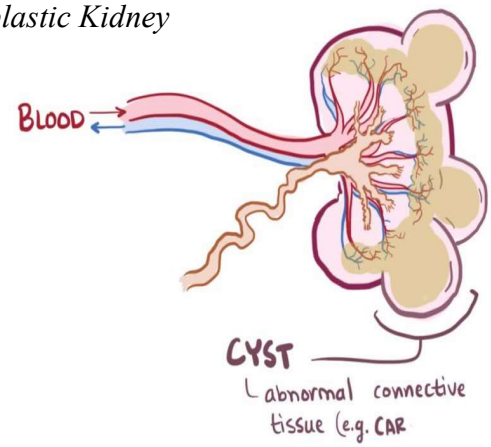
SECTION TWO: NEPHROLOGICAL CONDITIONS

COMMON RENAL DISEASES IN PEDIATRICS

1. DYSPLASTIC KIDNEYS

Figure 2.0

Dysplastic Kidney



Source. From "Multicystic Dysplastic Kidney" by Wikipedia, 2021, Creative Commons Attribution- Share Alike 2.0 Generic

The internal structure of one or both of a fetus' kidneys do not develop normally. During development, the tubules fail to connect to the ureters, therefore the urine has nowhere to go. The urine collects inside the kidney and forms cysts that prevent the kidney from functioning (National Institute of Diabetes and Digestive and Kidney Diseases, NIDDK, 2015).

WHAT CAUSES IT?

Genetic factors typically cause kidney dysplasia. Medications taken during pregnancy such as those to treat seizures, high blood pressure, or illegal drugs (NIDDK, 2015).

HOW COMMON IS IT?

About one in 4,000 babies are diagnosed with it. Half of these babies also have other urinary tract defects such as hypospadias and polycystic kidneys. (NIDDK, 2015)

WHAT IS THE TREATMENT?

Babies that survive birth will require dialysis or a kidney transplant. If both kidneys are affected, the child is likely to develop chronic kidney disease requiring HD (NIDDK, 2015).

2. ACUTE KIDNEY INJURY (AKI)

The sudden loss of renal capacity for filtration and tubular reabsorption, resulting in accumulation of wastes, fluid and electrolyte imbalance, and acid–base imbalances (Dokas, 2018).

MULTI-SYSTEM INFLAMMAROTY SYNDROME IN CHILDREN (MIS-C)

Figure 2.1

COVID-19 in Children

Source. From "Mask education project burgeons into creative remove teaching collaboration" by Swinger and Densmore, 2020, Microsoft Bing, Creative Commons Attribution – NoDerivs 2.0 Generic

Recognised in early 2020 in the United States and United Kingdom, MIS-C is related to COVID-19 infection. Most children who become infected with the COVID-19 virus have only a mild illness. But in children who go on to develop MIS-C, some organs and tissues - such as the heart, lungs, kidneys, digestive system, brain,

skin or eyes – become severely inflamed (Government of Canada, 2021). Clinical manifestations differ from adults (Son & Freidman, 2021).

*** Most MIS-C cases (> 70%) have occurred in children who were previously healthy (Son & Freidman, 2021)*

SYMPTOMS OF MIS-C:

- In children with a known history of COVID-19, the duration between acute infection and onset of MIS-C symptoms is two to six weeks.
- Kawasaki disease-like features: conjunctivitis, red eyes; red or swollen hands or feet; rash, red crackled lips, and swollen glands.
- Gastrointestinal symptoms such as abdominal pain, diarrhea, nausea/vomiting
- Toxic shock like symptoms such as hemodynamic instability and poor cardiac function.
- Thrombosis or acute kidney injury.
- Shortness of breath.

Government of Canada, 2021; Son & Friedman, 2021

COMMON LAB FINDINGS:

- An abnormal level of inflammatory markers including elevated erythrocyte sedimentation rate (ESR)/C-reactive Protein (CRP) and ferritin, lactate dehydrogenase
- Lymphopenia, thrombocytopenia, neutrophilia
- Elevated B-type natriuretic peptide (BNP), hyponatremia, elevated D-dimers

Government of Canada, 2021

In children presenting with a persistent fever (≥3 days) who are moderately to severely ill with clinical signs of organ dysfunction (e.g., gastrointestinal, respiratory,

cardiac, skin, or neurologic), the diagnosis of MIS-C should be considered (Government of Canada, 2021).

WHEN IS HEMODIALYSIS INDICATED?

- If MIS-C progresses to AKI, HD may be indicated to sustain life, specifically to maintain respiratory status through fluid removal and prevent cardiac arrest through electrolyte balance (CDC, 2021b).

TOXIN INGESTION

MEDICATION INGESTION

Up to 25% of toxin ingestion cases are the result of pharmacotherapy and occur between 8 and 30% of the children in the intensive care unit (Faught et al., 2014).

Figure 2.2

Child Medication Ingestion

Source. From "Toddler Prescription Bottle" by Flickr, 2021, Microsoft Bing, Creative Commons Attribute – NonCommercial 2.0 Generic

There are three common classes of drugs that cause AKI in children if ingested:

- Cancer chemotherapeutics
- Non-steroidal anti-inflammatory (Ibuprofen, Aspirin)
- Antimicrobials (Keflex, Flagyl, Ciprofloxacin)

Other medications may include lithium, salicylate, theophylline, and phenobarbital (Faught et al., 2014; McGregor et al., 2009).

Figure 2.3

Poison Ingestion

Some chemicals are highly toxin to children and may be lethal in small doses. Examples include:

- Ethylene glycol (antifreeze)
- Methanol (windshield wiper fluid)
- Acids (toilet cleaner, oven cleaner)
- Nail products (acetone)

McGregor et al., 2009

Source. From "Juice or Poison? Poison prevention" by staticflickr, 2015, Creative Commons Attribution – 2.0 Generic

SYMPTOMS OF TOXIN INGESTION

Symptoms differ depending on the toxin ingested. Respiratory, circulatory, and neurologic symptoms are the main indications of toxin ingestion however, other symptoms such as gastrointestinal may occur.

- A child that ingests a medication may experience abdominal pain, nausea/vomiting, tachycardia/bradycardia, and hypoventilation.
- A child that ingests a chemical substance may experience respiratory depression, seizures, hypotension, and hypoglycemia

McGregor et al., 2009

TREATMENT

Treatment is dependant on the toxin ingested and its effects.

- To remove ingested toxins or prevent their absorption activated charcoal and gastric lavage may be used.
- An antidote may be available, as in the case of many medications.
- HD may be appropriate for lithium, salicylate, theophylline, methanol, atenolol (Tenormin), phenobarbital, or valproic acid toxicity.
- HD provides more efficient solute clearance and ultrafiltration compared to other renal replacement therapies; therefore, it is important in the pediatric population for ingestions and drug toxicity.

Brophy & Jetton, 2020; McGregor et al., 2009

LABORATORY FINDINGS

Table 2.0

Laboratory Findings in Chemical Ingestion

	Containing Fluids	Clinical Findings	Unique Lab Findings
Methanol	Windshield wiper fluid, adulterated ethanol "moonshine"	Blurred ("snowstorm") vision, blindness, basal ganglia hemorrhage leading to Parkinsonism	Lactic acidosis
Ethylene Glycol	Antifreeze	Fluorescent urine, calcium oxalate crystals	Hypocalcemia, wide QRS, prolonged QTc
Propylene Glycol	Diluent in parenteral medications	Hepatic/Renal failure patients at higher risk	Lactic acidosis
Isopropyl Alcohol	Hand sanitizer, rubbing alcohol	May cause acute pancreatitis	Acetonemia (may falsely elevate Cr) [5], does not cause HAGMA

Source. From "Diagnostics: Toxic Alcohols" by Kimmel, 2019, Wikimedia Commons, Creative Commons Attribution – NonCommercial- ShareAlike 2.0 Generic

3. HEMOLYTIC UREMIC SYNDROME

Hemolytic uremic syndrome (HUS) is an acute kidney disease characterised by a triad of manifestations: AKI, hemolytic anemia, and thrombocytopenia. HUS occurs primarily in infants and small children between the ages of 6 months and 3 years (Hockenberry & Wilson, 2018).

CAUSE

In the majority of cases of HUS, no causative agents have been identified. The appearance of the disease has been associated with Rickettsia organisms; viruses such as coxsackievirus, echo virus, and adenovirus; E-coli; pneumococci; Shigella organisms and Salmonella organisms and may represent an unusual response to these infections (Hockenberry & Wilson, 2018).

SYMPTOMS

- The disease occurs after a prodromal period during which there is an episode of diarrhea and vomiting. Less often the preceding illness if an upper respiratory tract infection or, occasionally, varicella, measles, or a urinary tract infection.
- The hemolytic process persists for several days to two weeks. During this time, the child is anorexic, irritable, and lethargic. There is a rapid onset of pallor accompanied by hemorrhagic manifestations such as bruising, purpura, or rectal bleeding.
- Severely affected patients are often anuric (have no urine output) and hypertensive.

Hockenberry & Wilson, 2018; NIDDK, 2021

DIAGNOSTICS

- Proteinuria, hematuria, and urinary casts are evidence of renal involvement; blood urea nitrogen (BUN) and creatinine levels are elevated. A low hemoglobin and

hematocrit and a high reticulocyte count confirm the hemolytic nature of the anemia (Hockenberry & Wilson, 2018; NIDDK, 2021).

TREATMENT

- Treatment is directed to control of complications and hematologic manifestations of renal failure.
- The initial supportive measures are to manage renal failure and include fluid replacement, treatment of hypertension, and correction of acidosis and electrolyte imbalance.
- The most consistently effective treatment is HD. This is instituted when the child is anuric for 24 hours or oliguric (no urine output) with uremia and hypertension and seizures.
- With prompt treatment, the recovery rate is approximately 95%, however, residual renal impairment ranges from 10% to 50%.

Hockenberry & Wilson, 2018; NIDDK, 2021

SECTION THREE: CHILDREN ON HD – THE PATIENT/FAMILY AND NURSE EXPERIENCE

THE CHILD AND FAMILY EXPERIENCE

Figure 3.0

Teen Receiving HD

Source. Image from "Kidney dialysis" by bmj.com, 2020, Microsoft Bing. Creative Commons Attribute – 2.0 Generic.

The experience of being informed that initiating dialysis is essential to maintain life can be a devastating, life-altering experience for children diagnosed with kidney failure and their caregivers (Nuel, 2012). For as long as it is necessary, HD constitutes a central feature of their everyday lives, with significant consequences on home, school, and recreational activities (Zitzelsberger et al., 2019).

PHYSICAL AND SOCIAL DIFFICULTIES OF THE CHILD

Alterations in their physical appearance, particularly related to vascular access, may cause feelings of embarrassment. Socially, children may feel isolated and alone with a sense of everyday confinement and constraints having an impact on their lives outside of HD. Children may feel that HD limits their social time due to the amount of time taken for preparation, duration, and completion of the treatments (Abreu et al., 2014; El-Gamsay & Eldeeb, 2017; Kilis-Pstrusinska et al., 2013; Zitzelsberger et al., 2019).

FAMILY DIFFICULTIES

Family members, particularly parents of the children undergoing HD, have several sources of distress relating to their child being on HD. Emotional distress is a prominent issue for parents whose children undergo HD (Cimete 2002; Ong et al., 2021; & Wightman et al., 2019). Parents experience feelings of guilt, grief, and powerlessness as a result of their child's diagnosis. They feel grief because of their perceived role as a caregiver in contributing to the disease process, which is compounded by enforcing a strict diet and fluid restrictions on their children. Witnessing their child undergo dialysis and painful medical procedures causes feelings of grief and powerlessness. Emotional effects on the family dynamics may also occur as parents feel they are neglecting their other children and/or partners to care for their sick child. As HD requires several lengthy hospital visits, parents may feel that their time with their other family members is reduced. In particular, if they have other children, they may express feelings of uncertainty of how it will affect them in the future (Cimete 2002; Ong et al., 2021; & Wightman et al., 2019). They may also experience strain on their intimate relationships with frequent absences from each other and arguments relating to their child's medical care.

THE NURSES' EXPERIENCE

Figure 3.1

Nurse Caring for Child

The dialysis nurse plays a vital role in providing information, care, support, understanding, and therapeutic counseling to the pediatric patient and their family throughout the HD process (Ibrahim, 2019).

Source. Image from "Pediatric hemodialysis" © Fresenius Medical Care, 2021, *Used with permission.*

NURSE COMPETENCIES

Nurse competencies are driven by the needs of the patient and family. These competencies reflect the integration of nursing knowledge, skills, and experiences that are required to meet the patient's and family's needs and to optimize their health and wellness. Each competency has different levels of experience ranging along a continuum from novice to competent to expert practitioner. Although the competencies, as a whole, reflect the entirety of nursing practice, each competency becomes more or less important depending on the patient's needs at the time.

1. *Clinical Judgment*. Clinical reasoning and critical thinking skills.

2. *Caring Practices*. Creating a therapeutic environment based on the unique needs of the patient and family.

3. *Advocacy/Moral Agency*. Working on another's behalf; resolving ethical concerns.

4. *Collaboration.* Working with others in a way that encourages each person's contribution toward the patient's goals.

5. *Systems Thinking.* Recognizing the interrelationship within and across healthcare systems.

6. *Response to Diversity*. Recognizing and incorporating differences into care.

7. *Clinical Inquiry*. Ongoing questioning and evaluation of practice.

8. *Facilitator of Learning*. Facilitating patient and family learning.

Mullen & Pate, 2018

NURSING BURNOUT

Figure 3.2

Nursing Burnout

Source. From http://cloud3.nurse24.it. Unknown Author, Microsoft Bing. Creative Commons Attribution – Noncommercial, NoDerivs 2.0 Generic

High-quality nursing care is imperative to contribute to positive patient and family outcomes. Sometimes, however, nursing care lacks the necessary adequacy and safety of patients (Shahdadi & Rahnama, 2018). The many responsibilities of the nurse during the care of the pediatric patient undergoing HD can cause exhaustion, especially with a heavy workload and lack of resources. Providing care for patients with chronic diseases such as end-stage renal disease, working in an environment with complex HD machines demanding attention, and coping with the increased expectations of patients is stressful (Kavurmaci, 2014).

Ibrahim et al. (2019), Kavurmaci et al. (2014), and Shahdadi and Rahnama, (2018) found that nurses' attitudes about the care of children undergoing HD are often negative, due to feelings of burnout, depression, and anxiety. Excessively long workdays, high workloads, and insufficient resources to accomplish the job led to a depletion in the nurses' physical and emotional resources.

NURSING NEEDS

Increasing nurses' knowledge and experience with pediatric HD patients is necessary to resolve the challenges in the care of these patients as well as improve the quality of nursing care provided and prevent burnout (Shahdadi & Rahnama, 2018; Kavurmaci et al., 2014). AKI among pediatric HD patients can be very complex, as seen in MIS-C, causing an increased need for nursing education to improve patient and family outcomes. Keeping nurses updated on new information and procedures relating to HD will aid their ability to adapt to change to ensure best practice and ultimately, enhanced patient and family outcomes (Shahdadi & Rahnama, 2018). Emphasis needs to be placed on the importance of continuous training. This training should be the result of ongoing needs assessments, where gaps in nursing knowledge and skills for those caring for children undergoing HD are identified (Ibrahim et al., 2019).

SECTION FOUR: VASCULAR ACCESS

CENTRAL VENOUS CATHETER (CVC)

Figure 4.0

Child Receiving HD via CVC

Source. Image from http://staticflickr.com by Unknown Author. Microsoft Bing. Creative Commons Attribution – Noncommercial ShareAlike 4.0

The CVC represents the sole initial vascular access for HD in small children (Cho, 2020). CVC infection rates are high among the pediatric HD population (Araujo de Souza et al., 2011; Chand et al., 2009; O'Grady et al., 2017; Paglialonga et al., 2016).

For incident patients with an unplanned dialysis initiation and who desire HD, a CVC will be necessary irrespective of age, body habitus, venous anatomy, or comorbidities (Lok et al., 2020).

CVC INSERTION LOCATIONS/SIZES

The National Kidney Foundation/Kidney Disease Outcome Quality Initiative guidelines by Lok et al. (2020) recommend that the order of CVC placement be sequential: the **right internal jugular vein, right external jugular vein, the left internal and external jugular veins, subclavian veins, femoral veins**, or translumbar access to the inferior vena cava. This order is based on complication rates from lowest to highest.

Catheter sizes range from 6.5-14 French and are chosen according to the vessel size based on the weight of the child. In small children (weight between 5-10kg), the distance between the arterial and venous ends of the catheter in double-lumen catheters may be too far apart to allow successful positioning in both lumens. In this case, split catheters (two catheters of equal length joined proximally but separated distally) or the use of two separate single-lumen catheter systems (inserted in the same vein with different exit sites or in different veins altogether) can be used (Rees, 2020).

Figure 4.1

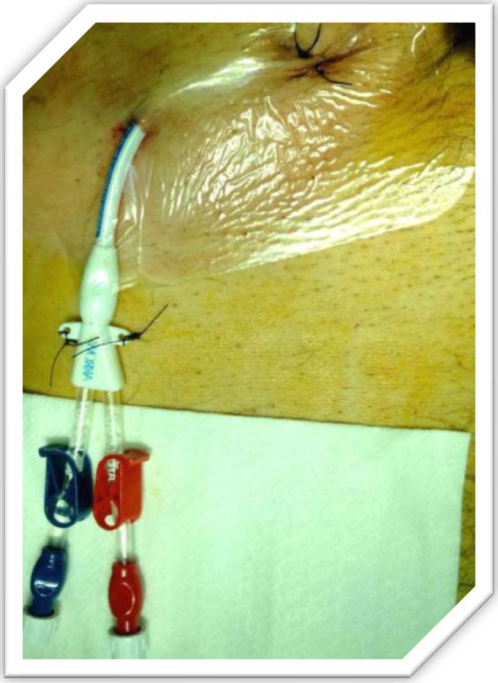
CVC Site

Source. Image from "Central venous catheter", by Wikipedia, 2021, Microsoft Bing. Creative Commons Attribution ShareAlike 2.0 Generic

INFECTION

Figure 4.2

CVC



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The most common reason for cuffed CVC removal is infections. These can range from *exit site infections* to *tunnel infections* to bacteremia (Kamil et al., 2009). The United States Renal Data System (2020) showed that of 332,442 incidents involving patients on dialysis with a CVC, the cumulative annual incidence of infection-related hospitalization was 26% for children and 31% for adults. The annual mortality rate secondary to sepsis was 100–300-fold higher in patients receiving HD than in the general population.

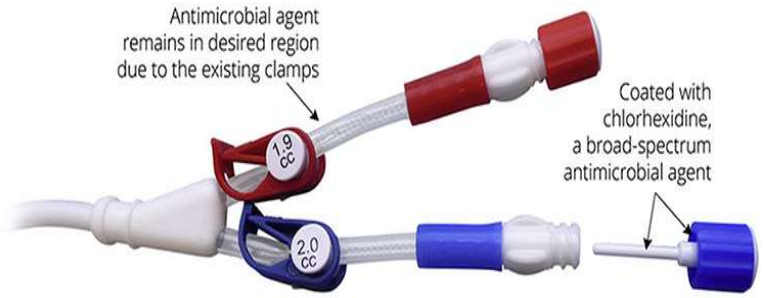
Catheter-related bloodstream infections (CRBSIs) alone have a reported incidence of 1.1 to 5.5 episodes per 1000 catheter days and are associated with increased morbidity, hospitalization, and death (Miller et al., 2016). Comparing adults and children, rates of CRBSI in patients in pediatric intensive care units are higher than those in patients in adult intensive care units (Paglialonga et al. 2004). The Public Health Agency of Canada (2020) reported the number of CRBSI's that occurred in 40 Canadian hospitals between 2008-2018; pediatric intensive care units (ICU) reported a higher infection rate at 1,450 CRBSI's compared to adult ICUs at 1,331. Therefore, nurses must have the knowledge and skill to prevent these infections and ultimately prevent high morbidity and mortality among this population (Chand et al., 2009).

The CVC can be colonized with organisms by either of two main routes. The first route is the intraluminal colonization which occurs during repeated handling of the line, the hub, or from administering contaminant solution via the catheter (Ouda et al., 2019). The second route is the extraluminal colonization which originates from the skin at the insertion site and migrates along the external surface of the line.

Intralumenal: Antimicrobial Locks

Figure 4.3

CVC Lumen Antimicrobial Locks



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Catheter lock is a technique by which an antimicrobial solution is used to fill a catheter lumen and then allowed to dwell some time while the catheter is idle (i.e., not in use) (O'Grady et al., 2011). This practice is recommended by both Lok et al. (2020) and O'Grady et al. (2017) in patients with a CVC who are at high risk of infection such as pediatric patients. Antimicrobial lock solutions may include taurolidine, 30% citrate, or ethanol. Nephrologists may also choose to lock the catheter with antibiotic solutions such as gentamycin or vancomycin if the patient is very high risk for CVC infection. However, antibiotic locks may create antibiotic resistance, therefore antimicrobial locks are suggested first (Lok et al., 2020).

Extraluminal: CVC Site Maintenance

Figure 4.4

CVC Exit-site Infection

Source. Image from "Prevention and management of catheter-related infection in hemodialysis patients" by Lok, C., & Mokrzycki, M. (2011). © Elsevier. *Used with permission.*

External CVC site maintenance includes dressing changes and physical examination of the CVC exit site. Both Lok et al. (2020) and O'Grady et al. (2017) recommend:

- Weekly CVC dressing changes with skin preparation of 2% chlorhexidine and sterile transparent or semi-permeable dressing to cover the catheter site.
- Monitoring of signs and symptoms of bacteremia/septicemia is imperative for early detection and treatment. Inspection of the CVC exit site may reveal *Dacron cuff migration* that places the CVC at risk of infection. Exit-site infection is indicated by the presence of erythema, swelling, tenderness, and purulent drainage around the CVC exit and the part of the tunnel external to the cuff (See above photo). Signs of tunnel infection are swelling, erythema, and tenderness over the CVC tunnel central or proximal to the cuff.
- If there is a suspect exit-site infection, dressing changes should be completed at every HD session with topical antibiotic ointment for two weeks or until symptoms resolve.

SECTION FIVE: NURSING ASSESSMENT

Figure 5.0

Nursing a Sick Child

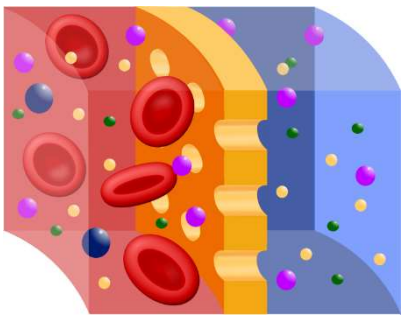
Although the principles of HD are similar for adults and children, there are technical aspects of the procedure and complications that are unique to the pediatric population (Rees, 2021).

Source. Image from "Nursing a sick child" by Wikimedia. Wikipedia Commons. Creative Commons Attribution – ShareAlike 4.0 International

FLUID ASSESSMENT

Figure 5.1

Dialysis Chemistry



Source. Image from http://www.mtstatic.com by Unknown Author. Microsoft Bing. Creative Commons

There are vast differences between the assessment of fluid removal between pediatric and adult populations (Fischbach et al., 2005; Rees 2021; Souza et al., 2008). For example, target weight assessment in children and adolescents is particularly challenging as it needs frequent adjustment in line with growth or periods of illness.

DRY WEIGHT

Figure 5.2

Weigh Scale

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Dry weight – the ideal body weight of a patient without any excessive fluid (Nemec, 2021).

- For children in the ICU, determine with the parents what their last weight was before their illness.
- It is difficult to determine the dry weight in pediatric patients due to changes in body composition with age, catabolic malnourished state, oliguric, anuric or polyureic, and failure to thrive.
- Dry weight assessments are recommended weekly for infants and every two weeks with nourishment issues and if they have hypotension/cramping on HD or at home.

(Nemec, 2021)

ULTRAFILTRATION (UF)

The amount of ultrafiltration (fluid removal) that a child can tolerate losing per hour varies, a generally safe starting point is approximately 10ml/kg per hour. Removal of more than 5% of body weight in one session, or 0.2ml/kg per minute (12ml/kg per hour), is very likely to result in symptomatic hypovolemia (intradialytic hypotension). In children who weight more than 40kg, typically 600ml/hour can be removed without significant symptoms in patients who are consistently volume overloaded (Rees, 2020).

Maximum ultrafiltration standards for SickKids Hemodialysis Program in Toronto, ON include:

- In a 2-hour treatment a maximum of 4% of the patient's weight may be removed in fluid
- In a 3-hour treatment a maximum of 6% of the patient's weight may be removed in fluid
- In a 4-hour treatment a maximum of 7% of the patient's weight may be removed in fluid
- * This may change based on the nephrologist's discretion and patient status

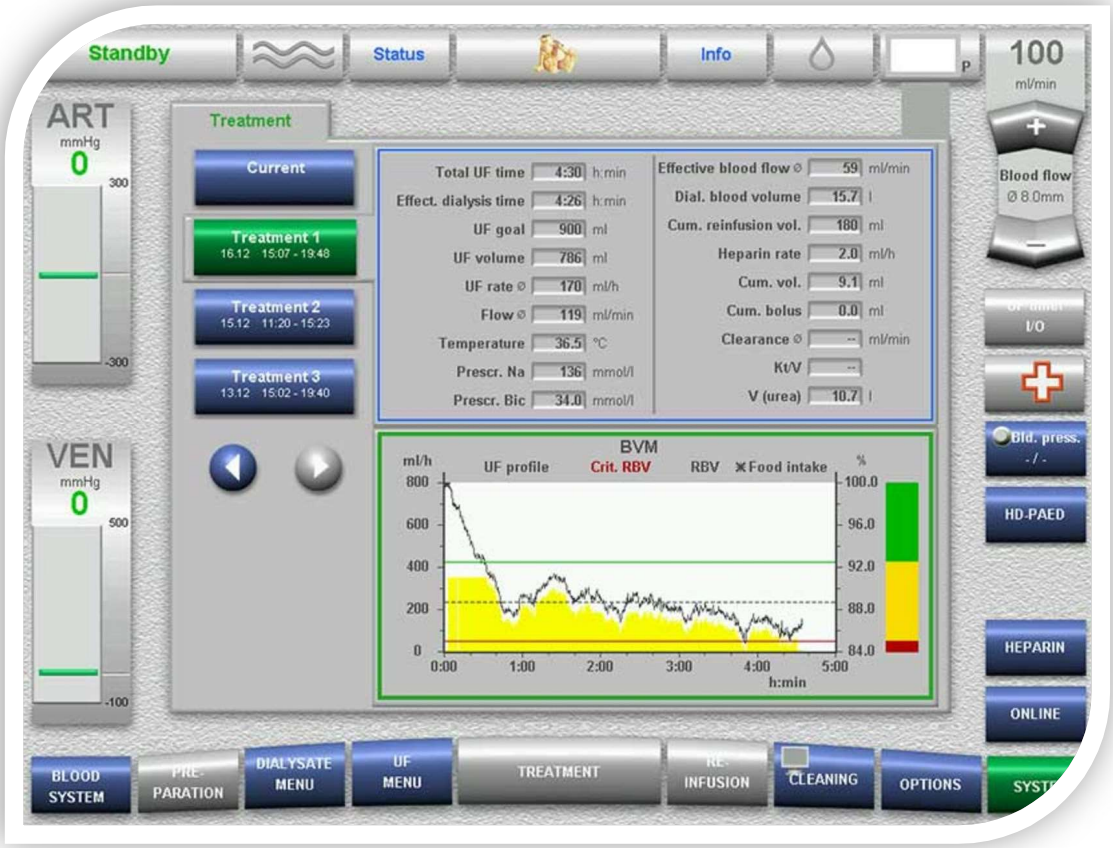
For example, a patient weighing 12 kg is to have a 4-hour treatment therefore the maximum UF will be:

12 kg x 7% = 0.84L = 840 mls (Nemec, 2021)

DIALYSIS PRESCRIPTION

Figure 5.3

Pediatric HD Prescription



Source. Image from "Pediatric hemodialysis", © Fresenius Medical Care, 2021. *Used with permission.*

There are significant differences between the pediatric and adult composition and indications for the dialysis prescription which includes the *dialyzer*, tubing, blood flow rate, and session duration and frequency. Nurses must be knowledgeable and competent in the ability to differentiate between the required prescriptions for adult and children. For

each patient, a nephrologist develops an individual dialysis prescription to ensure adequate solute clearance and the removal of excess fluid (Rees, 2021).

DIALYZER

The type of dialyzer used depends on the patient's residual renal function (Ashby et al., 2019; Cho, 2020; Rees, 2021; Fischbach et al., 2005) The dialyzer acts as the artificial kidney, removing fluid and solutes or toxins through *convection* and *diffusion.* There are two types of dialyzers: low-flux and high-flux. Low flux dialyzers have a moderate permeability, meaning the removal of solutes is moderate. High-flux dialyzers have high permeability, solutes are removed at a high rate. If the patient has a little residual kidney function, a high-flux membrane is recommended as they improve permeability for middle and larger molecules. For pediatric patients, the size of the dialyzer is much smaller compared to adults as the surface area is similar to that of the patient's body and selected according to the patient's size (Cho, 2020; Sousa et al.,2008)

Figure 5.4

Pediatric Dialyzer

Source. Image from "Pediatric hemodialysis", © Fresenius Medical Care, 2021. *Used with permission.*

Table 5.0

Dialyzer Sizes and Priming Volumes

Dialyzer	Priming Volume (mls)	Surface area (m^2)	kUF (ml/hr/ mmHg TMP)	Material
FX 40	32	0.6	20	Helixone (polysulfone)
FX 50	53	1.0	33	"
FX 60	74	1.4	46	"
FX 600	97	1.5	52	"
FX 800	118	1.8	63	"
FX 1000	138	2.2	75	"

(Nemec, 2021)

TUBING

The tubing, or circuit, used for pediatric HD patients is much smaller than that used for adult patients. The selection of tubing for the pediatric patient is dependant on the priming volume. The tubing contains between 100-200mls of the patient's blood at one time while HD is ongoing. It is imperative to ensure the tubing is small enough so that the child is not depleted of blood volume which can cause complications such as hypotension. A child can tolerate a maximum of 10 percent of their total blood volume in the circuit, and a safe volume of the circuit is targeted at eight percent of the total blood volume of the child (Cho, 2020; Fischbach et al., 2005; Rees, 2021; Souza et al., 2008). Tubing available for pediatric patients varies between 20-70 ml with internal diameters from 1.5ml to 3 ml (Souza et al., 2008).

TOTAL BLOOD VOLUME

A child can tolerate up to a maximum of ten percent of their total blood volume in the extracorporeal circuit (dialyzer and tubing), and a safe volume of the circuit is targeted at eight percent of total blood volume of the child (Rees, 2020).

To determine the total blood volume that you can remove from a child, you can do the following calculation as used by SickKids Hospital in Toronto, ON:

- 0- 1 month old = kg x 100ml/kg = TBV (ml)
- 1 month – 16 years old = kg x 80ml/kg = TBV (ml)
- 16 years old = kg x 70ml/kg = TBV (ml)

** Also need to account for dialyzer and tubing priming volume (E.g., tubing = 108 ml and dialyzer = 32 ml). Add to total.

Example:

2-year-old that weighs 12 kg

12 (weight) x 80 (volume) = 960 ml

Can remove 10% of total blood volume = 96 ml

THEN...Have to account for prime volumes of tubing and dialyzer:

107 ml (tubing) + 32 ml (dialyzer) = 139 ml

TOTAL: 235 ml can be removed from the child safely. (Nemec, 2021)

Figure 5.5

Blood Pump HD Machine

The speed at which the blood is pumped out of the child and around the circuit is an important determinant of solute clearance (Rees, 2021). Clearance of the blood is known as the removal of urea from the blood in mLs/min (Nemec, 2021).

Source. Image from "Pediatric hemodialysis", © Frenenius Medical Care, 2021. *Used with permission.*

PUMP SPEED

Blood flow speed has to be adjusted to the size of the child and should not exceed their maximum extracorporeal volume in mL/min (i.e., up to body weight x 8 mL/min) in order to safely maintain their cardiovascular status and prevent *dialysis disequilibrium* (Rees, 2021). A blood flow rate of 150-200 ml/min or 3-7ml/min per kilogram is recommended. This flow is much smaller than that of an adult, which is typically 300-400ml/min (Rees, 2021).

SESSION DURATION

For children, the session duration is similar to that of an adult as it is dependant on the predetermined amount and rate of solute clearance and fluid removal (Ashby et al., 2019; Fischbach et al., 2005; Rees, 2021; Souza et al., 2008). Sessions typically range from three to four hours, rarely being shorter than four hours. For most infants and children weighing less than 10 kilograms, the need for more than three sessions a week may be required as their diet consists of fluid (milk), hence four to five sessions a week are frequently prescribed to prevent fluid overload. As children are growing, frequent assessment of the adequate number and duration of each session is recommended.

Figure 5.6

Clock

Source. Image from Wikimedia, Microsoft Bing, 2021. Creative Commons Attribute – ShareAlike 2.0 Generic

DIALYSATE FLOW & TEMPERATURE

- The standard prescription for the *dialysate* is at 36.5º C and can go as low as 36ºC. The temperature can be lowered to help with vasoconstriction of the vessels, to aid in helping reduce hypotension. The temperature should also not be too high to prevent *hemolysis*.
- Dialysate flow is set at 500 mL/min. It can go as low as 300mL/min and high as 800mL/min. The nephrologist will order the flow based on the patient needs.

Nemec, 2021

HEPARINIZATION OF THE CIRCUIT

Figure 5.7

Heparin

Source. Image from "Heparin sodium" by Wikipedia, Microsoft Bing. Creative Commons Attribute – ShareAlike 2.0 Generic

To prevent clotting in the extracorporeal circuit, it is important to use anticoagulation. Loosing the circuit due to clotting can be detrimental to pediatric patients as it can cause hypovolemic shock due to their already low blood volumes (Rees, 2021).

- Patients < 25kg use 100 units/mL
- Patients > 26kg use 1000 units/mL

Dosage is 15-20 units/kg bolus and hourly dose

For example:

12 kg patient would use 100 units/mL = 2 x 10mL = 240 units/bolus and 240 units/hour = total in syringe would be 1100 units or 11 mLs

As per the dialysis unit policy, heparin will be held if the patient is experiencing bleeding. Nemec, 2021

POTASSIUM BATH

Potassium is a main component of the dialysate and aids in serum potassium balance through supplementation in hypokalemia or removal in hyperkalemia (Rees, 2021). The amount of potassium the patient requires is dependant on the patient's serum potassium as per the nephrologist order. This is a guideline as per SickKids in Toronto:

- Serum K 5.0 and > = 0 K bath (> 5.5 K requires cardiac monitoring)
- Serum K 4.0 to 4.9 = 1 K bath
- Serum K 3.5 to 3.9 = 2 K bath
- Serum K 2.0 to 3.4 = 3 K bath
- Serum K < 2.0 = 4 K bath

Nemec, 2021

SECTION SIX: MACHINE SET-UP

PRIMING

Figure 6.0

HD Machine Ready for Priming

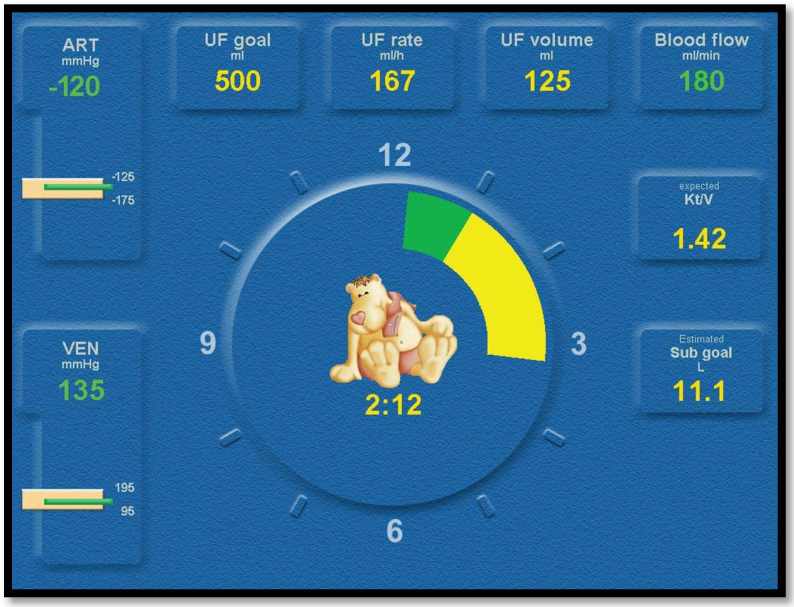
Source. Image from "Pediatric hemodialysis", © Fresenius Medical Care, 2021. *Used with permission.*

Set up and priming the machine for a pediatric patient is very similar to that of an adult with a few differences:

- Dialyzer and tubing size are smaller. These will be located in a dedicated area in the storage room of the dialysis unit and also in the Pediatric ICU at the Janeway.
- Consider the nephrologist orders and patient weight when calculating heparin dosages to set-up during priming.
- You will need a pediatric blood pressure cuff.

Figure 6.1

Pediatric Software



Source. Image from "Pediatric hemodialysis", © Fresenius Medical Care, 2021. *Used with permission.*

Some machines will have a pediatric software option. This software has pre-programmed alarm limits specific to pediatrics such as priming volumes of the tubing and dialyzer, heparin dosing, and blood pressure limits. The screen will look a little different then the adult software but the programming will be similar.

ADULT VS. PEDIATRIC MACHINE SET UP

Table 6.0

Differences Between Adult and Pediatric Machine Set-up

	ADULT	PEDIATRIC
Dialyzer	Large membrane & priming volume > 100 ml. Typically high-flux.	Small membrane & priming volume < 100 ml. Typically low-flux.
Tubing	100-200 ml priming volume.	20-100 ml priming volume.
QB	Limited restrictions based on patient status. 200-400 ml/min	Typically restricted to 30-200 ml/min based on patient status.
QD	500-800 ml/min	200-500 ml/min
Anticoagulation	25-75 units/kg	15-20 units/kg

(Ashby et al., 2019; Cho, 2020; Rees, 2021; Fischbach et al., 2005; Nemec, 2021)

SECTION SEVEN: SCENARIOS

SCENARIO ONE: MEDICATION INGESTION

- It's 3 am and your phone rings. The nephrologist is on the line, there is a patient in the pediatric intensive care unit (PICU) that requires emergency HD following ingestion of a medication.
- You arrive at the PICU and receive report from the nurse. It is as follows:
  - The patient is a 5-year-old female with AKI secondary to the ingestion of a high dose of aspirin.
  - The aspirin was ingested approximately 8 hours ago. The child's symptoms began with vomiting and diarrhea, confusion, and difficulty breathing. Symptoms then progressed to seizures, hypotension, and tachycardia. She is ventilated and sedated. She requires HD to remove the medication quickly and avoid multi-organ failure.

Figure 7.0

Intensive Care

Source. Image from http://blogspot.com by Unknown Author. Microsoft Bing. Creative Commons Attribution-ShareAlike 2.0 Generic

  - Her current vitals are: Blood pressure: 85/45 Pulse: 155 bpm Temperature: 36.9 po. Respiration Rate: 16. Her last weight was 20 kg.

- Her current bloodwork is: Potassium: 3.0 mmol/L, Hemoglobin: 1.58 mmol/L, Creatinine: 512 mmol/L, BUN: 9.4 mmol/L
- The nephrologist is present and you review the written orders to prepare the machine.

HD ORDERS

Figure 7.1

Physician Writing Orders

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- 4-hour HD
- FX 600 Dialyzer
- No UF (fluid removal)
- Heparin 1000 units per hour
- Heparin 1000-unit bolus
- QD 500 (dialysate flow)
- QB 200 (blood flow)
- Temperature 36.5 degrees
- Sodium 138
- Potassium 2.0, Calcium 1.25

KNOWLEDGE CHECK

1. ***After reviewing the orders along with the bloodwork and nurses report, what orders would you need to clarify with the nephrologist?***
   a) Temperature of 36.5° C and calcium 1.25 mmol/L
   b) Heparin dosage of 1000 unit bolus 10000 units per hour and potassium of 2.0 mmol/L

c) Blood flow of 200 and dialysate flow of 500
d) Dialyzer FX 600 and treatment time 4 hours

2. ***Why would you need to clarify the order?***
   a) The temperature and calcium are too high
   b) The heparin dosing is too high and potassium too low
   c) Blood flow and dialysate flow are too high
   d) Dialyzer is not pediatric and treatment time is too low
3. ***What are 3 components of the machine set-up that you ensure are specific to a pediatric patient versus an adult?***
   a) Dialyzer, tubing, blood pressure cuff size
   b) Acid bath, bicarbonate, sodium
   c) Temperature, UF profiling, treatment time
   d) Calcium, sodium, temperature
4. ***After 1 hour of treatment, the patient's oxygen requirements have increased and the chest x-ray shows pulmonary edema. You call the nephrologist who orders 1 Liter (1000ml) fluid removal. According to your maximum UF calculation, is this fluid removal safe?***
   a) No, it is not safe as it is greater than 4% of the patient's body weight or 800 ml
   b) Yes, it is safe as it is less than 7% of the patient's body weight or 1400 ml
   c) No, it is not safe as it is greater than 10% of the patient's body weight or 2000 ml
   d) Yes, it is safe as it is less than 10% of the patient's body weight or 2000 ml

SCENARIO TWO: MULTI-INFLAMMATORY SYNDROME

Figure 7.2

Child Receiving COVID-19 Test

Source. Image from http://www.newsmedia.tasnimnews.com by Unknown Author. Microsoft Bing. Creative Commons Attribute – 2.0 Generic

You're working in the dialysis unit and receive a call from the nephrologist. There is a child in the PICU at the Janeway that has had exposure to COVID-19 eight days ago and is presenting with symptoms of MIS-C.

- Due to the current snow storm, he is unable to be transferred to Toronto. His condition is worsening and he is requiring HD for life-sustaining treatment.
- The patient is transferred to the PICU. You arrive and receive report from the nurse, it is as follows:
- The child is 10 years old and presented to emergency eight days ago with symptoms including: fever for six days, abdominal pain and vomiting, rash on both legs, conjunctivitis, lethargy, and confusion. He swabbed positive for COVID-19. His condition has worsened since this morning and he is presently in shock including respiratory failure and AKI. He is intubated, ventilated, and sedated and in prone position to improve oxygenation. His chest x-ray shows bilateral pleural effusions and there is 3 + pitting edema to bilateral extremities.

- His current vitals are: Blood pressure: 110/62, Pulse: 90 bpm, Respiration Rate: 26, Temperature: 37.2 ºC. His weight is 33 kg.

- His current bloodwork is: Potassium: 5.0, BUN: 10.4 mmol/L, Creatinine 550 mmol/L, Calcium 1.70 mmol/L, Hemoglobin 1.80 mmol/L.

- The family is present at the bedside, they are visibly stressed and have many questions regarding dialysis.

HD ORDERS

- 4-hour HD
- FX 800 Dialyzer
- 2L UF
- Heparin 500 bolus
- Heparin 500 infusion per hour
- QD 300 (dialysate flow)
- QB 300 (blood flow)
- Temperature 35.5ºC
- Sodium 140
- Potassium 4.0
- Calcium 1.25 mmol/L

Figure 7.3

Physician

Source. Image from "Doctor cartoon", Wikimedia Commons, 2021. Creative Commons Attribution- ShareAlike 2.0 Generic

KNOWLEDGE CHECK

1. ***Your assessment of fluid removal involves calculating the maximum UF the patient can tolerate. Based on your calculation, is the nephrologist order safe?***

a) No, the fluid removal is greater than the 5% maximum UF for the patient's weight or 1650 ml
b) Yes, the fluid removal is less than the 7% maximum UF for the patient's weight or 2300 ml
c) Yes, the fluid removal is less than the 10% maximum UF for the patient's weight or 3300 ml
d) No, the fluid removal is greater than the 4% maximum UF for the patient's weight or 1300 ml

2. ***How much total blood volume (ml) can be removed from the patient safely based on the total blood volume calculation? The tubing priming volume is 107 ml and the dialyzer 118 ml.***
   a) 518 ml
   b) 489 ml
   c) 385 ml
   d) 400 ml
3. ***After reviewing the orders and bloodwork, what would you clarify with the nephrologist?***
   a) The calcium and fluid removal
   b) The temperature
   c) The heparin dosage
   d) The blood flow (QB) and potassium
4. ***Why would you need to clarify the order?***
   a) The calcium and fluid removal are too high
   b) The blood flow and calcium are high
   c) The heparin dosage is high
   d) The blood flow and potassium are too high
5. ***The patient's family is very upset and want to know what is happening during the dialysis. How would you respond?***

a) Explain what dialysis is and tell the family that the child is very sick and you are not sure what the outcome will be
b) Provide information, support, understanding, and therapeutic counseling to the family throughout the HD process
c) Provide information but tell them that they need to speak to the nephrologist again

SCENARIO THREE: CVC INFECTION

Figure 7.4

Accessing a CVC

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- An 8-year-old chronic HD patient arrives for their scheduled treatment. The patient mother states the patient has been scratching at his dressing on his CVC for the last two days and the patient states it is itchy. The patient's mother also stated the patient persistently removes his dressing while at home and she has difficulty ensuring the dressing is covering the CVC.
- Before you connect the patient to the machine for treatment, you do an assessment of the patient's CVC and notice the following:
  - Erythema, swelling, tenderness, and purulent drainage around the CVC exit site.
  - You also look in the patient's chart and realize that the patient has had four CVC infections within the last eight months which have been treated with IV antibiotics.

KNOWLEDGE CHECK

1. ***Based on the signs and symptoms the patient is experiencing, what type of infection is occurring at the CVC?***
   a) Tunneled infection
   b) Blood stream infection
   c) Exit-site infection
   d) Staph-aureus infection
2. ***As a nurse, what intervention would you immediately put into place to treat the suspected infection?***
   a) No intervention
   b) Begin dressing changes every HD session with application of topical antibiotic ointment to the exit-site for two weeks or until symptoms resolve
   c) Tell the patient to stop scratching the exit site immediately
   d) Immediately cover the exit site with a foam dressing
3. ***When speaking to the nephrologist, they order IV antibiotics. What suggestions for CVC infection prevention would you make based on the patient risk for infection?***
   a) Suggest no dressing as the patient continues to remove it at home as the patient is low risk for infection
   b) Suggest intralumenal antimicrobial locks as the patient is high risk for infection
   c) Suggest no change in the current treatment plan as the patient is low risk for infection
   d) Suggest prophylactic antibiotics as the patient is high risk for infection

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Appendix A: Scenario Knowledge Check Answers

Scenario One:

1. B- Heparin dosing too high & potassium too low. See page 57.
2. B- As above.
3. A- All smaller sizes than adult. See pages 27, 52, & 53.
4. B- Maximum 7% of the patient's weight can be removed. See page 50.

Scenario Two:

1. B- Maximum 7% of the patient's weight can be removed. See page 50.
2. B- 33 (weight) x 80 (volume) = 2640, x 10% (volume can be removed) = 264. Then add 107 for tubing volume and 118 for dialyzer = 489. See page 54.
3. D- Blood flow too high and potassium too high. See pages 57 & 60.
4. D- As above.
5. B- Provide support to the family. See pages 40 & 41.

Scenario Three:

1. C- Symptoms of exit site infection. See page 48.
2. B- Begin a new dressing regime. See page 48.
3. B- Antimicrobial locks are recommended in patients with a high risk for infection. See page 48.