

SURGICAL SITE INFECTION IN VASCULAR SURGERY:  
AN EXPLORATION OF RISK FACTORS AND  
NURSING INTERVENTIONS

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**Surgical Site Infection in Vascular Surgery: An Exploration of Risk Factors and  
Nursing Interventions**

By

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## *Abstract*

Background/Objectives: Surgical site infection (SSI) is the third most common type of healthcare-associated infection accounting for approximately 38% of all infections in the surgical patient population. In 2005, the Canadian “Safer Healthcare Now” campaign identified 4 strategies to reduce SSI risk based on available evidence: 1) antibiotic prophylaxis, 2) maintenance of glycemic control in the coronary artery bypass graft surgery population, 3) maintenance of intraoperative normothermia in the colorectal surgery patient population, and 4) appropriate preoperative hair removal. Published research is limited on the use of these four strategies in the prevention of SSIs in vascular surgery patients. The purpose of this study was to determine risk factors for SSI in vascular surgery and to identify nursing interventions to decrease this risk. A secondary purpose was to determine the SSI rate for vascular surgery patients.

Methods: A sample of 116 was drawn from all vascular surgery patients who underwent Class 1 (clean) vascular surgeries of interest (bypass and abdominal aortic aneurysm [AAA] repair) during 2005. Every second patient from a list with one of these surgeries formed the sample. Paper and electronic charts were retrospectively reviewed, including post discharge records from outpatients clinics, ER, and the Vascular Laboratory. Information on risk factors for SSI, practices related to the management of risk factors, and incidence of SSI was gathered. Standard CDC definitions were used. An attending physician saw 95.7% of patients within 6 weeks of their surgery.

Results: The SSI rate was 17.2%. Significant SSI risk factors were incorrect timing of antibiotic prophylaxis ( $p = 0.0068$ ), increased glucose or HbA1c level perioperatively in non-diabetic patients ( $p = 0.0468$ ), and abrasion in the incisional area preoperatively with no antibiotic prophylaxis ( $p = 0.0047$ ). Risk factors with a trend but not significant were: not receiving antibiotic prophylaxis with no artificial graft inserted, elevated HbA1c level, hypothermia despite receiving a warming intervention in the post-anaesthesia recovery room (PARR), hypothermia on transfer between units, abrasion in the incisional area preoperatively, emergency procedure, renal/liver disease, increased number of cigarettes smoked, blood loss of 1200-4499 mL, and anemia with blood loss 300-1199

mL. Practice findings included antibiotic prophylaxis was not given to all patients at the correct time or at all, the frequency of glucose and temperature assessments was inconsistent, interventions for hyperglycemia and hypothermia were inconsistently provided and evaluated for effectiveness, aspects of assessment and care were not documented, and policy and protocols for temperature assessment were inconsistently followed.

Implications: The findings highlight elements of care which might reduce SSI in vascular surgery patients. Improvements are needed in glucose and temperature assessment and control, and antibiotic prophylaxis. Additional research is required with a larger sample size, and on strategies to improve adherence to protocols and policies in existence.



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## Chapter 1: Introduction

Patient safety initiatives are important in preventing some of the adverse events that have been identified in Canadian Hospitals (Ross Baker et al., 2004). In order to promote patient safety it is critical to examine these adverse events and the risk factors associated with them. The most frequent type of adverse event reported in the 2004 Canadian Adverse Event study was surgical complications, including surgical site infection (SSI) (Safer Healthcare Now [SHN], 2009). SSIs are associated with high morbidity and mortality. There are a number of factors that increase the risk of SSI development (Spear, 2008). Much of the work that has been conducted on these risk factors has been done in general and coronary artery bypass graft (CABG) surgery. Less work has been done in vascular surgery and the specific risk factors associated with this type of surgery as well as the nursing interventions that may reduce these risk factors. This exploratory, descriptive study was designed to address these gaps in knowledge and contribute to increasing patient safety.

### *Background to the Problem*

Surgical site infection (SSI) is the third most common type of healthcare-associated infection (HAI), and accounts for approximately 38% of all infections in the surgical patient population (Neumayer et al., 2007). Of the surgical procedures performed in the USA each year, 3% of patients go on to develop an SSI (Odom-Forren, 2006). Patients unfortunate enough to develop an SSI are twice as likely to die and 60% more likely to require an Intensive Care Unit (ICU) admission than those who do not have this post-operative complication (Griffin, 2005; Kirkland, Briggs, Trivette, Wilkinson, &

Sexton, 1999; Woods, 2005). Patients who develop an SSI remain in hospital twice as long and have rates of readmission 6 times higher than those without infection (Griffin, 2005; Kluytmans & Voss, 2002; Kirkland et al., 1999). The monetary and time resources required to care for patients who develop an SSI places further stress on an already stressed nursing workforce. There are no recently published Canadian studies that report the financial cost associated with SSI. However, in 1998, Zoutman, McDonald, and Vethanayagan reported that each SSI cost close to \$4000 per wound infection. While this amount appeared high 11 years ago, it is likely that the cost is even higher now. For patients with an SSI, there is increased exposure to antibiotic resistant organisms (AROs) while in hospital, monetary loss due to time away from gainful employment, and decreased quality of life related to illness, pain, stress, decreased mobility and time away from family and loved ones. With vascular surgery in particular, a patient also has a greater chance of requiring an amputation if they develop an SSI (Calligaro et al., 1994).

In response to the preventable economic and personal burden of SSI, in 2004 the USA initiated the "100,000 Lives Campaign". Canada followed this plan in April 2005, and initiated the "Safer Healthcare Now" (SHN) campaign through the Canadian Patient Safety Institute (CPSI). The objectives of these 2 campaigns were to reduce medical errors that were causing suffering and death to patients in acute care institutions. Partnering hospitals in the Canadian SHN campaign received how-to kits, literature resources, access to resource staff, and on-going education to address six specific areas: 1) reduction in deaths from myocardial infarctions, 2) prevention of ventilator associated pneumonia, 3) prevention of SSI, 4) activation of rapid response teams, 5) prevention of medication errors, and 6) prevention of vascular access device infections.



These six interventions were targeted with the primary goal of improving processes for healthcare delivery by focusing on patients and their safety while in the care of health providers in acute care institutions. The program has since been expanded to include prevention of AROs, patient falls, and venous thromboembolism. Eastern Health, in the province of Newfoundland and Labrador, which includes the acute care city hospital used for this study, undertook three projects with the SHN campaign to reduce deaths from myocardial infarctions, prevent ventilator associated pneumonia, and prevent and reduce the rate of SSIs.

The SHN campaign has identified four strategies to reduce SSI risk based on available evidence, which are: 1) antibiotic prophylaxis, 2) maintenance of glycemic control in the Coronary Artery Bypass Graft (CABG) surgery population, 3) maintenance of intraoperative normothermia in the colorectal surgery patient population, and 4) appropriate preoperative hair removal. Published standards are currently available that outline appropriate methods of preoperative antibiotic prophylaxis and hair removal (Bratzler et al., 2005; Mangram, Horan, Pearson, Silver, & Jarvis, 1999; Operating Room Nurses Association of Canada [ORNAC], 2007). Glycemic control has been primarily studied in CABG surgery and critically ill ICU patients, while intraoperative temperature control has mainly been studied in colorectal surgery patients.

### *Study Rationale*

The SHN campaign recommends antibiotic prophylaxis and appropriate hair removal, both of which are accepted practices, to decrease the risk of SSI in most surgeries. However, there is little known information regarding the relevance of

hyperglycemia and hypothermia as risk factors in other surgeries. One such group where limited information exists about risk factors is the vascular surgery patient population.

Patients with peripheral arterial disease (PAD) requiring vascular surgery have a similar pathophysiological process of atherosclerosis as those patients with coronary artery disease (CAD) who require CABG surgery. Both groups also have increased rates of diabetes and hyperglycemia causing glycosylation of the lining of arteries, which leads to arterial complications. Because of the similarity in pathophysiological processes between these 2 groups, and the recommendation of SHN to maintain normoglycemia in CABG surgery patients due to the increased risk of SSIs with hyperglycemia, it seemed reasonable to investigate if hyperglycemia is a risk factor for SSI in vascular surgery patients as well. Because the SHN campaign identified maintenance of normothermia as an intervention to reduce SSI risk, it also seemed reasonable to explore the effect of hypothermia on SSI in the vascular surgery patient population.

Besides the 4 risk factors listed above, several other factors have been identified to increase SSI risk in vascular and other surgeries. Despite not being the focus of this study, these additional risk factors were included in data collection and analysis to assess and control for their effects. Some examples of these risk factors include, but are not limited to: gender, age, location of incision, body mass index (BMI), smoking, and blood transfusions (Abboud, Wey, & Baltar, 2004; Aragon, Ring, & Covelli, 2003; Borger et al., 1998; Kurz, Sessler, & Lenhardt, 1996; Malone, Genuit, Tracy, Gannon & Napolitano, 2002; Neumayer et al., 2007; Trick et al., 2000a; Wilson & Sexton, 2003; Wong, 2004; Yeung, Cope, Whittome, & Lintott, 2008). Additional SSI risk factors identified in other surgeries will be discussed in Chapter 2.



If SSI risk factors are identified in vascular surgery patients, then interventions can be taken to reduce these risks. However, there is little information available, either in the published literature or at Eastern Health, about perioperative nursing assessments and interventions related to addressing patients' SSI risk. Many SSI risk factors, including the 4 identified by the SHN campaign, are amenable to intervention by nurses. Nurses are involved at every stage of the perioperative process and can play a vital role in the reduction of SSIs. Preoperatively, nurses can influence patients through education about strategies to reduce risk factors such as anemia, smoking and increased BMI. Intraoperatively, nurses can ensure timely antibiotic prophylaxis is given and provide appropriate hair removal for each surgery. Intraoperatively as well, nurses can advocate for patients who do not have a voice while under anaesthetic through accurate monitoring and documentation of glucose and temperature control and employment of appropriate interventions to ensure that patients are kept normoglycemic and normothermic. Postoperatively, in the Post Anesthesia Recovery Room (PARR) and on the postoperative unit, nurses can provide timely and accurate assessment and maintenance of normoglycemia and normothermia as well as assessment of wound healing. This study therefore collected data on selected nursing assessments and interventions. Such information could help identify how nurses are caring for patients and if change is required; this information would be helpful to Eastern Health before resources are put into place to change practice.

While risk factors for SSI in vascular surgery in addition to perioperative assessments and interventions provided by nurses were the focus of this study, there was also interest in determining the incidence of SSI in vascular surgery patients as a



secondary objective. Although targeted surveillance is carried out on select patient populations within Canada, the results are not reported into a central registry as exists in the USA with the National Healthcare Safety Network (NHSN), formerly called the National Nosocomial Infections Surveillance reporting system (NNIS) (Edwards et al., 2008). In St. John's city hospitals within Eastern Health, postoperative SSI surveillance had been conducted on select patient populations including CABG, breast, C-section, neurosurgery, colorectal, and gynecologic oncology surgery, while SSI surveillance in vascular surgery has not been a focus. The results of our study could therefore contribute to Canadian statistics on vascular surgery SSI rates.

#### *Study Purpose and Research Questions*

The main purpose of this study was to learn more about vascular surgery patient risk factors for SSI and how nurses intervene to reduce SSI risk in these patients. Based on the recommendations for targeted interventions in other patient populations in the SHN campaign and risk factors for SSI identified in the research literature, the primary research questions were:

- 1) Was preoperative antibiotic prophylaxis appropriate?
- 2) Was perioperative normoglycemia maintained?
- 3) Was perioperative normothermia maintained?
- 4) Was preoperative hair removal appropriate?
- 5) What was the association between these factors and SSI?
- 6) What nursing interventions related to these four factors were used by nurses?

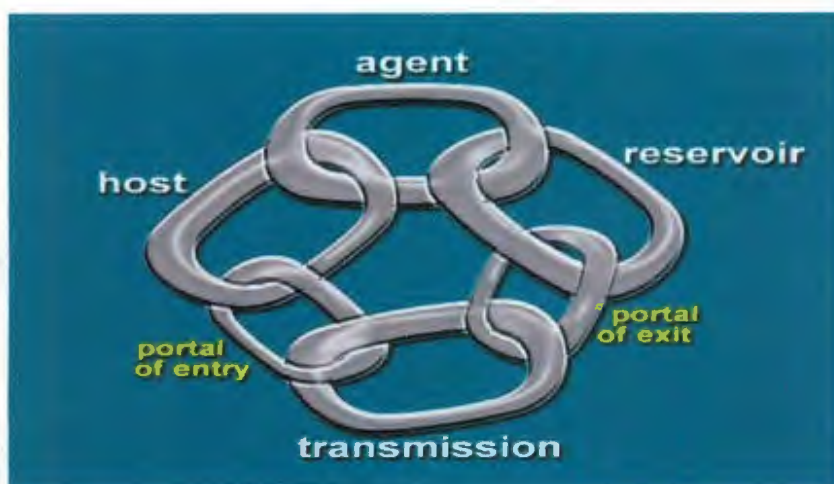
Secondary research questions were:

- 7) What was the incidence of SSI?
- 8) What were other important risk factors for SSI?

### *Study Framework*

The chain of infection model guides Infection Prevention and Control (IP&C) practice and was therefore chosen as the model to guide this research study. The basic tenet is that the chain is made up of links in a sequence of events that must happen for an infection to occur. If any of the links in the chain of infection are broken, then an infection cannot occur (Goering et al., 2008). Figure 1 shows a graphic representation of the chain of infection model.

Figure 1: Chain of Infection



(Used with permission from Dr. D. Moralejo, 2009)

An SSI cannot occur without an infectious agent at the site of the incision. The reservoir in the chain of infection model is the area where the infectious agent or microorganism resides. The source of the infectious agent may be endogenous, meaning from the patient, or exogenous, meaning from the environment (Chalmers & Straub, 2006). Typically, in SSI, there is no portal of exit because the reservoir in many cases is the patient's own skin. Preoperatively, ineffective skin cleansing may leave microorganisms on the skin, increasing the microbial load, which is the number of microorganisms in the area. This is especially relevant for vascular surgery when the incision site is the groin, which has a high microbial load to begin with due to the nature of its location and the moist environment that exists there. Intraoperatively, factors influencing the presence of an infectious agent include incorrect use of antibiotics that do not target the appropriate microorganism or antibiotics that are not given in sufficient time or amount to allow tissue antibiotic levels to be at their peak at the time of the incision. Attention to these factors with appropriate interventions may potentially decrease the microbial load of infectious organisms at the incision site and possibly break the chain of infection.

Transmission of an infectious agent in the chain of infection model occurs when the infectious agent is passed on to the patient. Typically in SSI, this occurs when the surgical incision is made, opening a portal of entry through the skin to the inside of the body. Another portal of entry may occur during hair removal when skin may be abraded or have microscopic nicks that allow entry of microorganisms from the reservoir (skin) into the wound. Health care workers may also be involved in transmission of an infectious agent from an exogenous source to the patient. Some factors affecting



transmission intraoperatively include the improper use of surgical attire like gowns, gloves, caps, shoe covers, and masks or broken sterile technique (Wong, 2004).

The susceptible host is the final link in the chain of infection model. In surgical patients, it is the patient undergoing surgery who may be exposed to the infectious agent that has been transmitted. Factors that increase host susceptibility, which have been termed risk factors, are the focus of Chapter 2 and will be discussed in detail there.

In this study, the chain of infection model provided a framework of links in a chain to consider in terms of risk factors to assess and areas for possible intervention to decrease the risk of SSI.

### *Study Methodology*

This descriptive study used a retrospective chart review of paper and electronic inpatient and outpatient charts to collect information on each patient's glycemic and temperature status, other risk factors for SSI, practices related to the management of risk factors with emphasis on glucose and temperature, and incidence of SSI. Further details of the study's methodology are found in Chapter 3.

### *Summary*

In summary, this exploratory, descriptive study will address gaps in the literature about risk factors for SSI in vascular surgery patients. It will also contribute to nursing literature about interventions to reduce SSI in vascular surgery patients that are amenable to nursing intervention. Finally, it will provide information on the incidence of SSI in vascular surgery within Eastern Health.

## Chapter 2: Literature Review

This chapter provides an overview of the literature relevant to this study. It begins with a summary of methods used for the literature review, a definition of surgical site infection (SSI) and a summary of strategies to use to identify SSIs, which were the outcome measure in this study. It next discusses the chain of infection model and the pathogenesis of SSI including the inflammatory response leading to signs and symptoms experienced by the patient. The literature will then be reviewed about antibiotic prophylaxis, glycemic and temperature control, and preoperative hair removal as these were the main foci of the “Safer Healthcare Now” (SHN) campaign and have been identified as risk factors in other surgical groups. Other risk factors for SSI that were assessed for effects, and to control for confounding, will be discussed as they pertain to surgery patients, with a more specific discussion of vascular surgery studies where studies are available. The chapter will conclude with a brief outline of SSI rates in vascular surgery, and a discussion of interventions nurses can provide to reduce SSI risk and rates.

### *Literature Review Methods*

Sources for the review of the literature were online databases, websites, the Google search engine, textbooks on nursing, microbiology, pathophysiology, and infection control, and the references/bibliographies of journal articles and book chapters. Specific websites reviewed were the Centers for Disease Control (CDC), the Public Health Agency of Canada (PHAC), the Canadian Diabetes Association (CDA), the Community and Hospital Infection Control Association (CHICA-Canada), the

Association for Professionals in Infection Control and Epidemiology (APIC), the International Federation of Infection Control (IFIC), the Operating Room Nurses Association of Canada (ORNAC), the National Association of PeriAnaesthesia Nurses of Canada (NAPANc), the Canadian Anesthesiologists Society, and the American Society of Anesthesiologists (ASA).

For this review an online search of PubMed, CINAHL, the Cochrane Collaboration, and the internet using Google was conducted for the years 1990 – 2009. Some key words used in this search were “risk factor”, “antibiotic prophylaxis”, “glycemic”, “glucose”, “diabetes”, “temperature”, “hypothermia”, “normothermia”, “hair removal”, “surgery”, “infection”, “SSI”, “surveillance”, “nursing”, “intervention”, “assessment”, and “protocol”. Searches were limited to English language publications and research involving humans only. Abstracts were reviewed and applicable articles were obtained. Pertinent full text articles were obtained through e-journals, paper journals and the interlibrary loan system.

#### *Definition of Surgical Site Infection and Risk Factor*

An SSI is an infection that occurs in the incision or surrounding tissue of a patient who has undergone a surgical procedure. The SSI does not exist before the incision is made; instead the microorganisms are transmitted into the incision during the surgical procedure once the skin has been incised. The Centres for Disease Control (CDC) has published criteria for diagnosing an SSI that are found in Appendix I and were used for the diagnosis of SSI in this study (Mangram, Horan, Pearson, Silver, & Jarvis, 1999).



As described in Chapter 1, a number of factors will influence whether or not an infection develops, even in the presence of infectious agents. A risk factor is any variable that has a significant, independent association with the development of an SSI (Horan, Andrus, & Dudeck, 2008). However, before determining the relationship between risk factors and SSI, which was the primary purpose of this study, it is important to have an accurate account of the number of SSIs that developed. Routine monitoring of SSIs is referred to as surveillance.

### *SSI Surveillance*

While this study was not a surveillance study, use of surveillance methods was appropriate to identify SSIs. Therefore, a review of the literature on surveillance methods was done to identify strategies that would balance the ability to find cases (sensitivity) with feasibility. The findings of this review will be presented briefly here. Several options exist for conducting SSI surveillance; each method has benefits and limitations (Mangram et al., 1999; Zoutman et al., 2003).

One of the most cost efficient methods is to mail out a questionnaire to patients; however, these may have a return rate as low as 2% (Gravel-Tropper, Oxley, Memish, & Garber, 1995), with most return rates being between 15.2 – 57.5% (Fanning, Johnston, MacDonald, LeFort-Jost, & Dockerty, 1995; Mitchell, Swift, & Gilbert, 1999; Poulsen & Meyer, 1996). Higher return rates were found in one study where the questionnaire return rate was 71.2% at week 4 after discharge, decreasing to 60.1% at week 6 after discharge (Whitby et al., 2002). Questionnaires may also have a low sensitivity measurement, which is the proportion of actual cases that are detected. A sensitivity of 0.09 – 0.28 has

been reported, meaning that the questionnaire is only able to detect 9 – 28% of cases of SSI that actually developed (Holtz & Wenzel, 1992; Sands, Vineyard, & Platt, 1996; Whitby et al., 2002). This low sensitivity measurement may be due to the fact that they are not completed and returned or that they rely on patient self-report.

In a systematic literature review, Petherick, Dalton, Moore, and Cullum (2006) reported on a study that assessed patient self-diagnosis of SSI through telephone survey or questionnaire (Seaman & Lammers, 1991). This study reported that only 52.4% (n = 11) of 21 patients accurately identified an SSI. Inflammation was incorrectly identified as an SSI in 47.6% of the cases. However, other studies have shown a high correlation between patient self-report and actual SSI presence (Mitchell et al., 1999; Valentine, Steele, & Zaloga, 1998).

Studies of telephone surveys by Infection Control Practitioners have reported that 72.3 -95.4% of patients were able to be reached for surveillance but they also have the potential to be very labour intensive as well if calls are not taken by the patients and repeat calls are necessary (Fanning et al., 1995; Martinez et al., 1997). Surgeons' reports are another logical way to identify an infection, as surgeon diagnosis is one of the criteria in the CDC guidelines to use for identification of SSI (Mangram et al., 1999). However, the sensitivity of this method may be diminished if the surgeon does not have the opportunity to assess the patient post-discharge, or does not return a questionnaire (Sands et al., 1996).

Accessibility of charts makes their review very feasible. Charts have different components that could be used for surveillance with variable sensitivity accorded to each part. For example, laboratory result based surveillance has a sensitivity of 0.77 – 0.91,



while reviewing antimicrobial usage has a sensitivity of 0.70, and screening hospital kardexes has a sensitivity of 0.75 – 0.94. Surveillance sensitivity measurements for other methods such as fever record reviews is much lower at 0.09 – 0.56 (Pottinger, Herwaldt, & Perl, 1997; Roy & Perl, 1997; Smyth & Emmerson, 2000). Total chart reviews, which review all sources including laboratory data, notes, and visits to the facility such as to the ER and OPD, are the most commonly used method for SSI surveillance, as they balance feasibility with an acceptable sensitivity of 0.74 – 0.94 (Haley et al., 1980). The total chart review was the chosen surveillance method for this study because of the feasibility and sensitivity of this method.

The sensitivity of any of these methods for detecting the true SSI rate is affected by the period of surveillance. According to the CDC guidelines, surveillance for SSI should not be limited to the hospital period only. For surgical patients without an artificial implant inserted during surgery, surveillance should be done up to 30 days after surgery including after the patient is discharged. For patients who have an artificial implant during surgery, their surveillance should be done for a full year (Mangram et al., 1999).

Post-discharge surveillance is essential to identifying an accurate SSI rate, as it has been estimated that 46 to 84% of infections occur after discharge (Burns & Dippe, 1982; Delgado-Rodriguez, Gomez-Ortega, Sillero-Arenas & Llorca, 2001; Jonkers, Elenbaas, Terporten, Nieman, & Stobberingh, 2003; Mitchell et al., 1999; Moro et al., 2005; Sands et al., 1996). The most common post-discharge surveillance method of total chart reviews, previously described, count only those patients who report back to the facility with an SSI up to 30 days or 1 year after surgery depending on the presence of an implant. This type of post-discharge surveillance will not identify patients who developed



an SSI but saw their family physician or went to another facility, or did not seek treatment, likely resulting in under-reporting of the true SSI rate.

For post-discharge surveillance to be complete, each patient should be assessed to determine whether an SSI did or did not develop, verifying that those counted as not having an SSI in fact did not have one. This post-discharge surveillance can take place through Infection Prevention and Control (IP&C) practitioners phoning patients, surgeons returning forms on all patients, with or without an SSI, or a chart review of clinic visits if all patients return to the same clinic. Yetman, Moralejo, and Coffin (2001) conducted a study with patients in St. John's, the site of this study, where they compared SSI rates as calculated by 3 methods: phone calls by the IP&C practitioner on all patients, return of SSI notification forms by community health nurses, and total chart reviews as previously described. Routine surveillance done on patients having undergone a C-section would have missed two thirds of infections that developed postoperatively if they had limited their surveillance to standard methods of total chart reviews only.

The final factor in SSI surveillance is the use of standardized criteria, such as those from the CDC, to diagnose infection. The use of standardized criteria ensures that results are comparable within an IP&C program, regardless of when the data were collected or who collected it, and between different studies that report SSI surveillance (Smyth & Emmerson, 2000).

#### *Overview of the Literature on Risk Factors*

A review of the literature yielded only 6 studies that specifically investigated risk factors for SSI in vascular surgery patients. One of these 6 studies was a systematic

literature review of 22 studies that focused primarily on antibiotic prophylaxis as a risk factor for SSI and did not report on other risk factors assessed in this study. There is more information available about SSI risk factors in other patient populations than vascular surgery. Because of the lack of literature related to vascular surgery patients, the focus of this review is on studies of other surgical patient groups, such as those with coronary artery disease (CAD) undergoing Coronary Artery Bypass Graft (CABG) surgery. There is a lot of emphasis on literature regarding patients with CAD because of similarities in the pathophysiological processes that occur in patients with CAD and peripheral arterial disease (PAD).

#### *Peripheral Arterial Disease, Coronary Artery Disease and Diabetes*

The pathophysiological process of atherosclerosis is common to CAD (the indication for CABG surgery) and PAD (the indication for vascular surgery). This process causes the development of hard plaques on the arteries of patients with CAD and PAD. These hard plaques thicken and subsequently narrow the opening in the affected arteries, thereby reducing blood flow and oxygen supply to the organs and tissues they supply. In CAD, the coronary arteries supplying the heart are affected, and in PAD, the peripheral arteries supplying the extremities are affected (McCance & Huether, 2006).

The most common symptom experienced by patients with PAD is intermittent claudication. This is a severe pain in the calf, thigh or buttock muscle caused by ischemia, or a lack of oxygen to the affected extremity (Fowkes, Dunbar & Lee, 1995; Garcia, 2006). PAD is a fairly common disease affecting 21-67% of nursing home residents in estimates in the USA (Vouyouka & Kent, 2007) and is a major cause of disability, loss of



work, and lifestyle changes (Garcia, 2006). It has been estimated that up to 50% of patients with PAD also have CAD though they may not know it (Brevetti et al., 2008). In fact, the majority of patients with PAD die from CAD (Leng et al., 1996; Monreal et al., 2008) but not before suffering through the severe pain and tissue gangrene and amputation associated with PAD (Garcia). Major risk factors for PAD, which are very similar to CAD, are hypertension, smoking, hypercholesterolemia, dyslipidemia, and increased body mass index (BMI) (Coughlin, Gulati, Mavor, Gough, & Homer-Vanniasinkam, 2007; Garcia; Hirsch et al., 2006; Leng et al.; Monreal et al.; Murabito et al., 2002; Selvin & Erlinger, 2004; Willigendael, Teijink, Bartelink, Kuiken, & Boiten et al., 2004). One of the primary contributors to PAD is diabetes, which is also a common contributor to CAD due to the same pathophysiological process of glycosylation of the capillary basement membrane of arteries which sets up the process of atherosclerosis (McCance & Huether, 2006).

The prevalence of diabetes in Canada in 2005 was 1.8 million Canadians, 5.5% of the population (Public Health Agency of Canada [PHAC], 2007). By the year 2016, this is expected to increase to 2.4 million Canadians with diabetes (Canadian Diabetes Association [CDA], 2008). With increased numbers of patients with diabetes, the rate of PAD will possibly also rise requiring more patients to undergo vascular surgery assuming there is no improvement in the prevention of diabetes or alternate therapies for better glycemic control discovered. Because CAD and PAD have such a similar pathophysiological process, it would seem reasonable that risk factors for SSI in CABG surgery, about which there is a lot of information, may also be similar to risk factors in vascular surgery, about which there is very little known.



### *Chain of Infection, Host Defenses, and Pathogenesis of SSI*

To understand risk factors, an understanding of the chain of infection, host defenses, and the pathogenesis of infection is necessary. As outlined in the introductory chapter, the chain of infection involves an infectious agent (microorganism) in the reservoir, transmission of the infectious agent through a portal of entry, and a susceptible host to receive the infectious agent. For an SSI to occur, there must be microbial presence in the wound that cannot be handled by available white blood cells (WBCs) and transmission of the infectious agent from a reservoir into the patient's surgical incision at the time of surgery (Mangram et al., 1999). Most often, the reservoir implicated in SSI development is the patient's own skin or gastrointestinal tract. Frequently, Gram-positive *staphylococci* are the offenders but if a groin incision is involved, there may also be Gram-negative bacteria due to close proximity to the perineum (Mangram et al.; Wong, 2004). However, other reservoirs with microorganisms may be in the operating room (OR) environment with transmission from the air or from contaminated equipment or surgical gloves. These microorganisms may then be transmitted to the patient undergoing surgery, the susceptible host in the chain of infection.

The probability that an infection may occur is increased by 3 factors: 1) host defenses, 2) the virulence of the microorganism, and 3) the microbial load (Goering et al., 2008). Host defenses include physiological defenses that enable the individual to fight off the offending microorganism and not allow an infection to take hold, such as adequate white blood cells to phagocytose the microorganism or adequate blood supply to bring nutrients and oxygen to the area affected. Thus, any comorbidity that reduces these defenses in the patient becomes a risk factor. Even for a patient with adequate host

defenses, an infection still may develop if the microorganism is especially virulent or resistant to many antibiotics and overcomes the host defenses. Alternatively, a high number of microorganisms entering the wound, known as the microbial load, may also overcome the normal defenses of the patient undergoing surgery. Therefore, antibiotics are given prophylactically and skin is cleansed preoperatively with an antiseptic to decrease the microbial load.

If infectious agents infiltrate the body's defenses and enter the area of the surgical incision, they will begin to replicate, damaging surrounding cells and initiating an inflammatory response. In the inflammatory response, blood vessels in the area will dilate leading to warm, red skin (erythema), WBCs will rush to the area to phagocytose the offending infectious agent leading to pus in the area, capillary membranes will become leaky leading to swelling (edema) in the area, and pain receptors (nociceptors) in the area will be stimulated by edema. In addition, chemical mediators from the inflammatory response will cause pain and fever (McCance & Huether, 2006). The inflammatory response that occurs with an infection leads to the signs and symptoms that herald the development of an infection: erythema, pus, edema, pain and fever.

The criteria of the most commonly used definition of SSI (Mangram et al., 1999) include the signs and symptoms experienced by the patient and are outlined in Appendix I. These signs and symptoms brought about by the aforementioned inflammatory response are important to clinically diagnose a patient with an SSI.



### *SSI Risk Factors*

Regardless of the location or depth of the SSI or the signs and symptoms experienced by the patient, an SSI will not occur if the offending microorganism cannot overcome the host defenses. Any factor that decreases the host defenses is a risk factor. As already mentioned, there are many studies that have explored the relationship between risk factors and SSI in other surgical populations. What follows in this section is a discussion of the 4 major risk factors identified by the "Safer Healthcare Now" (SHN) campaign, namely, inappropriate antibiotic prophylaxis, perioperative hyperglycemia and hypothermia, and inappropriate hair removal. In the vascular surgery literature on SSI risk factors, only 6 studies were found related to risk factors for SSI. One of these 6 vascular surgery studies investigated the effect of hyperglycemia on SSI risk, but no other vascular surgery studies investigated antibiotic prophylaxis, inappropriate hair removal, or intraoperative hypothermia as risk factors, which were the risk factors of the SHN campaign. This section will conclude with a discussion of other risk factors identified in studies of both vascular surgeries and other surgeries, as these other risk factors were assessed in this study to identify their effect and control for confounding.

#### *Antibiotic Prophylaxis and SSI*

Antibiotic prophylaxis refers to the administration of an antibiotic before the surgical incision is made. By giving the antibiotic prior to the surgical incision, this ensures that adequate tissue levels of antibiotic are available to reduce the microbial load to an amount that the body's WBCs can remove from the body. Consensus guidelines on antibiotic prophylaxis are widely available in the literature and are based on studies that



have examined the effect of antibiotic prophylaxis on the reduction of infection (Blondel-Hill & Fryters, 2006; Mangram et al., 1999). In a meta-analysis of 22 RCTs that explored risk factors for SSI in vascular surgery, prophylactic systemic antibiotics reduced the risk of wound infection by 69% ( $p = 0.02$ ) (Stewart, Evers, & Earnshaw, 2007). Guidelines specific for vascular surgery state that it is appropriate to use antimicrobial prophylaxis in vascular surgery when: 1) an intravascular prosthesis is to be placed, 2) a lower extremity is being revascularized, and/or 3) there is arterial surgery involving the abdominal aorta or a groin incision (Blondel-Hill & Fryters; Mangram et al.; Wong, 2004). In this study, all patients fulfilled at least one of these criteria.

In providing antibiotic prophylaxis, close attention must be paid to: 1) the microorganisms most likely to be encountered during the operation and therefore the appropriate drug, 2) the timing of the antibiotic so that tissue levels have reached their peak while the incision is being made, 3) the maximum therapeutic level of the antibiotic to be maintained throughout the operation, 4) the dose, which should be based on patient weight so that the drug reaches all tissues, and 5) the timely discontinuation of the antibiotic after surgery to prevent the development of antibiotic resistant organisms (AROs) (Wong, 2004).

The most commonly encountered microorganisms in vascular surgery are those found on the skin and in the groins, such as *Staphylococcus aureus* or *Staphylococcus epidermidis*, which are sensitive to cephalosporins (Blondel-Hill & Fryters, 2006; Mangram et al., 1999). Cefazolin, a first generation cephalosporin, is the antibiotic of choice in clean vascular surgery as it is directed against Gram-positive bacteria that are most commonly encountered (Bandyk, 2008; Blondel-Hill & Fryters; Bratzler & Houck,

2004; Griffin, 2005; Homer-Vanniasinkam, 2007; Mangram et al.). In the case of a penicillin allergy, clindamycin is the antibiotic of choice (Blondel-Hill & Fryters; Mangram et al.).

The dose of the antibiotic is also very important for prophylaxis. For heavier patients, there is more tissue to be perfused with antibiotics. For adult patients weighing less than 100 kilograms (kg), 1 gram (g) of cefazolin is sufficient for prophylaxis, but patients weighing greater than 100 kg should be given 2 g of cefazolin to reduce SSI risk (Bandyk, 2008; Blondel-Hill & Fryters, 2006; Bratzler & Houck, 2004; Ramiro, Kaplan, Guerami, Wrobel, & Marzouk, 2007).

The half-life of cefazolin is 1.5 – 2.5 hours for those with normal kidney function (Bratzler & Houck, 2004; Springer, 2007). A repeat dose of antibiotics after 4 hours in the OR is recommended in the literature to keep therapeutic levels of the antibiotic available (Bandyk, 2008; Blondel-Hill & Fryters, 2006; Bratzler & Houck; Mangram et al., 1999). Morita et al. (2005) reported that an SSI developed in 26.5% of patients who should have received a second dose but did not, compared to 8.5% of those patients who did receive a second dose as recommended.

Correct timing of the antibiotic is essential to reduce SSI risk and late administration of antibiotics has been suggested to raise SSI risk (Bandyk, 2008; Classen et al., 1992; Dellinger et al., 2005; Griffin, 2005; Silver et al., 1996; Stewart et al., 2007). In a study of 2847 surgical patients, regression confirmed that preoperative administration of antibiotics, compared to postoperative administration, is associated with the lowest risk of SSI. Patients who received the antibiotic after the incision was made had 5.8 times the risk ( $p < 0.0001$ ) of developing an SSI as those who received it before the incision was



made (Classen et al.). The antibiotic should be given preoperatively, within 0 – 60 minutes before the incision is made. The timing of the antibiotic in this way is essential to ensure that plasma levels have reached a peak and the incisional tissue is being perfused with antibiotic, thus providing bacteriocidal action, when the incision is made (Bandyk, 2008; Blondel-Hill & Fryters, 2006; Bratzler & Houck, 2004; Griffin; Odom-Forren, 2006).

A final factor in appropriate antimicrobial prophylaxis is discontinuation of the antibiotic within 24 hours of surgery. Stewart et al. (2007) reported, in a meta-analysis of 22 RCTs that explored prevention of SSI in vascular surgery patients that continuing the antibiotic past 24 hours conferred no additional benefit. In a study by Harbath, Samore, Lichtenberg, and Carmeli (2000), continuing the antibiotic past 24 hours was also not significantly associated with decreased SSI risk, but patients who continued to receive antibiotics after 48 hours for no indication had 1.6 times ( $p = 0.027$ ) the risk of having an ARO, compared to those patients who had their antibiotics discontinued. Other antibiotic protocols also recommend discontinuation of antibiotics within 24 hours to prevent organisms from developing drug resistance (Bratzler & Houck, 2004; Dellinger et al., 2005; Plonczynski, 2005).

#### *Diabetes, Hyperglycemia and SSI*

Having a diagnosis of diabetes mellitus has been identified as an independent risk factor for SSI in studies, particularly in patients undergoing CABG surgery, with risk increased by 2 – 6 times that of non-diabetic patients (Fietsam, Bassett, & Glover, 1991; Slaughter, Olson, Lee, & Ward, 1993; Talbot, 2005; Zacharias & Habib, 1996). In a study



by Latham, Lancaster, Covington, Pirolo, and Thomas (2001), SSI risk was increased significantly if a CABG surgery patient was diabetic (OR: 2.72; 95% CI: 1.64 – 4.66;  $p < 0.001$ ), and in a study by Borger et al. (1998), the proportion of diabetic patients having CABG surgery who developed a deep sternal wound SSI, 38%, was almost double that of nondiabetic patients, 19.3% of whom developed an SSI ( $p = 0.001$ ). Zacharias and Habib found similar results, in which the odds of developing a sternal wound SSI with CABG surgery were 5.9 times that of nondiabetic patients (OR: 5.9; 95% CI: 2.8 – 12.5;  $p < 0.01$ ). The presence of diabetes as a risk factor for SSI has also been seen in general surgery patients (OR: 1.55; 95% CI: 1.11 – 2.16;  $p = 0.010$ ) (Malone et al., 2002). In a study that combined general and vascular surgery patients ( $n = 28161$  vascular surgery patients as part of a study of 163,624 patients), having a diagnosis of diabetes was an independent risk factor for SSI ( $p < 0.0001$ ) though this study did not report the risk for the vascular surgery patients separately (Neumayer et al., 2007). In only vascular surgery patients, there was only 1 older study of 561 patients found, in which having diabetes incurred 2.9 times the risk ( $p = 0.03$ ) of developing an SSI (Richet et al., 1991).

Furnary and Wu (2006) stated that it is not the diagnosis of diabetes itself that raises risk but the common attributes of diabetic patients such as obesity and impaired renal function that increases risk. Over a 19-year period, they investigated whether it is actually hyperglycemia experienced by the patient and not the diagnosis of diabetes that raises SSI risk as well as risk for other outcomes such as death, and these studies will be discussed shortly (Furnary & Wu). Elevated glucose levels in the postoperative period have been significantly associated with: 1) a longer postoperative recovery period in the Intensive Care Unit (ICU) and in hospital, translated into increased cost and suffering, 2)

other health associated infections (HAIs) of the urinary tract, bloodstream, vascular access devices, and lungs, 3) cardiac dysfunction, and 4) higher mortality (Dronge et al., 2006; Estrada, Young, Nifong, & Chitwood, 2003; Furnary & Wu; Furnary, Wu, & Bookin, 2004; Grey & Perdrizet, 2004; Krinsley, 2003; Lazar et al., 2004; Neumayer et al., 2007; O'Sullivan et al., 2006; Umpierrez et al., 2002). When researchers provided interventions that lowered glucose levels to 11.1 mmol/L or less, decreases have been seen in: 1) length of ICU and hospital stay, 2) length of time on a ventilator or receiving inotropic medication in ICU, 3) HAI development, 4) incidence of atrial fibrillation, myocardial ischemia, and need for pacing, 5) mortality, 6) new organ failure and polyneuropathy, and 7) need for transfusion of blood (Furnary & Wu; Furnary et al., 2004; Grey & Perdrizet; Lazar et al.; Van Den Berghe et al., 2001).

With respect to infections in diabetic patients, an increased incidence in the numbers of infections seen in diabetic patients is owed to: 1) tissue hypoxia from micro and macrovascular disease, 2) elevated glucose levels in tissues promoting bacterial growth, 3) impaired neutrophil function with respect to chemotaxis, phagocytosis, and intracellular bacteriocidal activity, and 4) changes in vascular permeability leading to edema and promotion of bacterial growth, all of which decrease host defenses (Aragon et al., 2003; Campbell, 2007; Dronge et al., 2006; Golden, Kao, Peart-Vigilance & Brancati, 1999; McCowen, Malhotra, & Bistrian, 2001; Smiley & Umpierrez, 2006).

While it is clear that hyperglycemia increases risk of infection this factor has not been well researched in vascular surgery patients. Of the 6 studies found that looked at risk factors in the vascular surgery population, only 1 explored the relationship between elevated preoperative glycosylated hemoglobin (HbA1c) and SSI in vascular surgery



patients (O'Sullivan et al., 2006). This study will be discussed later in this section. A study by Vriesendorp, Morelis, DeVries, Legemate, and Hoekstra, (2004) found an independent association between elevated post-operative glucose and all HAIs ( $p = 0.007$ ), but did not specify the relationship between hyperglycemia and SSI in particular, so this study is not discussed further.

To determine for this study what level was to be considered hyperglycemic and what timeframe of hyperglycemia during the perioperative period incurred increased risk of SSI, a literature review was undertaken of other surgery patients. Because diabetes is a common comorbidity and atherosclerosis is the same pathophysiological process in patients with PAD as it is with patients with CAD, a review of the literature of CABG surgery patients that explored risk factors for SSI, particularly hyperglycemia was undertaken. Twelve studies examined the effect of postoperative hyperglycemia on SSI; 8 were studies of CABG surgery patients, and 4 were studies with other surgery or critically ill patients. The search also yielded 5 studies that explored the effect of preoperative hyperglycemia on SSI. All values in the discussion have been converted from mg/dL to SI units, mmol/L, for ease of comparison. Table 1 in Appendix B gives further details on these studies related to methodology, definition of SSI if available, results, and limitations. What follows is a discussion of the studies of postoperative and preoperative glucose control and their effects on SSI risk in critically ill patients or patients undergoing surgeries other than vascular surgery.

*Post-operative hyperglycemia and SSI.* Eight studies of CABG surgery patients found a significant association between postoperative glucose control and the



development of SSI (Furnary, Gao, Grunkemeier, Wu, Zerr et al., 2003; Furnary et al., 2004; Furnary & Wu, 2006; Furnary, Zerr, Grunkemeier, & Starr, 1999; Guvener, Pasaoglu, Demircin, & Oc, 2002; Latham et al., 2001; Lazar et al., 2004; Zerr et al., 1997). These studies had samples of 1000-5500 participants, with the exception of Lazar et al., who had 141 patients. In all 8 of these studies, SSI risk was increased for glucose levels of 11.1 mmol/L or greater. In Furnary et al. (1999, 2003, 2004) and Furnary & Wu (2006), which will be collectively referred to as the Furnary et al. (1999-2006) studies, as well as the study by Zerr et al., data had been collected cumulatively over a nineteen-year period with the same significant association being found between SSI and hyperglycemic values of 11.1 mmol/L or greater in the first 48 hours postoperatively. In Furnary & Wu, for every 2.8 mmol/L increase in glucose, the risk of deep sternal wound SSI increased more than two-fold ( $p < 0.0001$ ). Latham et al. reported that risk of SSI was 2.5 times higher in patients with glucose levels of 11.1 mmol/L or greater, compared to those with glucose levels less than 11.1 mmol/L. Risk more than tripled when glucose levels were greater than 16.7 mmol/L compared to less than 11.1 mmol/L ( $p < 0.0001$ ). In one study by Furnary et al. (2004), the value of 9.7 mmol/L appeared to be the critical point at which SSI risk began to increase significantly.

Some of these studies reported on hyperglycemia in the intraoperative and early postoperative period immediately after surgery only, while other studies reported glucose values throughout the perioperative period and up to 48 hours after surgery. Glucose values were averaged to find a daily glucose value and glucose control was maintained with a continuous intravenous infusion of insulin (CII), with glucose levels being checked at intervals ranging from every 20 minutes to every 2 hours (Furnary et al., 1999-2006

studies; Latham et al. 2001; Lazar et al., 2004), or every 4 hours (Guvener et al., 2002). The study by Zerr et al. (1997) used sliding scale subcutaneous insulin for treatment of glucose levels that were assessed every 1 – 2 hours. This study served as the basis of comparison for the studies by Furnary et al. (1999-2006). They compared patients with CII who had increasingly tighter glucose control postoperatively, as low as 3.9 mmol/L, and investigated the effects of this increasingly tighter control on SSI risk. Comparison of the rates of SSI and how the varying postoperative glucose levels affected this rate is quite challenging with these particular studies. This challenge was due to: 1) the inconsistency with how hyperglycemia was defined, 2) the variation in frequency with which the glucose values of patients were assessed and the interventions received for hyperglycemia, 3) the lack of information on the criteria used to diagnose an SSI, and 4) the differing periods of surveillance postoperatively. All of these challenges limit the comparability of the studies. Regardless of these limitations, hyperglycemia greater than 11.1 mmol/L increased SSI risk.

The association between hyperglycemia postoperatively and SSI risk has not been as well studied in populations other than CABG surgery. However, 4 studies were found that explored this relationship in other surgeries or critically ill patients. In 2008, Vilar-Compte et al. studied the association between perioperative hyperglycemia and SSI in 260 patients undergoing clean mastectomy surgery. The researchers found that postoperative glucose levels greater than 8.3 mmol/L tripled the risk of SSI ( $p = 0.02$ ) in multivariate analysis. The other 3 studies looked at postoperative hyperglycemia and SSI in critically ill patients (Collier et al., 2005; Grey et al., 2004; Krinsley, 2004). Only 1 study of 61 critically ill general surgery patients found that significantly more patients



with a mean postoperative glucose of  $9.9 \pm 3.4$  mmol/L developed an SSI compared to patients with a glucose level of  $6.9 \pm 2$  mmol/L ( $p < 0.05$ ) (Grey et al.). The other 2 studies did not find a significant association between elevated glucose postoperatively and SSI risk (Collier et al.; Krinsley). In both of these studies, 2 groups receiving different glucose control strategies were compared for SSI risk related to hyperglycemia. However, in both studies, independent of the treatment used, the patients' mean postoperative glucose levels were 8.3 mmol/L or less. This is lower than the value associated with an increased risk of SSI in other studies. These results suggest that tighter glucose control decreases the risk of SSI but this does not help identify the threshold or cut-off value at which SSI risk increases.

From this review, the conclusion has been drawn that risk for SSI increases when glucose levels are 11.1 mmol/L or greater in CABG surgery patients in the first 48 hours postoperatively and greater than 8.3 mmol/L in patients undergoing mastectomy surgery. What is unknown is how hyperglycemia in the first 48 hours and after 48 hours postoperatively affects vascular surgery SSI risk because there are no studies that report these associations. Although Furnary et al. (2004) found that 9.7 mmol/L was the point at which SSI risk began to rise, the majority of CABG surgery studies found that 11.1 mmol/L was the cut-off value. Therefore, 11.1 mmol/L was chosen as the definition for hyperglycemia in this study. This choice is further supported by recommendations from the CDA (2008) to maintain glucose levels of 8 – 11 mmol/L in the perioperative period.



*Preoperative hyperglycemia and SSI.* None of the 6 vascular surgery studies in the literature search assessed the effect of preoperative hyperglycemia on SSI risk. Five studies were found that did assess the effect of preoperative hyperglycemia on SSI risk in CABG surgery patients (Guvener et al., 2002; Latham et al., 2001; Trick et al., 2000a; Trick et al., 2000b; Wilson & Sexton, 2003). Table 1 in Appendix B gives further details on these studies related to methodology, definition of SSI if available, results, and limitations.

In two separate case-control studies of 309 and 1590 patients, a preoperative glucose level of 11.1 mmol/L or greater in diabetic patients, compared to normoglycemic patients, led to a four times greater risk of SSI at the radial artery donor site ( $p = 0.01$ ) (Trick et al., 2000a), and a ten times greater risk of a deep sternal incision SSI ( $p = 0.008$ ) (Trick et al., 2000b). In univariate analysis, Latham et al. (2001), with a sample of 1000 patients, found that patients with elevated preoperative glucose of 11.1 mmol/L or greater were twice more likely to develop SSI than normoglycemic patients ( $p = 0.005$ ) though elevated preoperative glucose was not identified as an independent predictor of SSI in multivariate analysis.

In a retrospective cohort study of 400 diabetic CABG surgery patients, Guvener et al. (2002) looked at pre-operative glucose levels 2 days before surgery and found that patients with deep sternal wound SSI had a mean preoperative glucose level of  $12.3 \pm 0.6$  mmol/L (which is above the cut-off of 11.1 mmol/L), compared to patients who did not develop an SSI who had a lower mean glucose level of  $9.2 \pm 2.0$  mmol/L ( $p = 0.006$ ). They also found that these patients had increased glucose levels 1 day preoperatively, though these levels were not as high. Those who developed an SSI had a mean 1-day

preoperative glucose level of  $10.1 \pm 0.5$  mmol/L, compared to patients who did not develop an SSI whose mean glucose value was  $7.7 \pm 1.7$  mmol/L ( $p = 0.009$ ). Another study of 258 patients found that a fasting preoperative glucose level of 7 mmol/L or greater incurred more than 5 times the risk of SSI than values less than this (OR: 5.25; CI 95%: 1.82 –15.11)( $p = 0.002$ ) when diabetes, gender and ASA score were controlled for (Wilson & Sexton, 2003).

As with the studies on postoperative glucose control, comparison between studies is quite difficult with these studies due to differing definitions of SSI, frequency of glucose monitoring, and periods of SSI surveillance. Further information on the limitations of these studies is found in Table 1 Appendix B. Overall however, these 5 studies support the conclusion that when glucose levels are elevated preoperatively to 11.1 mmol/L or greater in CABG surgery, there is increased risk of SSI development. What is unclear though is the actual level associated with increased risk as it varied by study, ranging from 7 mmol/L to 12.3 mmol/L. For this reason, as well as reasons already discussed in the section on postoperative glucose control, 11.1 mmol/L was chosen as the definition of hyperglycemia in this study.

*Hemoglobin A1c and SSI.* Because of the significant findings associated with preoperative glucose control, it would seem appropriate to speculate that an elevated HbA1c, as a measure of longer term glucose control over a 2 - 3 month period (Krishnamurti & Steffes, 2001), may also have a significant impact on SSI risk. An elevated HbA1c level has been demonstrated to significantly affect length of stay, mortality, adverse coronary events, cognitive impairment, restenosis of arteries after



angioplasty, and risk of lower limb amputation (Corpus et al., 2003; Kadoi, Saito, Fujita, & Goto, 2005; Malmberg, Norhammar, Wedel, & Ryden, 1999; Mazeika, Prasad, Bui, & Seidelin, 2003; Medhi et al., 2001; O'Sullivan et al., 2006). The CDA (2008) currently recommends that diabetics maintain HbA1c levels at less than 7% and nondiabetics at less than 6%.

In a review of the literature, 3 studies were found that explored the relationship between elevated HbA1c and increased infection risk in surgery patients. One study of 490 diabetic, non-cardiac surgery patients found, after multivariate analysis, that patients with a HbA1c level greater than 7% developed more than twice as many HAIs as those patients with a HbA1c level less than 7% ( $p = 0.007$ ), but the researchers did not report SSI rate specifically (Dronge et al., 2006). In a study by Latham et al. (2001) with 300 diabetic, CABG surgery patients who had HbA1c level measured, 42% had HbA1c values of 8% or greater at the time of surgery. Of these patients, 78% developed perioperative hyperglycemia compared with 43% of the patients with lower HbA1c values (OR 1.78; 95% CI: 1.47-2.16;  $p < 0.001$ ). In this study, while an association was not made between HbA1c and SSI, it was made between postoperative hyperglycemia and SSI as discussed in a previous section, with risk more than doubling for glucose values of 11.1 mmol/L or greater ( $p < 0.0001$ ). From this, it can be inferred that an increased HbA1c level does lead to perioperative hyperglycemia, which in turn leads to increased SSI risk, so an increased HbA1c level may lead to increased SSI risk.

There was only 1 vascular surgery study found that measured SSI as a component of all-cause postoperative morbidity as an endpoint, with elevated HbA1c as a predictor (O'Sullivan et al., 2006). In this study of 165 vascular surgery patients, it was found that a



less than optimal HbA1c level of greater than 6% in non-diabetic patients was a significant predictor of postoperative morbidity, including SSI. These non-diabetic patients with a suboptimal HbA1c developed significantly more incisional SSIs than did non-diabetics with normal HbA1c values (9.9% vs. 0%;  $p < 0.041$ ). The study does not report the SSI rate in diabetic patients with suboptimal HbA1c levels.

Thus, while there were few studies found that explored the relationship between elevated HbA1c and SSI, one study of vascular surgery patients did show that it was a significant risk factor in this patient population. Table 1 in Appendix B provides further details on the preceding 3 studies related to methodology, definition of SSI if available, results, and limitations.

#### *Conclusion: Hyperglycemia and SSI*

In these studies of the effect of preoperative and postoperative hyperglycemia, as measured by glucose levels or HbA1c on risk for SSI, glucose measurement methods, definitions of hyperglycemia, postoperative surveillance, and definitions of SSI varied widely or were not reported. Glucose readings entered for data analysis in each study ranged from the highest glucose reading of the day to the mean of all glucose readings during each day or a few days added together. Some studies identified their glucose levels only for the day of surgery and some studies for up to 48 hours post-operatively. HbA1c levels were measured anywhere from 180 days before surgery to after surgery. For treatment of elevated glucose, some studies used subcutaneous insulin for glucose control but the majority received CII. Some considered a patient hyperglycemic at glucose levels greater than 6.1mmol/L, while others didn't treat until the glucose was 11.1 mmol/L or

greater. Definitions of SSI did not always follow the guidelines set out by the CDC and post-operative surveillance ranged from hospital stay only to one-year postoperatively.

Because of the variability in the definitions used, as well as the period of surveillance, it is very difficult to compare SSI rates in these studies. Overall however, the evidence does support the conclusion that a preoperative or postoperative glucose level of 11.1 mmol/L or greater is a risk factor for SSI in CABG surgery patients with less information on other surgical groups.

In vascular surgery patients, there is no information available about how preoperative and postoperative hyperglycemia influences SSI risk. If HbA1c is considered a measure of preoperative glucose control though, the study by O'Sullivan et al. (2006) does provide evidence that HbA1c and thus, preoperative hyperglycemia is a risk factor for SSI. Because of this limited information on vascular surgery patients, research is necessary that explores these relationships further.

#### *Hypothermia and SSI*

Hypothermia has been defined as a core body temperature of less than 36°C (Kumar, Wong, Melling, & Leaper, 2005; Snyder, 2005); this is the definition of hypothermia that was used for this study. Hypothermia in surgical patients is caused by: 1) effects of general and regional anaesthesia leading to dysfunction in the body's thermoregulatory system, 2) cool, ambient temperatures in the OR suite, 3) cooled or room temperature intravenous fluids and large surface areas of skin that are exposed during operative procedures, and 4) exposure to room temperature skin preparations



(Cooper, 2006; Kumar et al.; Leslie & Sessler, 2003; Noble, 2006). Hypothermia interferes with the body's defences in fighting infection by: 1) causing vasoconstriction which leads to a decrease in the partial pressure of oxygen in tissues and availability of oxygen for tissue repair, 2) impairing neutrophil function, 3) leading to shivering thereby causing a build-up of lactic acid and changes in pH and function of enzymes, 4) altering the function of platelets and the activity of clotting factors, and 5) reducing the deposition of collagen essential for tissue repair (Barone et al., 1999; Doufas, 2003; Griffin, 2005; Kumar et al.; Kurz et al., 1996; Melling, Ali, Scott, & Leaper, 2001; Sessler & Akca, 2002).

Research studies have shown that hypothermia is associated with: 1) adverse myocardial outcomes like arrhythmias and reduced cardiac output, 2) increased organ dysfunction, 3) higher mortality, 4) increased thermal discomfort and shivering, 5) increased blood loss and need for transfusions due to its effect on the coagulation cascade, and 6) delayed post anaesthetic recovery (Akca & Sessler, 2002; Barone et al., 1999; D'Angelo, Braz, Modolo, Amorim, & Rodrigues, 2003; Doufus, 2003; Johansson, Lisander, & Ivarsson, 1999; Kumar et al., 2005; Kurz et al., 1996; Lenhardt et al., 1997; Schmied, Kurz, Sessler, Kozek, & Reiter, 1996; Weirich, 2008; Winkler et al., 2000).

There were no studies found that explored the relationship between intraoperative hypothermia and SSI in vascular surgery. There were 3 studies found however, that explored the relationship between hypothermia and SSI in other patient populations, but their results are conflicting (Barone et al., 1999; Flores-Maldonado, Medina-Escobedo, Rios-Rodriguez, & Fernandez-Dominguez, 2001; Kurz et al., 1996). Further details on



these 3 studies are found in Table 2 in Appendix B with information provided about the study methodology, definition of SSI, results, and limitations.

Kurz et al. (1996) studied 200 colorectal surgery patients who were randomly assigned to routine intraoperative thermal care (hypothermic group) or additional warming (normothermic group). They found that patients in the hypothermic group (mean core temperature at the end of surgery  $34.7 \pm 0.6^{\circ}\text{C}$ ) versus normothermic patients (mean core temperature at the end of surgery  $36.6 \pm 0.5^{\circ}\text{C}$ ) developed significantly more SSIs ( $p = 0.009$ ). Another research group attributed this significant finding in SSI risk with hypothermia for the Kurz et al. study to the increased number of blood transfusions received by the hypothermic group and their immune depressing effect (Barone et al., 1999). Kurz et al. had already reported that there was significant difference between the groups with patients developing an SSI having received more blood transfusions ( $p = 0.01$ ). Furthermore, they also reported that after multivariate analysis, the requirement for transfusion was not found to be a predictor of SSI while assignment to the hypothermic group was.

There was a second study that explored the relationship between intraoperative hypothermia and SSI (Flores-Maldonado et al., 2001). In this study of 290 general surgery patients undergoing cholecystectomy, a significant difference between groups that did or did not develop an SSI was found in bivariate analysis. Temperatures were measured on admission to the recovery room. Hypothermic patients had a mean temperature of  $35.4 \pm 0.4^{\circ}\text{C}$ , while normothermic patients had a mean temperature of  $36.2 \pm 0.2^{\circ}\text{C}$ . Of the patients who were hypothermic, 18.8% of the patients developed an

SSI, compared to 5.8% of normothermic patients ( $p = 0.009$ ). However, this difference was not found after logistic regression. It was also noted in this particular study that hypothermic patients had significantly longer periods of time in the OR which has been reported as a risk factor in other studies and may have explained the results. In addition, there were significantly more patients with diabetes and who were older that developed an SSI, also reported as risk factors in other studies, which may also have explained the results.

A third study with 150 colorectal surgery patients found that there was no significant difference in SSI development between groups with and without hypothermia (Barone et al., 1999). Hypothermia was defined as  $34.3^{\circ}\text{C}$  or less at any time in the OR or post anesthesia care unit. In this study, whether the patients were hypothermic or not, 12% of the patients developed an SSI in each group. However, the researchers also looked at the “lowest recorded temperature”. Their normothermic “lowest recorded temperature” was  $35.9 \pm 0.6^{\circ}\text{C}$ . These patients classified as normothermic in this study by Barone et al., would have been classified as hypothermic in the other studies on hypothermia and SSI risk. The only conclusion from this study is that low temperature hypothermia less than  $34.3^{\circ}\text{C}$  is not a risk, but a conclusion cannot be drawn about temperature less than  $36.0^{\circ}\text{C}$ . In the Barone et al. study, the hypothermic and normothermic groups did not receive a significantly different number of transfusions unlike the Kurz et al. (1996) study, so the effect of this as a confounding factor was not an issue.

Overall, from the 3 studies that have explored the relationship between hypothermia and SSI, there is insufficient evidence available to draw a strong conclusion



about the effect of hypothermia on SSI. Research studies are very few in number, have defined hypothermia differently, have utilized different patient populations and infection surveillance periods, and obtained contradictory results. There is no research available on the effect of hypothermia on vascular surgery patients. Despite the ability to make some comparisons between hyperglycemia and SSI in CABG surgery and vascular surgery patients because of the similar pathophysiological process of atherosclerosis, the same cannot be done with hypothermia. In CABG surgery, patients are intentionally cooled much lower than the patients in the studies discussed above and therefore do not provide a comparison group. Because of the gap in the literature related to perioperative hypothermia in vascular surgery patients, as well as the suggestion of the SHN campaign to reduce SSI by focusing on normothermia control in colorectal patients, the relationship between hypothermia and vascular surgery was also explored in this study.

#### *Inappropriate Hair Removal and SSI*

Historically, preoperative shaving of hair with a razor has been viewed as a risk factor for SSI, with clipping with a clipper or no hair removal preferred, as close to the surgical incision time as possible. Some reasons clippers may be beneficial are that they cut the hair close to the patient's skin, usually within 1 mm, without touching the skin and abrading it. As well, the head of the clippers can be disinfected between patients or thrown out after use thereby minimizing the risk of cross-contamination (Tanner, Woodings, & Moncaster, 2006). When compared to razors that may cause microscopic nicks or abrasions, or depilatory solutions that may cause irritation and disrupt skin integrity, the use of clippers does seem like the best choice.



In 2006, the Cochrane Collaboration undertook a literature review of 11 randomized controlled trials (RCTs) to determine if routine pre-operative hair removal resulted in fewer SSIs than not removing hair at all, or if different methods of hair removal such as depilatory solutions, shaving, or clipping hair increased SSI risk (Tanner, Woodings, & Moncaster, 2006). In 2 RCTs reported in the Cochrane Review, removal of hair by a depilatory solution or razor compared with no hair removal did not produce a statistically significant difference for SSI risk when results were pooled, with a total sample size of 358 patients (Court Brown, 1981; Rojanapirom et al., 1992). These studies were not considered of high quality due in part to randomization methods, but they were also insufficiently powered to detect a significant difference (Tanner, Woodings, & Moncaster). There were no trials found in the Cochrane review that compared clipping to no hair removal.

One of the 2 previously mentioned studies also compared different hair removal techniques, as did 9 other studies. In 7 trials comparing shaving with the use of depilatory solution for hair removal, there was no statistically significant difference found when study results were pooled (total  $n = 1420$ ) (Breiting & Hellberg, 1981; Court Brown, 1981; Goeau-Brissonniere et al., 1987; Seropian & Reynolds, 1971; Thorup et al., 1985; Thur de Koos & McComas, 1983). However, a significant difference in hair removal techniques was found in 3 trials that compared shaving with clipping (Alexander et al., 1983; Balthazar, Colt, & Nichlos, 1983; Ko, Lazenby, Zelano, Isam, & Krieger, 1992). Overall, these 3 studies, with a pooled sample size of 3193 patients, found SSI risk was significantly increased when hair was shaved rather than clipped, with 2.8% of patients

developing an SSI when hair was shaved, compared to 1.4% of patients whose hair was clipped (RR: 2.02; 95% CI: 1.21-3.36).

The Cochrane review reported on only 1 study about the timing of hair removal as a risk factor for SSI. In that study by Alexander et al. (1983) of 537 patients undergoing clean surgery, shaving on the day of surgery was compared to shaving the day before surgery and no significant difference was found in the development of SSI. In the same study of 476 other patients undergoing clean surgery, 4% of the patients who had hair clipped the day before surgery developed an SSI, compared to 1.7% of the patients that had hair clipped on the day of surgery. Although the proportion was more than double, the difference was not statistically significant.

The final conclusion drawn by the authors of this Cochrane review was that the available evidence suggests that there is no difference in SSI risk for patients who do or do not have hair removed before surgery (Tanner, Woodings, & Moncaster, 2006). This conclusion must be viewed with caution though, because it is based on 2 poorly designed, underpowered studies that are not of sufficient quality to determine if there was a difference. The Cochrane review authors also concluded that if a patient is to have hair removed, clipping the hair is preferable to shaving and results in fewer SSIs. They further concluded that there is insufficient evidence supporting the use of a depilatory solution as opposed to a razor for hair removal because there was no statistically significant difference found between the 2 methods when results were pooled among the 7 studies (Tanner, Woodings, & Moncaster).

Pending further evidence, current recommendations by the CDC and guidelines most commonly used, as well as the SHN campaign, are to remove hair only when



necessary when it interferes with the surgical incision as close to the time of incision as possible (Mangram et al., 1999; ORNAC, 2007). Recommendations for hair removal appear to differ based on country. Norwegian guidelines recommend using clippers or depilatory cream as close to the surgery time as possible, while the UK guidelines recommend using depilatory cream the day before surgery (Tanner, Woodings, & Moncaster, 2006).

#### *Other Risk Factors for SSI*

There are several other factors that are known to increase the risk of developing an SSI in surgical patients. These include but are not limited to gender, age, emergency surgery, insertion of an artificial graft during surgery, having a groin incision, blood loss, anemia and transfusion of blood, surgeon skill, certain comorbidities such as renal disease, increased American Society of Anesthesiologists (ASA) score, obesity and increased BMI, and smoking. In the remainder of this literature review, when studies are available that have been done with vascular surgery patients, they will be reported. If they are unavailable for vascular surgery patients, reports from other surgical patient populations will be discussed. These risk factors were not the focus of our study. However, their relationship to increased SSI risk in other studies necessitated control of these factors as potential risk or confounding factors in this study. All of these risk factors can be applied to the chain of infection model that guided this study; specifically, most, but not all, are either non-modifiable or modifiable factors that increase susceptibility of the host.



*Non-modifiable risk factors.* Some non-modifiable risk factors of the patient are gender and age. In the vascular surgery literature where gender is reported, there are more men than women actually in the studies (Belkin, Conte, Donaldson, Mannick, & Whittemore, 1995; Brevetti et al., 2008; Chang, Calligaro, Ryan, Runyan, Dougherty et al., 2003; Higgins & Higgins, 2003; Nicholson, Dennis, Makin, Hopkinson, & Wenham, 1994; O'Sullivan et al., 2006; Pounds et al., 2005; Schepers, Kinkert, Peeters, & Breslau, 2003; Sigvant et al., 2007; Turnbull, Zoutman, & Lam, 2005; van Himbeek, van Knippenberg, Niessen, & van Griethuysen, 1992; Vogel, Symons, & Flum, 2008; Vouyouka & Kent, 2007; Vriesendorp et al., 2004). It has been suggested that even though just as many women possibly have PVD, by the time they present with symptoms, their disease is not amenable to surgical reconstruction due to smaller arteries and more advanced disease (Allison et al., 2006; Brevetti et al.; Higgins & Higgins; Vouyouka & Kent).

Although there were more men than women in the above-mentioned studies, the results about gender as a risk factor for SSI are contradictory. In vascular surgery studies by Chang et al. (2003) and O'Sullivan et al. (2006), a non-significant trend towards SSI risk was demonstrated in men. In a study by Vogel et al. (2008), which explored incidence of aortic graft infection, a significant difference was found with more men than women developing an SSI ( $p < 0.001$ ). In contrast, a vascular surgery study by van Himbeek et al. (1992) found that significantly more women developed an SSI ( $p < 0.01$ ).

A second non-modifiable risk factor related to the vascular surgery patient is age. Peripheral arterial disease, which may necessitate having vascular surgery, is a disease that increases with age (Higgins & Higgins, 2003). In one study of 603 vascular surgery

patients by van Himbeeck et al. (1992), older men developed significantly more SSIs than younger men ( $p < 0.01$ ). As mentioned previously, older women are not frequently found in these studies so it is not possible to assess age as a risk factor for SSI in women.

Some non-modifiable risk factors related to the surgical intervention are also risk factors that increase the susceptibility of the host to SSI. Having an emergency or longer than average surgical procedure, insertion of an artificial prosthesis during surgery, having a groin incision, and transfusion of blood are the factors considered here.

Having an emergency procedure has not been identified as a risk factor directly in the vascular surgery literature. However, in a study by Neumayer et al. (2007) in which vascular surgery patients ( $n = 28,161$ ) were part of a much larger study with 163,624 combined vascular and general surgery patients, having an emergency procedure was identified as a risk factor for SSI ( $p < 0.0001$ ). There was no separate analysis reported for vascular surgery patients in this study.

For many countries that report SSI surveillance rates, patients are divided into risk groups based on their risk index. A higher risk index indicates that a patient is at an increased risk for SSI. One component of this risk index is the length of surgery. For surgeries that are longer than the average amount of time it would normally take a surgeon to complete a surgical procedure, the patient's risk index for SSI would rise to a higher level indicating increased risk (Coello et al., 2005; Edwards et al., 2008; Morton, Clements, Doidge, Stackelroth, Curtis, & Whitby, 2008; National Nosocomial Infections Surveillance [NNIS] system, 2004; Neumayer et al., 2007). As well, in a vascular surgery study by Chang et al. (2003) of 365 patients, longer operative time was identified as a risk



factor for SSI ( $p = 0.02$ ). As a result of this set of studies, increased length of surgery is considered a risk factor for SSI.

Artificial implants inserted during surgery have also been reported to increase SSI risk (Bandyk, 2008). It is thought that artificial implants produce a microenvironment that favours bacterial attachment and biofilm formation, which can protect infectious agents from host defenses and antibiotics (Bandyk). There was only 1 vascular surgery study found that reported an assessment of the effect of insertion of an artificial graft on SSI risk. In this vascular surgery study of 365 patients, it was found that artificial implants were actually protective against SSI, as significantly more patients with a vein graft developed an SSI than did those with an artificial graft ( $p = 0.02$ ) (Chang et al., 2003). This finding cannot be attributed to patients with artificial grafts receiving better antibiotic prophylaxis, as the overall antibiotic prophylaxis rate reported was quite good at 92% of patients. The finding of this study that artificial grafts are protective against SSI development should be viewed with some caution though as they may have underestimated the SSI rate in the implant group. While the authors of this study used standard CDC definitions for identification of SSIs, they reported that the period of surveillance ranged from 1 – 16 months with a mean follow-up of 6 months. For patients who did not have an artificial graft, their follow-up is probably quite good because they received a full 30 days of surveillance as recommended by the CDC. However, for patients who had an artificial graft inserted who should receive follow-up for a full year according to the CDC, it is unclear how many of these patients actually received the full follow-up so there may be an underestimation of the true SSI rate in this group.



The presence of an incision in the groin is a non-modifiable risk factor inherent to the surgical procedure. In most vascular surgeries of the lower extremity, the femoral artery needs to be accessed requiring a groin incision. In the vascular surgery study by van Himbeeck et al. (1992), the groin was the most common location for SSI development ( $p < 0.01$ ) in vascular surgery patients. Two other vascular surgery studies by Pounds et al. (2005) and Nicholson et al. (1994) reported that 64% and 85.7% of SSIs, respectively, involved the groin incision. In the study by Pounds et al., the presence of a groin incision was an independent risk factor for SSI ( $p = 0.04$ ). Some reasons for the increased incidence of SSI in the groin include difficulty draping the area, rich lymphatic supply, and overhanging adipose tissue which creates a moist environment for bacteria to flourish (Nicholson et al.; van Himbeeck et al.; Yeung et al., 2008).

*Modifiable risk factors.* There are many modifiable risk factors for SSI as well. However for some factors, it is not easy to determine if they are modifiable or not. Transfusion of blood products is one such example. Blood transfusion may be non-modifiable or modifiable depending on the patient situation. Blood loss during surgery that necessitates blood transfusion may be related to a multitude of factors including, but not limited to, surgeon skill and experience, a difficult surgical procedure, or other patient hematological factors such as impaired blood clotting. While blood transfusion has not been explored in the vascular surgery literature, in the general surgery literature, receipt of blood is associated with SSI as well as other HAIs (Blumetti et al., 2007; Insler, O'Connor, Leventhal, Nelson, & Starr, 2000; Jensen et al., 1992; Marik & Corwin, 2008; Olsen et al., 2008; Tang et al., 2001; Walz, Paterson, Seligowski, & Heard 2006).

Furthermore, in the Kurz et al. (1996) study already discussed, patients who developed an SSI received significantly more transfusions of blood ( $p = 0.01$ ), although it was not a significant independent predictor for SSI.

A second factor that may be modifiable or not depending on the situation is surgeon skill. There are variations in surgeon specific rates, partly explained by the risk index of patients the surgeons care for, partly because of the surgeon's experience in performing particular procedures, but also because of other reasons such as individual surgeon judgement to operate on patients with broken skin, or to prescribe antibiotic prophylaxis. Mangram et al. (1999) identified that reporting the surgeon specific rate back to the surgeon leads to a decrease in SSI rates, suggesting that surgeons pay attention to unspecified details.

A final factor that may be modifiable or not in terms of SSI risk is patient comorbidities. Modifying the risk of development of a disease such as renal disease may be possible in some instances such as good glycemic control in diabetes or adherence to treatment strategies such as dialysis or diet control. However, in other cases of renal disease, this may not be possible making this a non-modifiable risk factor. Whether modifiable or not, certain comorbidities are risk factors for infection.

In their vascular surgery study, O'Sullivan et al. (2006) identified a non-significant trend towards increased postoperative morbidity including SSI, for patients with renal disease. In another study that investigated the factors that led to increased wound complications in vascular surgery for patients with renal disease, an SSI rate of 43% for patients with renal disease was reported (Blankensteijn et al., 1996).



The ASA score is an index of the seriousness of comorbidities and their effect on risk of death during surgery, with an ASA score of 1 indicating that a patient is healthy, and an ASA score of 5 indicating that a patient has severe systemic disease (Aronson, McAuliffe, & Miller, 2003; Woodfield, Beshay, Pettigrew, Plank, & van Rij, 2007). The ASA score because it is calculated based on the effect of comorbidities, can provide information on the effect of comorbidity on SSI risk. A general review article by Bandyk (2008) suggested that the higher the ASA score is, the higher the SSI risk is in a vascular surgery patient. This relationship has not been explored in vascular surgery studies. In a study by Neumayer et al. (2007), having an increased ASA score was identified as an independent predictor of SSI ( $p < 0.0001$ ). The increased SSI risk in this study, however, was with combined general and vascular surgery patients, and did not assess vascular surgery patients separately. Besides renal disease, other comorbidities that would increase the ASA score include but are not limited to diabetes, CAD, and hypertension.

Obesity in patients increases the probability of having these above-mentioned comorbidities but is also an independent risk factor and is considered modifiable. When patients are obese, they have an increased BMI, which is a measure of body mass index in  $\text{kg/m}^2$ . A healthy BMI is 25 or less, while a BMI of greater than 25 is associated with increased risk of diabetes, CAD, and hypertension (Vuorisalo, Haukipuro, Pokela, & Syrjala, 1998). Increased BMI and obesity have been reported to increase SSI risk (Bandyk, 2008; Chang et al., 2003; Haas, Evans, Preston, & Larson, 2005; Kent, Bartek, Kuntz, Anninos, & Skillman, 1996; Russo & Spelman, 2002; Slaughter et al., 1993; Vuorisalo et al.) with significant differences found between healthy BMI and high BMI in a vascular surgery study by Nicholson et al. (1994) ( $p < 0.05$ ). This study found that



dehiscence of the wound from an SSI occurred more often in overweight or obese patients when wounds became infected ( $p < 0.01$ ). The authors attributed this increased risk of SSI with overweight/obese patients to increased wound size, difficulty in obliterating dead space during wound closure, poor blood supply to fatty tissue, and longer OR time (Nicholson et al.).

A final modifiable risk factor is smoking. Smoking was found to be an independent predictor of SSI in CABG surgery patients, and has been suggested as a risk factor for SSI in the vascular surgery literature (Bandyk, 2008; Haas et al., 2005; Wipke-Tevis, 1999). There are several effects of smoking that could contribute to SSI. Firstly, chemicals in cigarettes cause direct endothelial damage to arteries, which sets up the process of atherogenesis. Secondly, the chemicals in cigarettes mimic catecholamines, which increase peripheral vascular resistance in arteries. Both of these factors decrease the amount of blood that is available to bring red and white blood cells to the area to promote wound healing and phagocytose any infectious organisms. In addition, carbon monoxide, which is produced as a by-product of cigarette smoke, competes with oxygen and binds to hemoglobin thus making cells hypoxic. When cells are hypoxic, there is decreased oxygen and thus decreased cellular energy available for cell repair (McCance & Huether, 2006). While there were no studies of vascular surgery patients alone that explored this relationship, the previously discussed study by Neumayer et al. (2007) that combined vascular and general surgery patients, did find that smoking was an independent predictor of SSI ( $p < 0.0001$ ).

*Risk Factors and SSI: Conclusion*

As previously stated, one focus of this study was a description of risk factors for SSI in vascular surgery patients, particularly those risk factors of interest identified in the SHN campaign. Evidence was found that antibiotic prophylaxis is appropriate for vascular surgery patients with correct drug, timing, and dose being important aspects. Hyperglycemia is a key risk factor for SSI in CABG and other surgery patients; the conclusion can be generalized to vascular surgery patients as well due to the similar pathophysiological processes of atherosclerosis. One vascular surgery study did find evidence that a suboptimal HbA1c, as a marker for preoperative hyperglycemia, increased SSI risk in non-diabetic vascular surgery patients. There is conflicting evidence regarding hypothermia as a risk factor; it has not been studied in vascular surgery patients. Limited evidence was found supporting that, if hair removal was required, hair should be clipped instead of shaved, as close to the time of surgery as possible.

Other factors demonstrated to increase SSI in vascular surgery patients were older age in men, longer than average surgical procedure, presence of a groin incision, and obesity. Other factors demonstrated to increase SSI risk in other patient groups that were not studied or unclear in vascular studies included gender, emergency procedure, artificial implants, receipt of blood products, renal disease, increased ASA score, and smoking. Overall, data available on many risk factors for SSI in vascular surgery patients is limited or not available. This supports the need to look at risk factors in patients so that interventions can be identified and implemented to decrease incidence of SSI.



### *Vascular Surgery SSI Rates*

While risk factors for SSI were the focus of this study, to interpret the SSI rate found in this study it was important to identify vascular surgery SSI rates elsewhere. A search of the published literature yielded 15 reports. For studies that reported rates based on risk index, which takes into account length of surgery, ASA score and wound class, the rate for the highest risk index is reported, as these patients are the most comparable to the patients in this study. There was only 1 Canadian study found of vascular surgery SSI rates with data gathered from 1994 - 1998; they reported an SSI rate of 7% (Turnbull et al., 2005).

SSI rates were available from other countries from studies assessing risk factors with SSI as an outcome measure, while others conducted surveillance only to report SSI rates. In the USA, 5 reports of SSI rates ranged from 4.34 - 11%. Two of these 5 reports were research studies assessing risk factors (Chang et al., 2003; Pounds et al., 2005). Both studies were retrospective with one study reporting an SSI rate of 11%, (Pounds et al.), and a second study reporting an SSI rate of 8% (Chang et al.). The remaining 3 SSI rates from the USA were obtained from surveillance reports that reported rates of 8.1% (Hawn et al., 2008), 6.69% (Edwards et al., 2008), and 4.34% (NNIS system, 2004). In the Netherlands, 3 reports of SSI rates ranged from 5.3 – 21.1%. One of these 3 reports was a prospective research study examining risk factors for SSI with a reported SSI rate of 5.1% (van Himbeeck et al., 1992). The other 2 reports from the Netherlands were surveillance reports with SSI rates of 21.1% (Mannien et al., 2006), and 5.3% (Schepers et al., 2003). There were 2 reports from England. One report was a prospective study with an SSI rate of 16% (Nicholson et al., 1994), and the second report was a surveillance report with an



SSI rate of 14.9% (Coello et al., 2005). One prospective research study from Ireland reported an SSI rate of 9.9% for nondiabetic patients with suboptimal HbA1c levels (O'Sullivan et al., 2006). A vascular research study from France reported an SSI rate of 4.1% (Richet et al., 1991). The 2 remaining SSI rates from surveillance reports are from Australia and Italy. Australian researchers reported an SSI rate of 6.1% (Morton et al., 2008), while Italian researchers reported an SSI rate of 5.4% (Moro et al., 2005).

Overall, 12 of these 15 reports had SSI rates of 11% or less. Further details about these studies and reports are found in Tables 3 and 4 in Appendix B. Variation in SSI rates in studies on risk factors ranged from 5.1 – 16%. There was wider variation in SSI rates in the surveillance reports, ranging from 4.3 – 21.1%. The 2 oldest studies, from 1991 and 1992, had the lowest rates. A number of factors explained the variability seen. While most surveillance was done using standard definitions of SSI, some surveillance was done using a different definition or there was no information given as to what criteria had been used, thus limiting the comparability of these rates. Some studies used prospective surveillance only during patient hospitalization, while others used reports from voluntarily participating hospitals to report rates, possibly under-estimating the true SSI rate. Most studies did not use post-discharge surveillance, thereby underestimating the true SSI rate as well. The study by Mannien et al. (2006) from the Netherlands used post-discharge surveillance and reported an SSI rate of 21.1%. However, it was not reported how many patients were lost to follow-up. Given the variation in the methods and results, the rates must be compared and interpreted with caution. A discussion of these rates and our study's results is found in Chapter 5.

*Risk Factor Assessment, Documentation, and Intervention by Nurses*

Risk factors for SSI are identified so that interventions can be designed to decrease this risk. Some SSI risk reduction is amenable to intervention by nurses. However, before intervention occurs, the nurse must assess the patient to determine if the risk factor is present. This should be followed by documentation of the findings and then a plan of how to intervene.

In the nursing literature, there are some opinion-based articles available that make recommendations on how to assess and care for the perioperative patient (Aragon et al., 2003; Bandyk, 2008; Chalmers & Straub, 2006; Cooper, 2006; Griffin, 2005; Noble, 2006; Odom-Forren, 2006; Snyder, 2005; Springer, 2007; Weirich, 2008). However, the majority of information on how to care for the perioperative patient comes from medical-surgical nursing textbooks (Girard, 2005, 2006). The focus of the care recommended in these references is related to assessment, planning, intervention, and evaluation of patients, as well as patient education. There is also a strong emphasis placed on the importance of documentation.

Documentation is a communication mechanism between healthcare providers. Nursing documentation should answer 6 questions: what, why, when, where, who, and how (Navuluri, 2000). However, there have been some factors identified that impair the quality of documentation, namely: 1) nurses' attitude toward documentation, 2) documentation that fails to reflect the care that nurses have actually provided, 3) a feeling by nurses that something is not significant enough to document, 4) difficulty in documentation of conversations, and 5) a perceived lack of time (Taylor, 2003). Documentation is not necessary for intervention to occur. However, a vital piece of



permanent information is lost for other health care professionals who also care for the patient if assessment and care are not documented.

As already discussed in this literature review, SHN has identified 4 targeted interventions to reduce SSI risk, namely appropriate antibiotic prophylaxis, maintenance of normoglycemia, maintenance of normothermia, and appropriate hair removal. The state of knowledge at this time related to these and other risk factors and their relationship to SSI development has also already been discussed. However, less is known about what role nurses can and have taken to intervene to reduce the risk of SSI development.

#### *Antibiotic Prophylaxis*

Nurses can provide antibiotic prophylaxis to all patients for whom it is recommended (Blondel-Hill & Fryters, 2006; Mangram et al., 1999). Research has found that interventions that increase provision of antibiotic prophylaxis include: 1) development of a protocol by nurses and other key staff involved in antibiotic prophylaxis, 2) development of a system of checks or electronic reminders to ensure that the patient receives the antibiotic, 3) posting of the protocol in a prominent place in the OR room for all to refer to, 4) body weights of all individuals being assessed so that the appropriate dose of antibiotic may be ordered by the physician, 5) development of a preprinted physician's order form for medications with the opportunity to opt out only, ensuring that as many surgeons as possible opt in, 6) use of a pre-printed sticker with the antibiotic prescription printed on it to apply to the chart, 7) instituting a time-out protocol during which time it is verified that the antibiotic is infusing, 8) nurses preparing and administering the antibiotic at the appropriate time, 9) pre-mixed doses of antibiotic, and



10) taking the time to educate the surgical team about the protocol (Ritchie, Scanlon, Lewis, & Black, 2004; Rosenberg et al., 2008; White & Schneider, 2007; Zvonar, Bush, Roth, 2008).

### *Glucose Control*

The Canadian Diabetes Association (CDA) recommends that patients should maintain perioperative glucose levels of 7 – 11 mmol/L (CDA, 2008). Nurses have a role to play throughout the entire perioperative process to assist patients to achieve this control. Nursing assessment of the patient preoperatively includes glucose and HbA1c measurement as a measure of preoperative glucose control. Roles identified for nurses in nursing practice textbooks related to glucose control in the perioperative process center around patient education, monitoring of glucose and appropriate treatment, and advocating for patients if hyperglycemia is not controlled (Girard, 2005, 2006).

### *Temperature Control*

The goal of nursing care in the perioperative process is to assist patients to maintain normothermia. If patients are hypothermic, active warming interventions can be provided. If patients are normothermic, blankets should be provided to ensure they remain this way. Passive warming with blankets has not been demonstrated to be an efficient way to warm patients. However, active warming with forced air or warming of solutions has been shown to be effective at maintaining normothermia in the operative setting (Kumar et al., 2005; Negishi et al., 2003). There is also some evidence that preoperative warming

for 1 – 2 hours before surgery is effective in reducing hypothermia, increasing patient comfort, and decreasing anxiety (Just, Trevien, Delva, & Lienhart, 1993; Weirich, 2008).

Assessment is important to perform on patients throughout the perioperative process due to the exposure of patients to cold, as already discussed, as well as the use of certain anesthetic medications. Because patient shivering due to a cold sensation may be decreased by some anesthetic medications, reliance on visual cues that the patient is cold should not be the only assessment performed by nurses. As well, because warming interventions are provided, the assumption should not be that the patient is normothermic. When patients are transferred from the OR to PARR or PARR to the postoperative unit, this should be done as quickly as possible. Patients should be actively kept warm as active warming helps to maintain or increase core body temperature on transfer from one unit to another. Because hypothermia can occur on transfer from one unit to another, the nurse can ensure that the patient is kept normothermic during transfer with active warming interventions (Kumar et al., 2005). Nurses can also ensure that all patients have achieved a normothermic state before discharge from the PARR (Eastern Health Perioperative Program Policy, VII-a-20, 2008).

### *Hair Removal*

Nurses provide hair removal when it interferes with the surgical incision area. Published standards from the CDC, current literature, and ORNAC should be adhered to for recommendations on appropriate hair removal. Clippers should be used in the OR to remove hair only when hair interferes with the surgical incision to be made. Hair removal

should also be performed as close to the surgical incision time as possible (Mangram et al., 1999; ORNAC, 2007; Woodings & Moncaster, 2006).

Nurses can educate patients about the avoidance of shaving near the surgical incision site prior to surgery to avoid causing microscopic nicks and abrasions. Nurses can also assess the skin integrity of all individuals, with special attention to obese individuals, and these findings should be documented. Nurses should and do report any adverse findings to the surgeon performing the surgery prior to the surgery start (personal e-mail communication with G. Tapp, Clinical Educator for the Perioperative Program, Feb 4, 2009). Finally, nursing and medical staff requires education about the importance of appropriate hair removal and its effect on SSI risk.

#### *Other Risk Factors Amenable to Intervention by Nurses*

There are other patient risk factors that are amenable to intervention by nurses. Two examples would be smoking cessation and weight control. Preoperatively, nurses can recommend that patients quit smoking 30 days before surgery and maintain abstinence to reduce SSI risk, as well as other complications (Mangram et al., 1999). Nurses can assist patients with strategies to cease smoking such as referrals to other healthcare providers, nicotine replacement therapy, and support groups (Doolan & Froelicher, 2008; Lemmens, Oenema, Knut, & Brug, 2008). In the short term before surgery, nurses can assist patients who are obese to optimize their skin integrity before surgery. Education on the importance of cleansing skin folds, with avoidance of harsh chemicals or brushes can be recommended (Baugh, Zeulzer, Meador, & Blankenship, 2007). As a long-term strategy, referrals can be made to Public Health nurses to assist



patients to achieve a healthy body weight through education programs on diet and exercise which will help in preventing comorbidities such as diabetes that often develop with excess body weight and therefore raise SSI risk.

### *Other Nursing Roles*

Nurses have an important role to play in ensuring optimal wound care is provided through utilization of basic wound care principles (Nelson, 2002). As well, nurses have a key role to play in the identification of SSIs. During incisional care, assessment for signs and symptoms of infection can be performed and then documented. These signs and symptoms can then be reported to the surgeon, and a C&S swab can be requested and taken by the nurse. Based on the results of the C&S swab, appropriate antibiotic therapy can be prescribed by the physician and administered by the nurse (Goering et al., 2008).

### *Summary*

In conclusion, SSIs are a concern for patients and their families and the individuals who care for them in the health care system. As well, there are key factors that increase SSI risk. Nurses are involved at all stages of the perioperative process and have a role in assessing patients and deciding on appropriate interventions to reduce this SSI risk. While there is a lot of information in the literature about certain surgery patient groups and their risk factors for SSI, vascular surgery patients have not been as well studied. It is unknown if vascular surgery patients possess these same risk factors for SSI or if there are other factors that exert an influence. Once SSI risk factors are identified in vascular

surgery patients, nursing interventions may be developed to reduce this risk, thereby decreasing personal and monetary cost associated with SSIs.

### Chapter 3: Methodology

This chapter describes the methods used including the study design, target population, data collection method, definitions, ethical considerations, and data management and analysis.

#### *Study Design*

This was a exploratory, descriptive study that used a retrospective chart review of paper and electronic inpatient and outpatient charts to collect information on each patient's glycemic and temperature status, other risk factors for surgical site infection (SSI), practices related to the management of risk factors with emphasis on blood glucose and temperature, and incidence of SSI.

#### *Target Population*

The target population for this study was all patients over age 19 who underwent selected vascular surgery over a 12-month period between January 1 and December 31, 2005 at St. Clare's Hospital, a St. John's adult, acute care hospital of Eastern Health. Excluded patients were those who were younger than 19, had a surgical classification other than Class I (clean), or had a preoperative infection in the area of the body to be incised during surgery. Patients who had received steroid or chemotherapy in the four weeks prior to surgery were included but had these risk factors controlled for in the data analysis. As well, patients who had an artificial graft inserted into the body were also included; these patients are often excluded in other studies due to the extended period it



may take for infections to develop and thus the longer surveillance period required. Surveillance was conducted for one year for such patients as is recommended by the Centers for Disease Control (CDC).

Over a 12-month period from January 1 to December 31, 2005, according to a list provided by the Surgery Program Director, there were 236 vascular surgeries of interest performed at St. Clare's Hospital. The list of surgeries of interest was decided in consultation with the relevant Program Director, the Discipline Chair for Surgery and the Infection Control Program of Eastern Health. These surgeries included peripheral arterial bypass surgery and abdominal aortic aneurysm (AAA) repair surgery, with a complete list of surgeries found in Appendix III. A sample size calculation was done initially using the prevalence of hyperglycemic and normoglycemic patients and their rates of SSI development based on results from the literature. Using these proportions and assuming a similar distribution here, in addition to the prevalence of hyperglycemia in this study group as found in the first 50 patient charts examined, it was calculated that a sample size of more than 1000 patients would be needed to find such statistically significant differences (power 80%,  $\alpha = 0.05$ ). It was not feasible to include this many patients as this would have comprised 5 years worth of vascular surgery patients at this hospital in Eastern Health and resources were not available for this amount of data collection for this descriptive, exploratory study. A convenience sample was therefore used. Every second patient was selected from a list of all patients who underwent the selected surgeries provided by the Medical Records staff at St. Clare's Hospital. Data was collected on half of the patients but some were dropped because they were classified as clean-contaminated

or dirty and didn't meet the criteria for inclusion into the study. The final study sample consisted of 116 selected vascular surgery patients, over age 19 that had a Class I (clean) surgery performed in 2005.

### *Data Collection Method*

Medical Records staff at St. Clare's Hospital pulled applicable patient charts from a list provided by the Surgery Program Director. The researcher or research assistants, who were previously trained by the researcher, then reviewed the patient's electronic and paper chart to gather data on risk factors, practices, and signs and symptoms of SSI. These were recorded on the Data Collection Form developed by the researcher, which is found in Appendix D. The specific items included on this form were based on the literature that was reviewed that identified risk factors for SSI in vascular as well as other surgeries. It also included all of the items that are found on other surveillance instruments used by the Infection Prevention and Control Program of Eastern Health. The initial draft of the form was pilot tested on charts of 10 patients and then revised slightly in terms of ordering of information and addition of missing items considered important for the study. The items on this form included information on: a) demographics, b) glucose and temperature measurements, c) interventions provided for glucose and temperature control, d) antibiotic prophylaxis and hair removal, and e) potential confounding factors such as body mass index (BMI), blood transfusions and comorbidities to list a few.

The preoperative glucose level recorded was the closest measurement done prior to the surgery. The postoperative glucose measurements recorded included all measurements during the intraoperative and Post Anesthesia Recovery Room (PARR)



periods, and any readings of 11.1 mmol/L or greater in the postoperative period, up to and including the seventh day postoperatively. All interventions provided for glucose control during these times were also recorded.

Temperature readings recorded were those that were the closest preoperative temperature measurement done prior to the surgery, all temperature measurements in the intraoperative and PARR periods, and temperatures less than 36°C during the first 48 hours postoperatively. All interventions provided for temperature control during these times were also recorded.

The standard definitions for SSI from the CDC were used and are found in Appendix A (Mangram et al., 1999). These definitions have had some very minor changes made that created additional categories for the primary incision that did not affect this study (Horan, Andrus, & Dudeck, 2008). However, because the data for this study were collected on patients from 2005, it seemed appropriate to use the 1999 definitions. To collect data on SSI, patient records were reviewed for any pertinent laboratory or microbiology results indicative of infection, any progress notes, discharge summaries or physician correspondence about signs and symptoms or diagnosis of infection, and any medication orders for antibiotics. This was done for the hospitalisation period, as well as any post-discharge visits to the Emergency or Outpatients Department (OPD), or Non-Invasive Vascular Laboratory. Records were reviewed for a one-year period if the patient had an artificial implant inserted, and for a minimum of 30 days for all other surgeries. Any visits made to the Non-Invasive Vascular Laboratory at 6 weeks were available for 95.7% of the patients in this study.



### *Definitions*

The terms used in this study were defined as follows:

*Surgical site infection:* Standard definitions were used and classified as superficial or deep. Details of the CDC definition used are found in Appendix 1.

*Hyperglycemia:* A serum or capillary blood glucose reading of 11.1 mmol/L or greater.

*Ever hyperglycemic:* A serum or capillary blood glucose reading of 11.1 mmol/L or greater, and/or a serum glycosylated hemoglobin level of 6% or greater in non-diabetic patients or 7% or greater in diabetic patients at any point in the perioperative period.

*Hypothermia:* A body temperature less than 36°C.

*Ever hypothermic:* A body temperature less than 36°C at any point immediately prior to, during, or after surgery up to the first 48 hours after surgery.

*Complete post-discharge surveillance:* Surveillance of every patient after discharge from hospital, for a full 30 days if there is no artificial graft inserted during surgery, and for a full year if there is an artificial graft inserted during surgery. Data are collected to verify either absence of an infection or the presence of one.

### *Ethical Considerations*

Protection of each patient's privacy and maintenance of confidentiality were rigidly adhered to throughout all stages of this research study. All researchers and research assistants signed an oath of confidentiality from Eastern Health and Memorial University. Prior to the commencement of the study, approval was received from the Human Investigation Committee of Memorial University of Newfoundland (HIC) and the Research Proposal Approval Committee (RPAC) of Eastern Health. Letters of support for this study were also obtained from the Program Directors of the Surgery and Perioperative Programs. All letters of approval and support are found in Appendix V.

Because this was a chart audit, HIC specified that consent was not required from individual patients, because there was minimal risk to the patients involved. Charts were not removed from the author-review designated area. Each data collection form contained a tear-off section with the name and provincial medical number of the patient as well as a research code. A master list containing the name, provincial medical number, and research code of each patient was then compiled. The names and provincial medical number were used only to verify and correct any information accessed from the chart. The research code on the tear-off section of the data collection form corresponded to the research code on the rest of the data collection form. Once the chart was accessed and all data were collected on an individual patient, this tear-off section was removed and shredded.

All confidential material was kept in a secure, locked area. Computers used to store information and conduct analysis were password protected and accessible only to the researcher and research assistants. Only research codes, i.e., no provincial medical

numbers, names, or other patient identifiers, were entered into the computer. As well, specific surgeon names were not entered into the computer but instead a surgeon code was entered. Once all data were entered into the computer, the data collection forms were locked in a secure area and will be kept for the required time frame of five years until 2012, and then destroyed.

Unrestricted funding for support of data collection and data entry was obtained from 3 sources: Association of Registered Nurses of Newfoundland graduate research study award (\$1000.00), the Health Care Foundation research fund for new researchers (\$5000.00), and the Canadian Institutes of Health Research summer graduate student award (\$4000.00).

#### *Data Management and Analysis*

A database was created using STATA software (StataCorp, 2005), and data were entered by the researcher and a research assistant. Data were verified and cleaned by the researcher prior to running statistics. Descriptive statistic commands were used to identify: a) the current practices relating to glycemic and temperature control, b) percentages of patients who experienced hyperglycemia and hypothermia, and c) percentages of patients who developed an SSI. Frequencies and cross-tabulations were done on all variables to determine the number of patients with the risk factors of interest and then their association with SSI. Relative risk was the appropriate measure of risk, rather than odds ratio, as patients were followed from exposure to outcome. Chi squared testing was used to test for statistically significant differences in SSIs between groups where these differences appeared large enough to be clinically important which will be



discussed more in Chapter 5. This would be groups in which the proportion of patients with an SSI in one group was 1.5 times or more than that of another group or there was a difference of 10 percentage points or more between groups. Differences for 3 types of continuous variables: 1) length of stay, 2) length of surgery, and 3) hemoglobin level, were assessed for statistical significance. As the distributions were skewed, the medians were recorded for each variable and the differences tested using the Wilcoxon ranksum test. An alpha level of  $p \leq 0.05$  was chosen as the level of statistical significance for comparison.

This study was exploratory and descriptive in nature, not hypothesis testing. As such, extensive multivariate analysis was not warranted. However, logistic regression was used to identify the effects of hyperglycemia and hypothermia on SSI risk, while controlling for other potential confounding factors. Results of these analyses are presented in Chapter 4 and discussed in Chapter 5.

## Chapter 4: Results

Chapter 4 summarizes the results of the univariate analyses related to: 1) characteristics of the surgical interventions, 2) characteristics of the vascular patients, 3) intraoperative blood loss, anemia and treatment, 4) antibiotic prophylaxis, 5) patient glucose, patient glycosylated hemoglobin, and maintenance of normoglycemia, 6) patient temperature and maintenance of normothermia, and 7) hair removal. This is followed by a description of the bivariate and multivariate analyses related to surgical site infection (SSI) development and key risk factors of interest. When distribution was skewed, median is reported. Testing for statistical significance was conducted on associations related to antibiotics, glucose and temperature control or when differences in percentages looked potentially clinically meaningful. Because of the amount of data in each section, brief summaries are included throughout the chapter.

### *Characteristics of the Surgical Intervention*

There were 116 patients who had a vascular surgical intervention. About half of the patients, 51.7% ( $n = 60$ ), had a femoral-tibial or femoral-popliteal bypass with saphenous vein graft. The second most common procedure performed, in 23.3% ( $n = 27$ ) of the patients, was a femoral-tibial or femoral-popliteal bypass with artificial graft. The list of procedures is summarized in Table 1.

Table 1: Types of Vascular Surgical Procedures

<b>Surgical Procedure</b>	<b>n<sup>1</sup></b>	<b>%<sup>2</sup></b>
Femoral-tibial or femoral-popliteal bypass with <i>saphenous vein</i> graft	60	<b>51.7</b>
Femoral-tibial or femoral-popliteal bypass with <i>artificial</i> graft	27	<b>23.3</b>
Femoral-femoral bypass	13	<b>11.2</b>
Abdominal aortic aneurysm repair	9	<b>7.8</b>
Aortobifemoral bypass	7	<b>6.0</b>
<b>Total</b>	<b>116</b>	<b>100.0</b>

<sup>1</sup> Number of vascular surgery patients having specified surgery

<sup>2</sup> Percent of 116 vascular surgery patients having specified surgery

Of the 116 procedures performed, 87.1% (n = 101) were elective and 12.9% (n = 15) were done as an emergency procedure. All procedures (n = 116) were classified as clean procedures. About half, 47.4% (n = 55), had artificial implants and the remaining 52.6% (n = 61) did not.

The majority of patients, 94% (n = 109), had an epidural catheter for anaesthesia. Of these 109 patients, 62.4% (n = 68) had a combined epidural and spinal anaesthetic, while 17.4% (n = 18) of the patients had a combined epidural and general anaesthetic. Epidural anaesthetic was administered to all of the patients who had femoral-tibial or femoral-popliteal bypass with artificial graft (n = 27), and to 95% (n = 57) of the patients who had femoral-tibial or femoral-popliteal bypass with saphenous vein graft. General anaesthetic was administered to 23.3% of patients (n = 27). All of the patients (n = 9) who had abdominal aortic aneurysm (AAA) repair received general anaesthetic. Table 2 summarizes the combinations of anaesthetics received by the 116 patients.



Table 2: Types of Anaesthetics Received

<b>Anaesthetic Type</b>	<b>n<sup>1</sup></b>	<b>%<sup>2</sup></b>
Epidural/Spinal combined	68	<b>58.6</b>
Epidural alone	21	<b>18.1</b>
Epidural/General combined	19	<b>16.4</b>
General alone	7	<b>6.0</b>
Epidural/General/Spinal combined	1	<b>0.9</b>
<b>Total</b>	<b>116</b>	<b>100.0</b>

<sup>1</sup> Number of vascular surgery patients having specified anaesthetic

<sup>2</sup> Percent of 116 vascular surgery patients having specified anaesthetic

The length of surgery ranged from 43 - 357 minutes with a median length of 115 minutes (IQR: 80 - 145 minutes). As Table 3 shows, almost half of the surgeries, 47.4% (n = 55), were 61 – 120 minutes in length.

Table 3: Length of Surgery

<b>Category of length of surgery (minutes)</b>	<b>Range of actual length of surgery (minutes)</b>	<b>n<sup>1</sup></b>	<b>%<sup>2</sup></b>
1 – 60	43 – 60	8	<b>6.9</b>
61 – 120	64 – 120	55	<b>47.4</b>
121 – 180	125 – 178	38	<b>32.8</b>
181 – 240	184 – 235	10	<b>8.6</b>
241 – 300	266 – 278	4	<b>3.4</b>
> 300	357	1	<b>0.9</b>
<b>Total</b>		<b>116</b>	<b>100.0</b>

<sup>1</sup> Number of vascular surgery patients undergoing surgical procedure for specified amount of time

<sup>2</sup> Percent of 116 vascular surgery patients undergoing surgical procedure for specified amount of time

For the 112 patients for whom OR staff recorded information on break in sterile technique, 4.5% (n = 5) had a reported break in technique during the procedure. The nature of the break was not recorded.

In summary, the majority of patients in this study had a bypass procedure of a lower extremity performed with half having an artificial graft and half having a

saphenous vein graft. Most procedures were elective, with most taking between 1 – 3 hours to complete. Just about all patients had an epidural anaesthetic either alone or in combination with another anaesthetic.

### *Characteristics of the Patients*

The majority, 80.2% (n = 93), of the vascular surgery sample were men, with 19.8% (n = 23) women. Ages ranged from 48 - 89 years with a mean age of 66.5 years. The ages of the men and women were similar, with the mean age of the men being 66.7 years (range 48 - 89) and the mean age of the women being 65.9 years (range 52 -84). The distributions of age were normal as shown in the boxplot in Figure 2.

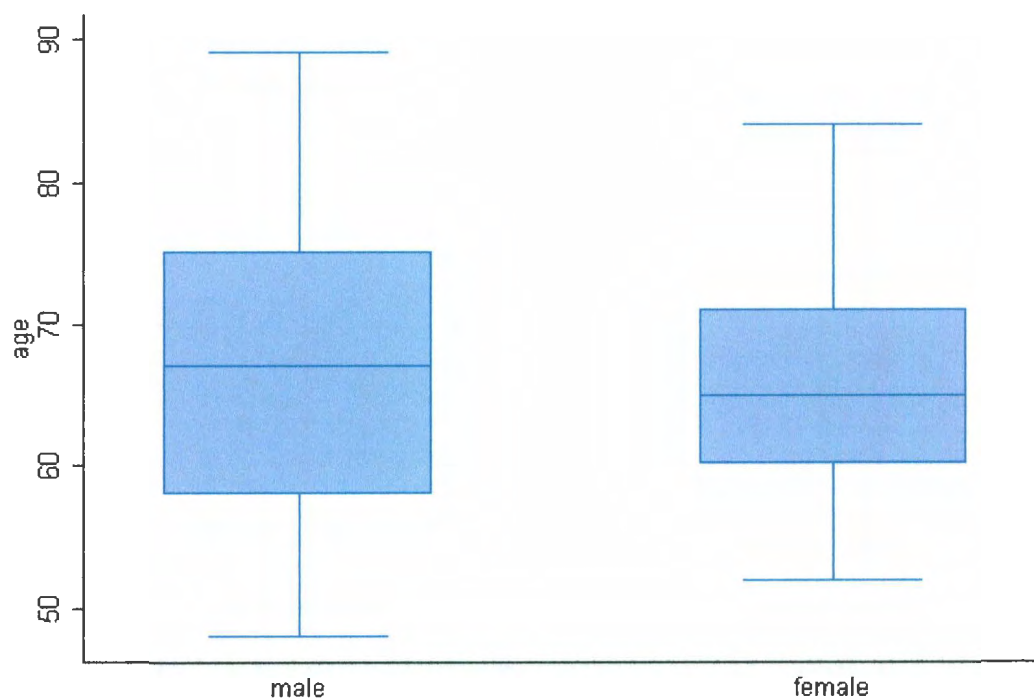


Figure 2: Distribution of Ages of Vascular Surgery Patients, by Sex

Data were gathered on the 10 different comorbidities listed in Table 4. All of the patients had at least one comorbidity. As expected, peripheral vascular disease (PVD) occurred in every patient having bypass surgery done, as well as every patient having AAA repair done. The second most common comorbidity was hypertension with 73.3% (n = 85) of the patients having this condition. Coronary artery disease (CAD) occurred in 64.7% (n = 75) of patients and diabetes mellitus was a comorbidity for almost half, 45.7% (n = 53), of the patients. About half, 49.1% (n = 57) had 1 – 3 comorbidities, 41.4% (n = 48) had 4 – 5 comorbidities, and the remaining 9.5% (n = 11) had 6 – 7 comorbidities.

Table 4: Number and Types of Comorbidities

<b>Comorbidity</b>	<b>n <sup>4</sup></b>	<b>% <sup>5</sup></b>
Peripheral vascular disease	116	<b>100.0</b>
Hypertension	85	<b>73.3</b>
CAD <sup>1</sup>	75	<b>64.7</b>
Diabetes	53	<b>45.7</b>
COPD <sup>2</sup>	24	<b>20.7</b>
Renal Disease	10	<b>8.6</b>
Stroke	8	<b>6.9</b>
Arrhythmias	7	<b>6.0</b>
Inflammatory bowel disease <sup>3</sup>	4	<b>3.5</b>
Liver disease	2	<b>1.7</b>

<sup>1</sup> Coronary artery disease including angina and past MI

<sup>2</sup> Chronic obstructive pulmonary disease including asthma

<sup>3</sup> Inflammatory bowel disease including ulcerative colitis, Crohn's disease and diverticulitis

<sup>4</sup> Number of vascular surgery patients having specified comorbidity

<sup>5</sup> Percent of 116 vascular surgery patients having specified comorbidity. Percentages do not total to 100% because patients may have had one or more comorbidities.

The American Society of Anesthesiologists (ASA) score was not recorded on 25% of patients (n = 29). The majority of patients for whom an ASA score was recorded, 80.5% (n = 70 of 87), had a score of 3 or greater on a scale of 1 – 5.



Prior to the day of the surgical procedure, 37.1% (n = 43) of the patients were admitted to an inpatient unit, referred to as pre-admitted. The range of pre-admitted length of stay (LOS) for this group of patients was 2 - 39 days, with a median of 7 days (IQR: 3 - 9). Table 5 shows the postoperative length of stay (LOS) (number of days from surgical procedure to discharge) for patients pre-admitted to an inpatient hospital unit prior to the surgical procedure and for those who were not pre-admitted. As can be seen from Table 5, the median length of stay postoperatively for both groups is quite similar, but the range is much larger for patients who were not pre-admitted prior to their surgical procedure than for those who were pre-admitted.

Table 5: Length of Stay

		<b>Patients Pre-admitted<sup>1</sup></b>	<b>Patients <u>Not</u> Pre-admitted<sup>1</sup></b>
n (%) <sup>2</sup>		43 (37.1%)	73 (62.9%)
Postoperative length of stay <sup>3</sup>	Median (IQR)	8 days (7 - 11)	7 days (5 - 9)
	Range	3 - 29 days	3 - 40 days

<sup>1</sup> Pre-admitted patients were admitted to a hospital unit on a day prior to the day of surgery, whereas patients not pre-admitted were admitted to hospital on the same day as their surgery

<sup>2</sup> Number and percent of 116 vascular surgery patients who were pre-admitted or not

<sup>3</sup> Length of time after surgical procedure that patient remained in hospital

Three known patient risk factors for SSI are steroid therapy, body mass index (BMI), and smoking. Only 6.9% (n = 8) of the patients were receiving steroid therapy at the time of their vascular surgery. Almost all of the patients, 94% (n = 109), had a height and weight measurement recorded from which a BMI was calculated. BMI ranged from 18.6 to 40.7 with a median BMI of 26.7 (IQR: 24 - 29.5). As can be seen in Table 6, more than two thirds of patients, 67% (n = 73), were either overweight or obese with a BMI

>25. There were 34.5% (n = 40) of the patients who self-reported to be smokers. The amount smoked per day was recorded on only 72.5% (n = 29) of the smokers. Table 6 also summarizes the amount smoked by these patients. The number of cigarettes smoked per day ranged from 1 - 80 cigarettes. The majority of patients who reported the amount they smoked, 86.2% (n = 25 of 29), reported smoking 20 or fewer cigarettes per day.

Table 6: BMI and Number of Cigarettes Smoked

	<b>Category <sup>1</sup></b>	<b>n <sup>2</sup></b>	<b>% <sup>3</sup></b>
<b>BMI</b>	18-25	36	<b>33.0</b>
	25.1-30	50	<b>45.9</b>
	>30	23	<b>21.1</b>
	<b>Total</b>	109	<b>100.0</b>
<b>Cigarettes smoked per day</b>	<10	10	<b>34.5</b>
	10-20	15	<b>51.7</b>
	>20	4	<b>13.8</b>
	<b>Total</b>	29	<b>100.0</b>

<sup>1</sup> Range of BMI or of cigarettes smoked per day

<sup>2</sup> Number of vascular surgery patients in specified category of BMI or number of cigarettes smoked per day

<sup>3</sup> Percent of 109 vascular surgery patients in specified category of BMI or of 29 vascular surgery patients in specified category of number of cigarettes smoked per day

In summary, every patient in this study had at least 1 comorbidity, with PVD occurring in all patients. This was followed closely by three quarters of patients having hypertension, two thirds having coronary artery disease (CAD), and half having diabetes. Comorbidities corresponded to ASA score with over 80% having an ASA score of 3 or greater. Postoperative LOS was very similar for patients who were pre-admitted compared to those admitted on the day of the surgical procedure. However, the range of the LOS postoperatively was longer for patients who were not admitted preoperatively. In

this sample, more than two thirds of patients were overweight or obese. Only one third reported to be smokers with most reporting that they smoked less than 20 cigarettes per day.

### *Blood Loss, Anemia, and Treatment*

This section outlines hemoglobin and ferritin assessment as indicators of anemia. Blood loss in the operating room (OR) is also discussed followed by the treatments used to treat anemia.

#### *Anemia Assessment and Treatment: Preoperative*

Preoperative hemoglobin levels were recorded on all patients and ranged from 88 - 182 g/L with a median preoperative hemoglobin level of 138 g/L (IQR: 122 - 150). Anemia, defined as a hemoglobin level of less than 100 g/L, occurred in 9.1% (n = 10) of the 116 vascular surgery patients. Only 1 patient in this anemic group received packed red blood cells (PRBC) preoperatively.

Table 7 shows the number of days preoperatively that patients had their hemoglobin level assessed. Slightly more than half of the patients, 56.9% (n = 66), had the level done more than 3 days and up to 6 days before the day of the surgical procedure. One quarter of patients, 25% (n = 29), had a preoperative hemoglobin level measured more than 7 days before the day of their surgical procedure.



Table 7: Time of Measurement of Preoperative Hemoglobin

<b>Time of Measurement <sup>1</sup></b>	<b>n <sup>2</sup></b>	<b>% <sup>3</sup></b>
OR Day	12	<b>10.3</b>
1 Day	21	<b>18.1</b>
2 Days	6	<b>5.2</b>
3 Days	11	<b>9.5</b>
4-6 Days	37	<b>31.9</b>
7-14 Days	20	<b>17.2</b>
15-21 Days	6	<b>5.2</b>
22-26 Days	3	<b>2.6</b>
<b>Total</b>	<b>116</b>	<b>100.0</b>

<sup>1</sup> When preoperative hemoglobin level was measured

<sup>2</sup> Number of vascular surgery patients who had preoperative hemoglobin measured at specified time

<sup>3</sup> Percent of 116 vascular surgery patients who had preoperative hemoglobin measured at specified time

#### *Blood Loss, Anemia Assessment and Treatment: Intraoperative*

There was no intraoperative blood loss in 54.3% (n = 63) of the patients, while blood loss during surgery occurred in 45.7% (n = 53) of patients. For those patients who lost blood, blood loss ranged from 30 millilitres (mL) – 25 litres (L) of blood.

Table 8: Amount of Blood Loss During Surgical Procedure

<b>Blood loss category (mL) <sup>1</sup></b>	<b>Range of actual blood loss (mL) <sup>2</sup></b>	<b>n <sup>4</sup></b>	<b>% <sup>5</sup></b>
0	0	63	<b>54.3</b>
1 - 299	30-250	21	<b>18.1</b>
300-1199	300-1100	21	<b>18.1</b>
1200-4499	1200-4499	8	<b>6.9</b>
≥ 4500 <sup>3</sup>	4500;10000; 25000	3	<b>2.6</b>
<b>TOTAL</b>		<b>116</b>	<b>100.0</b>

<sup>1</sup> Categories decided by the researcher

<sup>2</sup> Actual amount of blood lost by the patients in each group

<sup>3</sup> Only 3 patients lost ≥ 4500 mL of blood: 4500 mL, 10L, and 25L

<sup>4</sup> Number of vascular patients in each blood loss category

<sup>5</sup> Percent of 116 vascular patients in each blood loss category

Table 8 summarizes the amount of blood lost during the surgical procedure. While most patients who lost blood lost less than 4500 mL of blood, there were three patients who lost larger amounts: 4500mL, 10000mL and 25000 mL.

An intraoperative hemoglobin level was done on only 2.6% ( $n = 3$ ) of patients; these were the 3 patients who also lost the largest amounts of blood in the OR ranging from 4500 mL – 25L of blood. Intraoperative hemoglobin levels for these patients ranged from 63 – 83 g/L with each patient receiving PRBC and other blood products for treatment. None of these patients had been anemic preoperatively with hemoglobin levels ranging from 124 – 128 g/L.

*Anemia Assessment and Treatment: Post Anaesthesia Recovery Room (PARR)*

The hemoglobin level for patients in each of the blood loss categories is shown in Table 9. The categories in this table were based on the distribution of data after preliminary assessment of which categories were most relevant for the data as there is no standard category system to use. The number of patients having a PARR hemoglobin level assessed, increased as the amount of blood lost during the surgical procedure increased, but the number who received PRBC did not. As the amount of blood lost during the surgical procedure increased, the median hemoglobin level and range increased in the PARR, despite the fact that there were not more patients receiving PRBC in the PARR.

Table 9: Amount of Blood Loss in OR and PARR Hemoglobin Level

Blood loss category (mL) <sup>1</sup>	n in PARR postop	n with Hgb assessed in PARR	% with Hgb assessed in PARR <sup>2</sup>	Median (IQR) Hgb level	n (%) receiving PRBC in PARR <sup>2</sup>	n to ICU postop with no PARR
0 -	63	6	9.5	101 g/L (80-125)	3 (4.8%)	-
1 - 299	21	2	9.5	84 g/L (77-91)	1 (4.8%)	-
300-1199	21	8	38.1	99 g/L (87-105)	1 (4.8%)	-
1200-4499	6	4	66.7	109 g/L (104-117)	0	2
≥ 4500	-	-	-	-	-	3
<b>TOTAL</b>	<b>111</b>	<b>20</b>				<b>5</b>

<sup>1</sup> Categories decided by the researcher

<sup>2</sup> Percent of vascular surgery patients in each specified category; totals 100% per row, not column, as it is the % of patients in each category

#### *Anemia Assessment and Treatment: Postoperative*

Postoperatively, whether in the postoperative unit or the ICU, most patients had a hemoglobin level assessed as seen in Table 10. The lowest median hemoglobin level was seen in patients with 1200-4499 mL of blood loss during the surgical procedure. In this group, 75% (n = 6) of the 8 patients received PRBC postoperatively.

The patients with the greatest amount of blood loss, 4500mL – 25L, were only slightly anemic with a median postoperative hemoglobin of 99 g/L, and only 1 patient of the 3 in this group received PRBC postoperatively. However, these patients had received several units of PRBC to treat low hemoglobin in the intraoperative period.



Table 10: Amount of Blood Loss in OR and Postoperative Hemoglobin

Blood loss category (mL) <sup>1</sup>	n in each blood loss category	n having a postop Hgb assessed	% having a postop Hgb assessed	Median <sup>2</sup> (IQR)	Range (g/L)	n (%) in each blood loss category receiving PRBC
0	63	60	95.2	119 g/L (110-129)	81-153	0
1 - 299	21	20	95.2	113 g/L (101-134)	88-145	2 (9.5%)
300-1199	21	21	100.0	100 g/L (83-107)	76-132	4 (19.0%)
1200-4499	8	8	100.0	89 g/L (88-94)	88-115	6 (75.0%)
≥ 4500	3	3	100.0	99 g/L (88-129)	88-129	1 (33.3%)
<b>TOTAL</b>	<b>116</b>	<b>112</b>				

<sup>1</sup> Categories decided by the researcher

<sup>2</sup> A mean hemoglobin level was calculated for each patient having > 1 hemoglobin level assessed. The distribution of these means was skewed; the median is reported.

### *Anemia: Postoperative Hemoglobin*

As can be seen from Table 11, the greatest proportion of patients, 37.9% (n = 44), had only 1 hemoglobin level assessed postoperatively. The patient group with the greatest number of hemoglobin levels assessed also had the greatest proportion of patients with anemia postoperatively. For example, 4 patients had 8 hemoglobin levels assessed postoperatively and all 4 of these patients were anemic. In comparison, only 1 of 44 patients having only one test done was anemic. There were 22 patients who were anemic on the first postoperative hemoglobin level assessed. Of this group, 27.3% (n = 6) of the 22 patients were given PRBC.

Table 11: Number of Hemoglobin or Ferritin Levels and Postoperative Anemia

Number of Hgb tests done	n (%) having specified number of Hgb tests done <sup>1</sup>	n (%) with Hgb < 100 g/L having specified number of Hgb tests done <sup>2</sup>	n (%) with postop serum ferritin test done having specified number of Hgb tests done <sup>3</sup>	n with serum ferritin level < 100mcg/L having specified number of Hgb tests done <sup>4</sup>
8	4 (3.4)	4 (100)	2 (50.0)	0
7	2 (1.7)	2 (100)	0	0
6	1 (0.9)	1 (100)	0	0
5	6 (5.2)	5 (83.3)	0	0
4	12 (10.3)	11 (91.7)	1 (8.3)	0
3	19 (16.4)	8 (42.1)	1 (5.3)	0
2	24 (20.7)	5 (20.8)	1 (4.2)	1
1	44 (37.9)	1 (2.3)	1 (2.3)	1
0	4 (3.4)	-	-	-
<b>TOTAL</b>	<b>116</b>	<b>37 (31.9%)</b>	<b>6</b>	<b>2</b>

<sup>1</sup> Number and proportion of patients who had the specified number of hemoglobin levels assessed as indicated in column 1

<sup>2</sup> Number and proportion of patients who had the specified number of hemoglobin levels assessed as indicated in column 1 that had a hemoglobin level < 100g/L

<sup>3</sup> Number and proportion of patients who had the specified number of hemoglobin levels assessed as indicated in column 1 that had a serum ferritin level assessed

<sup>4</sup> Number and proportion of patients who had the specified number of hemoglobin levels assessed as indicated in column 1 that had a serum ferritin level < 100mcg/L

#### *Anemia: Postoperative Serum Ferritin*

Also seen in Table 11 is the low number of patients (n = 6) having a serum ferritin level assessed postoperatively despite the fact that 31.9% (n = 37) of the patients had anemic hemoglobin levels. Of the 6 patients having a serum ferritin level assessed, only 2 patients had a serum ferritin level of less than 100 mcg/L and neither of these 2 patients had a postoperative hemoglobin level less than 100 g/L. However, of the other 4 patients in this group with a normal serum ferritin level, all 4 had an anemic postoperative hemoglobin level for which 2 had received PRBC. Not one of the 116 vascular surgery



patients, despite the fact that almost one third of patients were anemic according to their hemoglobin level, was started on iron post-operatively.

#### *Anemia, Blood Loss and Treatment: Summary*

In summary, very few patients had preoperative anemia. Three quarters of the patients had a preoperative hemoglobin level assessed within a week preoperatively. Half of the patients in this study had no reported blood loss in the OR and for those that did the majority had lost less than 1200mL. For patients who lost 4500mL or more of blood, each was treated with PRBC in the OR. Postoperatively, slightly more than one third of patients had only one hemoglobin level assessed with just about all patients having at least one hemoglobin level assessed. For those patients who lost 1200 – 4499 mL of blood in the OR, 75% received PRBC post-operatively. Close to one third of the patients had an anemic postoperative hemoglobin level but serum ferritin levels were assessed in very few patients. No patients were started on iron replacement therapy.

#### *Risk Factors of Interest*

The following section outlines the findings of the univariate analyses of specific risk factors of interest in this study: inappropriate antibiotic prophylaxis, perioperative hyperglycemia and hypothermia, and inappropriate preoperative hair removal.

#### *Risk Factor: Inappropriate Antibiotic Prophylaxis*

Antibiotics were given in the OR or PARR to 66.4% (n = 77) of the patients. There was no prophylactic antibiotic given to 33.6% (n = 39) of the patients. Of 55



patients with an artificial graft, 87.3% ( $n = 48$ ) received a prophylactic antibiotic. In contrast, of 61 patients with no artificial graft, only 47.5% ( $n = 29$ ) received a prophylactic antibiotic. The difference between these groups was statistically significant ( $p < 0.0005$ ).

Table 12 shows the time of administration of antibiotics relative to the surgical incision time for patients who were given antibiotics.

Table 12: Administration Time of Antibiotic Relative to Surgical Incision Time

	<b>Time Antibiotic Given</b>	<b>n<sup>2</sup></b>	<b>%<sup>3</sup></b>
<b>NOT GIVEN</b>		39	<b>33.6</b>
<b>UNKNOWN</b>		3	<b>2.6</b>
<b>EARLY</b>	> 2 h pre-incision	1	<b>0.9</b>
	>1 – 2 h pre-incision	4	<b>3.4</b>
<b>RECOMMENDED<sup>1</sup></b>	<b>30-60 min pre-incision</b>	12	<b>10.4</b>
	<b>0-30 min pre-incision</b>	42	<b>36.2</b>
<b>LATE</b>	0-30 min post-incision	9	<b>7.8</b>
	30-60 min post-incision	4	<b>3.4</b>
	> 60 min post-incision	2	<b>1.7</b>
	<b>Total</b>	116	<b>100.0</b>

<sup>1</sup>The recommended time for prophylactic antibiotics to be given is within 60 minutes prior to surgical incision being made

<sup>2</sup>Number of vascular surgery patients receiving an antibiotic at the specified time

<sup>3</sup>Percent of 116 vascular surgery patients receiving an antibiotic at the specified time

As can be seen from Table 12, less than half of the vascular surgery patients, 46.6% ( $n = 54$ ), received the prophylactic antibiotic as recommended within 0 - 60 minutes prior to the surgical incision being made. Antibiotic prophylaxis was given after the surgical incision was made (too late) to 12.9% ( $n = 15$ ) of the patients, and too long before the surgical incision was made (too early) to 4.3% ( $n = 5$ ) of the patients. For 2.6%

(n = 3) of the patients, an antibiotic was recorded as given in the OR, but the time was not recorded.

The appropriate antibiotic to be given for prophylaxis prior to vascular surgery is cefazolin unless there is an allergy, at which time another antibiotic is to be selected. Of the 77 patients who received an antibiotic, 74 patients received the correct antibiotic. For the patients who did receive the correct antibiotic, 71 of these patients received cefazolin and the other 3 received clindamycin due to penicillin allergy. Of 116 patients, only 63.8% (n = 74) of the patients received the correct antibiotic and 36.2% (n = 42) either received the incorrect antibiotic (n = 3) or no antibiotic (n = 39).

Antibiotic dosages should be given based on body weight. Any patient weighing greater than 100 kg should be given cefazolin 2 g, instead of cefazolin 1 g, which is the standard dose. The correct weight based dose of cefazolin was given to 61.2% (n = 71) of the 116 vascular surgery patients. Weight was not recorded on 3.4% (n = 4) of the patients so it is unknown if they received the correct dose of antibiotic, and 1.7% (n = 2) of the patients did not receive the correct weight based dose.

The 2 patients with an incorrect dose for their weight were patients who weighed 100 kg or more and received the standard dose of cefazolin 1g, instead of cefazolin 2g. There were 7 other patients weighing more than 100 kg, 2 of who received the correct dose of antibiotic and 5 patients who received no antibiotic at all.

Five patients were in the OR for longer than 4 hours and should have received a second dose of antibiotic for prophylaxis. However, none of these patients received a second dose of antibiotic.

Antibiotic continuation is not recommended after 24 hours postoperatively without a clear indication for use. There were 59 patients who were given antibiotics after the 24-hour period postoperatively. Of these 59 patients, 78% (n = 46) were receiving antibiotics after 24 hours postoperatively for no documented indication. Only 22% (n = 13 of 59) of the patients were receiving postoperative antibiotics because they had a preoperative infection that was continuing to be treated or because they had developed an SSI.

Table 13 shows the number of patients who received the correct drug, at the right time and the right dose, and if it was discontinued (D/C) within 24 hours as recommended. As can be seen from Table 13, only 16.4% (n = 19) of the patients met all 4 criteria for correct administration of antibiotics. There was no patient with a weight greater than 100 kg who received antibiotics meeting all 4 criteria.

Table 13: Number of Patients Meeting Criteria for Correct Antibiotic Prophylaxis

Criteria	n <sup>1</sup>	% <sup>2</sup>
Right drug, right dose, right time, D/C > 24h	19	16.4
Right time, right drug, right dose, <u>not</u> D/C > 24h	30	25.9
Right time, right drug, wrong or unknown dose	2	1.7
Right drug only, wrong dose and time	15	12.9
Wrong drug, right dose or time	11	9.5
Not given	39	33.6
<b>Total</b>	116	100.0

<sup>1</sup> Number of vascular surgery patients who met specified criteria

<sup>2</sup> Percent of 116 vascular surgery patients who met specified criteria

In summary, slightly more than two-thirds of patients received an antibiotic around the time of incision in the OR, but less than half received it at the recommended



time. Less than two-thirds of the patients, who received an antibiotic, received the correct dose and of the 9 patients weighing more than 100kg, only 2 received the correct dose. Of patients who continued to receive an antibiotic after 24 hours from the surgical incision time, more than three-quarters of patients received these for no clear indication. There were only 16.4% of all patients in the study who received the correct drug, at the correct time and dose, and had the antibiotic discontinued within 24 hours.

*Risk Factor: Hyperglycemia*

A preoperative glucose level was measured on 71.6% (n = 83) of the vascular surgery patients. A glycosylated hemoglobin (HbA1c) level was measured within 120 days of surgery on 33.6% (n = 39) of the vascular surgery patients. Diabetic and non-diabetic patients will be discussed separately.

*Preoperative glucose control in diabetic patients.* Of 53 diabetic patients, 94.3% (n = 50) had a preoperative glucose level assessed; readings ranged from 4.8 – 15.7 mmol/L, with a median level of 8.7 mmol/L (IQR: 6.3 – 11). There were 20.8% (n = 11) of the 53 diabetic patients with a preoperative glucose reading of 11.1 mmol/L or greater.

The time that the preoperative glucose level was measured ranged from 2 hours prior to surgery to greater than 7 days preoperatively. As shown in Table 14, 54.7% (n = 29) of all 53 diabetic patients had the preoperative glucose level done on the OR day but not within 2 hours of surgery, with 3 diabetic patients having no preoperative glucose assessment at all. For the 11 diabetic patients with a preoperative glucose of 11.1 mmol/L or greater, 2 patients had the glucose measured 2 hours before surgery, 7 patients

had it done at another point on the OR day, 1 patient had it measured 3-4 days preoperatively, and 1 patient had it measured 5 – 6 days preoperatively.

**Table 14: Length of Time from Preoperative Glucose Assessment to Surgical Incision Time in Diabetic Patients**

<b>Time of Pre-Operative Glucose</b>	<b>n <sup>1</sup></b>	<b>% <sup>2</sup></b>
Within 2 hours of surgery	6	<b>11.3</b>
On OR Day (>2 hours from surgery)	29	<b>54.7</b>
1-2 days preoperatively	7	<b>13.2</b>
3-4 days preoperatively	4	<b>7.5</b>
5-6 days preoperatively	3	<b>5.7</b>
≥ 7 days preoperatively	1	<b>1.9</b>
Not done	3	<b>5.7</b>
<b>Total</b>	<b>53</b>	<b>100.0</b>

<sup>1</sup> Number of diabetic patients having a pre-operative glucose level done at the specified time

<sup>2</sup> Percent of 53 diabetic patients having a pre-operative glucose level done at the specified time

*Intraoperative glucose control in diabetic patients.* Intraoperatively, only 7.5% (n = 4) of the diabetic vascular surgery patients had a glucose reading measured. One patient had 3 readings done and the other 3 patients had 1 reading done each, with no elevated intraoperative glucose readings noted. These 4 diabetic patients also had normal preoperative glucose levels measured on the OR day. None of the 11 diabetic patients with an increased preoperative glucose (greater than or equal to 11.1 mmol/L) had an intraoperative glucose level measured.

*PARR glucose control in diabetic patients.* PARR glucose levels were done on 73.1% (n = 38) of the 52 diabetic patients who went to the PARR, with the other diabetic patient going to ICU.

Table 15: PARR Glucose Readings of Diabetic Vascular Surgery Patients

		n <sup>1</sup>	% <sup>2</sup>
<b>Number of glucose readings done per patient in PARR <sup>1</sup></b>	1	35	92.1
	2	1	2.6
	3	1	2.6
	4	1	2.6
	<b>Total</b>	38	100.0
<b>Number of glucose readings <math>\geq 11.1</math> mmol/L in PARR <sup>2</sup></b>	0	28	73.7
	1	9	23.7
	2	1	2.6
	<b>Total</b>	38	100.0
<b>Number of treated glucose readings <math>\geq 11.1</math> mmol/L in PARR</b>		0	0

<sup>1</sup> Specified number of PARR glucose levels measured with corresponding n and % of patients in each category

<sup>2</sup> Specified number of PARR glucose levels  $\geq 11.1$  mmol/L with corresponding n and % of patients in each category

Table 15 above shows the number of glucose readings done per patient in the PARR and that 92.1% (n = 35) of the 38 patients having a glucose level assessed in the PARR had only 1 measurement done. At least 1 glucose level of 11.1 mmol/L or greater in the PARR occurred in 26.3% (n = 10) of the diabetic patients. No diabetic patients with glucose levels of 11.1 mmol/L or greater received treatment in the PARR for their elevated glucose reading. Seven patients with an elevated PARR glucose level had also had an elevated preoperative glucose level.

*Postoperative unit / ICU glucose control in diabetic patients.* In the first 7 days postoperatively, all diabetic patients had a glucose level assessed and 73.6% (n = 39) of 53 diabetic patients had glucose levels of 11.1 mmol/L or greater. As seen in Table 16, almost two-thirds of the diabetic patients who had an elevated glucose level



postoperatively, 64.2% (n = 25), had more than 5 elevated glucose levels in the postoperative period.

Table 16: Postoperative Glucose Readings for Diabetic Vascular Surgery Patients

<b>Number of glucose values ≥ 11.1 mmol/L on postoperative unit</b>	<b>n <sup>1</sup></b>	<b>% <sup>2</sup></b>
1	7	17.9
2	3	7.7
3	2	5.1
4	2	5.1
5-9	9	23.1
10-15	8	20.5
16-20	4	10.3
>20	4	10.3
<b>Total</b>	<b>39</b>	<b>100.0</b>

<sup>1</sup> Number of diabetic patients having specified number of postoperative glucose levels ≥ 11.1 mmol/L

<sup>2</sup> Percent of 39 diabetic patients having specified number of postoperative glucose levels ≥ 11.1 mmol/L

Treatments used for elevated postoperative glucose levels included oral medication, subcutaneous (S/C) insulin given both as regularly scheduled and stat doses, and IV insulin. There were also many patients who received no treatment. S/C insulin or an oral medication was effective for 100% of the readings that were done on patients having only 1 reading assessed and lowered the next glucose reading to less than 11.1 mmol/L. However, for patients having between 5 to more than 20 elevated glucose readings, more patients had continued elevated glucose levels compared to those with fewer measurements, indicating ineffective treatment. For patients having more than 20 glucose levels of 11.1 mmol/L or greater, S/C insulin was ineffective in reducing 80% of

the elevated glucose levels it was given to treat, and oral medication was ineffective for 100% of the hyperglycemic levels it was given to treat. When no treatment was given, the next glucose level remained elevated in 82.8 – 100% of the readings for patients who had more than one glucose level assessed.

**Table 17: Treatments Received Post-Operatively for Glucose Values  $\geq 11.1$  mmol/L in Diabetic Patients**

		S/C Insulin		Oral medication		No treatment	
n <sup>1</sup> glucose levels $\geq 11.1$ mmol/L	n <sup>2</sup> pts with specified glucose level	n <sup>3</sup> glucose levels treated	n <sup>4</sup> (%) <sup>5</sup> effective	n <sup>3</sup> glucose levels treated	n <sup>4</sup> (%) <sup>5</sup> effective	n <sup>3</sup> glucose levels treated	n <sup>4</sup> (%) <sup>5</sup> effective
1	7	1	1 (100)	2	2 (100)	3	3 (100)
2-4	9	6	5 (83.3)	9	7 (77.8)	5	1 (20.0)
5-9	9	17	6 (35.3)	21	6 (28.6)	29	8 (27.6)
10-15	8	53	21 (39.6)	1	0 (0)	29	5 (17.2)
16-20	4	69	16 (23.2)	3	1 (33.3)	19	5 (26.3)
> 20	4	30	6 (20.0)	13	2 (15.4)	13	0 (0)

<sup>1</sup> Number of glucose levels that were  $\geq 11.1$  mmol/L

<sup>2</sup> Number of patients having at least that number of glucose levels that were  $\geq 11.1$  mmol/L

<sup>3</sup> Number of patient glucose levels treated with the specified treatment or no treatment for that number of glucose levels that were  $\geq 11.1$  mmol/L

<sup>4</sup> Number of patients who received effective specified treatment or no treatment for that number of glucose levels that were  $\geq 11.1$  mmol/L

<sup>5</sup> Percent of patients who received effective specified treatment or no treatment for that number of glucose levels that were  $\geq 11.1$  mmol/L

*Glycosylated hemoglobin level - diabetic patients.* HbA1c values were measured on 52.8% (n = 28) of 53 diabetic patients, with a range of 4.2 – 10.1%, and a mean value of 7.4% (SD  $\pm$  1.5). The Canadian Diabetes Association (2008) recommends that all individuals with Type I or II diabetes should maintain a HbA1c of less than 7%. In 28



diabetic patients for whom a HbA1c level was available, 57.1% ( $n = 16$ ) of these patients were above the recommended target. Of the 16 diabetic patients with an elevated HbA1c, 81.3% ( $n = 13$ ) of the patients had at least 1 elevated glucose reading on the postoperative unit. Despite the fact that 13 of 16 patients with an elevated HbA1c also had an elevated postoperative glucose level, only 6 patients received treatment on their first elevated reading. These 6 patients continued to have from 8 – 35 glucose readings of 11.1 mmol/L or greater postoperatively. The other 7 patients, who had an elevated HbA1c level and an elevated postoperative glucose level and received no treatment, had from 1 – 13 elevated glucose readings of 11.1 mmol/L or greater postoperatively.

There were 25 diabetic patients who did not have a preoperative HbA1c level measured. In this group, 2 diabetic patients did not have a preoperative glucose level done either. Of the remaining 23 diabetic patients with a preoperative glucose measured but no HbA1c, 17.4% ( $n = 4$ ) had a hyperglycemic level of 11.1 mmol/L or greater.

*Summary: Glucose control and treatment in diabetic patients.* In summary, preoperatively most diabetic patients had a glucose level assessed with 20% of the patients having a level of 11.1 mmol/L or greater. Slightly more than half of the patients had the preoperative glucose level measured on the OR day, but more than one third had it measured 1 day to more than 7 days preoperatively. Intraoperatively, only 7.5% of diabetic patients had a glucose level measured and none were elevated. None of the patients with an increased preoperative glucose level had intraoperative glucose levels assessed. In the PARR, almost three quarters of the diabetic patients had a glucose level assessed with over one quarter having a level of 11.1 mmol/L or greater and none



receiving treatment. There were 7 patients who had increased preoperative glucose levels, who also had increased PARR levels. Postoperatively, all patients had their glucose level measured with three quarters of the diabetic patients having a level of 11.1 mmol/L or greater. More than two thirds of patients had had more than 5 elevated glucose levels on the postoperative unit.

As the number of elevated postoperative glucose levels a patient experienced increased, treatment for the elevated glucose reading remained ineffective. Patients with a high number of elevated glucose readings largely received ineffective treatment ranging from 80% ineffectiveness for patients receiving subcutaneous insulin to 100% ineffectiveness for patients receiving oral medication. For patients who never received any intervention for elevated glucose levels, most of their glucose levels remained high as well. Half of the diabetic patients had a HbA1c level done with more than half of these having a level > 7%. Overall, 75.5% (n = 40) of 53 diabetic patients were “ever hyperglycemic” which includes any glucose measurement during the perioperative period of 11.1 mmol/L or greater or a HbA1c level of 7% or greater.

*Glucose control in non-diabetic patients.* Of 63 non-diabetic vascular surgery patients, 52.4% (n = 33) had a preoperative glucose level done with levels ranging from 4.4 – 11.9 mmol/L, and a median level of 5.8 mmol/L (IQR: 5.2 – 6.9). There were 6.1% (n = 2 of 33) of the non-diabetic patients with a preoperative glucose level greater than or equal to 11.1 mmol/L. The greatest proportion of preoperative glucose readings for non-diabetic patients, 48.5% (n = 16 of 33), were done 1 - 4 days preoperatively.

Intraoperatively, none of the non-diabetic patients had a glucose level assessed including the 2 patients with an increased preoperative glucose. Of 59 non-diabetic patients going to the PARR, 12 had a PARR glucose level assessed and none had elevated levels. Included in this group of 12 patients is 1 of the non-diabetic patients who had an elevated preoperative glucose level. The other non-diabetic patient with the elevated preoperative glucose level did not have a PARR glucose level measured.

On the postoperative unit, there were 3 non-diabetic patients with elevated glucose levels. One patient had 4 elevated glucose levels that were treated successfully each time with an oral medication. This patient also had an elevated preoperative glucose level. The 2 other non-diabetic patients had 1 elevated glucose level each; one patient was successfully treated with an oral medication and one successfully treated with IV insulin.

HbA1c values were measured on 17.5% ( $n = 11$ ) of 63 non-diabetic patients, with a range of 4.7 – 11.1%, and a mean value of 6.1% ( $SD \pm 1.8$ ). In non-diabetic patients, the CDA (2008) recommends that HbA1c values should be maintained at less than 6%. For the sample of 11 non-diabetic patients for whom a HbA1c was available, 27.3% ( $n = 3$ ) were above the recommended target. Of the 3 non-diabetic patients with an elevated HbA1c, 1 patient had an elevated preoperative glucose reading and 4 elevated postoperative readings for which he received an oral medication.

*Summary: Glucose control and treatment in non-diabetic patients.* In summary, slightly more than half of the non-diabetic patients had a pre-operative glucose level measured with 2 patients having an elevated level of 11.1 mmol/L or greater. Patients with an elevated preoperative glucose level did not have an intraoperative glucose level

assessed. Less than one-quarter of the non-diabetic patients had a glucose level assessed in the PARR and all glucose levels were less than 11.1 mmol/L. Postoperatively, 3 non-diabetic patients with a glucose level of 11.1 mmol/L or greater were treated successfully with oral medication or insulin. Less than one-fifth had a HbA1c level measured with more than one-quarter of these having a level > 6%. Overall, 12.5% (n = 5) of 40 non-diabetic patients for which there were glucose and/or HbA1c readings available, were “ever hyperglycemic” which includes glucose readings of 11.1 mmol/L or greater and HbA1c levels of 6% or greater in the perioperative period.

*Risk Factor: Hypothermia*

*Preoperative temperature.* Of 116 patients having vascular surgery, 10.3% (n = 12) of the patients did not have a preoperative temperature recorded.

Table 18: Preoperative Temperatures of Patients

<b>Temperature Category</b>	<b>n <sup>1</sup></b>	<b>% <sup>2</sup></b>
< 36°C	4	<b>3.4</b>
36 - 36.5°C	54	<b>46.6</b>
>36.5°C	46	<b>39.7</b>
Not recorded	12	<b>10.3</b>
<b>Total</b>	<b>116</b>	<b>100.0</b>

<sup>1</sup> Number of vascular surgery patients having a preoperative temperature measurement in each category

<sup>2</sup> Percent of 116 vascular surgery patients having a preoperative temperature measurement in each category

The mean preoperative temperature for the 104 patients for whom temperatures were recorded was 36.4°C (SD ± 0.36). Preoperative temperatures ranged from 35.6 - 37.6°C with preoperative hypothermia (temperature less than 36°C) occurring in 4 of



these patients, and no temperatures greater than 37.6°C recorded. Table 18 demonstrates the number of patients in each temperature category.

While there were 104 preoperative temperatures recorded, only 63.5% (n = 66) of the patients had the time when the temperature was taken recorded. The length of time from the preoperative temperature measurement to surgical incision start time ranged from 10 – 1220 minutes (20.3 hours) with a median time of 149 minutes (IQR: 105 - 235). There were 4 patients with pre-operative hypothermic temperature measurements less than 36 °C, measured between 95 - 210 minutes pre-operatively.

*Intraoperative temperature and warming interventions.* Intraoperatively, three warming techniques were used on patients: a forced air blanket in 69.8% (n = 81) of the patients, an intravenous fluid warmer/forced air blanket combination in 5.2% (n = 6) of the patients, and a warm thermal blanket/forced air blanket combination in 2.6% (n = 3) of the patients. A combination of the three interventions was used in 1.7% (n = 2) of the patients, while 20.7% (n = 24) of the patients received no interventions. The time these interventions were applied was not noted on the OR record.

Despite warming techniques being used intraoperatively, intraoperative temperatures were recorded on only 8.6% (n = 10) of vascular surgery patients. Of the 10 patients, 2 patients had an AAA repair and 8 patients had a bypass procedure performed. Intraoperative temperatures ranged from 34.7 - 36.4°C, with a mean intraoperative temperature of 35.4°C (SD ± 0.6). The number of temperatures recorded intraoperatively on these 10 patients ranged from 1 - 6 measurements.

Of the 10 patients who had an intraoperative temperature recorded, 8 patients were hypothermic at some point during the surgical intervention despite the fact that 7 of the patients had a warming intervention in place. Patients remained hypothermic intraoperatively ranging from 60 – 150 minutes, with a mean length of 119 minutes (SD  $\pm$  31minutes). The total length of time in surgery for these 8 hypothermic patients ranged from 95 – 278 minutes with a median time of 123 minutes (IQR: 107 – 173). Two of the 10 patients who had an intraoperative temperature recorded did not experience hypothermia with only one of these 2 patients having a warming intervention in place. Of the 4 patients with hypothermic preoperative temperature measurements, only 1 patient had an intraoperative temperature measured and this patient was hypothermic despite the use of a forced-air blanket.

*PARR temperature and warming interventions.* Five patients went directly to ICU, so there is no PARR temperature data recorded for these patients. An initial temperature was recorded in the PARR within the first five minutes on 90.1% (n = 100) of the 111 patients, between 5 -10 minutes on 4.5% (n = 5) of the patients, and after 10 minutes on the other 5.4% (n = 6) of the 111 patients. One patient did not have a temperature recorded until he was in the PARR for 25 minutes.

Hypothermia on arrival to the PARR from the OR occurred in 29.7% (n = 33) of the patients. As the length of time that patients awaited transfer from the OR to the PARR increased, so did the proportion of patients who were hypothermic on arrival to the PARR. Hypothermia on arrival to the PARR was noted in 25% (n = 4) of 16 patients who waited less than 5 minutes for transfer, in 29.3% (n = 22) of 75 patients who waited

between 5 – 10 minutes, and in 36.8% ( $n = 7$ ) of 19 patients who waited more than 10 minutes for transfer from the OR to the PARR. There were 4 patients who waited longer than 20 minutes in this last group. A greater proportion of patients, 33.3% ( $n = 29$ ) of the 87 who received at least 1 warming intervention in the OR were hypothermic on arrival to the PARR, compared to 16.7% ( $n = 4$ ) of the 24 patients who did not receive any warming interventions in the OR.

Hypothermia during the patient stay in the PARR occurred on at least one temperature measurement in 41.4% ( $n = 46$ ) of the patients. The PARR temperatures for these 46 hypothermic patients ranged from 33.8 – 35.9°C, with a median temperature of 35.7°C (IQR: 35.2 – 35.9). Only 21.7% ( $n = 10$ ) of these 46 hypothermic PARR patients had another temperature measured within 15 minutes to assess if temperature had returned to normal.

Only 8.1% ( $n = 9$ ) of the 111 patients received warming interventions in the PARR such as forced air blanket, warm thermal blanket, or fluid warmer and all of these patients were hypothermic on at least 1 measurement in the PARR. Patients only received one intervention; there were no recorded combinations of interventions. A fluid warmer was used on 2 hypothermic patients, with both patients remaining hypothermic despite its use. Of the 2 patients with a forced-air blanket in use, only 1 patient returned to normothermia while the other remained hypothermic. Warm, thermal blankets were used on 5 more PARR patients, with 2 patients remaining hypothermic despite its use. Overall, 55.6% ( $n = 5$ ) of the 9 patients with hypothermia who received a warming intervention remained hypothermic despite its use.



For the patients who experienced hypothermia in the PARR, the median length of time spent there was 94 minutes (IQR: 80 – 123), with a range of 58 – 222 minutes. The non-hypothermic PARR patients' median PARR time was less at 85 minutes (IQR: 70 – 96), ranging from 12 – 1450 minutes. The PARR length of stay for the 111 patients ranged from 12 - 1450 minutes with a median PARR length of stay of 86 minutes (IQR: 75 - 110).

According to the final recording of patient temperature in the PARR, hypothermia was experienced on discharge from the PARR in 18.9% (n = 21) of patients. Of these 21 patients, one patient had also been hypothermic on arrival to the postoperative unit, 1 patient's vital sign measurement sheet was missing so information was not available, and the other 19 patients had been normothermic.

One of the patients who had been hypothermic preoperatively and intraoperatively did not arrive hypothermic to the PARR, but did become hypothermic while there and was discharged from the PARR with a hypothermic temperature. This patient had not had any recorded warming intervention provided in the PARR.

*Postoperative unit temperature.* Two of the 111 patients who went to the postoperative unit after PARR did not have a temperature recorded. The length of time from discharge from the PARR to the first time temperature was recorded on the postoperative unit ranged from 0 – 695 minutes (11 hours, 35 minutes) with a median time of 5 minutes (IQR: 0 – 15). As Table 19 shows, 56.8% (n = 63) of patients had a temperature assessed on the postoperative unit within the first five minutes. There were 6 patients whose

temperature was not recorded on the postoperative unit for more than one hour after their arrival with a range of time of 75 minutes – 11 hours, 35 minutes.

Table 19: Time Temperature Recorded on Postoperative Unit

<b>Time of Temperature<sup>1</sup></b>	<b>n<sup>2</sup></b>	<b>%<sup>3</sup></b>
0 – 5 minutes	63	<b>56.8</b>
> 5 – 10 minutes	13	<b>11.7</b>
> 10 minutes	33	<b>29.7</b>
Not recorded	2	<b>1.8</b>
<b>Total</b>	<b>111</b>	<b>100.0</b>

<sup>1</sup> Time temperature was assessed relative to arrival time on postoperative unit

<sup>2</sup> Number of vascular surgery patients having a surgical unit temperature recorded in each time category

<sup>3</sup> Percent of 111 vascular surgery patients having a surgical unit temperature recorded in each time category

On the first recorded temperature on the postoperative unit, 7 of the 109 patients for whom a temperature was available were hypothermic. Of these 7 hypothermic postoperative unit patients, only 1 of these patients had been hypothermic on discharge from the PARR, which means that the other 6 patients developed hypothermia during transfer from the PARR to the postoperative unit. These 6 patients had their temperatures assessed on the postoperative unit within 0 – 20 minutes of their arrival on the postoperative unit.

Of the 5 patients who went directly to the ICU, 2 were hypothermic on arrival. Both of these patients had been hypothermic intraoperatively as well despite the use of a forced air blanket on each patient. The other 3 patients who went to ICU were normothermic on arrival and had not had their temperature assessed intraoperatively; each

patient had a forced air blanket in use in the OR. In ICU the initial temperature reading ranged from 34.6 – 36.0°C.

*Summary: Temperature and warming interventions.* In summary, a preoperative temperature was not recorded on 10% of patients. Of the patients with a preoperative temperature reading, only 66% had the time the temperature was taken recorded with most of these within 2 hours of the beginning of surgery. Four patients had preoperative hypothermia. Intraoperatively, almost 70% of patients had a recorded warming intervention but no time of application recorded and only 10 patients had intraoperative temperatures recorded; 8 registered as hypothermic on average for 2 hours of the surgical intervention despite 7 of the 8 patients having a warming intervention in place.

Most patients in the PARR had a temperature measured immediately on arrival with almost one third registering as hypothermic. As the length of time a patient waited for transfer from the OR to the PARR increased, so did the number of patients who were hypothermic on arrival to the PARR. When hypothermic temperatures were recorded in the PARR, which occurred in 40% of patients, only 20% of this group had a temperature reassessed within 15 minutes to assess if the patient had returned to normothermia. Only 8% of patients in the PARR had a warming intervention recorded and of these patients, half remained hypothermic despite the use of the warming intervention. The median length of time on the PARR was slightly less than 1.5 hours. On discharge from the PARR, almost one fifth ( $n = 21$ ) were hypothermic even though 19 of these patients had been normothermic on arrival to the PARR.



Postoperatively, slightly more than half of the patients had a temperature recorded within 5 minutes of arrival on the surgical unit, but almost 30% were not recorded until more than 10 minutes after arrival. There were 7 patients who were hypothermic on arrival to the postoperative unit even though only 1 of these patients had been hypothermic on discharge from the PARR. The other 6 patients developed hypothermia on transfer from the PARR to the surgical unit. Overall, for the 116 vascular surgery patients, 44.8% (n = 52) were "ever hypothermic" which is a body temperature less than 36°C at any point immediately prior to, during, or after surgery up to the first 48 hours after surgery.

*Risk Factor: Inappropriate Hair Removal*

Hair removal is included as part of the preparation of the surgical area where the skin is to be incised for surgery. Only 12.9% (n = 15) of the 116 vascular surgery patients had no hair removal, while 87.1% (n = 101) had hair clipped at the operative site. Shaving is not recommended and none of the vascular surgery patients had hair shaved near the operative site. Intact skin at the operative site at time of surgery was reported on 90.5% (n = 105) of the patients. Conversely, 7.7% (n = 9) of the patients had abrasions, 1.7% (n = 2) of the patients had redness, and 0.9% (n = 1) of the patients had a nick at the operative site.

### *Surgical Site Infection*

This section describes the SSI rate in this sample of vascular surgery patients, followed by a presentation of results related to the diagnosis of SSI, the treatment of SSI, the characteristics of the surgical intervention and SSI, the characteristics of the patient and SSI, and anemia, blood loss, and SSI.

#### *Diagnosis of SSI*

A surgical site infection developed in 17.2% ( $n = 20$ ) of the vascular surgery patients. A superficial SSI developed in 14.7% ( $n = 17$ ) of the 116 vascular surgery patients and a deep incision SSI developed in 2.6% ( $n = 3$ ) of the patients. Almost half of the infections, 45% ( $n = 9$ ), involved the groin/thigh area of the incision, 50% ( $n = 10$ ) involved another area of the leg, and only 5% of infections ( $n = 1$ ) developed in an abdominal incision.

Of the 20 infections identified, 60% ( $n = 12$ ) were identified in the post-operative surgical unit and 40% ( $n = 8$ ) in the emergency department (ER). Post-operatively, only 15% ( $n = 3$ ) of the SSIs were diagnosed within 2 – 5 days of surgery, while 55% ( $n = 11$ ) of the SSIs were identified within 6 - 10 days postoperatively, and 30% ( $n = 6$ ) were identified 11 days or greater. Of the 2 patients who developed a SSI after 30 days, 1 had an artificial implant and was diagnosed in the ER at 98 days. The other patient did not have an implant and presented to the ER at 33 days post-operatively reporting that the signs and symptoms of infection had been present by 30 days. For this reason, an SSI was diagnosed.

Diagnosis was made based on Centers for Disease Control (CDC) Guidelines for Diagnosis of SSI found in Appendix I. A physician documented a diagnosis of SSI in 9 of the patients, 9 additional patients had documented purulent drainage and 2 patients had a positive microbiology swab for culture and sensitivity (C&S).

Overall, 13 of the patients with an SSI had purulent drainage in the wound with only 50% ( $n = 7$ ) having a swab for C&S taken. Of the 7 remaining patients with no purulent drainage reported, 3 had a swab for C&S done of the wound. Of the 10 patients who had a C&S swab done, 5 patients had positive C&S results: 2 patients had methicillin resistant *staphylococcus aureus* (MRSA), 1 patient had a moderate growth of beta haemolytic *streptococcus* - group G, 1 patient had a heavy growth of *pasteurella multocida*, 1 patient had a heavy growth of *bacillus* species. The other 5 patients had negative C&S swabs.

#### *Treatment of SSI*

Table 20 shows that 30% ( $n = 6$ ) of the patients who developed an SSI needed to be re-hospitalised. All 6 of these patients had been diagnosed in the ER. There were 2 additional patients who were not re-hospitalised who had been diagnosed in the ER; both these patients were given a prescription for oral antibiotics to take at home. IV antibiotics in combination with other treatments were required for 50% ( $n = 10$ ) of the patients who developed an SSI. Of these 10 patients, 6 patients were re-hospitalized and 4 were not.



Table 20: Treatment of SSI

<b>Treatment</b>	<b>n<sup>1</sup></b>	<b>%<sup>2</sup></b>
IV antibiotics, re-operation and re-hospitalisation	1	5
IV antibiotics, dressings and re-hospitalisation	1	5
IV antibiotics and re-hospitalisation	3	15
Oral and IV antibiotics and re-hospitalisation	1	5
Oral and IV antibiotics and dressings	1	5
IV antibiotics and dressings	1	5
IV antibiotics	2	10
Oral antibiotics	6	30
No treatment	4	20
<b>Total</b>	<b>20</b>	<b>100</b>

<sup>1</sup> Number of patients with an SSI having specified treatment

<sup>2</sup> Percent of patients with an SSI having specified treatment

Also of note in Table 20 is that there were 4 patients who did not receive any treatment at all. These 4 patients all had documented purulent drainage, 1 of which had a C&S swab done that showed a heavy growth of bacillus species. These patients also had other signs and symptoms of SSI including redness, swelling, heat, fever, and pain and met the CDC criteria for SSI.

#### *Characteristics of the Surgical Interventions and SSI*

Patients who had a femoral-tibial or femoral-popliteal bypass with an artificial graft comprised the largest proportion of patients, 25.9% (n = 7 of 27), who developed an SSI. An SSI developed in 22.2% (n = 2 of 9) of the patients with an AAA repair, and in 7.7% (n = 1 of 13) of the patients with a femoral-femoral bypass. None of the 7 patients with an aorto-bifemoral bypass developed an SSI.

Charts were reviewed for a full year after surgery for patients with artificial grafts, and for a full 30 days for patients with saphenous vein grafts. Artificial grafts were

inserted during surgery on 56 patients undergoing femoral-tibial or femoral-popliteal bypasses, aorto-bifemoral bypasses, femoral-femoral bypasses and AAA repairs. Of the 56 patients with these particular surgeries, 17.9% ( $n = 10$ ) of the patients developed an SSI compared to 16.7% ( $n = 10$ ) of 60 patients without an artificial graft who developed an SSI.

There were 25.9% ( $n = 7$  of 27) of the patients who had a femoral-tibial or femoral-popliteal bypasses with an artificial graft alone, excluding the other surgeries, that developed an SSI, compared to 16.7% ( $n = 10$ ) of 60 patients without an artificial graft who developed an SSI; the results were not statistically significant (RR: 1.56, CI 0.66 – 3.65;  $p = 0.3136$ ). There was only 12% power to detect a statistically significant difference.

Of the 15 patients who had an emergency procedure performed, 33.3% ( $n = 5$ ) developed an SSI compared to 14.9% ( $n = 15$  of 101) of patients with an elective procedure. The difference was not statistically significant (RR: 2.24, CI 0.95 – 5.28;  $p = 0.0770$ ). There was only 34% power to detect a statistically significant difference. There was no noted difference in type of anaesthetic received by those who did or did not develop an SSI.

A break in technique during the surgical procedure was reported for 4.3% ( $n = 5$  of 116) of the patients and none of these 5 patients developed an SSI. An SSI occurred in 1 of the 4 patients who did not have information reported on a break in technique during the surgical procedure. Of the 107 patients who had no break in technique reported, 17.8% ( $n = 19$ ) of the patients developed an SSI. Surgeon SSI rates ranged from 12.5 – 19.4%.

The length of surgery for the 20 patients who developed an SSI ranged from 53 – 266 minutes, with a median time of 87 minutes (IQR: 77 – 151). For the 96 patients who did not develop an SSI, the length of time in the surgery ranged from 43 – 357 minutes, with a median of 119 minutes (IQR: 85 – 145). Patients who developed an SSI thus usually had shorter surgeries but this difference was not statistically significant ( $p = 0.3475$ ).

#### *Characteristics of the Patients and SSI*

Patients were assessed for the presence of preoperative infections. Of the 12 patients with a preoperative infection, 16.7% ( $n = 2$ ) developed an SSI, compared to 20.9% ( $n = 18$ ) of 86 patients without a preoperative infection but this was not identified as a risk factor ( $p = 0.9556$ ). One patient had a preoperative infection in ulcers on his left foot that was treated with antibiotics, and a second patient had purulent drainage in a left heel cavity that was also treated with antibiotics. Both patients had bypass procedures performed and the SSI in each case developed in the incision, in an area separate from the preoperative infected area.

Overall, 18.3% ( $n = 17$ ) of 93 men and 13% ( $n = 3$ ) of 23 women developed an SSI. A similar proportion of patients with 1 – 3 comorbidities, 18.3% ( $n = 10$ ), and 4 – 5 comorbidities, 20.8% ( $n = 10$ ), developed an SSI. No patients with 6 – 7 comorbidities developed an SSI.

Vascular surgery patients had multiple comorbidities and 16 – 18% of patients having one or more comorbidities developed an SSI. The exception to this was the 10 patients with renal disease, 30% ( $n = 3$ ) of whom developed an SSI, and the 4 patients



with liver disease, 50% ( $n = 2$ ) of who developed an SSI. The difference between those patients with liver and/or renal disease and other comorbidities and those without liver or renal disease but with other comorbidities was not statistically significant (RR: 2.17, CI 0.86 – 5.43;  $p = 0.1191$ ). There was only 25% power to detect a statistically significant difference. There were no patients with stroke, arrhythmias, or inflammatory bowel disease who developed an SSI.

Of the 29 patients with no ASA score recorded, 2 patients developed an SSI. Of the 17 patients with an ASA score of 2, 11.8% ( $n = 2$ ) developed an SSI, compared to 24.6% ( $n = 16$ ) of 65 patients with an ASA score of 3. The difference was not statistically significant (RR: 2.09, CI 0.53 – 8.23;  $p = 0.2544$ ). There was only 9% power to detect a statistically significant difference. None of the 5 patients with an ASA score of 4 or 5 developed an SSI. There were 2 of these 5 patients that went to ICU postoperatively.

Of the 43 patients that were pre-admitted to a surgical unit prior to the operative day, 18.6% ( $n = 8$ ) developed an SSI compared to a similar proportion, 16.4% ( $n = 12$ ), of the 73 non pre-admitted patients. The median preoperative length of stay (LOS) for pre-admitted patients both with and without an SSI was 7 days (IQR: 3 – 11).

The median postoperative LOS for the 8 preadmitted patients who developed an SSI, 10.5 days (IQR: 7.5 – 13), was longer than those patients who were preadmitted and did not develop an SSI, 8 days (IQR: 7 – 10). This difference approached statistical significance ( $p = 0.0648$ ). For the patients who were not preadmitted who developed an SSI, the median postoperative LOS for those patients was 8 days (IQR: 6 – 10), which was only slightly longer than those patients who were not preadmitted and did not develop an SSI, 7 days, (IQR: 5 – 8).

Other known risk factors for SSI include steroid therapy, BMI and smoking. None of the 8 patients receiving steroid therapy developed an SSI. Of 7 patients with no BMI measurement, 3 patients developed an SSI. SSI developed in a greater proportion of those patients with a BMI measurement of 25.1-30, 18% (n = 9 of 50), than in those patients with a BMI of 25 or less, 13.9% (n = 5 of 36), or those with a BMI of greater than 30, 13% (n = 3 of 23).

Of the 40 self-reported smokers, 20% (n = 8) developed an SSI compared to 15.8% (n = 12) of 76 non-smokers. The amount smoked by 11 patients is unavailable; 2 patients in this group developed an SSI. Table 21 shows the number of patients who developed an SSI in each of the categories of number of cigarettes smoked per day.

Table 21: Number of Cigarettes Smoked and SSI

n cigarettes smoked per day	n patients smoking specified number of cigs	SSI		No SSI	
		n <sup>1</sup>	% <sup>2</sup>	n <sup>1</sup>	% <sup>2</sup>
<10	10	1	<b>10.0</b>	9	90.0
10-20	15	3	<b>20.0</b>	12	80.0
>20	4	2	<b>50.0</b>	2	50.0
Unknown	11	2	<b>18.2</b>	9	81.8
<b>Total</b>	40	8		32	

<sup>1</sup> Number of vascular surgery patients in each specified category that did or did not develop an SSI

<sup>2</sup> Percent of vascular surgery patients in each specified category that did or did not develop an SSI; proportion values are added per row, not column, and total 100% as it is the % of patients in each category

As the number of cigarettes smoked per day increased, the proportion of patients developing an SSI also increased. Although 50% (n = 2 of 4) of those who smoked greater than 20 cigarettes per day developed an SSI compared to 10% (n = 1 of 10) of

those who smoked less than 10 cigarettes per day, the difference was not statistically significant (RR: 2.5, CI 0.20 – 31.00;  $p = 0.4687$ ). There was only 17% power to detect a statistically significant difference. One of 4 patients who smoked more than 20 cigarettes per day, 25%, developed an SSI compared to 15.8% ( $n = 12$  of 76) of non-smokers but this difference also was not statistically significant (RR: 1.58, CI 0.27 – 9.34;  $p = 0.6265$ ). There was only 7% power to detect a statistically significant difference.

*Blood Loss, Anemia, and Transfusion of Blood and SSI: Preoperative, Intraoperative and PARR*

The hemoglobin range for the 20 vascular surgery patients who developed an SSI was 89 – 182 g/L, with a median of 137 g/L (IQR: 118–146). This was very similar to the 96 patients who did not develop an SSI; their hemoglobin levels ranged from 88 – 175 g/L, with a median level of 139 g/L (IQR: 122-153). Only 10% ( $n = 1$ ) of the 10 patients with preoperative anemia developed an SSI compared to 17.9% ( $n = 19$ ) of 106 patients without preoperative anemia with no statistically significant difference found. Intraoperative or PARR hemoglobin levels were not assessed on any patients who developed an SSI and none received PRBC in either the OR or PARR.

*Intraoperative blood loss, postoperative anemia, and SSI.* As seen in Table 22, the patient group that lost between 1200 – 4499 mL of blood during the surgical procedure had the greatest proportion of patients, 25% ( $n = 2$  of 8), that developed an SSI. In the group that lost 300 – 1199 mL of blood, 9.5% ( $n = 2$  of 21) of the patients developed an SSI.



However, the difference was not statistically significant (RR: 2.63, CI 0.44 – 15.61;  $p = 0.2800$ ). There was only 11% power to detect a statistically significant difference.

**Table 22: Blood Loss During Surgical Procedure, Postoperative Hemoglobin and SSI**

Blood loss category	n <sup>1</sup>	SSI			No SSI		
		n <sup>2</sup>	% <sup>3</sup>	Median <sup>4</sup> (IQR)	n <sup>2</sup>	% <sup>3</sup>	Median <sup>4</sup> (IQR)
0	60	13	<b>21.7</b>	118 g/L (115-125)	47	<b>78.3</b>	119 g/L (108-131)
1-299	20	3	<b>15.0</b>	102 g/L (88-114)	17	<b>85.0</b>	119 g/L (101-141)
300-1199	21	2	<b>9.5</b>	81 g/L (80-83)	19	<b>90.5</b>	101 g/L (84-107)
1200-4499	8	2	<b>25.0</b>	89 g/L (88-89)	6	<b>75.0</b>	90 g/L (89-99)
>4500	3	0	<b>0</b>	-	3	<b>100.0</b>	99 g/L (88-129)
<b>Total</b>	112	20			92		

<sup>1</sup> Number of vascular surgery patients in each blood loss category that had a postoperative hemoglobin level assessed

<sup>2</sup> Number of vascular surgery patients in each specified blood loss category that did/did not develop an SSI

<sup>3</sup> Percent of vascular surgery patients in each specified blood loss category that did or did not develop an SSI; proportion values are added per row, not column, and total 100% as it is the % of patients in each category

<sup>4</sup> Median hemoglobin level of all patients in each blood loss category

Postoperatively, the median hemoglobin levels for patients who lost 1200 – 4499 mL of blood were anemic; hemoglobin levels were similar whether the patient developed an SSI or not with a median postoperative hemoglobin level of 89 g/L and 90 g/L respectively. The patient group with an SSI who lost 300-1199 mL of blood were also anemic postoperatively with a median hemoglobin level of 81g/L, compared to patients in the same blood loss group without an SSI who had a median postoperative hemoglobin level of 101 g/L. This difference approached statistical significance ( $p = 0.0722$ ).

Of the 22 patients who received PRBC at any time during hospitalisation, 22.7% ( $n = 5$ ) developed an SSI compared to 16.0% ( $n = 15$ ) of 94 patients who never received PRBC. This difference was not statistically significant (RR: 1.42, OR 0.58 – 3.50;  $p = 0.4492$ ). There was only 8% power to detect a statistically significant difference.

There were 22 patients who were anemic on their first post-operative hemoglobin level that was assessed. There were 27.3% ( $n = 6$ ) of this group of 22 patients who developed an SSI. To treat the anemia in this group of 22 patients, 5 patients were given PRBC. Of those receiving PRBC, 40% ( $n = 2$ ) of 5 patients developed an SSI compared to 23.5% ( $n = 4$  of 17) of the anemic patients who never received blood. The difference was not statistically significant (RR: 1.7, CI 0.43 – 6.71;  $p = 0.4673$ ). There was only 5% power to detect a statistically significant difference.

### *Risk Factors of Interest and SSI*

#### *Risk Factor: Antibiotic Prophylaxis and SSI*

Of 77 patients who received antibiotics in the OR or PARR, 14.3% ( $n = 11$ ) developed an SSI compared to a greater proportion, 23.1% ( $n = 9$ ), of the 39 patients that never received antibiotics in the OR or PARR who developed an SSI. The difference was not statistically significant (RR 1.62, CI 0.73 – 3.57;  $p = 0.2364$ ). There was only 16% power to detect a statistically significant difference.

Of 55 patients with an artificial graft, 87.3% ( $n = 48$ ) received a prophylactic antibiotic. In contrast, of 61 patients with no artificial graft, only 47.5% ( $n = 29$ ) received a prophylactic antibiotic. For patients without an artificial graft, the SSI risk was higher in



those who did not receive antibiotics compared to those who did. The relative risk was 1.7, with a 95% CI of 1.11 – 2.6, indicating an elevated risk, although the difference did not achieve significance ( $p = 0.0565$ ).

Risk of getting an SSI was not increased in the same way in patients with an artificial graft. There were 14.3% ( $n = 1$  of 7) of the patients that never received an antibiotic and developed an SSI, compared to 18.8% ( $n = 9$  of 48) of the patients who did receive an antibiotic ( $p = 0.7748$ ).

Table 23 shows that the highest proportion of patients developing an SSI, 44.4% ( $n = 4$  of 9), occurred in patients who received an antibiotic late, specifically 0 – 30 minutes after the surgical incision was made.

Table 23: Antibiotic Administration Time and SSI

	Time antibiotic given relative to incision time	n <sup>2</sup>	SSI		No SSI	
			n <sup>3</sup>	% <sup>4</sup>	n <sup>3</sup>	% <sup>4</sup>
<b>Not Given</b>		39	9	<b>23.1</b>	30	<b>76.9</b>
<b>Unknown</b>		3	1	<b>33.3</b>	2	<b>66.7</b>
<b>Early</b>	> 2 h pre	1	0	<b>0</b>	1	<b>100.0</b>
	>1 – 2 h pre	4	0	<b>0</b>	4	<b>100.0</b>
<b>Recommended<sup>1</sup></b>	30-60 min pre	12	2	<b>16.7</b>	10	<b>83.3</b>
	0-30 min pre	42	4	<b>9.5</b>	38	<b>90.5</b>
<b>Late</b>	0-30 min post	9	4	<b>44.4</b>	5	<b>55.6</b>
	30-60 min post	4	0	<b>0</b>	4	<b>100.0</b>
	> 60 min post	2	0	<b>0</b>	2	<b>100.0</b>
	<b>Total</b>	116	20		96	

<sup>1</sup> The recommended time of antibiotic administration is within 0–60 minutes prior to surgical incision

<sup>2</sup> Number of vascular surgery patients receiving antibiotics in specified time period

<sup>3</sup> Number of vascular surgery patients receiving antibiotics in specified time period, with or without an SSI

<sup>4</sup> Percent of vascular surgery patients receiving antibiotics in specified time period, with or without an SSI; proportion values are added per row, not column, and total 100% as it is the % of patients in each category



Patients who received the antibiotic late, specifically 30 – 60 minutes late ( $n = 4$ ) and more than 60 minutes late ( $n = 2$ ) did not develop an SSI. Of the patients who received the antibiotic more than 60 minutes prior to the surgical incision being made ( $n = 5$ ), none of these patients developed an SSI as well.

Table 24 shows that receiving an antibiotic 0 – 30 minutes after the surgical incision was made, was a risk factor for SSI. Patients who received an antibiotic anytime after the surgical incision was made also had a higher relative risk of infection when compared to any time periods prior to the incision. Differences between patients who received the antibiotic anytime early ( $p = 0.0519$ ) or 0 – 30 minutes prior to the incision ( $p = 0.0576$ ) compared to anytime after the incision approached statistical significance.

**Table 24: Relative Risk for Antibiotic Administration Time 0 – 30 Minutes Post Incision versus Prior to Incision and SSI**

<b>Time</b>	<b>n</b>	<b>Rate</b>	<b>Relative Risk (95% CI)</b>	<b>p</b>
<b>Anytime early <sup>1</sup></b>	6 of 59	10.2%	4.37 (1.52 – 12.53)	<b>0.0068</b>
<b>0-30 min pre</b>	4 of 42	9.5%	4.67 (1.43 – 15.25)	<b>0.0089</b>
<b>0-60 min pre <sup>2</sup></b>	6 of 54	11.1%	4.60 (1.40 – 11.43)	<b>0.0113</b>
<b>Early (before 60 min)</b>	0 of 5	0%	Comment <sup>3</sup>	0.0778
<b>30-60 min pre</b>	2 of 12	16.7%	2.67 (0.62 – 11.49)	0.1632

<sup>1</sup> Anytime early is a combination of 0-60 min pre and early (before 60 min)

<sup>2</sup> 0-60 min pre is a combination patients 0-30min pre and 30-60 min pre

<sup>3</sup> Because zero patients of 5 developed an SSI, unable to calculate relative risk

In addition to correct timing of antibiotic administration, patients should receive the correct drug and appropriate dose for their body weight. There were 74 patients who received the correct prophylactic antibiotic, cefazolin, or in the case of a penicillin allergy, clindamycin. Of these 74 patients, 14.9% ( $n = 11$ ) developed an SSI. Of the 3

other patients who did not receive the correct prophylactic antibiotic, none of these patients developed a SSI. The correct weight-based dose of cefazolin was given to 71 patients and of these patients, 14.1% (n = 10) developed an SSI. Of the 3 patients for which it is unknown if they received the correct weight-based dose because they did not have a weight recorded, 1 patient developed an SSI. Of the 9 patients weighing more than 100 kg, 5 patients did not receive antibiotics and 2 developed an SSI. Of the remaining 4 obese patients who did receive antibiotics, 2 received the correct dose and 2 received the incorrect dose, but none of the 4 patients developed an SSI. Correct dosing also includes giving a second dose of antibiotic if the patient's surgical time is longer than 4 hours. None of the 5 patients in the OR for longer than 4 hours received a second dose of antibiotics and 1 of these patients developed an SSI.

Table 25 shows the criteria for correct administration of antibiotics and SSI.

Table 25: Criteria for Correct Administration of Antibiotics and SSI

Criteria	n <sup>1</sup>	SSI		No SSI	
		n <sup>2</sup>	% <sup>3</sup>	n <sup>2</sup>	% <sup>3</sup>
Right drug, right dose, right time	49	6	12.2	43	87.8
Right time, right drug, unknown or wrong dose	2	0	0	2	100.0
Right drug only, wrong dose or time	15	5	33.3	10	66.7
Wrong drug, right dose or time	11	0	0	11	100.0
Not given	39	9	23.1	30	76.9
<b>Total</b>	116	20		96	

<sup>1</sup> Number of vascular surgery patients with specified criteria

<sup>2</sup> Number of vascular surgery patients with specified criteria that did or did not develop an SSI

<sup>3</sup> Percent of vascular surgery patients with specified criteria that did or did not develop an SSI; total is 100% per row, not column, as it is the % of patients in each category



As can be seen from Table 25, 12.2% ( $n = 6$ ) of the 49 patients who received the correct drug and dose at the correct time developed an SSI compared to those patients who received the correct drug only with the incorrect dose and time, 33.3% ( $n = 5$  of 15) of whom developed an SSI. The difference was not statistically significant (RR: 1.75, CI 0.56 – 5.54;  $p = 0.3400$ ). There was only 10% power to detect a statistically significant difference. There was also no statistically significant difference between patients who did not receive an antibiotic and those who received the correct drug, at the correct dose and time (RR: 1.48, CI 0.90 – 2.43;  $p = 0.1660$ ).

*Risk Factor: Glucose and SSI*

*Preoperative glucose control in diabetic patients and SSI.* Of 53 diabetic vascular surgery patients, 18.9% ( $n = 10$ ) developed an SSI, compared to 15.9% ( $n = 10$ ) of 63 non-diabetic patients. The difference was not statistically significant (RR: 1.19, CI 0.54 – 2.64;  $p = 0.6706$ ). Eleven of the diabetic patients had an elevated preoperative glucose level greater than 11.1 mmol/L, and of these patients, 18.2% ( $n = 2$ ) developed an SSI. Of the other 39 diabetic patients with a normal preoperative glucose level, 17.9% ( $n = 7$ ) developed an SSI. One of 3 patients who did not have a preoperative glucose level measured developed an SSI.

*Intraoperative and PARR glucose control in diabetic patients and SSI.* Intraoperative glucose levels were assessed on only 4 diabetic patients. There were no glucose levels greater than 11.1 mmol/L and none of the 4 patients developed an SSI. Of



the 52 diabetic patients who went to PARR, 73.1% ( $n = 38$ ) had a PARR glucose level assessed. Of 10 diabetic patients that had at least 1 PARR glucose level of 11.1 mmol/L or more, 10% ( $n = 1$ ) of the patients developed a SSI. In comparison, of 28 diabetic patients with normal PARR glucose levels, 17.9% ( $n = 5$ ) developed an SSI. The other 14 diabetic patients never had a PARR glucose assessed and 28.6% ( $n = 4$ ) of these patients developed an SSI.

*Postoperative unit glucose control in diabetic patients and SSI.* At least 1 postoperative glucose level was elevated in 39 of 53 diabetic patients and of these patients, 15.4% ( $n = 6$ ) developed an SSI. The elevated glucose values for these 6 patients ranged from 12 – 15.4 mmol/L, with a median of 13.2 mmol/L (IQR: 12.1 – 14.4). Of the 14 remaining diabetic patients without an elevated postoperative glucose level, 28.6% ( $n = 4$ ) developed an SSI.

*Glycosylated hemoglobin level and SSI - diabetic patients.* Of the 28 diabetic patients with a HbA1c level assessed, 57.1% ( $n = 16$ ) had a HbA1c level above 7%. SSI developed in 37.5% ( $n = 6$ ) of these 16 diabetic patients. In comparison, 16.7% ( $n = 2$ ) of the 12 diabetic patients without an elevated HbA1c developed an SSI. The difference between the groups was not statistically significant (RR: 2.25, CI 0.55 – 9.26;  $p = 0.2272$ ). There was only 11% power to detect a statistically significant difference.

*Ever hyperglycemic – diabetic patients and SSI.* There were 40 diabetic patients who were “ever hyperglycemic” meaning they had an elevated glucose of 11.1mmol/L or

HbA1c level greater than 7% in the perioperative period. Of these 40 diabetic patients, 20% (n = 8) developed an SSI, compared to 15.4% (n = 2) of 13 diabetic patients who were “never hyperglycemic”. The difference between groups was not statistically significant (RR: 1.3, CI 0.32 – 5.36; p = 0.7118).

*Glucose control in non-diabetic patients and SSI.* Of 63 non-diabetic patients, 15.9% (n = 10) developed an SSI. Of 2 nondiabetic patients with an elevated preoperative glucose level greater than 11.1 mmol/L, 1 patient developed an SSI and 1 did not. There were no intraoperative glucose levels measured on non-diabetic patients. Of the 59 non-diabetic patients who went to the PARR, 20.3% (n = 12) had a glucose level assessed in the PARR with none having an elevated PARR glucose level. Three non-diabetic patients had an elevated glucose reading on the postoperative unit and 1 of these patients developed an SSI. For the 20 non-diabetic patients for whom no glucose measurement was available, 15% (n = 3) developed an SSI.

HbA1c levels were measured on 11 of 63 non-diabetic patients and of these patients, 27.3% (n = 3) had a HbA1c level above 6%. One patient, 33.3% developed an SSI. Eight non-diabetic patients had HbA1c levels within normal limits and of these 8 patients, 12.5% (n = 1) developed an SSI. The difference between the groups was not statistically significant (RR: 2.67, CI 0.23 – 30.40; p = 0.4250). There was only 5% power to detect a statistically significant difference.

Overall, 12.5% (n = 5) of 40 non-diabetic patients for whom there were glucose and/or HbA1c readings available were “ever hyperglycemic”. Of these 5 “ever hyperglycemic” patients, 40% (n = 2) developed an SSI. In contrast, of the 35 non-

diabetic patients who were “never hyperglycemic” who had levels measured, 8.6% ( $n = 3$ ) developed an SSI. This was a statistically significant difference between groups (RR: 4.67, CI 1.02 – 21.4;  $p = 0.0468$ ).

*Perioperative hyperglycemia in all patients and SSI.* Of 93 diabetic and non-diabetic patients combined for whom a glucose or HbA1c level was measured, 16.1% ( $n = 15$ ) developed an SSI, compared to 21.7% ( $n = 5$ ) of 23 patients who did not have a glucose or HbA1c levels measured. There were 45 patients in the combined group that were “ever hyperglycemic” and of these, 22.2% ( $n = 10$ ) developed an SSI. In contrast, of the 48 patients in the combined group that were “never hyperglycemic”, 10.4% ( $n = 5$ ) developed an SSI. Although the proportion that was “ever hyperglycemic” and developed an SSI was almost double those who did not develop an SSI, the difference between groups was not statistically significant (RR: 2.13, CI 0.79 – 5.76;  $p = 0.1219$ ). There was only 24% power to detect a statistically significant difference.

*Risk Factor: Temperature and SSI.*

*Preoperative temperature and SSI.* A preoperative temperature was assessed on 104 of 116 patients. There were 4 patients with hypothermic preoperatively; none developed an SSI. Of the group of 16 patients who did not have a preoperative temperature assessed, 25% ( $n = 4$ ) developed an SSI, while 15.4% ( $n = 16$  of 104) of the patients who did have a temperature assessed developed an SSI. The difference was not statistically significant (RR: 2.16, CI 0.86 – 5.43;  $p = 0.1191$ ). There was only 38%



power to detect a statistically significant difference. The median time from preoperative temperature being assessed to surgical incision was very similar between patients who did and did not develop an SSI, at 147 minutes (IQR: 100 – 179) and 150 minutes (IQR: 110 – 245) respectively.

*Intraoperative temperature and SSI.* For the 10 vascular surgery patients with a temperature measured in the OR, 8 patients were hypothermic and did not develop an SSI, while 2 patients who were normothermic did develop an SSI. Of 106 patients who had no intraoperative temperature recorded, 17.0% ( $n = 18$ ), developed an SSI.

In the patient group with only a forced air blanket in place in the OR for maintenance of normothermia, 19.8% ( $n = 16$  of 81) of the patients developed an SSI. Of this group with the forced air blanket only, all 6 which had a temperature assessed while receiving this intervention were hypothermic, but none developed an SSI. Of the 6 patients with a forced air blanket/ intravenous fluid warmer combination, 16.7% ( $n = 1$ ) developed an SSI. There was only 1 patient who had a temperature assessed while receiving these 2 interventions and this patient was hypothermic but did not develop an SSI. Of the 3 patients with a forced air blanket/warm thermal blanket combination, 33.3% ( $n = 1$ ) developed an SSI. Of the 2 patients with all three interventions, 1 patient had intraoperative temperatures measured and this patient was hypothermic, but neither patient developed an SSI. Overall, 19.6% ( $n = 18$  of 92) of the patients with an intervention developed an SSI compared to those who had no interventions, 16.7% ( $n = 4$  of 24); the difference was not statistically significant (RR 1.04, CI 0.38 – 2.83;  $p = 0.9333$ ).

*PARR temperature and SSI.* A greater proportion of patients who were hypothermic on arrival to the PARR from the OR developed an SSI, 24.2% ( $n = 8$  of 33), compared to 14.1% ( $n = 11$  of 78) of those who were not hypothermic. The difference was not statistically significant (RR: 1.72, CI 0.76 – 3.88;  $p = 0.1949$ ). There was only 19% power to detect a statistically significant difference. As well, a greater proportion of patients who were hypothermic on at least one measurement in the PARR, 20% ( $n = 9$  of 45), developed an SSI compared to 15.2% ( $n = 10$  of 66) of the patients who were not hypothermic in the PARR. The difference was not statistically significant (RR: 1.27, CI 0.57 – 2.88;  $p = 0.5646$ ).

Of the 9 patients receiving a warming intervention in the PARR, 5 patients remained hypothermic and 60% ( $n = 3$ ) of these patients developed an SSI. The other 4 patients returned to normothermia after the use of a warming intervention and none developed an SSI. The difference approached statistical significance ( $p = 0.0578$ ). There was only 13% power to detect a statistically significant difference.

The length of PARR stay for the 19 patients who went to the PARR and developed an SSI ranged between 50 – 195 minutes, with a median time of 86 minutes (IQR: 73 – 142). The length of PARR stay for the 92 patients without an SSI had an identical median time of 86 minutes (IQR: 75 – 110), with a range of 12 – 1450 minutes.

In the final recording of temperature in the PARR, 81.1% ( $n = 90$  of 111) of the patients were normothermic and 18.9% ( $n = 21$  of 111) were hypothermic. Of the patient group with hypothermia on discharge, 9.5% ( $n = 2$  of 21) developed an SSI. Of the group who were normothermic on discharge, double the proportion, 18.9% ( $n = 17$  of 90),

developed an SSI. The difference was not statistically significant (RR 0.50, CI 0.13 – 2.02;  $p = 0.3049$ ).

*Postoperative unit temperature and SSI.* There were 109 patients who had a temperature assessed on arrival to the surgical unit and of these patients, 6.4% ( $n = 7$ ) were hypothermic on arrival. Of the 7 hypothermic patients, 42.9% ( $n = 3$ ) of the patients developed an SSI compared to 15.7% ( $n = 16$  of 102) of the patients who were not hypothermic on arrival to the post-operative unit. The difference approached statistical significance (RR: 2.73, CI 1.04 – 7.18;  $p = 0.0668$ ). There was only 35% power to detect a statistically significant difference. Six of the 7 patients were hypothermic on arrival to the surgical unit had not been hypothermic on discharge from the PARR. Conversely, 90.5% ( $n = 19$  of 21) patients who had been hypothermic on discharge from PARR were no longer hypothermic on arrival to the postoperative unit and 2 of these patients developed an SSI.

Five patients went directly to ICU, 2 of whom were hypothermic on arrival there from the OR. Neither of these patients developed an SSI. Of the 3 other normothermic patients in ICU, 1 patient developed an SSI.

*Ever hypothermic and SSI.* Of 64 patients who were “ever hypothermic”, an SSI developed in 15.6% ( $n = 10$ ) of the patients. In comparison, an SSI occurred in more, 19.2% ( $n = 10$ ), of the 52 patients who were “never hypothermic”. The difference was not statistically significant (RR: 1.23, CI 0.55 – 2.72;  $p = 0.6091$ ).



*Risk Factor: Inappropriate Hair Removal and SSI*

There were 101 patients who had hair clipped at the surgical incision site prior to surgery, 16.8% ( $n = 17$ ) of whom developed an SSI. There were 15 other patients who had no hair removal at the surgical incision site, 20% ( $n = 3$ ) of whom developed an SSI.

Of 105 patients with intact skin, 16.2% ( $n = 17$ ) of the patients developed an SSI compared to 37.5% ( $n = 3$ ) of the 8 patients with abrasions noted at the surgical incision site prior to surgery. The difference was not statistically significant (RR: 2.38, CI 0.88 – 6.45;  $p = 0.1159$ ). There was only 23% power to detect a statistically significant difference. There were 6 of 8 patients with noted abrasions from unspecified reasons on the OR chart who received cefazolin; 5 patients received it 0 – 60 minutes pre-incision and did not develop an SSI, and 1 patient received it 0 – 30 minutes post-incision and developed an SSI. Of the 2 remaining patients of 8 with abrasions who did not receive an antibiotic, both developed an SSI. There was a statistically significant difference noted between those patients with abrasions who received antibiotics in a timely manner ( $n = 5$ ), none of whom developed an SSI, compared to 100% ( $n = 3$ ) of those patients who did not receive antibiotics or did not receive them in a timely manner ( $p = 0.0047$ ). No patients with nicks or redness noted at the surgical incision site developed an SSI.

*Risk Factors and SSI – Multivariate Analysis*

The bivariate analysis in the preceding sections showed that several factors were significantly associated with increased SSI risk. However, bivariate analysis cannot control for confounding factors. Therefore, a multivariate analysis was carried out to determine which factors were independent predictors of the development of an SSI. A

stepwise logistic regression process was used whereby variables were dropped and effects were assessed using the likelihood ratio test. All variables that showed statistically significant differences in effect on SSI development or variables that appeared to be of clinical interest were entered into the logistic regression. The variables included in the model were: surgeon (3 categories - surgeon having the lowest SSI rate was baseline), presence of an artificial graft, number of cigarettes smoked per day (no cigarettes as the baseline, presence of renal and/or liver disease, undergoing an emergency procedure, having broken skin in the surgical area prior to incision, blood loss categories (>1200 mL, 300-1199 mL, and 0-299 mL with this last category being the baseline), antibiotics categories (3 categories with wrong antibiotic time but right dose and drug as the highest risk, nor receiving antibiotics as the next highest risk, and correct time of antibiotic as the baseline), hypothermia on arrival to the PARR, having diabetes, hypothermia on arrival to the surgical unit, having hyperglycemia, and receipt of blood products. Logistic regression did not identify any of the variables as independent predictors for SSI, most likely because of the small sample size and low power. The model explained less than 22% of the variance ( $\text{pseudo-R}^2 = 0.2204$ ). Table 26 shows the risk factors for SSI that were assessed in the logistic regression.

**Table 26: Odds Ratios for the Logistic Regression Model for the Prediction of SSIs (n = 109)**

<b>Variable</b>	<b>Odds Ratio</b>	<b>Standard Error</b>	<b>95% CI for OR</b>
Surgeon 2	0.8321	1.0035	0.0783-8.8453
Surgeon 3	2.2300	2.5514	0.2368-20.9979
Artificial graft	2.9854	2.3353	0.6444-13.8311
Number of cigarettes per day	0.9988	0.0316	0.9387-1.0628
Renal/liver disease	5.0046	5.2733	0.6346-39.4701
Emergency procedure	4.0315	3.2014	0.8502-19.1163
Broken skin	3.4937	3.7864	0.4176-29.2282
Blood loss 300-1199 mL	0.1383	0.1789	0.0109-1.7448
Blood loss > 1200 mL	0.5385	0.8369	0.02559-11.3295
Right antibiotic, wrong dose and time	7.1751	6.5900	1.1859-43.4127
Not receiving antibiotic	4.7019	3.9062	0.9229-23.9565
Hypothermia on arrival to PARR	2.1812	1.5197	0.5568-8.5453
Diabetes	0.5658	0.5675	0.0792-4.0406
Hypothermia on arrival to the surgical unit	5.0824	5.4892	0.6119-42.2085
Hyperglycemia	2.2493	2.2228	0.3243-15.6035
Receipt of PRBC	1.8084	1.6586	0.2996-10.9143

### *Conclusion*

An SSI developed in 17.2% of the vascular surgery patients in this study. The 4 main risk factors for SSI that were examined included: 1) antibiotic prophylaxis, 2) hyperglycemia, 3) hypothermia, and 4) inappropriate hair removal.

Results show that antibiotic prophylaxis was not being followed as recommended in the literature and this contributed to increased SSI risk in vascular surgery patients. Antibiotics were not being given prophylactically to all patients, many were given too late, they were not repeated in the OR for procedures past 4 hours, and the dose was not



adjusted for patients with weights greater than 100 kg. Significant risk factors for SSI were antibiotics given after the surgical incision was made, and for patients with skin abrasions, not receiving antibiotics in a timely manner or at all.

Hyperglycemia was also a problem for vascular surgery patients. Hyperglycemia, measured by glucose levels and HbA1c levels, occurred often, through all stages of the perioperative process in both diabetic and non-diabetic patients. In non-diabetic patients, hyperglycemia in the perioperative period was a significant risk factor for SSI.

Hypothermia was a common occurrence through all stages of the perioperative process, much like hyperglycemia. Despite the use of warming interventions, hypothermia persisted. While hypothermia was not shown to be a risk factor for SSI, trends towards increased SSI risk were seen when patients were hypothermic in the PARR and on transfer from one unit to another.

Hair removal practices in the OR followed protocols that are commonly recommended. There were some patients with abrasions on their skin, and while this was not identified as a risk factor for SSI, a trend was seen. Patients with abrasions on their skin who did not receive correct antibiotic prophylaxis had a significantly increased risk of SSI development.

Additional risk factors that approached significance included having an emergency procedure, anemia with blood loss between 300-1199 mL of blood, not receiving an antibiotic if there was no artificial graft inserted during surgery, and hypothermia on arrival to the postoperative unit. There were also some noteworthy issues with documentation. There was missing documentation with respect to ASA scores, patients' weights, preoperative and intraoperative temperatures, and diagnosis of SSI by

the physician. As well, assessment of glucose and temperature in particular was inconsistent, and there did not appear to be good follow-through of patients throughout the perioperative process if they had experienced hyperglycemia or hypothermia. Hyperglycemia was inadequately treated, and warming interventions used for normothermia were not evaluated and appeared relatively ineffective. These and other issues will be discussed in Chapter 5.

## Chapter 5 Discussion

Because surgical site infections (SSIs) incur such high personal and financial costs on individuals who develop them, they are an area targeted by the “Safer Healthcare Now” (SHN) campaign to reduce preventable occurrences in hospital. Four interventions suggested by the SHN campaign to reduce SSI occurrence are: 1) antibiotic prophylaxis, 2) glycemic control in the Coronary Artery Bypass Graft (CABG) surgery population, 3) maintenance of intraoperative normothermia in the colorectal surgery patient population, and 4) appropriate preoperative hair removal. There is little information available about the effect of these risk factors on vascular surgery patients, which is why this study was undertaken. This study also determined the SSI rate of vascular surgery patients undergoing select surgeries. With this information on risk factors and rates as well as how these patients are cared for, factors amenable to intervention by nurses may be addressed. This chapter discusses the main findings of the study, starting with incidence rates and focusing on the risk factors of interest. Practice is also described in each section pertaining to the risk factor under discussion. The factors explored in this study related to SSI risk will be compared to relevant studies as discussed in the literature review.

Prior to this discussion, the aspect of “clinical importance” must be introduced. For the purpose of this study, clinical importance recognizes that decisions about optimal patient care should be made at times despite there being a lack of statistical significance. In my study as in many other studies, statistical significance was not achieved possibly because of the small sample size and therefore decreased power to find a relationship. The reverse is also true, a small sample size does not mean that a relationship does exist;



chance hasn't yet been ruled out. Deciding if something is clinically important enough to change practice must also take into account published guidelines, previous research findings, and accepted standards of care. If all clinical importance was decided based on statistical significance, much of nursing research would be disregarded because there is no statistical significance with qualitative research or descriptive research and not all of the human condition is amenable to a randomized, controlled study (Dyer, 1997). In this chapter, findings described as clinically important means that they should be addressed by either exploring them further or taking action until higher powered studies become available.

#### *Incidence of SSI in Vascular Surgery Patients*

A surgical site infection (SSI) developed in 17.2% of the vascular surgery study patients. This SSI rate seemed high, so a comparison of rates across Canada was undertaken. However, there was no national SSI surveillance system for comparison of SSI rates available in Canada. There was only one study found with a Canadian SSI rate in which 7.0% of 473 patients having vascular surgery developed an SSI (Turnbull et al., 2005).

The primary purpose of the Turnbull et al. (2005) study was an exploration of the effect of antibiotic prophylaxis on SSI risk. Prospective in-hospital surveillance was completed through chart review and assessment of patients while they were in hospital. As well, any patient who was readmitted to the emergency department (ER) or to the hospital with an SSI was included in the overall SSI rate for up to 30 days if there was no prosthetic graft and for up to one year if there was a prosthetic graft. There were

similarities between the Turnbull et al. study and my study with respect to patient characteristics and comorbidities, and the use of standard definitions of SSI from the Centers for Disease Control (CDC). In the Turnbull et al. study however, despite indications that patients were followed for the recommended time period, the proportion of patients who were actually assessed post-discharge is not reported. Standard SSI surveillance only focuses on the number of cases that come back to the facility, but it does not ensure that other cases of SSI that have developed are counted. It is a possibility that patients returned to other hospitals or to their family physician with signs or symptoms of an SSI and never presented to the hospital that originally performed their surgical procedure. Such patients would not be counted as a patient who developed an SSI. This may have led to an underestimation of the proportion of SSIs that truly developed with a lower than actual SSI rate reported in the Turnbull et al. study.

Within six weeks after surgery, 94% of the vascular surgery patients in my study were seen by an attending vascular surgeon, therefore validating that those patients did or did not have an SSI in that time frame. As well, as recommended by the CDC, complete 30-day post-discharge surveillance for 60 patients without an artificial graft was completed on 95% of patients. This indicates that there is high accuracy in the SSI rate of the vascular surgery study patients without a graft in my study.

For the 56 patients with an artificial graft who the CDC recommends have surveillance for a full year, post-discharge surveillance was incomplete though comparable to methods used in most studies. While charts were reviewed for up to 1 year to assess for visits to the ER, outpatients department or vascular lab for signs or symptoms of infection, it is unknown how many patients with an artificial graft SSI may



have been missed because they did not return to the facility but instead went to another facility or their family doctor. However, 92.9% of vascular surgery patients with an artificial graft in my study were seen within 6 weeks after surgery. Of the 10 patients with an SSI who had an artificial graft, 9 of these patients were seen within 6 weeks of surgery, indicating that the SSI rate in vascular surgery patients with an artificial graft is accurate within this time period. Because every patient was not assessed after 6 weeks, the SSI rate from my study represents the proportion of SSIs that developed in this particular time period only. The difference in surveillance methods and follow up in my study compared to the Turnbull et al. (2005) study explains, at least in part, the difference in SSI rates between the two studies and indicates a possible underestimation of their SSI rate. As discussed in the literature review, when post-discharge surveillance is not complete with verification of patients not having an SSI as well as identification of those who do, SSI rates are much lower and many SSIs are missed.

Because there were no other studies available with Canadian vascular surgery SSI rates and no national reporting system in place to compare the rate from my study, the literature was reviewed from other countries for further comparison. At first glance, the rate from my study appeared to be much higher than other countries. With the exception of 1 report of 11 in the last 10 years (since 1999), all other SSI rates were considerably lower than my study rate, with most being less than half this rate, ranging from 11% to 4.34%. However, on further examination of these reports, differences were again seen in post-discharge surveillance as with the Turnbull et al. (2005) study. There is little point in comparing to reports from 3 older studies, because surgical techniques, antibiotic protocols, and other practices differed at that time. These older studies reported SSI rates



of 4.1%, 5.1%, and 16% (Nicholson et al., 1994; Richet et al., 1991; van Himbeeck et al., 1992).

There were 2 studies that did do post-discharge surveillance (Mannien et al., 2006; Moro et al., 2005). In the Mannien et al. study, an SSI rate of 21.1% was reported which was the outermost limit of SSI rates found in vascular studies. The authors indicated that patients were followed for the appropriate time period for development of SSI but did not report how many patients were lost to follow-up once discharged home suggesting that post-discharge surveillance was incomplete. In this case, it is likely that their SSI rate may be under-reported even though it was higher than the SSI rate in my study. In the second study that used post-discharge surveillance, a much lower SSI rate of 5.4% was reported (Moro et al.). However, in this study, the post-discharge surveillance consisted of a phone call to the patient or a form to be filled out by a physician and sent back to the facility, if the patient presented to them with an SSI. An SSI was only counted if both of these criteria were met, which would grossly underestimate the true SSI rate.

There were 9 additional reports of SSI rates in the last 10 years that either did not report if post-discharge surveillance was done, or did not do any post-discharge surveillance (Chang et al., 2003; Coello et al., 2005; Edwards et al., 2008; Hawn et al., 2008; Morton et al., 2008; NNIS system, 2004; O'Sullivan et al., 2006; Pounds et al., 2005; Schepers et al., 2003). Assuming that post-discharge surveillance was not done because it was not reported, it is likely that the reports underestimated the true SSI rate in each area while making the rate from my study seem inflated, even though it is possibly the most accurate rate. Further details of these studies are found in Appendix B, Tables 3 and 4.

### *SSI Risk Factors*

Because the SSI rate was 17.2% in my study, it was important to identify risk factors that increase SSI risk with the ultimate goal of defining interventions that may decrease the effect of a risk factor on SSI development, thereby reducing the SSI rate. As discussed in the literature review, the SHN campaign targeted four specific interventions to reduce SSI risk, namely inappropriate antibiotic prophylaxis, perioperative hyperglycemia and intraoperative hypothermia in specific patient populations, and inappropriate preoperative hair removal. Because there was a gap in the literature about the effect of these risk factors on SSI development in vascular surgery patient population as well, these relationships were explored. As my study's primary research questions also related to nursing practices, a discussion of both the risk factors and nursing interventions to reduce these risk factors will be included in this section. This discussion will begin with antibiotic prophylaxis because inappropriate antibiotic prophylaxis emerged as the greatest risk factor for SSI in my study.

#### *Inappropriate Antibiotic Prophylaxis*

During 2005, the time period during which patients in my study had their vascular surgery, the SHN campaign was just getting started and there were no specific protocols being followed within Eastern Health for antibiotic prophylaxis in vascular surgery patients. The literature at that time did recommend the administration of a prophylactic antibiotic within 60 minutes prior to the surgical incision, but at Eastern Health the decision to give antibiotics prophylactically or not was made by the physicians involved in the care of the patient undergoing surgery. Because the SHN campaign had



recommended antibiotic prophylaxis as a strategy to reduce SSI and there was limited information in the literature related to vascular surgery patients and risk factors for SSI, it was decided to explore this relationship in my study.

An antibiotic was not received by 33.6% of the patients. Of the other 77 patients who did receive an antibiotic, 14.3% developed an SSI compared to 23.2% of the 39 patients who did not receive an antibiotic ( $p = 0.2364$ ). Of 55 patients with an artificial graft, 87.3% received a prophylactic antibiotic. In contrast, of 61 patients with no artificial graft, only 47.5% received a prophylactic antibiotic.

For patients without an artificial graft, the receipt of antibiotics appeared to decrease risk although the difference did not achieve significance ( $p = 0.0565$ ). Risk of getting an SSI was not increased in the same way in patients with an artificial graft. There were 14.3% of 7 patients that never received an antibiotic and developed an SSI, compared to 18.8% of 48 patients who did receive an antibiotic ( $p = 0.7748$ ). Although none of these differences achieved statistical significance, it would appear that receiving an antibiotic was more beneficial than not, particularly in patients without an artificial graft. However, just receiving an antibiotic was insufficient to reduce the risk of SSI. Of importance also were the microorganisms the antibiotic was directed against, the time it was received, the dose based on body weight, and receipt of a second dose after 4 hours in the OR.

*Correct antibiotic choice and dose.* As outlined in the literature review, cefazolin, a first generation cephalosporin, is the antibiotic of choice in clean vascular surgery because it is directed against Gram-positive bacteria that are most commonly encountered



during vascular surgery (Blondel-Hill & Fryters, 2006; Mangram et al., 1999). In the case of a penicillin allergy, clindamycin is the antibiotic of choice (Blondel-Hill & Fryters; Mangram et al.). Cefazolin or clindamycin was received by 92.2% of patients who received an antibiotic in my study.

In addition to receiving the correct drug, most patients also received the correct dose. However, of 9 patients who weighed more than 100kg, less than half received an antibiotic, and of those that did, less than one-quarter received the correct dose. This is similar to findings of another Canadian study where only 15% of patients with a high BMI received the correct dose (Zvonar et al., 2008). The literature is clear that patients weighing greater than 100kg should be given 2 grams (g) of cefazolin instead of 1g to reduce SSI risk (Bandyk, 2008; Blondel-Hill & Fryters, 2006; Bratzler & Houck, 2004; Ramiro et al., 2007), but this did not always occur in my study.

There was no difference found in SSI risk for patients who did or did not receive the correct dose of antibiotic based on weight. However, of the patients with a missing weight measurement and therefore no BMI calculated, half developed an SSI. For this reason, there may be an underestimation of the effect that a weight-based dose of antibiotic has on SSI risk. If these patients without a BMI measurement had weighed more than 100 kg, a greater difference related to the effect of incorrect weight-based antibiotic prophylaxis and SSI risk may have been seen. It is unclear from my study if receiving the correct weight based dose of an antibiotic is associated with SSI. However, it still may be helpful for the OR record of patients weighing more than 100 kg to be flagged in some way to serve as a reminder that these patients should receive a higher dose based on research from other patient groups.

*Correct antibiotic timing.* Maintenance of a therapeutic dose of antibiotic in the tissues during surgery decreases SSI risk. Key to this occurring is not only the correct weight-based dose as previously discussed, but also the timing of antibiotic administration and repeat dosing for patients in the OR for longer than 4 hours so that tissue antibiotic levels are optimal (Bandyk, 2008; Blondel-Hill & Fryters, 2006; Classen et al., 1992; Dellinger et al., 2005; Griffin, 2005; Silver et al., 1996; Stewart et al., 2007). Despite the strength of the evidence in the literature regarding antibiotic prophylaxis timing, less than half of the patients in my study received an antibiotic at the recommended time of 0 – 60 minutes prior to the incision being made. The highest proportion of SSIs occurred in patients who received antibiotics late, specifically, within 30 minutes after the surgical incision was made. Results showed that when antibiotics were given after the incision was made compared to before the incision was made, the SSI risk was increased as much as 4.7 times ( $p = 0.0089$ ).

For patients in the OR for longer than 4 hours, a second dose of antibiotic should be given to maintain optimal tissue antibiotic levels as previously mentioned. However, of the 5 patients in the OR for longer than 4 hours, none received a second dose. Of these patients, 1 patient developed an SSI. Morita et al. (2005) reported that 26.5% of patients who should have received a second dose but did not developed an SSI, compared to 8.5% of those patients who did receive a second dose as recommended.

From my study findings on increased SSI risk with incorrect timing and the literature already available drawing the same conclusion, it can be concluded that incorrect antibiotic timing in vascular surgery patients is a risk factor for SSI. However,



because of the small sample of patients who never received a second dose, a conclusion regarding the need for a second dose if the surgery is longer than 4 hours cannot be made.

It was not assessed why antibiotics were not given to all vascular surgery patients. In informal discussion during a presentation with nurses from the OR, the nurses indicated that they felt it was the responsibility of the anaesthetist to administer the prophylactic antibiotic. Tan, Naik, and Lingard (2006), explored obstacles to proper timing of antibiotic prophylaxis with anesthetists and found recurrent themes emerged including low priority and inconvenience. In an opinion article by Klein (2008) that explored standardization of perioperative care, he indicated that there are still significant barriers to adopting established standards such as those related to antibiotic prophylaxis which involve the anaesthetist's and surgeon's opinions on what is appropriate. In a study by van Kasteren, Kullberg, deBoer, Mintjes-de Groot, & Gyssens (2003), a lack of agreement by the surgeon to the antibiotic guidelines was one of the greatest contributors to incorrect antibiotic prophylaxis. At the time of this study, there was no protocol followed at Eastern Health and antibiotic administration was at the discretion of the physicians in the OR. Perhaps with the development of a protocol that addresses these issues, antibiotic prophylaxis rates will improve and SSI rates will drop. There has been evidence to this effect reported in the literature with SSI rates dropping as much as 27% when antibiotic administration protocols were put in place (Dellinger et al., 2005). In a study with vascular surgery patients, when strategies were implemented that addressed compliance with antibiotic prophylaxis, compliance rose by 34%, from 53% to 87% (White & Schneider, 2007).



*Correct antibiotic prophylaxis – getting it all right.* Addressing individual aspects of appropriate antibiotic prophylaxis has already been discussed, but putting it all together so that the patient received the correct drug at the correct dose and time was also explored. The greatest proportion of patients developing an SSI occurred in those who received the right drug only but with the wrong dose and time. Of patients who only received the right drug, 33.3% developed an SSI compared to 12.2% of the patients who received the right drug at the right dose and time ( $p = 0.3400$ ). A statistically significant difference between correct and incorrect antibiotic administration times has already been reported, but it is also reasonable to conclude from this that the dose of the antibiotic in addition to the time is clinically important.

To address the overall issues with inappropriate antibiotic prophylaxis, an exploration of where nurses and physicians initially learn about antibiotic prophylaxis and whether it is included in their basic educational curriculum needs to be undertaken. For those seasoned nurses and physicians, it is unclear how they remain current with changing recommendations or how the importance of antibiotic prophylaxis is recognized, so further exploration of this is also necessary. Research on what nurses and physicians envision as their role with respect to antibiotic prophylaxis is also warranted. Some examples of solutions would be to develop a protocol with members of the healthcare team that will champion the effort to follow current recommendations, and identify and implement strategies that will promote compliance with the protocol such as having the protocols visible, and developing reminders throughout the perioperative period about antibiotic prophylaxis. This must be done involving all key members in the OR.

### *Diabetes and Hyperglycemia*

Hyperglycemia has been identified as a risk factor for SSI in the CABG surgery patient population as already discussed in the literature review. Hyperglycemia was one of the targeted interventions to reduce SSI risk in the SHN campaign as well. Because there is little information available about the relationship of hyperglycemia to SSI risk in the vascular surgery patient population, it was decided to explore this relationship in my study. For ease of interpretation of results and to demonstrate that it is hyperglycemia and not diabetes that increases SSI risk, results from diabetic and non-diabetic patients were separated for this discussion.

*Diabetes and SSI risk.* A diagnosis of diabetes has been identified as an independent risk factor for SSI in the CABG, general, and vascular surgery literature (Borger et al., 1998; Fietsam et al., 1991; Latham et al., 2001; Malone et al., 2002; Neumayer et al., 2007; Richet et al., 1991; Slaughter et al., 1993; Talbot, 2005; Zacharias & Habib, 1996). In my study, a slightly higher proportion of diabetic patients, 18.9%, developed an SSI compared to 15.9% of non-diabetic patients ( $p = 0.6706$ ). While there was not a big difference between proportions of diabetics and non-diabetics that developed an SSI, there were some greater differences found when hyperglycemia was the focus and not just the diagnosis of diabetes.

*Hyperglycemia and SSI risk.* Furnary and Wu (2006) asserted that it is not necessarily being diabetic that places a patient at risk, but instead it is uncontrolled hyperglycemia that increases the SSI risk. As already discussed in the literature review, a



relationship between hyperglycemia and SSI risk has been found in CABG surgery, general surgery and critically ill patients. This appeared to be true in this study as well.

Regardless of diabetic status, when the groups of non-diabetic and diabetic patients were combined, 29.6% of the patients with either or both an increased preoperative glucose or HbA1c level developed an SSI, compared to 13.1% who developed an SSI with a normal preoperative glucose or HbA1c ( $p = 0.0640$ ). This study may need to be repeated with a larger sample to ensure that there is enough power to assess this association. Overall though, results indicate that control of preoperative glucose and HbA1c, and patient education efforts that can be employed by nurses about glycemic control, are important whether the patient is diabetic or non-diabetic.

*Hyperglycemia and SSI risk – diabetic patients.* My study determined that SSI risk was not increased with a diagnosis of diabetes. Hyperglycemia, not diabetes, was the risk factor of interest. Of 40 diabetic patients who were “ever hyperglycemic”, meaning at some point in the perioperative period they had an elevated glucose reading of 11.1 mmol/L or greater or a HbA1c level of 7% or greater, 20% developed an SSI compared to 15.4% of 13 patients who were “never hyperglycemic” ( $p = 0.7118$ ). This data suggests that there is no difference in SSI risk between those who are hyperglycemic and those who are not. For this reason, it was decided to look more closely at specific time periods as other studies had done.

In the OR, there were no elevated glucose levels noted, so intraoperative hyperglycemia risk on SSI cannot be determined. An elevated preoperative glucose level did not increase the risk of SSI as 18.2% ( $n = 2$ ) of the patients with an elevated



preoperative glucose developed an SSI, compared to 17.9% ( $n = 7$ ) of the patients with a normal glucose level. This differs from studies that have found that an increased preoperative glucose level significantly increased SSI risk (Guvener et al., 2002; Latham et al., 2001; Trick et al., 2000a, 2000b; Wilson & Sexton, 2003).

When the glucose levels in the PARR and postoperative unit and their impact on SSI risk were assessed, surprisingly, patients who were normoglycemic developed more SSIs than those who were hyperglycemic. In the PARR, 10% of the 10 patients with hyperglycemia developed a SSI compared to 17.9% of 28 diabetic patients with normal PARR levels. However, complete information is not available on glucose levels in the PARR. There were 14 diabetic patients who did not have a PARR glucose level assessed, 28.6% of whom developed an SSI. For this reason, a conclusion cannot be drawn from my findings on the risk of SSI with hyperglycemia in the immediate postoperative period in PARR. Postoperatively, 15.4% ( $n = 6$ ) of the patients with an elevated glucose level developed an SSI compared to 28.6% ( $n = 4$ ) of the 14 diabetic patients without an elevated postoperative glucose level. This finding is opposite to findings from other studies that have shown an increased risk of SSI with elevated postoperative glucose (Furnary et al., 1999, 2003, 2004; Furnary & Wu, 2006; Grey et al., 2004; Guvener et al., 2002; Latham et al., 2001; Lazar et al., 2004; Vilar-Compte et al., 2008; Zerr et al., 1997). However, my findings do support the findings of studies of Collier et al. (2005), and Krinsley (2004), in which there was no significant association found between elevated postoperative glucose and SSI. An explanation for the non-association between postoperative hyperglycemia and SSI risk in my study is that there may be a stronger influence from another factor in the postoperative period.

Overall, when looking at glucose levels, my study results did not provide support for the argument that hyperglycemia is a risk factor for SSI in vascular surgery patients. However, of diabetic patients with an elevated HbA1c level, 37.5% developed an SSI compared to 16.7% of the diabetic patients with a normal HbA1c level ( $p = 0.2272$ ). Despite the fact that these differences were not statistically significant in terms of risk for SSI, it may still be clinically important and warrants further validation as it may have implications for clinical practice. This is especially true given the Canadian Diabetes Association (CDA) (2008) current recommendations to maintain glucose levels of 8 – 11 mmol/L in the perioperative period and the increased incidence of SSI related to hyperglycemia because of 1) elevated glucose levels in tissues promoting bacterial growth, 2) impaired neutrophil function with respect to chemotaxis, phagocytosis, and intracellular bacteriocidal activity, and 3) changes in vascular permeability leading to edema and promotion of bacterial growth, all of which decrease host defenses to infectious agents (Aragon et al., 2003; Campbell, 2007; Dronge et al., 2006; Golden, Kao, Peart-Vigilance & Brancati, 1999; McCowen, Malhotra, & Bistrian, 2001; Smiley & Umpierrez, 2006).

*Assessment and occurrence of hyperglycemia – diabetic patients.* Of interest in my study as well was how many patients had glucose levels measured, and at which points in the perioperative period hyperglycemia actually occurred. By determining the frequency with which glucose assessment was occurring and the timing of the increased glucose levels, nursing interventions designed to assist a patient in achieving



normoglycemia could be designed and implemented. This would follow the guidelines set out by the CDA.

Preoperatively, 50 of 53 diabetic patients had a glucose level measured with 20.8% of the diabetic patients having a level of 11.1 mmol/L or greater. Slightly more than 66% of the patients had the preoperative glucose level measured on the operative day. HbA1c values were measured on only 52.8% ( $n = 28$ ) of 53 diabetic patients; more than half of these had a level greater than 7%. There is no specific protocol within the study hospital on when glucose or HbA1c levels should be measured preoperatively or which patients should have these levels assessed. A convenient time would be when nurses see patients in the preadmission clinic, which usually occurs at least one week before surgery. This would give the nurse time to obtain pertinent results and then provide the patient with education on strategies to reduce their glucose level before surgery. This could be done through education on diet, exercise, a medication regime, and referral to other health professionals for postoperative care. Following this initial assessment and appropriate interventions, the patient could then return on the day of surgery and the nurse could again assess the patient's glucose and report it to the physician who could decide on interventions to maintain optimal intraoperative glucose control.

There were only 7.5% of diabetic patients in my study with a glucose level measured intraoperatively and none of the levels were elevated. It was surprising that more patients did not have intraoperative glucose levels assessed as one-fifth of the diabetic patients had elevated preoperative glucose levels. In the PARR, 73.1% of diabetic patients had a glucose level assessed and 10 of these patients had at least 1 PARR



glucose level of 11.1 mmol/L or more. There were 7 patients with an elevated level in the PARR that also had an elevated preoperative glucose level. It is not unreasonable to assume that these patients may have had an elevated glucose throughout the surgical procedure as well. It was beyond the scope of this study to explore the reasons for why all diabetic patients returning to the PARR did not have a glucose level assessed or why glucose levels remained elevated throughout the intraoperative period, but this is an area that warrants further research. By nurses assessing glucose in the intraoperative and PARR periods, interventions can then be provided based on the results which assist patients to achieve a state of normoglycemia. This should then thus decrease the negative effects of elevated glucose as reported in the literature review.

On the postoperative surgical unit, all diabetic patients had their glucose levels assessed with at least 1 glucose level being elevated in 39 of 53 diabetic patients. The focus of this study was not to determine why diabetic patient's glucose levels were or were not assessed. However, because there are recommendations from the CDA (2008) to maintain glucose levels of 7 – 11 mmol/L in the perioperative period to decrease surgical risks including SSI risk, a treatment protocol would be helpful in providing direction on who should receive glucose assessment and when the assessment should be done.

*Management of hyperglycemia – diabetic patients.* The main purpose of assessing perioperative glucose levels is to develop and provide interventions that reduce the negative effects that increased glucose can have on the patient undergoing surgery. Preoperatively, there was no record of patients receiving intervention for increased glucose. Intraoperatively, because so few diabetic patients had a glucose level assessed,

data were not gathered on treatment. In the PARR, despite the fact that 10 patients had an elevated glucose level, none were treated. This study did not explore the reasons that hyperglycemia was untreated but this is an area requiring further research.

On the postoperative unit, patients received treatment but it was largely ineffective. Treatments included short acting, sliding scale insulin and oral hypoglycemics. There were some patients who received no treatment at all. More than two-thirds of patients had more than 5 elevated glucose levels on the postoperative unit, which 80-100% of the time were ineffectively treated, meaning the next glucose level was greater than 11.1 mmol/L.

Treatment protocols to prevent hyperglycemia, particularly in CABG surgery patients, abound in the literature with these authors maintaining tight glucose control of 11.1 mmol/L or less with intravenous insulin (Furnary et al., 1999, 2003, 2004; Furnary & Wu, 2006). It was not explored in this study if nurses intervened and requested treatment for elevated glucose levels in the PARR or postoperatively and if they did, why patients remained hyperglycemic. While the frequency of glucose assessment and interventions for glucose control are left to each individual physician to monitor and prescribe, nurses have a strong advocacy role in ensuring that optimal care is provided for the patient, including glycemic control.

The development and usage of a protocol to treat hyperglycemia could help with providing optimal care for the patient. Consideration could also be given to using intravenous insulin to maintain glucose levels within an acceptable range in the postoperative period, particularly in the Special Care Unit. This unit is staffed with a registered nurse for the vascular surgery patient who stays there for 24 hours. Some areas



of further research could include an exploration of continuity of care in terms of glycemic control throughout the perioperative period, and development of protocols to guide decision-making in the assessment and treatment of hyperglycemia intraoperatively.

*Hyperglycemia and SSI risk – non-diabetic patients.* In this study it was identified that it was not diabetic status that affected SSI risk, rather it was the hyperglycemia that the patient experienced. This has also been supported in the research as discussed in the literature review. For this reason, the effect of hyperglycemia on SSI risk in non-diabetic patients was explored.

Of 40 non-diabetic patients with a glucose or HbA1c level measured, 5 patients were “ever hyperglycemic”, meaning at some point in the perioperative period they had a glucose reading of 11.1 mmol/L or greater, or a HbA1c level of 6% or greater. Of these “ever hyperglycemic” non-diabetic patients, 40% of the patients developed an SSI. In comparison, 8.6% of 35 non-diabetic patients who were “never hyperglycemic” developed an SSI ( $p = 0.0468$ ). Hyperglycemia in non-diabetic patients was identified as a significant risk factor for SSI, although this had not been the same for the diabetic patients in this study.

There were relatively few glucose levels assessed and/or elevated in non-diabetic patients. Of 2 patients with an elevated preoperative glucose level, 1 patient developed an SSI. Postoperatively, of 3 non-diabetic patients with elevated glucose levels, 1 patient developed an SSI. Because of these few numbers, no conclusions can be drawn about the specific perioperative time period that a patient has an elevated glucose and how this affected SSI risk.



As with diabetic patients, elevated SSI rates were associated with elevated HbA1c levels despite differences not achieving statistical significance. However, these differences still warrant further attention and exploration. As discussed in the literature review, prolonged exposure of hemoglobin to glucose raises the HbA1c level and levels greater than 6% are sub-optimal in non-diabetic patients and are known to increase risk (CDA, 2008; McCance and Huether, 2006). Of non-diabetic patients with an increased HbA1c, 33.3% developed an SSI, compared to 12.5% with a normal HbA1c ( $p = 0.4250$ ). In a study by O'Sullivan et al. (2006), non-diabetic vascular surgery patients with a suboptimal HbA1c developed significantly more wound infections than did non-diabetics with normal HbA1c values (9.9% vs. 0%;  $p < 0.05$ ).

Overall, hyperglycemia does appear to be an important risk factor in non-diabetic patients. Further research is needed to verify this association and clinical attention should be paid to glucose and HbA1c levels in non-diabetic patients.

*Assessment and occurrence of hyperglycemia – non-diabetic patients.* Given the association between hyperglycemia and SSI risk in non-diabetic patients, it is interesting to note the assessments done in this group. Of 63 non-diabetic vascular surgery patients, 52.4% had a preoperative glucose level assessed. Two of these non-diabetic patients had glucose levels of 11.1 mmol/L or greater. It is of interest that 2 patients not previously diagnosed with diabetes would have such elevated readings. Research has shown that increased glucose is an independent marker of in-hospital mortality in patients with undiagnosed diabetes (Umpierrez et al., 2002). Because of this risk of increased in-hospital mortality and the finding of studies demonstrating that SSI risk is increased with

hyperglycemia regardless of diabetic status, it would be a reasonable expectation that nurses would ensure that all patients' preoperative glucose levels are tested whether they are diabetic or not.

HbA1c levels were measured on 17.5% of 63 non-diabetic patients. More than one-quarter of these patients had HbA1c levels greater than 6%, perhaps indicating a pre-diabetic state. One of the 2 non-diabetic patients with an elevated preoperative glucose level had the highest registered HbA1c in the study at 11%. Intraoperatively, no patients had glucose levels assessed, despite the fact that 2 non-diabetics had elevated preoperative levels. In the PARR, 12 of 59 non-diabetic patients had a PARR glucose level assessed and there were no elevated glucose levels found. This included 1 of the 2 patients who had an elevated preoperative glucose level. Because glucose levels were not assessed postoperatively on many of the non-diabetic patients, data are not available on the proportion non-diabetic patients who experienced postoperative hyperglycemia. However, there were 3 non-diabetic patients who had glucose levels assessed that were found to have levels in excess of 11.1 mmol/L.

It was not surprising that most of these patients did not have glucose levels done as they were identified as non-diabetic. It was not explored in this study why some non-diabetic patients had glucose or HbA1c levels done and others did not, or what the selection process was. Consideration should be given to checking everyone preoperatively with interventions provided for those with an elevated preoperative level. The development of a protocol to guide initial assessment and when to continue to assess a patient throughout the perioperative period may also be helpful



*Management of hyperglycemia – non-diabetic patients.* With respect to treatment for hyperglycemia in non-diabetic patients, nurses have a great responsibility to first assess all patients for hyperglycemia regardless of their diabetic status, and then to advocate for interventions to assist patients to return to a normoglycemic state. However, the 2 non-diabetic patients with an elevated preoperative glucose level in this study did not receive an intervention to reduce the glucose level preoperatively. Since there was no hyperglycemia in the OR and PARR in the few patients that had glucose assessed, treatment was only given postoperatively. In the postoperative period, there were 3 non-diabetic patients with hyperglycemic levels who were each treated successfully meaning that their next glucose level was less than 11.1 mmol/L.

Besides the advocacy role for hyperglycemia interventions that a nurse must assume, there is also a strong patient education role. Patients who are newly diagnosed with diabetes need education about diet, exercise, and medication to control hyperglycemia, as well as referrals for post-discharge education from other health professionals. Nurses can provide this education for patients and advocate for optimal perioperative glycemic control for patients so that SSI risk is reduced (Girard, 2005, 2006).

### *Hypothermia*

As part of the SHN campaign, maintenance of normothermia in the OR has been suggested as an intervention to reduce SSI risk in colorectal surgery patients. This recommendation is based on a study by Kurz et al. (1996), in which a significant association was found between intraoperative hypothermia and SSI. Because hypothermia



and its effect on SSI risk have not been studied in vascular surgery patients, this relationship was explored in my study. Included in this analysis was the effect of hypothermia at any point during the entire perioperative period, not just the intraoperative period as recommended by SHN, and its association with SSI. Part of this investigation looked at the time period during which hypothermia developed to assess if this increased SSI risk. This exploration also included an assessment of the interventions provided to assist a patient to return to a normothermic state, and if/when temperature was monitored.

*Hypothermia and risk for SSI.* Of patients who were “ever hypothermic”, meaning they had a body temperature less than 36°C at some point in the perioperative period, 19.2% of 52 patients developed an SSI compared to 15.6% of 64 patients who were “never hypothermic” ( $p = 0.6091$ ). Because these proportions are so similar, the results suggest that being “ever hypothermic” is not a risk. However, when the temperature was viewed in different time periods, intraoperative hypothermia did appear to show a trend towards being a risk factor if arrival to the PARR with a hypothermic temperature level is reflective of intraoperative hypothermia. This study found that double the proportion of patients who arrived to the PARR hypothermic developed an SSI, compared to those who were normothermic ( $p = 0.1949$ ).

In the PARR, despite the use of a warming intervention, 5 patients remained hypothermic and 60% developed an SSI. In comparison, there were no patients who developed an SSI of the 4 patients that became normothermic with the warming intervention ( $p = 0.0578$ ). Of 7 patients who were hypothermic on arrival to the

postoperative unit, 42.9% developed an SSI, compared to 15.7% who were normothermic ( $p = 0.0668$ ). While none of these findings are statistically significant given the low sample size, trends in the results suggest that the difference may be clinically important. Overall, more research with a larger sample size is needed to explore these associations further.

*Occurrence and management of hypothermia.* While it is not clear if hypothermia is a risk factor for SSI, interventions are warranted for patient comfort. Therefore, it is important to assess patient temperature throughout the perioperative process to determine if a patient is hypothermic or not. Once that assessment is completed, interventions to treat any hypothermia that has occurred can be provided and documented.

Of the 104 patients who had their temperature assessed preoperatively, 4 patients were noted to be hypothermic preoperatively. None had any warming intervention noted in the chart. Studies have shown that preoperative warming for 1 – 2 hours before surgery is effective in reducing hypothermia, increasing patient comfort, and decreasing anxiety (Just et al., 1993; Weirich, 2008). My study did not explore why patients were not warmed preoperatively.

Only 10 of 116 patients had an intraoperative temperature recorded; 8 were hypothermic on at least one temperature measurement. The mean length of time that patients were hypothermic in the OR was 119 minutes. Of these 8 hypothermic patients, 7 were still hypothermic even with the warming intervention recorded to be in use. A greater proportion of patients, 33.3% of the 87, who received at least 1 warming intervention in the OR were hypothermic on arrival to the PARR, compared to 16.7% of



the 24 patients who did not receive any warming interventions in the OR. These findings suggest that the warming interventions provided in the OR were largely ineffective. Studies by Kumar et al. (2005) and Negishi et al. (2003) have found that active warming with forced air or warming of intravenous solutions reduces intraoperative hypothermia. These were some of the interventions provided in the OR and PARR in my study. Consideration may need to be given to nurses providing additional or different interventions to assist patients to achieve normothermia. As well, more research is warranted about different hypothermia interventions and when they should be applied to restore or maintain normothermia.

Despite the fact that 80% of patients had some form of warming intervention in the OR, 29.7% of patients who arrived to the PARR from the OR were hypothermic. A possible explanation for this hypothermia may be that the warming intervention was removed during transfer, but this was not investigated in this study. The finding showed that the longer a patient waited for transfer from the OR to the PARR, possibly with no warming intervention, the more likely they were to be hypothermic on arrival to the PARR. It needs to be recognised that this is occurring and that patients need to be kept warm or transferred as quickly as possible.

Of the 111 patients in the PARR, only 9 patients had a recorded warming intervention in the PARR despite the fact that 41.4% of the patients were hypothermic on at least one temperature measurement there. Five of the 9 patients who received a warming intervention in the PARR remained hypothermic despite its use, leading to the same conclusion that the warming intervention was ineffective and that different warming



interventions need to be used. For this reason, further action through additional or different warming interventions is warranted.

There were close to one-fifth of patients who were discharged from the PARR with a hypothermic temperature. However, according to Eastern Health's Perioperative Program Policy, VII-a-20 (2008), patients should be returned to a normothermic state before discharge from the PARR. The reasons the policy was not adhered to were not explored in this study. Future research would be helpful to determine what nurses' attitudes are towards policies, as well as different strategies to employ to increase adherence to policies and protocols.

Seven patients of 111 that went to the postoperative unit were hypothermic on arrival there. Only 1 of these 7 patients left the PARR hypothermic, so 6 developed hypothermia on transfer. No warming interventions were recorded on transfer or on arrival to the unit. In a report by Kumar et al. (2005) on studies that explored loss of heat during transfer from one hospital area to another, results showed that patients were able to maintain core body temperature or even raise their body temperature when active warming interventions were applied but not so otherwise. These study results suggest that more or different interventions are required during transfer.

Overall, 44.8% ( $n = 52$ ) of the patients were "ever hypothermic" in the perioperative period. Hypothermia occurred in a number of patients and occurred at each stage of the perioperative process and during transfer. While there were many interventions provided in the OR, these were largely ineffective, as the patients remained hypothermic. Elsewhere not many interventions were provided despite assessments being done and patients found to be hypothermic. These findings have clinical importance.

Hypothermia makes patients uncomfortable and leads to many other deleterious effects as already outlined in the literature review. Providing interventions that assist a patient to return to a normothermic state should be a focus of nursing care.

*Assessment of temperature.* While there is limited information from this study on the proportion of patients who experienced perioperative hypothermia, there is still evidence that hypothermia is occurring and that warming interventions are not always working or being provided. Nurses need to focus on temperature assessment to guide their practice (Girard, 2005, 2006). Furthermore, this study found that 25% of patients with no temperature measured preoperatively developed an SSI compared to 15.4% who did have a temperature assessed. While it is not the fact that the temperature was not measured that is the risk factor for SSI, it is not unreasonable to speculate that these patients without the temperature measurement may possibly have been hypothermic thus increasing their risk of SSI.

The American Society of Anesthesiologists basic monitoring standards indicate that every patient receiving an anaesthetic shall have temperature monitoring done when clinically significant changes in body temperature are intended, anticipated, or suspected (Auerbach, 2001). The American Society of Perianaesthesia Nurses says that all patients [temperatures] should be measured accurately and consistently (Weirich, 2008). Eastern Health's Perioperative Program Policy, VII-a-20 (2008), which is based on the American Society of Perianesthesia Standards, also has frequent temperature monitoring standards. Despite the existence of these guidelines, many patients did not have thorough perioperative assessment of temperature status.



Preoperatively, 10% of patients did not have a temperature recorded and for those that did, 34% did not have the time their temperature was taken recorded. For the 66% of patients that did have the time recorded, most of the temperature recordings were within 2 hours of surgery. It was not explored in this study why all temperatures were not taken or why times weren't recorded. Some possibilities may include the increased activity in the preoperative period during which many other preparations are occurring for the patient about to undergo surgery. Despite this, the implications of not having a temperature taken are that patients may be hypothermic, but because the temperature has not been measured, interventions may not be provided and patient discomfort, as well as the risk of other negative effects of hypothermia, may be increased.

Only 8.6% of the patients in the OR had their temperature assessed and/or recorded even though almost 80% of the patients had some form of warming intervention applied in the OR. According to a personal e-mail communication with the Perioperative Program Clinical Educator, G. Tapp, there is no policy/protocol or temperature guideline in the Operating Room Nurses Association of Canada (ORNAC) Standards on the frequency of monitoring temperature in the OR and that this decision is left up to the individual anesthetist for each patient (February 4, 2009). Perhaps if the number of patients who had a temperature assessed was increased, then interventions to maintain normothermia or reverse hypothermia could be provided and OR staff could be sure that the interventions they are providing are effective. The value of assessing patients is to determine if interventions are working. If they are not working, then further or different interventions should be used.



In the PARR, most patients had their temperature measured within the first five minutes in the PARR in keeping with Eastern Health's Perioperative Program Policy, VII-a-20 (2008). According to the same policy, when a patient had a hypothermic temperature, the patient should be re-assessed within 15 minutes, but this only occurred in about one-fifth of the patients who had a hypothermic temperature. Because one of the goals of care in the PARR is to return a patient to, or maintain a normothermic state before discharge from PARR, reassessing a patient who has been hypothermic should be followed by an intervention to warm the patient. However, interventions to warm the patient and at what temperature this should be done are not part of Eastern Health's Perioperative Program Policy, VII-a-20. If an intervention is provided by a nurse, the final step is to evaluate if the intervention has actually worked by re-assessing the patient.

Only 9 patients had a recorded warming intervention in the PARR in this study. According to a personal e-mail communication with the PARR Clinical Educator, D. Whalen-Brake (February 4, 2009), nurses are taught during their orientation to the PARR and through ongoing education that 'aggressive' re-warming is indicated for hypothermic patients, and passive insulation is indicated for normothermic patients. As well, all patients are provided with warm blankets from the blanket warmer, and some patients will have the forced air warmer for low temperatures, but it is usually 35.5°C before this happens. Contrary to what is taught and expected though, interventions are not being recorded on the majority of patients if they are being provided. Even if these interventions are provided and not documented, there was still no record of additional or different interventions recorded for patients who remained hypothermic.

On arrival to the postoperative unit, some patient temperatures took a long time to be assessed and/or recorded as well. Almost 30% of the patients waited longer than 10 minutes for the first temperature measurement; six of these patients waited more than an hour. The reasons for why temperatures were not assessed or recorded were not explored in this study. It is reasonable to assume that the longer it takes for patients to be assessed for normothermia and no warming intervention is applied, the longer it may take for patients to return to a normothermic state and the more uncomfortable they may be. Therefore, early assessment and warming interventions can prevent this from happening.

There was one patient who was hypothermic in the preoperative and intraoperative phases, was normothermic on arrival to the PARR but became hypothermic while there and was discharged from the PARR with a hypothermic temperature. This one patient example shows how labile the vascular surgery patient's temperature can be and emphasizes the importance of temperature measurement, intervention and evaluation by nurses throughout the entire perioperative period (Girard, 2005, 2006). Traditionally, nurses focus on hyperthermia (fever), with little attention paid to hypothermia. Nurses are advocates for patients undergoing surgery and for this reason, they can decide when and how often to assess a patient's temperature, and when and how to intervene to provide optimal care to the perioperative patient

### *Inappropriate Hair Removal*

The SHN campaign has identified appropriate hair removal as an intervention to reduce SSI risk. As with the other interventions previously discussed as part of the SHN campaign, the effect of inappropriate hair removal on SSI risk in vascular surgery patients



has not been explored. Current CDC recommendations are for patients to not shave hair in the surgical incision area prior to surgery to prevent microscopic nicks from occurring and thus prevent the introduction of microorganisms. From a literature review by Tanner, Woodings, and Moncaster (2006), not removing any hair is considered optimal, but if hair interferes with the surgical incision, then it should be clipped as close to the time of surgery as possible. The limited strength of the evidence of these studies has already been discussed in the literature review, but this recommendation remains as the standard of preoperative hair removal endorsed by the CDC (Mangram et al., 1999) and ORNAC, which is followed in Canada.

*Inappropriate hair removal and SSI risk.* The majority of patients in my study, 87.1%, had hair clipped, with no patients having hair shaved at the operative site. Because these patients did not have hair shaved, and current recommendations for hair removal were adhered to very closely, an assessment of SSI risk with respect to inappropriate hair removal could not be explored. It is not recorded on the paper intraoperative record from which data was extracted at what time the hair was clipped. It was assumed that the clipping was done just prior to the operation as the clipping is recorded on the intraoperative record and not the preoperative record. As well, in a personal e-mail communication with the Perioperative Clinical Educator, G. Tapp (February 4, 2009), she indicated that if a patient has hair clipped, it is done in the OR immediately prior to the procedure. However, because the time was not recorded, this study could not explore the effect of hair removal timing on SSI risk. It was also impossible to report if patients who shave near the surgical area increased their SSI risk in this study. There is no designated



place to record this information on the preoperative checklist and therefore, there was no data available to be collected on this risk factor for my study.

While there was not a lot of information available from this study on risk associated with hair removal method or timing, it was identified that at the time of surgery, over 10% of patients had abrasions, redness, or nicks at the operative site. As already discussed, this may allow a portal of entry to the body that infectious agents can enter. Of the patients with non-intact skin, 37.5% developed an SSI compared to 16.2% with intact skin ( $p = 0.1159$ ). While this result was not statistically significant due to small sample size and therefore decreased power, this information warrants further assessment. When applied to the chain of infection theory, it is thought that an abrasion or nick in the skin opens a portal of entry to infectious agents. The role of the nurse, which is the focus of the next section, revolves around preoperative education and appropriate hair removal. Nursing interventions of this type may decrease the proportion of patients with broken skin areas.

Because the chain of infection theory asserts that an abrasion or nick in the skin opens a portal of entry to infectious agents, for this reason, patients with these nicks and abrasions could particularly benefit from antibiotic prophylaxis directed against the most common organisms to be encountered. My study findings showed that none of the 5 patients with non-intact skin who received correct antibiotic prophylaxis developed an SSI, compared to all 3 of the patients with non-intact skin who received antibiotics at the incorrect time or not at all ( $p = 0.0047$ ). This again emphasizes the importance of antibiotic prophylaxis, particularly with non-intact skin.

*Management of appropriate hair removal.* Interventions for appropriate hair removal are within the scope of nursing practice (Girard, 2005, 2006; ORNAC, 2007). An important intervention is preoperative patient education that is provided by nurses. A major focus of this patient education should be on preparation of the skin prior to surgery. Emphasis should be placed on avoidance of shaving or using a depilatory in the surgical incision area prior to surgery by the patient. As well, patients should receive instruction on methods to properly cleanse the skin including the avoidance of harsh chemicals or brushes that may abrade the skin. Patients should also be instructed to report any rashes or broken areas to the nurse prior to the surgery.

Another important nursing role with appropriate hair removal is documentation and communication of adverse findings. At present there is no space on the preoperative record where a nurse can indicate what information she has provided to a patient about preoperative skin preparation. If such a place were available on the preoperative record, this could serve as a communication mechanism among perioperative staff. Communication of adverse findings to the surgeon prior to surgery, including any cuts, abrasions, rashes, or broken areas is also within the scope of practice of the nurse. Written communication about any adverse finding was recorded on the patient intraoperative record in my study. According to the Perioperative Program Clinical Educator G. Tapp, the surgeon also received notification of any of adverse findings prior to surgery (personal e-mail communication February 4, 2009). It is then up to the surgeon to decide to cancel or go ahead with the surgery.

The decision to remove hair in the surgical incision area is collaborative between the nurse and the surgeon (personal e-mail communication, Perioperative Program

Clinical Educator G. Tapp, February 4, 2009). Because nurses are part of this decision making process, it is important that they decide what is most optimal for the patient to reduce the risk of SSI.

### *Modifiable and Non-Modifiable Risk Factors for SSI*

As outlined in Chapter 2, there are many SSI risk factors that may be non-modifiable or modifiable, with some that are not clearly identifiable as one or the other depending on the patient situation. Research in other studies has shown that there are other factors that increase SSI risk. While these factors were not the focus of the SHN campaign or my study, it was still interesting to explore what effect, if any, these factors have on SSI risk in vascular surgery patients. As well, it was also important to determine the effect of these risk factors on SSI as they may have confounded the effect of the key risk factors this study was exploring. Some examples of other risk factors include but are not limited to gender, age, emergency procedure, insertion of an artificial graft during surgery, having a groin incision, blood loss, anemia, and transfusion of blood, surgeon skill, obesity and increased BMI, smoking, certain comorbidities such as renal disease, and increased ASA score. Other risk factors were explored and the results are available in Chapter 4 related to these factors, but the factors discussed here were the most noteworthy.

### *Non-Modifiable Risk Factors*

The following non-modifiable risk factors included in this discussion are: gender, age, emergency procedure, insertion of an artificial graft during surgery, and having a



groin incision. None of these risk factors were determined to increase SSI risk in vascular surgery patients possibly due to the small sample size and therefore, decreased power. However, there were some interesting findings that merit further discussion.

In the vascular surgery sample, there were considerably more men, 80.2%, than women, 19.8%, which is similar to vascular studies reported in the literature review (Belkin et al., 1995; Chang et al., 2003; Nicholson et al., 1994; O'Sullivan et al., 2006; Pounds et al., 2005; Schepers et al., 2003; Sigvant et al., 2007; Turnbull et al., 2005; van Himbeeck et al., 1992; Vogel et al., 2008; Vriesendorp et al., 2004). A reason offered for this phenomenon is that even though just as many women possibly have PVD, by the time they present with symptoms, their disease is not amenable to surgical reconstruction due to smaller arteries and more advanced disease (Brevetti et al., 2008; Higgins & Higgins, 2003; Vouyouka & Kent, 2007). For this reason, they would not be admitted for vascular surgery and be part of the sample. However, this does not underestimate the importance of paying attention to other risk factors in all patients regardless of gender. As a broader health goal, nurses can educate women on the risks for PAD and how to modify them before permanent damage has occurred.

Neumayer et al. (2007), in their study of combined vascular and general surgery patients found that having an emergency procedure was identified as a risk factor ( $p < 0.0001$ ). Some possible explanations for the increase in rate of SSI with emergency surgery may be that the surgery is more rushed causing more damage to delicate tissues, lack of control over bleeding, uncontrolled hyperglycemia, or lack of provision of antibiotic prophylaxis. Of the patients who underwent an emergency surgical procedure in this study, 33.3% developed an SSI compared to 14.9% of patients who underwent an

elective procedure ( $p = 0.0770$ ). Because this study had only a small sample of patients undergoing emergency surgery, this may have decreased the power of the study to find a significant difference. While the results did not reach statistical significance, they are still clinically important and lend support to the idea that surgery should be performed in a pre-planned environment if possible.

Of the 56 patients with artificial grafts, 17.9% of the patients developed an SSI, compared to 16.7% of 60 patients without an artificial graft who developed an SSI, indicating that this was not a risk factor for SSI. A key statement made by a nurse during an informal presentation to the nurses in the OR suggested one possible explanation. This nurse indicated that she thought only the patients having artificial grafts inserted were supposed to receive prophylactic antibiotics. However, the literature indicates that all patients having the vascular surgeries of interest in my study should receive prophylactic antibiotics as discussed in the literature review (Blondel-Hill & Fryters, 2006; Mangram et al., 1999; Wong, 2004). Analysis showed that patients with artificial grafts received more antibiotics than patients without artificial grafts, which is what this nurse had thought, was correct. As previously discussed in the section on antibiotic prophylaxis, for patients without an artificial graft, the receipt of antibiotics appeared to decrease risk although the difference did not achieve significance ( $p = 0.0565$ ). This same trend was not seen in patients with an artificial graft. The conclusion to draw from these findings is not that the patients with artificial grafts did not have a greater risk of SSI, but that the receipt of prophylactic antibiotics in this group reduced their risk to a similar level as patients without an artificial graft.



Finally, the presence of a groin incision was not found to be a risk factor for SSI in this study. There were 92.2% of the patients with a groin incision, and 50% of the SSIs that developed were in the groin. The increased SSI risk of a groin incision has previously been found in vascular surgery studies already discussed in the literature review (Nicholson et al., 1994; Pounds et al., 2005; Van Himbeeck et al., 1992). The implication of this for nurses is that extra attention should be paid to preparation of the groin prior to surgery in terms of assessment of skin integrity and cleansing of the incisional area.

Despite these non-modifiable risk factors not being found to independently increase SSI risk in this vascular surgery patient study, there was still some very valuable information obtained from reviewing these factors. There is further support that antibiotic protocols are necessary so that all patients get antibiotics as recommended in the literature (Blondel – Hill et al., 2006; Mangram et al., 1999; Wong, 2004), that a pre-planned surgery is better for the patient than an emergency surgery, and that special attention to groin incisions is required.

### *Modifiable Risk Factors*

The following modifiable risk factors included in this discussion are: blood loss, anemia and blood transfusion, surgeon skill, obesity and increased BMI, smoking and number of cigarettes, particular comorbidities such as renal disease, and elevated ASA score. Similar to the non-modifiable risk factors, there were no modifiable risk factors that significantly increased SSI risk.



*Blood loss, anemia, and transfusion of blood and SSI risk.* Blood loss and need for transfusion is linked to SSI in the CABG surgery literature possibly due to its effect in contributing to hypothermia (Insler et al., 2000), though there were no vascular studies found that explored this as a risk factor. For half of the patients in my study, there was no reported blood loss in the OR and for those that did lose blood the majority lost less than 1200 mL of blood. It is unknown if patients developed hypothermia with blood loss though as their temperature was not assessed in the OR. The amount of blood lost is affected by many causes including how quickly the patient's own blood clots because of the body's initiation of the coagulation cascade, difficulty of the surgical procedure, and how quickly the surgeon controls the blood loss based on experience and skill level.

In terms of blood loss being a risk factor for SSI, results showed that 9.5% of those who lost less than 1200 mL of blood developed an SSI. In comparison, of the patients who lost 1200-4499 mL of blood in the OR, 25% developed an SSI ( $p = 0.2800$ ), suggesting that greater volumes of blood loss may impose a higher SSI risk. However, none of 3 patients who lost 4500 – 25000 mL of blood in the OR developed an SSI. It is difficult to interpret these findings. Greater amounts of blood loss beyond 4500 mL did not appear to increase SSI risk, but a factor that may have confounded the results was the speed with which blood loss was treated in these patients. Patients who lost 4500 – 25000 mL of blood were treated immediately in the OR. In comparison, of 8 patients that lost 1200 – 4499 mL of blood, hemoglobin levels were assessed in the PARR but were found to be normal until they went back to the postoperative unit. Anemia, which is a measurement of low blood hemoglobin, did not present itself until later on the operative day in 4 out of 8 patients, and they all received blood products as treatment. Because of

the difference in times of treatment for anemia, it is difficult to determine if it is blood loss, or the timing of the anemia, or the time it takes to receive treatment that affects SSI risk.

From a pathophysiological perspective, if a patient loses a volume of blood, they lose all of the erythrocytes contained in that volume of blood. Each of these erythrocytes presumably has normal hemoglobin content. The hemoglobin content of all of these cells together is what is referred to as the "hemoglobin" in a blood sample. Until the blood cells that have been lost are replaced, either through the body's own mechanisms called erythropoiesis, which may take some time, or through a transfusion of blood, the hemoglobin level in the blood is going to be low, also known as anemia. Some of the adverse effects of anemia include fatigue, poor wound healing, and decreased oxygen in the blood (McCance & Huether, 2006). Because the process of erythropoiesis requires time to produce more erythrocytes, as well as the adverse effects of anemia, it is important that nurses on the postoperative unit are vigilant in assessing the hemoglobin level of the patient postoperatively. By assessment of hemoglobin levels, anemic levels can be brought to the attention of the physician and blood transfusions and/or iron replacement may be ordered.

As already discussed, because anemia, blood loss, and blood transfusion are interrelated in this study, it is difficult to determine what influence these factors individually have on SSI risk. In terms of transfusion of blood, of patients who received blood at any point during the perioperative period for anemia, 22.7% developed an SSI compared to 16% who did not receive blood ( $p = 0.4492$ ). Of 22 patients who were anemic on their first post-operative hemoglobin level that was assessed, 5 received PRBC



and 17 did not. Of those receiving PRBC, 40% ( $n = 2$ ) of 5 patients developed an SSI compared to 23.5% ( $n = 4$  of 17) of the anemic patients who never received blood ( $p = 0.4673$ ). The trend with the receipt of blood seems to be that it increases risk, although differences were not statistically significant. Receipt of blood has been identified in the general surgery literature to be a risk factor for SSI though (Blumetti et al., 2007; Jensen et al., 1992; Marik & Corwin, 2008; Olsen et al., 2008; Tang et al., 2001; Walz et al., 2006), but this relationship has not been explored in vascular surgery. More research in vascular surgery patients who do or do not receive blood transfusions and their anemia status would be helpful in determining this association.

*Anemia assessment.* As the amount of blood lost in the OR increased, so did the number of patients having a PARR hemoglobin level assessed. For this reason, it appeared as though the nurses in the PARR were conscientious about assessment of the amount of blood loss in the OR. On the postoperative unit, just about all patients had at least one hemoglobin level assessed and slightly more than one-third of patients had only one level assessed. It appeared that patients did have postoperative hemoglobin levels assessed and when it was required, further assessment was done.

While hemoglobin assessment was well done, serum ferritin level assessment needs some improvement. There were few serum ferritin levels assessed even though almost one-third of patients had an anemic post-operative hemoglobin level. Low serum ferritin is linked to weakness, fatigue, and impaired wound healing. Even with a blood transfusion, iron stores are not restored after substantial blood loss which may put a patient at risk for iron deficiency anemia, particularly if iron replacement therapy is not



initiated (McCance & Huether, 2006). None of the patients with previously diagnosed or newly diagnosed anemia were started on iron replacement therapy in this study. It is important that nurses advocate for patients by closely monitoring the development of anemia, as well as providing education around iron-rich foods and initiation of supplemental iron therapy as indicated.

In keeping with the discussion on blood loss in this section, the level of surgeon skill is one factor that may or may not affect the amount of blood loss or how quickly it is controlled and how this affects SSI risk. In some ways, it seems that increased blood loss may be more likely to occur with newer surgeons because they would not have as much experience with handling this type of emergency. However, the reverse of this is that the more experienced surgeon may have patients with increased amounts of blood loss, because the patient seen by this surgeon are more acutely ill and therefore riskier to perform surgery on and may possibly bleed more. Surgeon SSI rates in this study ranged from 12.5 – 19.4%. There are many factors that affect SSI risk that the surgeon is involved in. For this reason, the relationship between surgeon skill and SSI risk cannot be determined from this study.

More than two thirds of the patients, 67%, in this study were either overweight or obese with a BMI greater than 25, so it seemed important to explore this as a risk factor for SSI. For 50 patients who were overweight (BMI 25.1-30), 18% developed an SSI, compared to 36 patients who were a healthy weight (BMI 25 or less) in which 13.9% developed an SSI. Of 23 patients with a BMI greater than 30 who were considered obese, 13% developed an SSI. There was no obvious relationship found between BMI and SSI risk. It is unclear why increased BMI did not increase SSI risk in the obese patient group.

It could possibly be explained by missing weight measurements that may underestimate effect in this particular group.

An increased BMI is thought to increase SSI risk as there is an increased wound size, difficulty in obliterating dead space during wound closure, poor blood supply to fatty tissue, and longer OR time (Bandyk, 2008; Chang et al., 2003; Haas et al., 2005; Kent et al., 1996; Nicholson et al., 1994; Russo & Spelman, 2002; Slaughter et al., 1993; Vuorisalo et al., 1998). In addition, because obese patients do have more skin folds that can harbour microorganisms, this could potentially lead to an increased microbial load that the patient's own defences may not be able to fight. For this reason, it is important for nursing interventions to focus on education of these patients on good skin care and on the assessment by nurses of the skin folds of these individuals before surgery (Baugh et al., 2007).

Decreasing the BMI of patients is amenable to nursing intervention with the patient's cooperation. However, it may not always be feasible depending on how close the patient's imminent surgery is. Patient education could centre on strategies to decrease weight while waiting for surgery. In the short term, nurses can ensure that all patients have their weight assessed so that optimal antibiotic prophylaxis can be prescribed and administered, that hyperglycemia is controlled, and that careful attention is paid to skin cleansing before surgery. A broader health goal is for nurses to educate patients on the risks associated with obesity and having an increased BMI, as well as strategies to reduce this risk (Turner, Thomas, Wagner, & Mosley, 2008). Education of this variety is a population based health goal that requires the support of many individuals including public health nurses, which is beyond the scope of the perioperative nurse.



Smoking has been suggested as a risk factor for SSI in the vascular surgery literature (Bandyk, 2008; Haas et al., 2005; Neumayer et al., 2007; Wipke-Tevis, 1999). There has also been a strong association made between smoking and PAD (Allison et al., 2006; Murabito, D'Agostino, Silbershatz & Wilson, 1997; Vogt, Cauley, Kuller, & Hulley, 1993). It was surprising that only 34.5% ( $n = 40$ ) of the patients reported to be smokers in my study. In a systematic literature review of studies that explored the influence of smoking on the prevalence of PAD, it was reported that in countries where approximately 30% of the population are smokers, 50% of the PAD prevalence can be attributed to smoking (Willigendael et al., 2004). The prevalence of smokers in Canada in 1996/1997 was 29%, and in Newfoundland was 32% (Public Health Agency of Canada [PHAC], 1999). Because these proportions in Canada and NL are close to 30%, it was expected that close to 50% of this study's population would be smokers.

Of the 40 self-reported smokers, 20% developed an SSI compared to 15.8% of non-smokers. This result may be related to how smoking status is recorded on the preoperative health history. If a patient self-identifies as a non-smoker in the health history, there is no section asking how recently they quit or how much and how long they smoked. Prior to this preoperative health history being taken by the nurse, the patient would have seen a vascular surgeon who would have asked about their smoking status and strongly encouraged them to quit. Because many of these visits to the vascular surgeon occur close to the time of the preoperative health history taken by the nurse, there may have been several recent quitters who were recorded as non-smokers even though the negative, long-term effects of their smoking would influence their SSI risk. If the recent



quitters had been identified as smokers, this may have given a more accurate representation of the true association between smoking and SSI risk.

Only 13.8% of the smokers in my study reported that they smoked more than 20 cigarettes per day. The average number of cigarettes reported by smokers in Newfoundland in 1996/1997 was 16 cigarettes a day, and in Canada was 17.5 cigarettes a day (PHAC, 1999). Because this was the average, it was expected that a higher proportion of patients than 13.8% would report that they smoked more than 20 cigarettes per day. Some reasons for this difference may be due to the fact that these Newfoundland and Canadian findings are based on data gathered in 1996/1997 and that there has been an overall decrease in the incidence of smoking in Canada due to stronger anti-smoking legislation in public buildings. Another reason may be that the smokers may have under-reported the amount they smoke due to guilt or fear of not having the operative procedure performed if they were not in good enough health.

Findings showed that as patients smoked an increased number of cigarettes, there was a trend towards increased SSI risk. Of the individuals who smoked more than 20 cigarettes per day, 50% developed an SSI compared to 10% of those who smoked less than 10 cigarettes per day ( $p = 0.4687$ ). For the 40 self-identified smokers, 11 patients did not have the number of cigarettes they smoked per day recorded. If all of these patients were heavy smokers, this risk factor may have been demonstrated to incur more risk and a significant difference may have been found between groups.

It is important for nurses to complete a full health history including the date the patient quit smoking, as well as the amount smoked and for how long. In this study, data were missing on the amount smoked by several patients, and who the recent quitters were

compared to non-smokers. Because smoking is a factor that is amenable to nursing intervention, it is helpful to know this information so that interventions can be individualized to each patient. There are many teachable moments during the preoperative and postoperative stay during which nurses can reinforce smoking cessation and nicotine replacement therapy and thus reduce SSI risk (Doolan & Froelicher, 2008; Lemmens et al., 2008; Mangram et al., 1999).

In this study, certain comorbidities, rather than the number of comorbidities in general, affected SSI risk. Of the patients with renal disease, 30% developed an SSI, and of the patients with liver disease, 50% developed an SSI. While the difference in SSI development between those with renal disease and/or liver disease versus other comorbidities was not statistically significant, there was certainly a trend seen that the risk of SSI increased if a patient had either of these comorbidities. This same trend in vascular surgery patients with renal disease has been seen in O'Sullivan et al. (2006). Blankensteijn et al. (1996) reported an SSI rate of 43% for patients with renal disease undergoing vascular surgery. Patients with these comorbidities should be identified preoperatively to institute appropriate measures to decrease SSI risk. A key intervention in patients with renal disease is to dialyze individuals both before and after surgery, so that antibiotic prophylaxis and wound healing are optimal.

As already discussed in the literature review, a component of the ASA score is the number of comorbidities that a patient is living with and how these affect the patient's health. Over 25% of patients did not have an ASA score recorded for unknown reasons. The ASA score very quickly identifies which patients, in the anesthetist's educated opinion, are at greatest risk for complications during and after surgery. Not having an



ASA score recorded is problematic in SSI surveillance and research because it diminishes the comparability of SSI rates when they are reported stratified by ASA score.

For the patients with an ASA score recorded, 80.5% had a score of 3 or greater on a scale of 1 – 5. It has been reported that the higher the ASA score is, the increased risk a patient has for developing an SSI (Aronson et al., 2003; Bandyk, 2008; Neumayer et al., 2007; Woodfield et al., 2007). The same trend was seen in my study where double the proportion, 24.6%, of patients with an ASA score of 3 developed an SSI compared to 11.8% of patients with an ASA score of less than 3 ( $p = 0.2544$ ). While this result was not statistically significant, it is clinically important. It indicates that patients with multiple comorbidities as represented by an ASA score need to have other factors that are amenable to intervention by nurses dealt with to optimize the surgical experience and decrease risk.

Similar to the non-modifiable risk factors, modifiable risk factors in this study were not found to increase SSI risk in vascular surgery patients. However, of clinical importance is that patient charts are missing information such as BMI, number of cigarettes smoked, and ASA score. As well, trends have been found with certain risk factors. Ongoing assessment by nurses and education of perioperative staff is necessary to reduce SSI risk and communicate important findings.

### *Practice Issues*

Several practice issues that require further education, research and protocol development have already been discussed in the preceding sections. Three additional practice issues emerged when analysing the data in this study. First, there was a noted



lack of consistency in documentation of SSI by the physician and second, the swabbing of wounds for culture and sensitivity (C&S) did not appear to follow a specific protocol when patients had been diagnosed with an SSI by a physician or had purulent drainage reported by the nurse. Third, it appeared as though discontinuation of antibiotics after surgery did not follow current recommendations to prevent the development of antibiotic resistant organisms (AROs).

*Documentation of SSI by physicians.* On the issue of documentation by physicians on SSIs that have occurred, of the 20 patients categorized as developing an SSI in this study, only 9 patients had written documentation from a physician that they had developed an SSI. An additional 7 patients did not have such documentation but did have treatment prescribed so it can be assumed that the physician was aware of the SSI. There were 4 remaining patients that neither had a physician document a diagnosis of SSI, nor had treatment prescribed. These 4 patients were categorized in this study as having an SSI because they had documented signs and symptoms that met the criteria of the CDC for SSI, such as presence of purulent drainage.

*Swabbing of wounds for C&S.* A diagnosis of an SSI is important if treatment is to be prescribed by a physician. Doing a C&S swab can help with diagnosis, but it is more important to choosing the appropriate antibiotic to treat the patient who has developed the SSI (Goering et al., 2008). With respect to the swabbing of wounds for C&S, a protocol did not exist at the time of this study that guided decisions on whether to swab a wound or not when infection was suspected due to signs and symptoms experienced by the patient,

or when a physician diagnosed the patient as having an SSI. This is a practice issue that requires attention because patients need the correct microorganism identified to have appropriate antibiotic treatment.

Specific antibiotics must be chosen for a specific microorganism as the antibiotics are often composed of products or derivatives of the same microorganism they are being given to eradicate. Antibiotics target microorganisms to destroy them by affecting their structure and function (Goering et al., 2008). When a patient is given empiric therapy, a broad-spectrum antibiotic is often chosen that may not be effective against the microorganism the patient has, so the infection is not eradicated. As well, the use of empiric therapy in this way contributes to the development of AROs. By swabbing wounds and obtaining results, specific therapy can be prescribed that is directed against the specific microorganism the patient has.

In this study, 13 patients had purulent drainage reported but only 7 had a C&S swab taken. Of the 9 patients diagnosed with an SSI by a physician, only 4 had a wound swab for C&S. It was curious that approximately half of the wounds with no evidence of purulent drainage were swabbed, and approximately half with evidence of purulent drainage were swabbed. At the time of this study there were no policies or protocols within the hospital utilized for this study for swabbing wounds when purulent drainage is seen in a wound. Development of policies such as these would assist in the decision making of nurses on whether to swab a wound or not if an infection is suspected. As well, with the results of C&S swab results, optimal antibiotic therapy directed at the microorganism(s) in the wound could be provided.



*Discontinuation of antibiotics.* The third practice issue that was noteworthy was appropriate antibiotic prophylaxis which involves discontinuation of antibiotics within 24 hours of surgery in vascular surgery patients (Blondel-Hill & Fryters, 2006; Mangram et al., 1999; Stewart et al. 2007). The reason for discontinuation of antibiotics within 24 hours after vascular surgery is to prevent AROs from forming and to reduce the risk of *Clostridium difficile* infection (CDI) from occurring (Bratzler & Houck, 2004; Dellinger et al., 2005; Harbath et al., 2000; Plonczynski, 2005). However, in my study, antibiotics were continued after 24 hours post-surgery in 59 patients, and 78% (n = 46) of these patients did not have a clear indication for why they were receiving an antibiotic. For example, these patients did not have another healthcare-associated infection that was being treated. The reason antibiotics were continued past 24 hours was not explored. While AROs are not a risk factor for SSIs, they are far more difficult to treat. Of the 10 patients in this study with an SSI for which there was a C&S swab result, 2 patients were infected with methicillin resistant *staphylococcus aureus* (MRSA). For this reason, an antibiotic protocol that includes the proper drug, dose and time should also include the appropriate timeframe in which to discontinue the antibiotic.

### *Strengths and Limitations*

This exploratory, descriptive study had many strengths. It examined a patient population that has not been researched to the same extent as other higher profile disease populations such as coronary artery disease. In addition, risk factors for SSI that had previously not been studied as extensively in this population as it has with CABG and other surgeries were included. This study also assessed if some assumptions about care



that is being provided are valid. There are recommendations in the literature about nursing practice and interventions in caring for surgical patients such as keeping patients normothermic, monitoring vital signs, providing education, and preparation for surgery. As a result of this study, contributions have now been made to the vascular surgery literature, the SSI risk literature, and nursing literature. Because of the explorations in this study, we now know about nursing practices and the risk factor profile of vascular surgery patients. This study begins a program of nursing research into the many aspects of caring for vascular surgery patients.

In addition to this, the results of this study give an estimate of the SSI rate in clean, vascular surgery. Because this study had follow-up information on 95% of patients within 6 weeks after surgery, it is now known what the true SSI rate is in patients without an artificial graft, whereas before it could only be speculated based on anecdotal evidence or studies from elsewhere. Eastern Health now has a baseline SSI rate to compare future SSI rates against in this patient population. This result may also be useful elsewhere for comparison once the results of this study become available.

Due to the simple design of this study, it is easily replicated at other healthcare facilities making it feasible. The data collection tool has content validity as it collects risk factor data based on findings from the literature. This tool had been pilot tested and data was collected by a researcher and research assistants who were trained in data collection by the researcher. Standard measures were used to measure outcomes such as glucose measurements with standard glucose monitoring machines, or culture and sensitivity testing for specific microorganisms, or diagnosis of SSI based on well-accepted criteria published by the CDC. This group of 116 patients is fairly representative of vascular

surgery patient populations described in the literature in terms of proportion of patients related to age, gender, diabetic and/or smoking status, and undergoing clean surgery to name a few.

There were also limitations to this study. The sample size was small which in turn reduced the power of this study to find statistically significant findings. The explanation for this is that it simply was not feasible to retrospectively review over 1000 charts for this study, which is what would have been required as described in Chapter 3. The choice to include half of the patients who underwent vascular surgery in 2005 for a total of 116 patients was a conscious one knowing that it would limit analysis. The focus of this study was exploration and description, not hypothesis testing.

Another limitation of this study which has been described in other retrospective studies is the distortion of results because of missing data due to inconsistencies in documentation. This was primarily limited in this study with respect to ASA scores, preoperative and intraoperative temperatures, warming interventions utilized, and number of smokers or amount smoked and so did not impact the main research questions. This study was also limited by the retrospective design as it was not possible to identify reasons for decisions that were made in the provision of care which may have enhanced understanding of some of the findings. The primary focus of this study though was to explore and describe nursing practices so the sample size was sufficient for this purpose.

### *Discussion Conclusion*

In conclusion, the primary risk factors found to increase SSI risk in vascular surgery patients were: 1) incorrect timing of antibiotic prophylaxis, 2) inappropriate or no

antibiotic prophylaxis for patients with non-intact skin, and 3) being “ever hyperglycemic” in non-diabetic patients. There were also many clinically interesting factors found such as a trend towards increased SSI risk with having an emergency procedure, anemia with blood loss between 300-1199 mL of blood, not receiving an antibiotic if there was no artificial graft inserted during surgery, and hypothermia on arrival to the postoperative unit. Some of the key practice issues identified that are amenable to nursing intervention included assessment throughout the perioperative period, appropriate interventions based on these assessments, and documentation of key assessments and care provided to improve communication among the perioperative team. There were many strengths in this study as well as limitations due to sample size, but this study has contributed to areas that were previously understudied.



## Chapter 6: Recommendations, Implications and Conclusion

Chapter 6 summarizes recommendations based on the results presented in Chapter 4 and the discussion of these results in Chapter 5. It also includes implications of the study findings for nursing administration, education, practice, and research.

### *Recommendations for Practice*

#### *Antibiotic Prophylaxis*

From this study, it appeared that some components of appropriate antibiotic prophylaxis were not consistently applied to patients undergoing vascular surgery. While many patients received optimal antibiotic prophylaxis, others received antibiotics late or not at all, or received an insufficient dose particularly so in heavier patients and patients without an artificial graft. For patients in surgery longer than 4 hours, optimal tissue concentrations of antibiotics were not maintained as recommended as these patients did not receive a repeat dose of antibiotics. Because antibiotics were not discontinued within the 24 hour period as recommended, this also may have contributed to the development of antibiotic resistant organisms. Both incorrect timing of antibiotic prophylaxis, and inadequate antibiotic prophylaxis in patients without an artificial graft emerged as statistically significant SSI risk factors in bivariate analysis.

Providing antibiotic prophylaxis falls under the practice domain of both the physician and the nurse in the perioperative process. When physicians prescribe antibiotics for patients, it is within the scope of practice of a nurse to prepare and

administer these antibiotics in collaboration with the anesthetist, who is also in control of other medications being delivered preoperatively.

*Recommendations.* A working team consisting of key members of the perioperative team could be brought together to develop a protocol or policy for antibiotic prophylaxis. This protocol should include an identification of: 1) the correct drug, which is based on the microorganisms most likely to be encountered during surgery, 2) the correct dose, based on different body weights, and 3) the correct time, which is 0 – 60 minutes prior to the surgical incision being made, and repeated after 4 hours for surgeries longer than 4 hours. Eastern Health has already developed a protocol such as this for colorectal surgery patients; this protocol could be very easily adapted to vascular surgery patients. Some additional strategies to improve antibiotic prophylaxis include pre-printed order forms, adding a “time-out” protocol where it is ensured that the antibiotic is ready to infuse before the incision is made, posting the protocol in a prominent place in the OR, having ready mixed antibiotic solutions, and having nurses administer the antibiotic instead of the physician.

#### *Glucose Control*

The Canadian Diabetes Association (2008) recommends that patient glucose levels in the perioperative period should be maintained between 8 – 11 mmol/L. This level was achieved for many patients in this study. However, this control did not occur in every patient. Many patients were provided with interventions and returned to a

normoglycemic state, while there were other patients that did not have interventions provided in the perioperative period or they were ineffective.

The study results show that nursing practice in the area of assessment and evaluation of patient glucose levels requires some improvement. While there were several non-diabetic patients who would not normally require glucose assessment who had an assessment followed by interventions in some cases, there were some diabetic patients who did not have glucose levels assessed or did not receive interventions. For those diabetic patients that did receive interventions, some received effective interventions and returned to a normoglycemic state. However, there were other diabetic patients that remained hyperglycemic for long periods despite receiving an intervention. For some patients on sliding scale insulin, hyperglycemia persisted for several days indicating the insulin therapy they were receiving was ineffective. At the time of this study, there was no protocol for glucose control and orders for frequency of monitoring were at the discretion of the physician.

It was determined from this study that regardless of diabetic status, hyperglycemia was a risk factor for SSI. Non-diabetics in this study who had hyperglycemia at any stage of the perioperative process referred to as "ever hyperglycemic" had a significantly increased risk of SSI, compared to those non-diabetic patients who were "never hyperglycemic".

Like antibiotic prophylaxis, maintaining optimal glucose control is also a shared role between the nurse and the physician. Nurses have within their scope of practice to assess, intervene, evaluate, and communicate both verbally and through written



documentation. However, the intervention to be provided to the patient must be prescribed by the physician before it is given by the nurse.

*Recommendations.* A standard preoperative process for patients that is mailed to them and their family doctor for review when their vascular surgery time is booked, could be employed that would instruct the patient to have their glucose and HbA1c levels done regardless of diabetic status. A preoperative nurse could then examine these results and notify the attending surgeon if a patient needs intervention preoperatively to attempt to lower glucose levels. As well, all patients on admission, whether preoperatively or postoperatively, could have a pre-printed order sheet placed on their chart with instructions on when to assess glucose levels and how often. This sheet also could include instructions on what interventions to provide, including medication, diet orders, and referral to other health professionals involved in hyperglycemia interventions. This would remove some of the inconsistency on when to intervene and when to notify the physician that there is a problem. There is already such a protocol in existence within the Critical Care Program of Eastern Health that could be adapted to this setting for this particular group of patients.

### *Temperature Control*

As with issues with glucose assessment and intervention, issues with temperature assessment and intervention occurred. Preoperatively, most patients were assessed but for many patients, the time they were assessed was not recorded, so it is difficult to determine what preoperative period of time this temperature assessment represents. In the OR most

patients received an intervention to maintain normothermia, indicating that hypothermia is a concern for intraoperative staff. However, only 10 of 116 patients had their temperature recorded. Of the 10 patients with temperature measured, 8 were still hypothermic with the warming intervention. This indicated that the interventions were not working and that an additional or different intervention was required. In the PARR, assessment was done, but interventions were not recorded as being provided. The issue here may be documentation rather than the provision of an intervention. However, even with intervention in the PARR, some patients were still hypothermic and additional warming interventions were not provided. While many patients in the PARR were normothermic, many patients were also hypothermic. A policy on temperature assessment exists in the PARR in terms of frequency of assessment. Despite the existence of this policy, there were still patients who were not assessed at the frequency outlined in the policy. As well, some patients were discharged from the PARR with their last temperature measured as hypothermic, which is contrary to the policy recommendations. Patients were also found to be hypothermic after transfer from one unit to another and it is unknown if interventions for warming were provided during transfer or not as it is not recorded.

Temperature control is a shared practice between the physician and the nurse. As with glucose control, nurses have within their scope of practice to assess, intervene, evaluate, and communicate both verbally and through written documentation about temperature control in the perioperative patient. Temperature control differs from glucose control though, in that the nurse can decide what intervention is most suitable for the patient and apply it independently.

*Recommendations.* One primary recommendation from this study is to maintain perioperative normothermia. This should occur throughout the perioperative process including transfer from one unit to another. When hypothermic temperatures are found with a warming intervention in place, then consideration should be given to providing an alternative or additional intervention. A second recommendation is to assess patient temperatures. Assumptions should not be made that patients are normothermic because they are not shivering and don't look cold as this can be influenced by certain anesthetic medications. There are many warming interventions in use at Eastern Health in the OR which could be applied as soon as the patient enters the preoperative holding area instead of waiting until they get in the OR. Other warming strategies are the focus of future research that needs to be done. There are already broad recommendations available for intraoperative temperature care. However, a specific written protocol, such as the one for antibiotic prophylaxis and glucose control, could be developed that very clearly identifies the time and frequency with which patients are to be assessed in the perioperative period. A policy of this type is already in existence in the PARR. For this reason, nurses need to be educated about the assessment component of this policy as well as warming interventions that are available. Administration may need to get involved to audit temperature assessment and interventions and then provide feedback to the nurses caring for these patients. Future research could involve a study that compares different warming strategies or a study that evaluates what strategies are found to be the most beneficial to increasing nurses' adherence to policy.



### *Inappropriate Hair Removal*

Preoperative hair removal was performed following all recommendations currently in practice, and all patients had a documented skin assessment. However, while not a statistically significant difference in this study, double the proportion of patients with non-intact skin developed an SSI, compared to those that did have intact skin. As well, for patients with non-intact skin, not receiving the correct antibiotic prophylaxis was a significant risk factor for SSI.

Preoperative hair removal is a task performed by the nurse which is dictated by protocols. However, skin assessment is a shared practice between the physician and the nurse because of the incisional area assessment that must be done so that a decision can be made about appropriate hair removal.

*Recommendations.* The ORNAC and CDC guidelines are very clear in their recommendations about hair removal and skin assessment preoperatively and these should continue to be followed (Mangram et al., 1999; ORNAC, 2007). Because not receiving antibiotics when a patient had non-intact skin was identified as a risk factor in this study, adherence to antibiotic prophylaxis is also very important. As well, serious consideration should be given to the decision to proceed with the surgical procedure if skin areas are broken in the area to be incised.

### *Documentation*

While many assessments and interventions were documented, there were some specific aspects that require more attention. Some examples of physician documentation

requiring improvement are ASA score, patient temperature in the OR, and diagnosis of infection. Some examples of nursing documentation requiring improvement are time of assessment of preoperative temperature, if warming interventions were provided, patient weight, and components of the health history about smoking. As well, documentation about the effectiveness of different interventions that have been provided should also be included.

*Recommendations.* Education should be provided to physicians and nurses about the legal ramifications and the lack of communication of important findings that can occur with incomplete documentation. Education can also be provided on how to complete a full health history including a smoking history with the components: amount smoked, length of time smoked, and how recently they quit if a recent quitter. Administration could audit charts for incomplete documentation and then provide feedback to the staff involved.

#### *Modifiable and Non-Modifiable Risk Factor Practice Issues and Recommendations*

A non-modifiable factor that emerged with a trend towards increased risk of SSI was having an emergency surgery. A very broad health goal can involve education of the population on risk factor reduction for peripheral arterial disease and other comorbidities, so that they do not require such surgery. An audit can be undertaken to determine why patients who have emergency surgery are at increased risk of SSI. Once these factors are determined, then interventions can be directed at improving processes such as optimal prophylaxis during an emergency surgery, which may reduce these factors.

A risk factor that may be modifiable or not is intraoperative blood loss as has already been discussed in Chapter 5. A trend was seen in this study toward increased risk of SSI with intraoperative blood loss that led to anemia postoperatively. If increased blood loss is anticipated due to medications the patients is taking or hematological conditions a patient may have, this should be reported to the physician in advance of surgery. As well, any anemic patients discovered should be prescribed iron therapy with appropriate follow-up.

Smoking is a modifiable risk factor. While smoking did not emerge as a risk factor in this study, a trend was seen which merits discussion. Patients who smoke more than 20 cigarettes per day develop more SSIs than those who smoke less than 10 cigarettes per day. As already discussed, health histories were often incomplete in this study with respect to smoking. All information related to how long a patient has smoked and how much they smoke, or if they quit, for how long they have maintained abstinence, and how much they smoked when they did smoke should be included in the health history. With complete information like this, then interventions to assist a patient to quit smoking can be individualized. Even without this complete history though, education can still be provided to all patients on strategies to quit smoking including the suggestion of nicotine replacement. In addition, nurses can counsel patients on quitting smoking and make appropriate referrals to smoking addiction services.

Another modifiable risk factor is having an increased BMI. In this study however, this did not emerge as a risk factor but trends towards increased risk were seen. Patient education provided by nurses on weight reduction is complex and requires a long term strategy that begins in school-aged children. It is very difficult for a nurse preoperatively



to counsel a patient on weight loss that will have any dramatic effect on SSI risk so quickly. However, adherence to a healthy diet before surgery could help normalize glucose levels and begin a process that could be reinforced by postoperative and community health nurses. As well, for obese patients, nurses can reinforce the importance of preoperative skin care and cleansing with particular attention to skin folds.

### *Administrative Implications*

From an administrative perspective, key perioperative team members could be brought together as a working group to develop protocols or policies that address areas needing improvement. Follow-up for adherence to the protocols or policies is also necessary. Development of a protocol is an important first step but it does not mean that it will be adhered to. Improving adherence may be done through administrators releasing staff for continuing education to learn about the latest research and protocols or policies that have been developed. Second, administrators can audit perioperative records to assess for adherence to the protocol with reward for those who follow the protocol and reminders for those who don't. Third, if protocols are not being followed, administrators need to determine the reason why, through an assessment with the perioperative staff directly involved in the provision of care under review. Actions then need to be designed and further support strategies put in place to increase adherence.

### *Education Implications*

#### *Staff Education*

Education provided by staff and clinical educators in these areas should focus on SSI prevention and the use of antibiotic therapy in which an antibiotic is selected based on C&S results. Strategies should also be employed that promote and increase adherence to policies and protocols. Such strategies include but are not limited to in-servicing of staff, having journal clubs that discuss these issues, identification of leading staff members who reinforce education in the practice setting about the protocol or policy, and making the protocol meaningful to the staff that provide the care. To make the protocol meaningful, evidence needs to be provided to staff that demonstrates how improvements in SSI rates were achieved when protocols or policies were followed and care processes were changed and improved. In a collaborative project that addressed antibiotic prophylaxis, maintenance of normoglycemia and intraoperative normothermia, and appropriate hair removal, a reduction of 27% in the SSI rate was reported (Dellinger et al., 2005). Nurses and physicians throughout the entire perioperative period need to be educated about the importance of documentation of findings not only for legal reasons but also for continuity of care of the patient and communication between the perioperative care team. Because nurses are educators of patients, nurses also require educations about the best strategies to use to educate patients in their care.

#### *Implications for the Staff/Clinical Educator*

Staff and clinical educators need to develop a diversified set of strategies to deliver education. Perioperative team members require different levels of detail and

educational support (Farrington, 2007). The message to be delivered needs to be clear, concise, realistic, meaningful, and inspiring towards change. Some learners are motivated and self-directed, while others are non-motivated and resistant to change. With educational interventions, it is essential to involve key perioperative team members, relying on the enthusiasm of new staff and the wisdom of more experienced staff.

### *Basic Education*

Basic education in nursing and medical schools needs to focus on infection and risk factors for infection. This should include a discussion about the chain of infection theory, other healthcare-associated infections, and personal protective equipment. The implications of glycemic control and other risk factors for SSI and other infections should be included. The importance of antibiotic prophylaxis and the presence of new and emerging strains of antibiotic resistant microorganisms should be reinforced.

### *Patient and Family Education*

Patients and families under the care of nurses also require education in the preoperative clinic or postoperative setting. Patients and families need to be educated at a level that is understandable to them. Education must involve a discussion of risk factors such as obesity for example and how lifestyle may be modified to reduce this particular risk. Education of the patient and family is important through the entire perioperative process. It may begin with preoperative education on the avoidance of shaving in the incisional area or special cleansing of skin, to the postoperative unit education about smoking cessation or maintenance of normoglycemia and healthy weight.



### *Research Implications*

There were no statistically significant findings that emerged from this study after multivariate analysis. This may be because they are not risk factors for vascular surgery patients, or because this small study had insufficient power to detect if certain factors are actually risk factors for SSI. For this reason, a larger, multi-site study with an adequate sample size to do all sub-analyses is indicated using the same methods. Data should be gathered on the same broad range of risk factors to ensure that as many factors as possible are explored for their possible effect on SSI risk in this understudied population.

As recommended previously, the use of protocols to guide practice is important. Another interesting and relevant study would therefore be an examination of the use of specific protocols aimed at dealing with risk factors for SSI. This study could assess if SSI outcomes are affected by changes in practice because of the use of protocols. An example of this kind of study would be a randomized, controlled study of normothermia/hypothermia interventions that compares a study group that receives warming interventions throughout the perioperative period including transfer from one unit to another, compared to a control group that only receives the warming interventions once the patient becomes hypothermic. These two groups of patients could then be compared to determine which group developed the most SSIs. Another possible study would be to determine what strategies are the most successful to promote adherence to protocols such as antibiotic prophylaxis by health care professionals. Strategies such as education, administrative reinforcements or involvement of key health care workers in the provision of care could be compared in this study.

In conclusion, this study has led to a number of recommendations for changes and improvements in practice that could address some of the known and hypothesized risk factors for SSI. This study is only the beginning of a program of nursing research that can be conducted to determine definite risk factors for SSI, as well as evaluate the use of evidence-based protocols that will improve patient outcomes.

### *Infection Prevention and Control Implications*

#### *Use of Standard Criteria and Post-Discharge Surveillance*

Standard definitions recommended by the CDC were used in this study to identify SSIs. This makes my study comparable to other studies that report SSI rates. However, this is only helpful when other studies report their post-discharge surveillance methodology as well. Surveillance in this study followed the guidelines of the CDC; patients without an artificial graft had surveillance for 30 days, and patients with an artificial graft were followed for 1 year for visits to the facility where they had their surgery done. This was very similar to the post-discharge surveillance completed in studies reviewed in the literature review, and is an accepted practice. However, optimal surveillance of patients in this study would have been to follow up on every patient with an artificial graft through phone calls to the patient or family physician, for up to a year after surgery to determine if they had developed an SSI or not. However, there were 95% of patients seen by 6 weeks by the vascular surgeon in this study so a baseline rate has been established. It would be interesting to study the sensitivity of this surveillance by once again studying vascular surgery patients but the next time, having the full follow up as recommended by the CDC on every single patient.

*Recommendations:* Infection Prevention & Control practitioners play a vital role in the surveillance of infection. However, surveillance is only helpful if interventions are planned to decrease the infection rate. IP&C practitioners can play an important role in both education about risk factors and strategies to reduce these risk factors, and in policy and procedure development around these interventions based on the best evidence available.

Because this study had identified that the SSI rate in vascular surgery patients requires attention and that this is a surgical group at risk, periodic surveillance of infections in vascular surgery patients is warranted. Standard definitions of SSI from the CDC should be used to increase comparability between studies and IP&C programs. As well, with feasibility under consideration, IP&C practitioners should perform surveillance for the maximum length of time including post-discharge, to identify as many cases of SSI as possible. Additionally, when IP&C practitioners are reporting SSI rates, this should be done with an identification of the post-discharge surveillance methodology used. Finally, total chart reviews are a feasible and sensitive way to obtain good information on SSI development. If SSIs are then found, the retrospective chart review is very helpful in identifying the possible risk factors. Another alternative will be to use the electronic health record which will have this data readily available to analyze. However, this assumes that the information is recorded, downloadable and has capabilities for data extraction which is not currently available in Eastern Health.



### *Dissemination of Findings*

The purpose of this study was to determine risk factors for SSI in vascular surgery as well as identify nursing interventions to decrease this risk. A secondary purpose was to determine the SSI rate for vascular surgery patients. It is important to share these findings with others including the perioperative team, Eastern Health, and the larger population of professionals that are interested in vascular surgery, infection control, and SSI risk factors.

Practice issues, SSI rates, risk factors for SSI, and interventions that are successful in reducing risk, will be shared with all who are interested. This may be accomplished by local presentations, conferences, and publication in journals that appeal to these groups of professionals.

### *Conclusion*

Even though this study did not identify any risk factors that independently increased SSI risk, it did identify areas in practice, administration, education, and research in the care of vascular surgery patients that require improvement. If these areas are addressed, it is anticipated that improvements will be seen in the preoperative care of vascular surgery patients, with an associated decrease in the SSI rate. The implications of this study are that the body of research about SSI and SSI risk factors has been strengthened, there is a current Canadian SSI rate for others to compare to as a benchmark, there is more known about how nurses and physicians care for patients, and the SHN program has some added information to support their suggested interventions to reduce SSI risk.

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## Appendix A: Criteria for Defining a Surgical Site Infection (Mangram et al., 1999)

### **Superficial Incisional SSI**

Infection occurs within 30 days after the operation and infection involves only skin or subcutaneous tissue of the incision and at least one of the following:

1. Purulent drainage, with or without laboratory confirmation, from the superficial incision.
2. Organisms isolated from an aseptically obtained culture of fluid or tissue from the superficial incision.
3. At least one of the following signs or symptoms of infection: pain or tenderness, localized swelling, redness, or heat and superficial incision is deliberately opened by surgeon, unless incision is culture-negative.
4. Diagnosis of superficial incisional SSI by the surgeon or attending physician.

Do not report the following conditions as SSI:

1. Stitch abscess (minimal inflammation and discharge confined to the points of suture penetration).
2. Infection of an episiotomy or newborn circumcision site.
3. Infected burn wound.
4. Incisional SSI that extends into the fascial and muscle layers (see deep incisional SSI).

*Note:* Specific criteria are used for identifying infected episiotomy and circumcision sites and burn wounds.

### **Deep Incisional SSI**

Infection occurs within 30 days after the operation if no implant† is left in place or within 1 year if implant is in place and the infection appears to be related to the operation and infection involves deep soft tissues (e.g., fascial and muscle layers) of the incision and at least one of the following:

1. Purulent drainage from the deep incision but not from the organ/space component of the surgical site.
2. A deep incision spontaneously dehisces or is deliberately opened by a surgeon when the patient has at least one of the following signs or symptoms: fever ( $>38^{\circ}\text{C}$ ), localized pain, or tenderness, unless site is culture-negative.
3. An abscess or other evidence of infection involving the deep incision is found on direct examination, during reoperation, or by histopathologic or radiologic examination.
4. Diagnosis of a deep incisional SSI by a surgeon or attending physician.

*Notes:*

1. Report infection that involves both superficial and deep incision sites as deep incisional SSI.

2. Report an organ/space SSI that drains through the incision as a deep incisional SSI.

### **Organ/Space SSI**

Infection occurs within 30 days after the operation if no implant is left in place or within 1 year if implant is in place and the infection appears to be related to the operation and infection involves any part of the anatomy (e.g., organs or spaces), other than the incision, which was opened or manipulated during an operation and at least one of the following:

1. Purulent drainage from a drain that is placed through a stab wound into the organ/space.
2. Organisms isolated from an aseptically obtained culture of fluid or tissue in the organ/space.
3. An abscess or other evidence of infection involving the organ/space that is found on direct examination, during reoperation, or by histopathologic or radiologic examination.
4. Diagnosis of an organ/space SSI by a surgeon or attending physician.

## Appendix B: Literature Review Tables

Table 1: Glucose and SSI studies

Table 2: Temperature and SSI studies

Table 3: Vascular Surgery and SSI Risk Factor Studies

Table 4: Vascular Surgery SSI Surveillance Studies



**Table 1: Glucose and Infection**

Study authors, year, country, sample	Methodology	Definitions of Hyperglycemia and SSI	Results	Limitations
<b>Collier et al.</b> <b>(2005)</b> <b>USA</b> <b>n = 818</b>	<p>Prospective, consecutive-series, historically controlled study</p> <p>Trauma surgery patients</p> <p>Compared SSIs in 1 historical group who had physician controlled glucose to a second group who had glucose controlled by an algorithm</p> <p>Target glucose control: 4.4 – 6.1 mmol/L</p>	<p>Hyperglycemia: Maximum daily glucose level &gt; 8.3 mmol/L</p> <p>SSI: not provided</p>	<p>SSI rate: 5.4%</p> <p>Both groups (protocol and historical control ) did not maintain glucose at target</p> <p>No difference between group in SSI risk : protocol group 5.0% vs nonprotocol group 5.7% (p = 0.645)</p>	<p><u>Limited comparability:</u></p> <ol style="list-style-type: none"> <li>1.Does not report on period of surveillance</li> <li>2. Does not give definition of SSI</li> <li>3. No data on pre-operative glucose control</li> </ol> <p><u>Underestimation of effect:</u></p> <p>Does not report if post-discharge surveillance was done</p>
<b>Dronge et al.</b> <b>(2006)</b> <b>USA</b> <b>n = 77</b>	<p>Retrospective cohort study</p> <p>Looked at all HAI, did not specify SSI</p> <p>Mixed surgery patients including vascular</p> <p>Unknown how many patients had an implant</p> <p>HbA1c levels done within 180 days were included</p>	<p>Hyperglycemia: HbA1c &gt;7% in diabetic patients</p> <p>SSI: CDC definition</p>	<p>HbA1c &gt;7% increased HAI risk (OR: 2.13; 95%CI, 1.23-3.70; p = 0.007)</p>	<p><u>Limited Comparability:</u></p> <ol style="list-style-type: none"> <li>1. Does not report if post-discharge surveillance was done</li> <li>2. HbA1c is a measurement of previous 2 -3 month (60-90 days) glucose control, this study accepted HbA1c determinations done up to 6 months before the surgical procedure</li> </ol> <p><u>Underestimation of effect:</u></p> <p>Only completed surveillance for 30 days, not 1 yr</p>

Study authors, year, country, sample	Methodology	Definitions of Hyperglycemia and SSI	Results	Limitations
<p><b>Furnary et al. (1999)</b></p> <p><b>USA</b></p> <p><b>n = 2467</b></p> <p>CABG surgery patients</p> <p>All diabetic patients (defined as experiencing chronic glucose intolerance at time of surgery)</p>	<p>Prospective case-control study</p> <p>Compared glucose control between 2 groups and its effect on outcomes such as SSI</p> <p>Control group (n = 968) had sliding scale S/C insulin (SQI) post-op with glucose measured q4h, with goal to keep glucose of 11.1mmol/L or lower</p> <p>Study group (n = 1499) received continuous IV insulin infusion (CII) until glucose levels of 8.3 – 11.1 mmol/L were maintained</p> <p>Intraoperative and postoperative glucose levels were prospectively monitored q 1-2h, daily. Mean blood glucose levels were calculated by averaging all daily glucose levels. Measured from the operative day to 2nd post-operative day</p>	<p>Hyperglycemia: &gt; 11.1 mmol/L</p> <p>SSI: Not given</p>	<p>SSI rates:</p> <ol style="list-style-type: none"> <li>1. Deep sternal wound SSI: 1.3%</li> <li>2. Superficial sternal wound SSI: 0.6%</li> <li>3. Superficial donor site SSI: 0.6%</li> </ol> <p>CII produced a significant decrease in deep sternal wound SSI by 66% (p = 0.005)</p> <p>POD#1 Glucose levels of 11.1 mmol/L or greater are significantly associated with the development of a deep sternal wound SSI (p = 0.002)</p>	<p><u>Limited Comparability:</u></p> <ol style="list-style-type: none"> <li>1. Does not report on period of surveillance</li> <li>2. Does not report if post-discharge surveillance was done</li> <li>3. Does not give definition of SSI</li> <li>4. No data on preoperative glucose control</li> </ol>

Study authors, year, country, sample	Methodology	Definitions of Hyperglycemia and SSI	Results	Limitations
<p><b>Furnary et al., (2003)</b></p> <p><b>USA</b></p> <p><b>n = 3554</b></p> <p>CABG surgery patients</p> <p>All diabetic patients (defined as history of diagnosis of diabetes or persistently increased glucose levels of 11.1 mmol/L or greater and discharged home requiring pharmacologic management of glucose)</p>	<p>Historic case-control study</p> <p>Compared glucose control between 2 groups and its effect on outcomes such as SSI</p> <p>Control group (n = 942) had sliding scale S/C insulin (SQI) post-op with glucose measured q4h, with goal to keep glucose of 11.1mmol/L or lower</p> <p>Study group (n = 2612) received continuous IV insulin infusion (CII) until glucose levels of 5.6 – 8.3 mmol/L were maintained – some of these patients from Furnary et al (1999) had glucose levels maintained between 8.3 – 11.1 mmol/L)</p> <p>Perioperative glucose levels were measured q 30min – 2h. Mean blood glucose levels were calculated by averaging all daily glucose levels. Glucose levels done from operative day to 2nd post-operative day.</p>	<p>Hyperglycemia: &gt; 8.3 mmol/L</p> <p>SSI: Not given</p>	<p>SSIrates:</p> <p>Overall Mediastinitis: 0.9%</p> <p>CII mediastinitis rate: 0.6%</p> <p>SQI mediastinitis rate:1.8%</p> <p>Difference in insulin protocols on mediastinitis risk (p = 0.05)</p>	<p><u>Limited Comparability:</u></p> <ol style="list-style-type: none"> <li>1. It is unclear how many patients received CII protocol to keep glucose levels between 8.3 – 11.1 mmol/L (1<sup>st</sup> arm of study) and 5.6 – 8.3 mmol/L (2<sup>nd</sup> arm of study)</li> <li>2. Does not report on period of surveillance</li> <li>3. Does not report if post-discharge surveillance was done</li> <li>4. Does not give definition of SSI</li> <li>5. No data on pre-operative glucose control</li> </ol>



Study authors, year, country, sample	Methodology	Definitions of Hyperglycemia and SSI	Results	Limitations
<p><b>Furnary et al. (2004)</b></p> <p><b>USA</b></p> <p><b>n = 4864</b></p> <p>CABG surgery patients</p> <p>All diabetic patients (defined as history of diagnosis of diabetes or persistently increased glucose levels of 11.1 mmol/L or greater and discharged home requiring pharmacologic management of glucose)</p>	<p>Historic case-control study</p> <p>Compared glucose control between 2 groups and its effect on outcomes such as SSI</p> <p>Control group (n = 968) had sliding scale S/C insulin (SQI) post-op with glucose measured q4h, with goal to keep glucose of 11.1mmol/L or lower</p> <p>Study group (n = 3896) received continuous IV insulin infusion (CII) until glucose levels of 5.6 – 8.3 mmol/L were maintained – some of these patients from Furnary et al (1999) had glucose levels maintained between 8.3 – 11.1 mmol/L)</p> <p>Perioperative glucose levels were measured q 30min – 2h. Mean blood glucose levels were calculated by averaging all daily glucose levels. Glucose levels done from operative day to 2nd postoperative day</p> <p>A composite 3-day post-operative blood glucose value (3-BG) was calculated by averaging the mean glucose level on the operative day, as well as POD#1 and POD#2</p>	<p>Hyperglycemia: &gt; 8.3 mmol/L</p> <p>SSI: Not given</p>	<p>CII deep sternal wound SSI rate: 0.7%</p> <p>Glucose of 11.1 mmol/L or greater in the first 48 hours after cardiac surgery was independently associated with a significant increase in deep sternal wound SSI (p = 0.017)</p> <p>Identified an inflection point at 9.7 mmol/L at which the incidence of deep sternal wound SSI begins to increase significantly</p> <p>CII is independently protective against deep sternal wound SSI by 61% (p &lt; 0.01)</p>	<p><u>Limited Comparability:</u></p> <ol style="list-style-type: none"> <li>1. It is unclear how many patients received CII protocol to keep glucose levels between 8.3 – 11.1 mmol/L (1<sup>st</sup> arm of study) and 5.6 – 8.3 mmol/L (2<sup>nd</sup> and 3<sup>rd</sup> arm of study)</li> <li>2. Does not report on period of surveillance</li> <li>3. Does not report if post-discharge surveillance was done</li> <li>4. Does not give definition of SSI</li> <li>5. No data on pre-operative glucose control</li> </ol>

Study authors, year, country, sample	Methodology	Definitions of Hyperglycemia and SSI	Results	Limitations
<p><b>Furnary &amp; Wu (2006)</b></p> <p><b>USA</b></p> <p><b>n = 5534</b></p> <p>CABG surgery patients</p> <p>All diabetic patients (defined as history of diagnosis of diabetes or persistently increased glucose levels of 11.1 mmol/L or greater and discharged home requiring pharmacologic management of glucose)</p>	<p>Historic case-control study</p> <p>Compared glucose control between 2 groups and its effect on outcomes such as SSI</p> <p>Control group (n = 1065) had SS S/C insulin (SQI) post-op with glucose measured q4h, with goal to keep glucose of 11.1mmol/L or lower</p> <p>Study group (n = 4469) received CII until glucose levels of 3.9 – 6.1 mmol/L were maintained – some of these patients from Furnary et al (1999) had glucose levels maintained between 8.3 – 11.1 mmol/L) and from Furnary et al. (2003, 2004) had glucose levels maintained between 5.6 – 8.3 mmol/L</p> <p>Perioperative glucose levels were measured q 20min – 2h. Mean blood glucose levels were calculated by averaging all daily glucose levels. Glucose done from operative day to 2nd post-operative day. A composite 3-day post-operative blood glucose value (3-BG) was calculated by averaging the mean glucose level on the operative day, as well as POD#1 and POD#2.</p>	<p>Hyperglycemia: &gt; 6.1 mmol/L</p> <p>SSI: CDC definition</p>	<p>CII deep sternal wound SSI rate: 0.3%</p> <p>For every 2.8 mmol/L increase in 3-BG, the risk of deep sternal wound SSI is increased more than two-fold (<math>p &lt; 0.0001</math>)</p> <p>Identified an inflection point at 9.7 mmol/L at which the incidence of deep sternal wound SSI begins to increase significantly</p> <p>CII has the independent effect of reducing deep sternal wound SSI by 63% (<math>p &lt; 0.002</math>)</p>	<p><u>Limited Comparability:</u></p> <ol style="list-style-type: none"> <li>1. It is unclear how many patients received CII protocol to keep glucose levels between 8.3 – 11.1 mmol/L (1<sup>st</sup> arm of study) and 5.6 – 8.3 mmol/L (2<sup>nd</sup> and 3<sup>rd</sup> arm of study) and 3.9 – 6.1 mmol/L (4<sup>th</sup> arm of study)</li> <li>2. Does not report on period of surveillance</li> <li>3. Does not report if post-discharge surveillance was done</li> <li>4. No data on preoperative glucose control</li> </ol>

Study authors, year, country, sample	Methodology	Definitions of Hyperglycemia and SSI	Results	Limitations
<p><b>Guvener et al.</b></p> <p><b>(2002)</b></p> <p>CABG surgery patients</p> <p>diabetic n = 400</p> <p>non-diabetic n = 690</p> <p><b>Turkey</b></p> <p><b>n = 1090</b></p> <p>Diabetes defined by history of diabetes on admission</p>	<p>Retrospective cohort study</p> <p>Compared glucose control between 2 groups and its effect on outcomes such as SSI</p> <p>Glucose levels were monitored 6 times daily. Daily mean glucose levels were calculated by averaging all glucose levels in the 2 days prior to surgery and for 3 POD.</p> <p>Blood glucose levels of diabetic patients were manipulated with a CII to maintain glucose levels of 8.3 – 11.1 mmol/L</p>	<p>Hyperglycemia: <math>\geq 11.1</math> mmol/L</p> <p>SSI: Not given</p>	<p>Deep sternal wound SSI rate in diabetics: 1.25% vs 0.57% of non-diabetics (<math>p = 0.048</math>)</p> <p>Donor site SSI rate in diabetics: 1% vs 0.28% of non-diabetics (<math>p = 0.013</math>)</p> <p>Glucose control preoperative day 2: for diabetics with deep sternal wound SSI, glucose was <math>12.3 \pm 0.6</math> mmol/L compared to diabetics without deep sternal wound SSI whose glucose was <math>9.2 \pm 2.0</math> mmol/L (<math>p = 0.006</math>)</p> <p>Glucose control pre-operative day 1: for diabetics with deep sternal wound SSI, glucose was <math>10.1 \pm 0.5</math> mmol/L compared to diabetics without deep sternal wound SSI whose glucose was <math>7.7 \pm 1.7</math> mmol/L (<math>p = 0.009</math>)</p> <p>Glucose control post-operative day 2: For diabetics with deep sternal wound SSI, glucose was <math>11.7 \pm 1.7</math> mmol/L compared to diabetics without deep sternal wound SSI whose glucose was <math>9.3 \pm 1.9</math> mmol/L (<math>p = 0.012</math>)</p>	<p><u>Limited Comparability:</u></p> <ol style="list-style-type: none"> <li>1. Does not report on period of surveillance</li> <li>2. Does not report if post-discharge surveillance was done</li> <li>3. Unknown how often glucose was measured</li> </ol>



Study authors, year, country, sample	Methodology	Definitions of Hyperglycemia and SSI	Results	Limitations
<b>Grey et al. (2004)</b>  <b>USA</b>  <b>n = 61</b>  Mixed surgery patients	Prospective, randomized, controlled trial  Compared glucose control between 2 groups and its effect on outcomes such as SSI  Standard glucose control group: received standard intravenous insulin therapy to keep glucose 10 – 12.2 mmol/L  Strict glucose control group: received intravenous insulin therapy to keep glucose 4.4 – 6.7 mmol/L	Hyperglycemia: $\geq 7.8\text{mmol/L}$  SSI: CDC definition	Standard glucose control SSI rate 3% vs 0.8% in strict glucose control group ( $p < 0.05$ )	<u>Limited Comparability:</u> 1. Does not report on period of surveillance  2. Does not report if post-discharge surveillance was done  3. Unknown how often glucose was measured (according to algorithm)
<b>Krinsley (2004)</b>  <b>USA</b>  <b>n = 1600</b>  General surgery patients	Historical case-control study  Compared glucose control between 2 groups and its effect on outcomes such as HAI, did not report on SSI specifically  Compared 800 patients admitted to ICU before institution of a glucose management protocol to 800 patients admitted to ICU after the institution of the diabetes management protocol  Glucose measured every 3 hours or less depending on stability of glucose and protocol recommendations	Hyperglycemia: $\geq 7.7\text{mmol/L}$  SSI: Not given	No significant difference seen in all HAI developed with or without the protocol for the period patients were in ICU	<u>Limited Comparability:</u> 1. Not clear if surveillance for HAI continued after ICU stay  2. Does not report on period of surveillance  3. Does not report if post-discharge surveillance was done  4. No definition of SSI given  5. Does not outline how glucose values were calculated (ie mean glucose or single glucose)

Study authors, year, country, sample	Methodology	Definitions of Hyperglycemia and SSI	Results	Limitations
<p><b>Latham et al. (2001)</b></p> <p>USA</p> <p>n = 1000</p> <p>CABG surgery patients</p> <p>diabetic n = 300</p> <p>non-diabetic n = 700</p>	<p>Prospective, cohort study</p> <p>Compared glucose control between 4 groups and its effect on outcomes such as SSI</p> <p>Pre-operative HbA1c obtained on all patients. HbA1c values <math>\geq 7</math> were considered indicative of previously undiagnosed diabetes</p> <p>Glucose levels were separated into quartiles and quartiles 2 – 4 were compared to quartile 1 to assess for risk of infection</p> <p>Quartile 1: <math>&lt; 11.1</math> mmol/L  Quartile 2: <math>11.1 - 13.8</math> mmol/L  Quartile 3: <math>13.9 - 16.6</math> mmol/L  Quartile 4: <math>\geq 16.7</math> mmol/L</p>	<p>Hyperglycemia: <math>\geq 11.1</math> mmol/L</p> <p>SSI: CDC definition</p>	<p>Total SSI rate: 7.7%</p> <p>Quartile 2 compared to Quartile 1 OR of SSI 2.54</p> <p>Quartile 3 compared to Quartile 1: OR of SSI 2.97</p> <p>Quartile 4 compared to Quartile 1: OR of SSI 3.32</p> <p>Of 700 non-diabetics, 25% had HbA1c levels <math>&gt; 6.2</math> (6% of these patients had HbA1c levels <math>\geq 7</math>)</p> <p>Of the known diabetics, 42% had HbA1c values <math>\geq 8\%</math> at the time of surgery – of these patients, 78% developed perioperative hyperglycemia compared with 43% with lower HbA1c values (OR 1.78; 95% CI, 1.47-2.16; <math>p &lt; 0.001</math>)</p> <p>Patients with preoperative hyperglycemia did not have significantly more SSIs than those with normoglycemia</p> <p>Patients with post-operative hyperglycemia did have significantly more SSIs than those with normglycemia (OR: 2.02; 95%CI, 1.21 – 3.37; <math>p = 0.007</math>).</p>	<p><u>Limited Comparability:</u></p> <p>1. Does not report on period of surveillance</p> <p>2. Does not report if post-discharge surveillance was done</p> <p>3. Does not outline how glucose values were calculated (ie mean glucose or single glucose)</p>

Study authors, year, country, sample	Methodology	Definitions of Hyperglycemia and SSI	Results	Limitations
<b>Lazar et al. (2004)</b>  <b>USA</b>  <b>n = 141</b>  CABG surgery patients - all diabetic	Randomized controlled trial  Compared glucose control between 4 groups and its effect on outcomes such as SSI  Glucose levels were measured every hour and treated with either a glucose/ insulin/ potassium (GIK) IV solution continuously or given sliding scale S/C insulin  Total study period 18 hours including surgery  GIK group to maintain glucose between 7.1 – 11.1mmol/L  Sliding scale S/C group to maintain glucose between 4.4 – 13.8	Hyperglycemia: Different depending on treatment received – see methods  SSI: Not given	Patients achieved better glucose control with GIK immediately before cardiopulmonary bypass ( $p < 0.0001$ ), and at 12h after surgery ( $p < 0.0001$ ). This persisted at 18h even though the solution was shut off ( $p < 0.0001$ ).  Did not separate pneumonia and wound infections, but said that in patients with no GIK, 9% developed an infection compared to 0% in the GIK group ( $p = 0.010$ )  GIK treated patients had significantly less sternal and wound SSIs at 5 years GIK group 1% vs No-GIK group 7% ( $p = 0.03$ )	<u>Limited Comparability:</u> 1. Does not report on period of surveillance  2. Does not report if post-discharge surveillance was done  3. Does not outline how glucose values were calculated (ie mean glucose or single glucose)  4. Did not describe methods of randomization



Study authors, year, country, sample	Methodology	Definitions of Hyperglycemia and SSI	Results	Limitations
<p><b>O'Sullivan et al. (2006)</b></p> <p><b>Ireland</b></p> <p><b>n = 165</b></p> <p>Vascular surgery</p> <p><u>non-diabetic</u> (no history, plasma HbA1c <math>\leq 7\%</math>; preop fasting glucose <math>&lt; 7.0</math> mmol/L) n = 122</p> <p><u>diabetic:</u> (history of Type 1 or 2 on admission medical history and/or those taking insulin or oral hypoglycaemic agents or 2 consecutive preop fasting glucose levels <math>\geq 7</math> mmol/L n = 43)</p>	<p>Prospective cohort study</p> <p>Pre-operative HbA1c values were collected from all vascular surgery patients on average 5.5 days before the procedure</p> <p>Patients separated into 4 groups: Group 1: HbA1c <math>\leq 6\%</math> Group 2: HbA1c = 6.1 – 7.0% Group 3: HbA1c = 7.1 – 8.0% Group 4: <math>&gt; 8\%</math></p> <p>Post-op blood glucose measured 2 – 4 times per day</p>	<p>Hyperglycemia: Suboptimal HbA1c non-diabetic: 6.1 – 7%</p> <p>Suboptimal HbA1c diabetic: <math>&gt; 7\%</math></p> <p>SSI: Not given</p>	<p>Higher incidence (9.9%) of postop wound infection in non-diabetic patients with suboptimal HbA1c compared to non-diabetic [patients with optimal HbA1c (0%) (<math>p=0.041</math>)</p> <p>Suboptimal HbA1c found in 58.2% of non-diabetics and 51.2% of diabetics</p>	<p><u>Limited Comparability:</u></p> <p>1. Does not report on period of surveillance</p> <p>2. Does not report if post-discharge surveillance was done</p> <p>3. Definition of SSI not given</p>

Study authors, year, country, sample	Methodology	Definitions of Hyperglycemia and SSI	Results	Limitations
<b>Trick et al. (2000a)</b>  <b>USA</b>  <b>n = 309</b>  CABG surgery patients	Retrospective case-control study  Compared glucose control between 2 groups and its effect on outcomes such as SSI  Pre-operative glucose level was the level within 24 hours of surgery pre-operatively	Hyperglycemia: $\geq 11.1$ mmol/L  SSI: Used CDC criteria but also included patients who developed an radial donor site SSI > 30 days	Radial artery graft site SSI: 8.3%  Independent risk factor for SSI: preoperative glucose level $\geq 11.1$ mmol/L or greater (OR: 4.4; $p = 0.01$ )	<u>Limited Comparability:</u> 1. Post discharge surveillance not done on all patients  2. Does not follow CDC guidelines for definition of SSI
<b>Trick et al. (2000b)</b>  <b>USA</b>  <b>n = 120</b>  CABG surgery patients	Retrospective case-control study  Compared glucose control between 2 groups and its effect on outcomes such as SSI  Pre-operative glucose level was the level within 24 hours of surgery pre-operatively	Hyperglycemia: $\geq 11.1$ mmol/L  SSI: Not given	Deep sternal wound SSI rate: 1.7%  Independent risk factor for SSI: preoperative glucose level $\geq 11.1$ mmol/L or greater (OR: 10.2; 95%CI, 2.4 – 43; $p = 0.008$ )	<u>Limited Comparability:</u> 1. Post discharge surveillance not done on all patients  2. Definition of SSI not given  <u>Overestimation of effect:</u> Case pts had significantly more internal thoracic artery harvests which has been linked to SSI in the literature
<b>Vilar-Compte et al. (2008)</b>  <b>Mexico</b>  <b>n = 260</b>  Mastectomy surgery patients	Nested case-control study  Compared glucose control between 2 groups and its effect on outcomes such as SSI  Each patient has 5 glucose levels done  Patients followed for SSI development for at least 30 days	Hyperglycemia: $\geq 7.3$ mmol/L  SSI: Not given	Independent risk factor for SSI: At least 1 glucose level $\geq 7.3$ mmol/L (OR: 3.05; 95%CI, 1.5-6.3; $p = 0.006$ )	<u>Limited Comparability:</u> 1. Does not report if post-discharge surveillance was done  2. Definition of SSI not given

Study authors, year, country, sample	Methodology	Definitions of Hyperglycemia and SSI	Results	Limitations
<b>Wilson et al., (2003)</b>  <b>USA</b>  <b>n = 258</b>  CABG surgery patients	Nested case-control study  Compared glucose control between 2 groups and its effect on outcomes such as SSI  Preoperative glucose was the first morning draw before 7am on the operative day	Hyperglycemia: 7.0 mmol/L  SSI: CDC definition	Preoperative glucose values of patients who developed mediastinitis: $7 \pm 2.8$ mmol/L compared to the control group without mediastinitis $5.3 \pm 1.3$ mmol/L; $p < 0.0001$  A preoperative glucose level of 7 mmol/L or greater is a independent predictor of post-operative mediastinitis (OR: 5.25; 95% CI, 1.82 – 15.11; $p = 0.002$ )	<u>Limited Comparability:</u> 1. Does not report on period of surveillance  2. Does not report if post-discharge surveillance was done
<b>Zerr et al. (1997)</b>  <b>USA</b>  <b>n = 1585</b>  CABG surgery patients - all diabetic  Defined diabetes by history at time of surgery	Retrospective, observational cohort study  Daily mean glucose levels were calculated by getting the average of levels obtained every 1 – 2 h.  Glucose levels were compared before the institution of a strict protocol to after the protocol stopped	Hyperglycemia: $\geq 11.1$ mmol/L  SSI: Not given	2.1% developed deep wound SSI before protocol  After institution of the CII protocol, at 3 years after, 0.98% developed a deep wound SSI  Elevated BG $> 11.1$ mmol/L at 48 hours was found to be significantly associated with increased risk of deep wound infection ( $p < 0.05$ )	<u>Limited Comparability:</u> 1. Does not report on period of surveillance  2. Does not report if post-discharge surveillance was done  3. Does not outline how glucose values were calculated (ie mean glucose or single glucose)



**Table 2: Temperature and SSI**

Study authors, year, country, sample size	Methodology	Definitions	Results	Limitations
<b>Barone et al.</b>  <b>(1999)</b>  <b>USA</b>  <b>n = 150</b>  Colorectal surgery patients	Retrospective cohort study  Compared temperatures in colectomy patients to determine if hypothermia is a risk factor for SSI	<b>SSI:</b> Suppuration (the formation of pus) requiring the removal of sutures  <b>Hypothermia:</b> < 34.3 °C in OR or PARR	<b>SSI rate:</b> 12% of patients categorized as hypothermic developed SSI compared to 12% of patients classified as normothermic	<u>Limited comparability:</u> 1. Definition of hypothermia is not standard of < 36 °C  2. Unclear as to how hypothermia measurements were calculated  3. Some patients categorized as normothermic were hypothermic according to our definition  4. Does not report on period of surveillance  5. Does not report if post-discharge surveillance was done  6. Does not use standard CDC definition
<b>Flores-Maldonado et al.</b>  <b>(2001)</b>  <b>Mexico</b>  <b>n = 290</b>  Cholecystectomy patients	Prospective, cohort study  Examined the association between mild perioperative hypothermia (< 36.0 °C) on arrival to PARR and SSI  Did post-discharge surveillance at 30 days	<b>SSI:</b> Positive wound culture  <b>Hypothermia:</b> < 36.0 °C	<b>SSI rate</b> 7.6%  Patients who were hypothermic had a significantly longer surgery time ( $p < 0.0001$ )  Hypothermia is a significant independent predictor of SSI ( $p = 0.004$ )	<u>Limited comparability:</u> 1. Did not use CDC definition of SSI  <u>Underestimation of effect:</u> 1. 10% of patients lost in post-discharge surveillance  <u>Overestimation of effect:</u> Longer OR time for hypothermic group

Study authors, year, country, sample size	Methodology	Definitions	Results	Limitations
<b>Kurz et al.</b>  <b>(1996)</b>  <b>Austria</b>  <b>n = 200</b>  Colorectal surgery patients	Prospective case-control study  Compared temperatures in colorectal surgery patients to determine if hypothermia is a risk factor for SSI  Patients were randomly assigned to a temperature control group  Normothermia group: temperature maintained around 36.5 °C  Hypothermia group: Temperature maintained around 34.5 °C  Temperature measurements were done every 10 minutes intra-operatively and 20 minute intervals during recovery  Post-discharge surveillance done at 14 days or a call was made to patient's physician	SSI: Presence of pus and a positive culture  Hypothermia: $\leq 34.5$ °C	18.8% of hypothermic patients developed an SSI compared to 5.8% of normothermic patients ( $p = 0.009$ )  94% of patients had post-discharge surveillance at 14 days after surgery.  Of the 6% of patients who did not have complete surveillance, a call was made to the patient's physician to determine if patients had developed an SSI or not	<u>Limited comparability:</u>  1. Definition of hypothermia is not standard of $< 36$ °C  2. Was unclear as to how hypothermia measurements were calculated  3. Did not use standard CDC definition of SSI  <u>Underestimation of effect:</u>  1. Surveillance only done for 15 days, not full 30 days  2. Some patients may have been lost to follow up – not reported if patients whose doctors were contacted actually saw their patient after surgery

**Table 3: Vascular Surgery and Risk Factors Studies**

Study – Authors, Year, Country, SSI definition	Methodology	Outcomes	Limitations
<b>Nicholson et al.</b>  <b>1994</b>  <b>England</b>  n = 150  <b>SSI definition:</b> Purulent discharge from the wound	Prospective cohort study  Chart audit  No post-discharge surveillance  <u>Main focus:</u> determination of the effect of obesity on vascular surgery outcomes  <u>Definitions:</u> normal weight: BMI < 27 men; BMI < 25 women overweight: BMI 27-29 men; BMI 25-29.9 women obese: BMI ≥ 30	<u>SSI rate overall:</u> 16%  SSI rate in obese patients: 31%  <u>Risk factors for SSI:</u> Compared to normal weight:  Overweight increased risk (p < 0.01)  Obesity increased risk (p < 0.05)	<u>Limited comparability:</u> 1) Used different antibiotic prophylaxis than standard 2) Did not use standard definitions of SSI  <u>Underestimation of SSI rate:</u> 1) No post D/C surveillance conducted 2) Did not follow prosthetic grafts for 1 year
<b>Pounds et al.</b>  <b>2005</b>  <b>USA</b>  n = 410  <b>SSI definition:</b> CDC definition	Retrospective case-control study  Chart audit  Post-discharge surveillance not reported  Surveillance: cases of infection were identified through MD reporting, M&M records, and readmission to hospital for infection  <u>Main focus:</u> determination of risk factors for SSI	<u>SSI rate:</u> 11% (2/3 were organ/space)  <u>Risk factors for SSI:</u> Previous hospitalisation (p = 0.03)  Younger age (p = 0.047)  Presence of a groin incision (p = 0.04)	<u>Underestimation of SSI rate:</u> 1) Unknown if post D/C surveillance conducted 2) Did not follow prosthetic grafts for 1 year



Study – Authors, Year, Country, SSI definition	Methodology	Outcomes	Limitations
<b>O'Sullivan et al.</b>  <b>2006</b>  <b>Ireland</b>  n = 165  <b>SSI definition:</b> Not provided	Prospective cohort study  Chart audit  Post-discharge surveillance not reported  <u>Main focus:</u> the effect of pre-operative hyperglycemia as measured by HbA1c on SSI	<u>SSI rate:</u> For nondiabetic patients with pre-operative HbA1c level between > 6 and ≤ 7% (suboptimal): 9.9%  <u>Risk factor for SSI:</u> Non-diabetic patients with suboptimal HbA1c (p < 0.05)	<u>Limited comparability:</u> No definition of SSI given  <u>Underestimation of SSI rate:</u> 1) Unknown if post D/C surveillance conducted 2) Did not follow prosthetic grafts for 1 year
<b>Chang et al.</b>  <b>2003</b>  <b>USA</b>  n = 365  <b>SSI definition:</b> CDC definition	Retrospective cohort study  Chart audit and review of postoperative infection surveillance surveys and a vascular registry  <u>Main focus:</u> effect of risk factors on SSI	<u>SSI rate:</u> 8.0%  <u>Risk factors for SSI:</u>  Time in OR: SSI group – 318 min no SSI group - 265 min (p = 0.02)  Vein grafts developed more <i>superficial</i> infections (9.2%) than artificial grafts (0.3%) p = 0.02	<u>Underestimation of SSI rate:</u> 1) Did not report how many patients lost to followup 2) Did not report if all patients with artificial graft had 1 year surveillance 3) Did not look at every chart – only looked at a registry and did not elaborate on what was included in the surveillance survey

Study – Authors, Year, Country, SSI definition	Methodology	Outcomes	Limitations
<b>van Himbeeck et al.</b>  <b>1992</b>  <b>the Netherlands</b>  n = 603  <b>SSI definition:</b> Purulent discharge/leakage from the wound edges which had a positive culture and signs of inflammation	Prospective cohort study  Observed by an ICN while in hospital  Once pts were d/c they were followed up as outpatients by the vascular surgeons in collaboration with an Infection Control Nurse (mean f/u time 45 months; range 21-75 mos)  14.9% lost to follow-up  <u>Main Focus:</u> effect of risk factors on SSI	<u>SSI rate:</u> 5.1%  <u>Risk factors for SSI:</u> Female gender ( $p < 0.01$ )  Older men ( $p < 0.01$ )  Groin incision ( $p < 0.01$ )	<u>Limited comparability:</u> 1) Did not use standard definition of SSI 2) They shaved their patients but did not look at this as a risk factor or control for it in the regression  <u>Underestimation of SSI rate:</u> Unknown what effect the 14.9% of patients who were lost to follow-up may have had on SSI rate  <u>Overestimation of SSI rate:</u> Period of surveillance was longer than standard
<b>Richet et al.</b> <b>1991</b>  <b>France</b>  n = 561  <b>SSI definition:</b> CDC definition	Prospective cohort study  Patients were followed for at least 30 days  <u>Main Focus:</u> effect of risk factors on SSI	<u>SSI rate:</u> 4.1%  <u>Risk factors for SSI:</u>  Delayed surgery IDDM Past history of vascular surgery Short antimicrobial prophylaxis ( $p \leq 0.05$ )	<u>Limited comparability:</u> Used non-standard antibiotic prophylaxis  <u>Underestimation of SSI rate:</u> Did not follow prosthetic grafts for 1 year

**Table 4: Vascular Surgery SSI Surveillance Studies**

<b>Authors, Year, Country</b>	<b>Methodology</b>	<b>Definition of SSI</b>	<b>Outcomes</b>	<b>Limitations</b>
<b>Mannien et al.</b>  <b>2006</b>  <b>The Netherlands</b>  n = 317	Pre and post intervention study  Intervention: Strict, restrictive antimicrobial prophylaxis  Post-discharge surveillance done	CDC definition	SSI rate: 21.1%	Relied on voluntary reporting from hospitals  Number of patients lost to follow-up not reported
<b>Hawn et al.</b>  <b>2008</b>  <b>USA</b>  n = 1248	Retrospective cohort study  Post-discharge surveillance not reported	CDC definition but did not follow prosthetic grafts for 1yr	SSI rate: 8.1%	Post-discharge surveillance: not reported  Did not follow prosthetic grafts for 1 year
<b>Coello et al.</b>  <b>2005</b>  <b>England</b>  n = 3732	Retrospective cohort study  Participating hospitals voluntarily reported SSI surveillance results into central registry  Hospital surveillance only (maximum 120 days for those with prosthetic graft; 30 days without)	Not provided	SSI rate: 7.7%	Post-discharge surveillance: not done  Did not follow prosthetic grafts for 1 year  Relied on voluntary reporting from hospitals



<b>Authors, Year, Country</b>	<b>Methodology</b>	<b>Definition of SSI</b>	<b>Outcomes</b>	<b>Limitations</b>
<b>Morton et al.</b>  <b>2008</b>  <b>Australia</b>  n = 440	Prospective cohort study  Participating hospitals voluntarily reported SSI surveillance results into central registry  Hospital surveillance only	CDC definition	SSI rate: 6.1%	Post-discharge surveillance: not reported  Unknown if prosthetic grafts followed for 1 year  Relied on voluntary reporting from hospitals
<b>Turnbull et al.</b>  <b>2005</b>  <b>Canada</b>  Main focus of study: Antibiotic prophylaxis  n = 473	Prospective cohort study  ICP assessed all pts in hospital, reviewed charts, lab data, x rays, observed wound for healing, consulted with the nurse, surgeon or both q48h during admission, for 1 month if readmission occurred (to ER or hospital), or for 1 year if prosthetic device implanted	CDC definition	SSI rate: 7%	Number of patients lost to follow-up not reported
<b>Edwards et al.</b> <b>(National Healthcare Safety Network)</b>  <b>2008</b>  <b>USA</b>  n = 3676	Prospective cohort study  Participating hospitals voluntarily reported SSI surveillance results into central registry  Does not report on post-discharge follow-up	CDC definition	SSI rate: 6.69%	Post-discharge surveillance: not reported  Did not follow prosthetic grafts for 1 year  Relied on voluntary reporting from hospitals

<b>Authors, Year, Country</b>	<b>Methodology</b>	<b>Definition of SSI</b>	<b>Outcomes</b>	<b>Limitations</b>
<b>Moro et al.</b>  <b>2005</b>  <b>Italy</b>  n = 274	Prospective cohort study  Active observation of 94.5% of the patients after D/C for up to 30 days with no implant and 1 yr if implant – MD filled out form on patients seen and phone call made	CDC definition	SSI rate: 5.4%	Underestimation of SSI rate because MDs may have not sent in form or patients may not have been able to be reached by phone
<b>Schepers et al.</b>  <b>2003</b>  <b>The Netherlands</b>  n = 373	Prospective cohort study  Hospital surveillance only	No definition given	SSI rate: 5.3%	Post-discharge surveillance: not done  Did not follow prosthetic grafts for 1 year
<b>NNIS system</b>  <b>2004</b>  <b>USA</b>  n = 107,076	Retrospective cohort study  Participating hospitals voluntarily reported SSI surveillance results into central registry  Does not report on post-discharge follow-up	CDC definition	SSI rate: 4.34%	Post-discharge surveillance: not reported  Did not follow prosthetic grafts for 1 year  Relied on voluntary reporting from hospitals

## Appendix C: List of Surgeries

Total number: 236 surgeries

1. Aortobifemoral bypass
2. Aorto to femoral bypass
3. Axilla axilla bypass
4. Bypass
5. Femoral femoral bypass
6. Femoral peroneal bypass
7. Femoral popliteal bypass
8. Femoral tibial bypass
9. Ileo femoral bypass
10. Popliteal tibial bypass
11. Aorto bilateral iliac bypass
12. Aorto iliac bypass
13. Polytetrafluoroethylene (PTFE) graft



**Appendix D: SSI Study Data Collection and Surveillance Form**

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**Name:** \_\_\_\_\_ **MCP:** \_\_\_\_\_

**Code:** \_\_\_\_\_

.....tear away line.....

**Code:** \_\_\_\_\_ **Date of data collection:** \_\_\_\_\_

**Site:** ☐ St. Clare's ☐ General

**Surgeon:** \_\_\_\_\_

**Age:** \_\_\_\_\_ **Sex:** ☐ M ☐ F

**Admission Date:** \_\_\_\_\_

**Discharge Date:** \_\_\_\_\_

**Smoker:** ☐ Yes ☐ No **Amount smoked:** \_\_\_\_\_

**Comorbidities:** ☐ Diabetes ☐ Angina ☐ Hypertension ☐ CAD

☐ COPD ☐ PVD ☐ Asthma ☐ CVA ☐ MI

☐ Other Specify: \_\_\_\_\_

**Chemotherapy :** ☐ Yes ☐ No **Date:** \_\_\_\_\_

**Steroid Therapy:** ☐ Yes ☐ No **Date:** \_\_\_\_\_

**Date of procedure:**

☐ Emergency ☐ Elective

**Procedure:** \_\_\_\_\_

**Procedure Code:** \_\_\_\_\_

Anaesthetic Type: ☐ Epidural with catheter ☐ Epidural without catheter

☐ Spinal ☐ General ☐ Local Other \_\_\_\_\_

	<u>Temp (° C)</u>	<u>Mode</u>	<u>Time/Date</u>	<u>Intervention</u>
Preop				

Surgical Start Time: \_\_\_\_\_ Surgical End Time: \_\_\_\_\_

Height: \_\_\_\_\_ Weight: \_\_\_\_\_ BMI \_\_\_\_\_

Hair removal by patient near surgical site < 5 days preop: ☐ Yes ☐ No ☐ Unknown

Hair removal technique in OR: ☐ Clipping ☐ Shaving ☐ None

Condition of skin at surgical site: ☐ Intact ☐ Nicks ☐ Abrasions  
☐ Redness ☐ Other

Estimated Blood Loss in OR: \_\_\_\_\_

OR Exit Time: \_\_\_\_\_

	<u>Temp (° C)</u>	<u>Mode</u>	<u>Time/Date</u>	<u>Intervention</u>
Intraop				
Intraop				
Intraop				
Intraop				
Intraop				
Intraop				

Intraoperative: Record all temperatures < 36.0 °C and readings after this until temp returns to 36.0°C again

Surgical Classification: \_\_\_\_\_

Implants: ☐ Mesh ☐ Artificial graft ☐ Wires ☐ Artificial valve

Break in technique: ☐ Yes ☐ No ☐ Not recorded

ASA Score: \_\_\_\_\_ ☐ Not recorded

Allergy : Yes ☐ No ☐ If yes, type: \_\_\_\_\_

Preop infection : Yes ☐ No ☐ If yes, location: \_\_\_\_\_

Antibiotics received for preop infection: \_\_\_\_\_

Antibiotics received in OR/PARR/Surgical unit:

<u>Drug</u>	<u>Dose</u>	<u>Date/Time</u>

Antibiotics given when: ☐ > 2h precut ☐ >1-2h precut ☐ 30-60min precut  
☐ 0-30 min precut ☐ 0-30 min postcut ☐ 30-60 min postcut

Was antibiotic appropriate for surgery? ☐ Yes ☐ No

Received repeat A/B after > 4h in OR? ☐ Yes ☐ No

Was dose appropriate for BMI? ☐ Yes ☐ No



How many doses of A/B within 24 hours postop: \_\_\_\_\_

PARR Entrance Time: \_\_\_\_\_

	<u>Temp (° C)</u>	<u>Mode</u>	<u>Time/Date</u>	<u>Intervention</u>
<u>PARR Entrance</u>				
PARR				
PARR				
PARR				
PARR				
<u>PARR Exit *</u>				

PARR: Record temp on entrance to and exit from PARR and any other temp < 36.0 °C and readings after this until temp returns to 36.0°C again

PARR Exit Time: \_\_\_\_\_

	<u>Temp (° C)</u>	<u>Mode</u>	<u>Time/Date</u>	<u>Intervention</u>
<u>Surgical Unit Entrance</u>				
<u>Surgical Unit</u>				
Surgical Unit				
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Surgical Unit				
Surgical Unit				

Surgical unit: Record temp on entrance to surgical unit and any other temp < 36.0 °C and readings after this until temp returns to 36.0°C again

Date of postop visit with surgeon: \_\_\_\_\_

**SSI surveillance:****Purulent Drainage:** Yes ☐ No ☐ Location: \_\_\_\_\_**Pain/Tenderness:** Yes ☐ No ☐ Location: \_\_\_\_\_**Localized swelling:** Yes ☐ No ☐ Location: \_\_\_\_\_**Redness:** Yes ☐ No ☐ Location: \_\_\_\_\_**Heat:** Yes ☐ No ☐ Location: \_\_\_\_\_**Superficial incision deliberately opened by surgeon:** Yes ☐ No ☐**Deep incision spontaneously dehisces:** Yes ☐ No ☐**Deep incision is deliberately opened by the physician:** Yes ☐ No ☐**Abscess/ Other evidence of infections on direct examination, during reoperation, or by histopathologic or radiologic exam:** Yes ☐ No ☐ Location: \_\_\_\_\_**Surgeon/Attending Physician diagnosis:** Yes ☐ No ☐**Microbiology report:** Yes ☐ No ☐ Date done: \_\_\_\_\_**Type/Location of specimen:** \_\_\_\_\_**Organism identified** \_\_\_\_\_**Culture positive:** Yes ☐ No ☐**Fever ( $> 38^{\circ} \text{C}$ ):** Yes ☐ No ☐**Conclusion from above data:****Superficial SSI** ☐**Deep incisional SSI** ☐**Organ/Space SSI** ☐**Location of SSI:** \_\_\_\_\_**No infection developed** ☐

**Where and when was SSI identified:**Postop unit ☐ Date: \_\_\_\_\_ER ☐ Date: \_\_\_\_\_OPD ☐ Date: \_\_\_\_\_Vascular lab ☐ Date: \_\_\_\_\_**Treatment prescribed for infection:**

- ☐ None   ☐ PO Antibiotics   ☐ IV antibiotics   ☐ Reoperation  
☐ Dressings   ☐ Follow up with family MD   ☐ Rehospitalization

**Other Nosocomial Infections:**
☐ Urinary   ☐ Pneumonia   ☐ VAD   ☐ Other \_\_\_\_\_

Date: \_\_\_\_\_ Treatment: \_\_\_\_\_

**Laboratory Results:**Hb A1C \_\_\_\_\_%   Date done: \_\_\_\_\_   Not available: ☐Ferritin level: \_\_\_\_\_   Date done: \_\_\_\_\_   Not available: ☐

WBC preop: \_\_\_\_\_   Date and Time done: \_\_\_\_\_

WBC postop: \_\_\_\_\_   Date and Time done: \_\_\_\_\_

**Hemoglobin and Blood Loss**

	<u>Value</u>	<u>Date/Time</u>	<u>Treatment</u>
Hemoglobin preop			
Hemoglobin intraop			
Hemoglobin PARR			
Hemoglobin postop			
Hemoglobin postop			
Hemoglobin postop			
Hemoglobin postop			

**Codes:** Treatment: I – iron supplement; PRBC – packed red blood cells; W – Whole blood





Surgical Unit			
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Surgical Unit			

**Other complications:**

## Appendix E: Letters of Approval

Human Investigation Committee (HIC)

Research Proposal Approval Committee (RPAC)

Program Director: Surgery Program

Program Director: Perioperative Program





Human Investigation Committee  
Research and Graduate Studies  
Faculty of Medicine  
The Health Sciences Centre

July 12, 2006

**Reference #06.129**

Ms. K. Dobbin-Williams  
C/o Dr. D. Moralejo  
School of Nursing  
Memorial University of Newfoundland

Dear Dr. Dobbin-Williams:

Your application entitled "**An exploration of the relationship between hyperglycemia and hypothermia as risk factors for the development of a surgical site infection**" was reviewed by a Sub-Committee of the Human Investigation Committee and **full approval** was granted.

This will be reported to the full Human Investigation Committee, for their information, at the meeting scheduled for **July 20, 2006**.

Full approval has been granted for one year. You will be contacted to complete the annual form update approximately 8 weeks before the approval will lapse on **July 11, 2007**. It is your responsibility to ensure that the renewal form is forwarded to the HIC office not less than 30 days prior to the renewal date for review and approval to continue the study. The annual renewal form can be downloaded from the HIC website <http://www.med.mun.ca/hic/downloads/Annual%20Update%20Form.doc>.

For a hospital-based study, it is **your responsibility to seek the necessary approval from the Health Care Corporation of St. John's and/or other hospital boards as appropriate.**

This Research Ethics Board (the HIC) has reviewed and approved the application for the study which is to be conducted by you as the qualified investigator named above at the specified study site. This approval and the views of this Research Ethics Board have been documented in writing. In addition, please be advised that the Human Investigation Committee currently operates according to the Tri-Council Policy Statement and applicable laws and regulations.

Notwithstanding the approval of the HIC, the primary responsibility for the ethical conduct of the investigation remains with you.

We wish you success with your study.

Sincerely,

John D. Harnett, MD, FRCPC  
Co-Chair  
Human Investigation Committee

Richard S. Neuman, PhD  
Co-Chair  
Human Investigation Committee

JDH;RSN:jd

C Dr. C. Loomis, Vice-President (Research), MUN  
Mr. W. Miller, Director of Planning & Research, HCCSJ



# Eastern Health

244  
St. Clare's Mercy Hospital  
154 LeMarchant Road  
St. John's, NL  
Canada A1C 5B8  
T: (709) 777-5000  
F: (709) 777-5210  
www.easternhealth.ca

September 13, 2006

Ms. K. Dobbin-Williams  
5 East  
St. Clare's

Dear Ms. Dobbin-Williams:

Your research proposal "*HIC # 06.129 – Hyperglycaemia and Hypothermia as risk factors for the development of a surgical site infection*" was reviewed by the Research Proposals Approvals Committee (RPAC) of Eastern Health at its meeting on September 12, 2006 and we are pleased to inform you that the proposal has been approved.

The approval of this project is subject to the following conditions:

- The project is conducted as outlined in the HIC approved protocol;
- Adequate funding is secured to support the project;
- In the case of Health Records, efforts will be made to accommodate requests based upon available resources. If you require access to records that cannot be accommodated, then additional fees may be levied to cover the cost;
- A progress report being provided upon request.

If you have any questions or comments, please contact Lynn Purchase, Manager of the Patient Research Centre at 777-7283.

Sincerely,

Mr. Wayne Miller  
Senior Director, Corporate Strategy & Research  
Chair, RPAC

cc: Ms. Lynn Purchase, Manager, Patient Research Centre  
Ms. Elaine Warren, Program Director Surgery  
Dr. A. Felix, Clinical Chief Surgery

June 26, 2006

Dear Committee Members of HIC and RPAC,

I have reviewed Karen Dobbin-Williams' outline for the study she proposes looking at hypothermia and hyperglycemia as risk factors for surgical site infection. I am pleased to offer the support of the Surgery Program for this study.

Sincerely,

Elaine Warren  
Program Director  
Surgery Program  
Eastern Health



June 29, 2006

Dear Committee Members of HIC and RPAC,

I have reviewed Karen Dobbin-Williams' outline for the study she proposes, looking at hypothermia and hyperglycemia as risk factors for surgical site infection. I am please to offer the support of the Perioperative Program for this study.

Sincerely,

**Maria Tracey**  
Perioperative Program Director  
Eastern Health

MT/jmy







