Predicting surgical site infection in orthopedic trauma: the need for a recommended wound classification system

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The Need for a Recommended Wound Classification System

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Dedication

To my mom and dad, brothers and sister-in-law, as well as the rest of my family and friends…for all of their love and support, in whatever form it came, over the past three years. I could not have made it through without each and every one of you. Also, to Professor Gentry, PA-C for her continued support of and passion for our medical education, and for helping us recognize our greatness.
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Introduction

Trauma is defined as cellular disruption caused by an exchange with environmental energy that is beyond the body’s resilience (Cothren, Biffe, & Moore, 2010). It encompasses a vast range of severity, and may involve any part of the body, for example, head trauma, abdominal trauma, or skeletal trauma. Severe trauma injuries will likely necessitate surgical intervention, and orthopedic traumas account for a great deal of these cases. Prior to the modern surgical era, the three major obstacles of surgery were bleeding, pain, and infection (Magner, 1992). Therefore, orthopedic surgeons were limited in their methods of treatment; abscesses, simple fractures, dislocations, and amputations were the main procedures performed (Rutkow, 2008). Before the 19th century, standard of care for open orthopedic fractures was amputation, resulting in high morbidity and mortality (Bowen & Widmaier, 2005).

Control of hemorrhage and hemostasis were mostly resolved in the 1600s, with major breakthroughs and developments occurring in 1800s. General anesthesia began to take form in the 1830s, and in 1846 William Morton performed the first procedure with ether as an inhalational anesthetic (Magner, 1992). Within the next two years, ether and other anesthetics like nitrous oxide and chloroform were being used in surgery, obstetrics, and dentistry (Magner, 1992). However, these advances were limited by infection that often caused death in over sixty percent of patients with compound fractures (Magner, 1992). It quickly became apparent that antisepsis and asepsis were vital determinants on success of surgical procedures, more important than anesthesia. Yet it was not until the late 19th century that scientists like Pasteur, Lister, and Koch made discoveries that contributed to advancement of antisepsis and aseptic technique. It was even later, in 1928, when Sir Alexander Fleming discovered the first antibacterial agent, penicillin (Beilman & Dunn, 2010). This discovery paved the way for development and use of
antimicrobials as prophylaxis against, and treatment for, surgical infections. Modern era highlights involve technological advances, which focus on instruments and procedures that have increased the sophistication of operations performed today (Rutkow, 2008). However, without the discovery and development of antibiotics, these technological advances would not have been nearly as significant.

At the end of World War II, the economic expansion occurring in the United States included healthcare. There was vast growth of hospitals and surgical centers across the country, and surgeons began to branch off into specialties and subspecialties (Rutkow, 2008). Today, there exists a gamut of procedures varying in length and complexity, which before were unimaginable. Other advances include the increased number of laparoscopic procedures, and more recently, robotic surgical procedures from urology to cardiothoracic operations. However, with longer and complicated surgeries comes increased risk of surgical infection. In addition, patients undergoing surgery today have more chronic disease and co-morbidities than ever before (Anaya & Dellinger, 2008). This is partially due to increased life expectancy; the number of elderly patients undergoing surgical operations is on the rise due to increasing age of the population, and patients over the age of 65 accounted for 43% of procedures in 1998 (Kaye, Schmader, & Sawyer, 2004). There are currently more than 18 million surgical procedures performed each year in the United States, with 2.7% of these complicated by surgical site infection (SSI), or at least 486,000 (Kirkland, Briggs, Trivette, Wilkinson, & Sexton, 1999).

Despite the numerous advances made in surgical procedures and technique, SSIs, formally known as postoperative wound infections, continue to be a leading cause of nosocomial infection. According to the National Nosocomial Infection Surveillance (NNIS) of the Centers for Disease Control and Prevention (CDC), SSIs are the third most common nosocomial
infection after urinary tract infections and pneumonia (Anderson & Sexton, 2007). SSIs are
divided into two categories, either incisional or organ/space. Incisional SSIs are additionally
separated into superficial or deep: superficial incisional includes the skin and subcutaneous
tissue; deep incisional includes deeper soft tissue fascia and muscle (Mundy & Doherty, 2010).
An organ/space SSI involves any part of the operative field except the body wall tissues incised,
for example osteomyelitis or an abdominal abscess (Kirby & Mazuski, 2009). Incisional
infections are the most common type of SSI, accounting for 60% to 80%, while organ/space have
a smaller incidence, but account for 93% of SSI mortality (Anaya & Dellinger, 2008).

In 1985, the first sample-based estimates of the magnitude of nosocomial infections in the
U.S. were published. During the period from 1975-1976, approximately 2.1 million infections
occurred in 37.7 million admissions, for a nationwide nosocomial infection rate of 5.7 per 100
(Haley, Culver, White, Morgan, & Emori, 1985). SSI accounted for 510 cases, 402 of these
admissions, or 23.8% (Haley et al., 1985). When looking only at surgical patients, SSIs are the
most common hospital-acquired infection at 38% (Mundy & Doherty, 2010). This translates into
one of every 24 in-patient surgical procedures in the United States (Anderson & Sexton, 2007).
In addition, of all nosocomial infections in the elderly, SSIs account for 11% (Kaye et al., 2004).

As evidenced by these statistics, SSIs continue to be a significant complication of
surgical procedures in the 21st century. While prophylactic antibiotics originally helped reduce
the number of SSIs, improper and overuse is now leading to antibiotic-resistant bacteria such as
methicillin-resistant S. aureus (MRSA) and vancomycin-resistant enterococci (VRE), two of the
most common pathogens. In a cohort study performed at Duke University Medical Center
(DUMC), mortality and hospital cost were compared for patients with MRSA infections versus
methicillin-susceptible S.aureus (MSSA) infections. Of the 121 MRSA patients, 25, or 20.7%,
died within a 90-day post-operative period, versus only 11 of 165 MSSA, or 6.7% (Engemann et al., 2003). In a follow-up study also at DUMC, elderly patients with MRSA SSI had five times greater risk of mortality, an excess of 12 additional hospital days, and costs of greater than $40,000 compared to younger patients (McGarry, Engemann, Schmader, Sexton, & Kaye, 2004). Other factors contributing to the incidence of SSIs despite antimicrobial prophylaxis include, again, longer and more complex procedures, patients with multiple chronic diseases and co-morbidities, implants of foreign material, and organ transplantation in immunosuppressed patients (Anaya & Dellinger, 2008).

The effects of SSI are extensive, affecting both tangible and intangible aspects of a patient’s life. An SSI can increase the length of initial hospital stay by seven to ten days, and increase direct hospital costs by $2,000 - $4,500 (Anderson & Sexton, 2007). In a matched cohort study, patients who developed an SSI were five times more likely to be readmitted to the hospital within 30 days of discharge versus patients who did not develop an SSI (Kirkland et al., 1999). If an SSI requires additional procedures, such as debridement, or removal of a foreign implant, the costs only continue to rise. A study of patients with infection after a total knee arthroplasty found the average number of laboratory tests performed per patient was 57.8, increasing costs by an additional $15,359 (Dal-Paz, et al., 2010). Taking into account indirect costs in the post-operative period, such as home health, physical therapy, medications, time away from work, it is hard to ascertain the exact cost of an SSI. What is certain, however, is that costs are greatly underestimated. More significant than financial cost is patient morbidity and mortality; patients who acquire an SSI have a 2.2 relative risk of death, and are 60% more likely to spend time in an intensive care unit (Mostofi, Browner, Grey, Calhoun, & MacArthur, 2008).
Factor in emotional distress and physical pain, and possible life-long disability, it is hard to equate a monetary amount with patient suffering.
Background

The epidemiology of orthopedics is changing rapidly. Due to improvements in social conditions and public health initiatives, life expectancy has increased, along with the elderly population. This has resulted in orthopedic surgeons seeing additional fractures in older patients due to osteopenia and osteoporosis. Stricter laws on speeding, drunk driving, and gun control have also shaped orthopedics today, decreasing the number of trauma injuries in younger patients. Trauma, however, is still the leading cause of morbidity in the young, and the number one cause of death in those one to forty-four years old (Cothren et al., 2010). The result is orthopedic physicians performing more complex operations on poor-quality bone, thereby increasing the potential for infection in the elderly (Court-Brown & Koval, 2006).

Increased life expectancy can be attributed to sanitation, antibiotics, vaccinations, public health programs, and healthier lifestyles. The U.S. Census Bureau reported the American life expectancy in 2007 to be 80.4 years for women, and 75.4 years for men; by 2020, it is projected that this will increase to 81.9 and 77.1, respectively ("National vital statistics report," 2010). With increased lifespan and aging baby boomers, there has been a rapid increase in the 65 and older age group. In fact, by 2030, one in five Americans will be over the age of 65 (Berger, Dardik, & Rosenthal, 2008). Consequently, the percentage of operations performed on those older than 65 has also increased. Within the past two decades, the number of surgical procedures performed on those older than 65 increased from 19% to 35% of all operations, the most common procedures performed being orthopedic and cardiac (Berger et al., 2008).

Of all orthopedic procedures, 39% are on those older than 65, and 34% are on patients 45-65; majority of these operations are joint arthroplasty or fracture care (Berger et al., 2008). Falls are a common cause of trauma in older patients, with 33% of those over 65 having a fall
each year in the United States (Jones, Koval, Zuckerman, Aharonoff, & Skovron, 1998). The incidence of fracture or other serious injury from even a simple fall from level surface to the ground is as high as 40% (Berger et al., 2008). Women are more likely than men to have a fall, and they also sustain more serious injuries. Hip fractures of the proximal femur are the most worrisome complication, occurring in about 1% of falls (Jones et al., 1998). Spine and distal forearm fractures are other common fractures in the elderly due to osteoporosis. Along with falls and fractures in older and elderly patients, there is also chronic pain and disability from osteoarthritis and other degenerative changes. Total joint arthroplasty has become a cost-effective and successful intervention, with total knee arthroplasty increasing by 68% from 2000 to 2006 (Morgan & Slover, 2011).

As demonstrated previously, orthopedic surgeons now and in the future will be managing increasing numbers of trauma fracture care. A significant number of these will be fractures in older and elderly patients related to falls or pathologic fractures. However, younger patients will persist from motor vehicle accidents, sports related injuries and other traumas. Therefore, it is important to be able to predict occurrence of SSIs when operations must be performed. It is reported that in 2002, of the 43 million procedures in the United States, over 600,000 were open reduction and internal fixation (Mostofi et al., 2008). Currently, there is limited data and research on SSI risk for orthopedic trauma and fractures; more is known for joint arthroplasty and spine surgery. Traumatic injuries, especially open fractures, are at more risk for development of SSI. If this occurs, recovery time is extended, revisions and additional procedures may be necessary, and there likely could be decreased physical ability or function of the affected limb. According to Whitehouse, Friedman, Kirkland, Richardson, and Sexton (2002), orthopedic SSIs led to additional surgical procedures and hospitalizations with a total 14-day increased length of stay.
compared to the control. Orthopedic SSIs were also found to increase total cost of hospitalization, and to have a negative effect on quality of life. Therefore, it will be beneficial to have a classification system that can effectively predict patients most at risk for developing an SSI, and help guide medical treatment. With an effective and efficient system in place, it will be possible to conduct appropriate preventative measures and post-discharge surveillance. The significant morbidity of orthopedic SSIs makes it crucial to identify the best classification system for predicting potential SSI.

Various classification systems are available and applied to surgical patients across the country. Some are classifications of the patients’ overall health status, such as the Acute Physiologic Assessment and Chronic Health Evaluation (APACHE) score. The APACHE system is a disease-specific scoring system used for adult patients (over age 15 years) in the intensive care unit (ICU). Others are more specific to wounds and surgical patients, such as the National Research Council (NRC) wound classification system. The NRC system classifies surgical cases into one of four categories: clean, clean-contaminated, contaminated, and dirty. Further, there are wound classifications for specific specialties. The Gustilo-Anderson classification system was developed in 1976 as a classification for orthopedics, separating open fractures into Types I – III based on degree of soft tissue injury. Clearly, the many functional classification schemes provide for considerable variability in use among hospitals, surgical centers, and specialties.

The frequency, clinical, and economic impact of orthopedic SSIs warrants a wound classification system that will effectively categorize at risk patients. However, there are many wound classification systems available in the peer-reviewed medical literature for predicting SSI. This poses a dilemma: hospitals must choose the system that best meets its needs and provides the best measure of SSI risk. Because of increased numbers of orthopedic procedures being
performed today, a specific recommendation for wound classification system is essential for orthopedic trauma surgeries.

The purpose of this clinical review is to summarize the current incidence, risk factors, and impact of orthopedic trauma SSIs on patient outcomes and healthcare costs. The review will then evaluate and compare existing wound classification systems for use in orthopedic surgery, and identify areas of research that are lacking and should be pursued in the future. The wound classifications evaluated will include several generalized wound classes that are used in all surgical cases, as well as two classifications specific to orthopedic trauma injuries. Those included will be: the National Research Council (NRC), the Study on the Efficacy of Nosocomial Infection Control (SENIC) risk index, the National Nosocomial Infection Surveillance (NNIS), Gustilo-Anderson, and Tscherne and Western/Hannover Fracture Scale (HFS). The secondary purpose is to make a recommendation on which, if any, classification best predicts rate of SSI for orthopedic surgeries, and areas of necessary research.

This review summarizes published literature on the above mentioned classification systems. Searches were performed in PubMed, MEDLINE, Cochrane library, and CINAHL for the named classifications, as well as keywords: surgical site infection, post-operative infection, surgical wound infection, wound classification, injury, trauma, and orthopedic procedures. References from reviewed articles were traced using the same databases. Websites of relevant organizations, such as the Centers for Disease Control and Prevention, US Census Bureau, and the American Academy of Orthopaedic Surgeons, were also consulted. Full-text resources such as Up To Date, Access Medicine, and Access Surgery, as well as several surgical textbooks were used for background information. Google Scholar was also utilized due to limited results for the orthopedic classification systems, which were developed by German physicians.
Changes in U.S. Healthcare

New discoveries, diagnostic approaches, treatment options and other developments are constantly changing the medical landscape and how care is provided to patients. One aspect in medicine that has seen such change is healthcare delivery. Take, for example, the expansion and utilization of urgent care centers, implementation of preventative screenings, and recent legislation that will require insurance to cover vaccinations and birth control for women. Other changes in how patients receive care include things like outpatient versus inpatient procedures, length of hospital stay, payment and reimbursement, and safety surveillance systems. All of these changes are made with hopes to improve patient satisfaction, control cost, and attain better outcomes, and also can either directly or indirectly affect SSIs.

The change from retrospective to prospective payment and diagnosis related groups (DRGs) in the United States greatly affects how much hospitals are reimbursed for SSIs and other nosocomial infections. In 1985, estimates show that of nearly $600 million spent on healthcare, $4 million of this was on nosocomial infections (Jarvis, 1996). Due to continued escalation of healthcare costs, federal government changed how hospitals are reimbursed. A change was made to prospective payment, in which a set fee based on a patient’s initial diagnosis would be paid, and very little would be given for additional co-morbidities or hospital-acquired infections (Jarvis, 1996). In one study performed to assess reimbursement for nosocomial infections, it was found that only 1703 of 9423 infections would have increased the admission DRG to a higher paying code; and while SSIs were more likely than other infections to increase payment, they also were documented less often. In fact, it was found at the time of this study that only 28% of diagnoses for nosocomial infections were recorded; of those cases that would increase DRG, best-case scenario payment would be $93 per nosocomial infection, and worst-
case only $21 per nosocomial infection (Haley, White, Culver, & Hughes, 1987). Under the prospective payment system, a hospital will receive 5-18% payment for a nosocomial infection, and realistically only retain between 1-5% of the cost to treat that infection (Haley et al., 1987). Although these numbers are over 20 years old in some cases, one can see that hospitals would save significant amounts of money if they prevent nosocomial infections from occurring. In fact, an estimate for the average 250-bed hospital shows gains of $954,000 per year if all nosocomial infections could be prevented through effective infection control programs (Haley et al., 1987). Again, most of these studies and financial figures are significantly outdated and hard to compare to today, but they are the only research available and give somewhat of an idea of the trouble SSIs can create.

Improved healthcare delivery is also achieved through quality assurance programs like infection surveillance. Infection surveillance and control programs do not provide direct revenue to hospitals; however, they do help decrease SSI rates, thereby reducing costs and increasing profits. Some hospitals may be wary of implementing surveillance programs due to the up front cost without any tangible return, but the cost savings from an infection control program would be nearly five times the cost of the program itself under prospective payment plans (Haley et al., 1987). In one study, “even a minimally effective control program that prevented only 6% of all nosocomial infections would offset the $60,000 estimated annual cost of the infection control program” (Jarvis, 1996). Another change related to infection surveillance involves publicizing surgeons’ personal SSI rates; infection rates of clean wounds of individual surgeons are the easiest to compare. In a study performed by Cruse and Foord (1980), there was a reduction in overall and clean wound infection rates within six months of implementing SSI rates at monthly staff meetings. Additionally, the SENIC study confirmed that hospitals with the lowest infection
rates also had strong surveillance and prevention programs (Gaynes et al., 2001). Again, these surveillance systems provide financial incentive for hospitals by preventing nosocomial infections.

A third modification in healthcare delivery today is change in proportion between inpatient and outpatient procedures. Considerable numbers of procedures are now done on an outpatient basis, and patients who are admitted are being discharged earlier. The focus has become more on outpatient, ambulatory, and home health settings. Jarvis reports that home therapy costs were estimated to rise from approximately $2 billion in 1988 to $25 billion in 1999 (1996). This brings into question whether post-discharge surveillance is being performed, and whether enough emphasis is being placed on infection control activities.

Not only has the state of healthcare been changing, but also has the profile of the average American patient. Patients today have increased risk factors, many with multiple intrinsic risk factors. Part of this is due to the increased life expectancy. Public health policies, vaccinations, lifestyle, nutrition and antibiotics have people living longer than they ever have. By 2030, one in five people will be over 65, with 85 and older being the fastest growing age group (Berger et al., 2008). Older patients are now making up greater percentages of overall surgical procedures, with an increase from 19% to 35% in the past two decades (Berger et al., 2008). With older patients comes more co-morbidity, such as cardiovascular disease or diabetes, and increased risk of complications.

Along with age, obesity rates in the United States have continued to climb. According to the CDC, 33% of American adults are obese, along with 17% of children and adolescents (Centers for Disease Control and Prevention, 2010). In fact, in 2010, no state had an obesity rate of less than 20%, and 36 states had a prevalence of 25% or more; of these 36 states, 12 had an
obesity rate of at least 30% or more (Centers for Disease Control and Prevention, 2010). These patients are likely to have other co-morbidities such as diabetes, hypertension, high cholesterol, artherosclerosis, cardiovascular disease, and decreased functional status, making them less than ideal surgical candidates.

These intrinsic host risk factors have been identified as specific risk factors for SSI. Age, especially over 74, has been confirmed as an independent risk factor for SSI in orthopedic surgery (de Boer, Mintjes-de Groot, Severijnen, van den Berg, & van Pelt, 1999). Diabetes and congestive heart failure have also been confirmed as risk factors for SSI, with odds ratios of 2.1 and 2.8 respectively (Bachoura et al., 2010). In addition to intrinsic risk factors, there are also peri-operative risk factors that exist. The use of surgical drains, number of operations, and site of injury can all influence development of SSI (Bachoura et al., 2010). Injury to the tibial shaft or plateau, or the elbow, carry increased risk of infection as well (Bachoura et al., 2010). Length of hospital stay, not only after but also prior to surgery, is another risk factor for orthopedic SSIs. Patients with a hospital stay greater than four days prior to surgery were 3.3 times more likely to develop an SSI (de Boer et al., 1999).

Orthopedic traumas are more at risk for SSI than other orthopedic procedures, mainly because of the associated soft tissue damage and contamination of the wound. Thus, while intrinsic host risk factors and peri-operative risk factors are important, wound classification also plays an important role in helping predict the possibility of SSI. In fact, after age as an independent risk factor, wound class was the second most important independent risk factor; contaminated wounds had an odds ratio of 4.1 (de Boer et al., 1999). In hospitals today, the standard classification of clean, clean-contaminated, contaminated, and dirty-infected is applied to all surgical procedures. However, with the ever-increasing population age, associated increase
in orthopedic procedures, and known risk of SSIs in orthopedic cases, it thus seems logical to have a specific wound classification system for orthopedic injuries.
Post-Operative SSI Rates and Clinical Impact

Post-operative SSI rates can be challenging to establish due to early discharge in the post-operative period as well as loss of follow-up. However, several studies have attempted to determine timing and type of SSI when first diagnosed. Most commonly, SSIs occur five to six days into the post-operative period, and between 80% and 90% will present within the first 30 days after the procedure (Kulaylat & Dayton, 2008). One study found a broad range of 12-84% for SSIs found after discharge, either in the post-discharge outpatient setting, or upon readmission (Walenkamp, 2003). A separate article proposes that approximately 30% to 40% of wound infections occur after hospital discharge, again involving post-discharge surveillance and readmissions (Kulaylat & Dayton, 2008).

The most serious infections appear to be detected either before discharge or upon readmission. Of SSIs diagnosed via post-discharge surveillance, the majority were superficial skin infections at 78%; 13% were deep incisional, and only 9% organ/space (Gaynes et al., 2001). Those diagnosed before discharge were 43% skin infections, 19% deep incisional, and 38% organ/space; of SSIs detected on readmission, 40% were skin infections, 31% were deep incisional infections, and 29% were organ/space infections (Gaynes et al., 2001). Infection is more common in orthopedic skeletal traumas than arthroplasty or spine surgery with an incidence of 4.2% (Bachoura et al., 2010). This is due to soft tissue involvement, contamination, and other factors. Orthopedic SSIs were also found to most commonly present within the first 30 days (Bachoura et al., 2010).

There are serious clinical implications for all surgical site infections, whether superficial or organ/space. The most severe infections are usually detected before discharge, which leads to increased length of initial stay. Cruse and Foord (1980) found that infection of a wound
lengthened a patient’s hospital stay on average by 10.1 days. Another study performed by Kirkland, Briggs, Trivette, Wilkinson, and Sexton (1999) concluded that increased length of stay attributable to SSI was 6.5 days. Additionally, 41% of these patients with an SSI required readmission within 30 days of being discharged; coupled with the initial stay, these patients had an excess length of stay of 12 days (Kirkland et al., 1999). With readmissions come laboratory tests, additional surgical procedures, and use of antibiotics. In a study performed in a Brazilian tertiary hospital, an additional 1,965 laboratory tests were required for the study population, and use of additional antibiotic therapy totaled $20,845 (Dal-paz et al., 2010). Surgical procedures required to treat orthopedic SSI patients include debridement, vacuum assisted closure therapy, microsurgical flaps, implant removals, spacers, and revisions, which again will increase cost and length of stay.

There is no doubt that orthopedic SSIs have an extremely high cost of treatment. In the study performed by Dal-paz et al., (2010), looking specifically at SSIs in total knee arthroplasty, the additional direct cost per patient was $2,701, and the study as a whole totaled $91,843. This study was based only on total knee arthroplasty infections, and did not consider orthopedic trauma surgeries, which likely would have propelled costs even higher. The use of direct hospital costs has traditionally been the best method to estimate costs of nosocomial infections since they represent the real costs to the hospital for items and services used by the patients (Dal-paz et al., 2010). However, one must also consider the effect on quality of life. Orthopedic SSIs put patients at risk for extreme morbidity due to decreased function and mobility. An infection can potentially ruin the outcome of a procedure, requiring a revision or even possibly an amputation that can leave a patient with permanent disabilities. This significant morbidity of orthopedic SSIs makes it crucial to identify the best classification system for predicting potential SSI.
NRC

The National Research Council (NRC) was created in 1916 due to the need for science and technical services following World War I. It subsequently adopted a wound classification system, which was tested for the first time in their 1964 study on the use of ultraviolet light in the operating room. The NRC wound classification is the traditional wound classification system recognized and recommended in hospital operating rooms since 1964. The NRC system classifies wounds into one of four categories: clean, clean-contaminated, contaminated, and dirty. Class I (clean) is an uninfected, non-traumatic wound with no inflammation and with no break in technique (Beilman & Dunn, 2010). The respiratory, alimentary, genital and urinary tracts are not entered during surgery. Class II (clean-contaminated) is a non-traumatic wound in which a hollow viscus is entered under controlled conditions without significant spillage of contents, or which has a minor break in technique (Beilman & Dunn, 2010). Class III (contaminated) includes open, fresh traumatic wounds from a clean source, operations with major breaks in technique, or gross spillage from a viscus (Beilman & Dunn, 2010). If a wound has acute inflammation or infection, it is also considered in this category, or if a foreign body is present. Class IV (dirty) includes traumatic wounds from a dirty source, or traumatic wounds with delayed treatment; also foreign bodies, bacterial inflammation, or fecal contamination may affect the wound (Beilman & Dunn, 2010). The NRC wound classification system continues to be useful and has been shown to be independently predictive of wound infections in several large studies using multivariate analysis.

Infection rates expectedly increase with NRC wound class. Class I clean wounds, for example a breast biopsy, have expected infection rates from 1.0-5.4%; Class II clean-contaminated, for example elective gastrointestinal procedures range from 2.1-9.5%; Class III
contaminated, like penetrating abdominal trauma, will range from 3.4-13.2%; and lastly, Class IV dirty wounds with necrotic tissue will range from 3.1-12.8% (Beilman & Dunn, 2010). In 1980, a prospective study of 62,939 wounds generated a set of wound infection rates for the four NRC wound classes: clean, 1.5%; clean-contaminated, 7.7%; contaminated, 15.2%; and dirty 40%, twenty-five times higher than clean wounds (Cruse & Foord, 1980). The overall infection rate was found to be 4.7%, which was comparable to results of other published reports at this time (Cruse & Foord, 1980). In a study performed by Culver et al. (1991), wound class remained a moderately effective predictor of SSI risk; infection rates were lower than in the study performed by Cruse and Foord, but still increased with each class: clean, 2.1%; clean-contaminated, 3.3%; contaminated, 6.4%; and dirty 7.1%.

While the studies above found increased rates of SSI with severity of wound class, the NRC wound classification system is perhaps only a moderately effective predictor of SSI risk. The NRC system has been effective, but fails to account for intrinsic patient risk of developing an SSI (Gaynes et al., 2001). A considerable number of procedures are now performed on an outpatient basis, and surgical patients admitted to the hospital tend to have higher intrinsic risk and often are discharged earlier (Gaynes et al., 2001). For this reason, a composite risk index that would account for both host risk factors as well as wound classification is necessary. This would then allow for meaningful comparison of SSI rates among surgeons, institutions, and over time (Gaynes et al., 2001). In addition, the NRC system is not specific to orthopedic trauma injuries, and does not take into account the precise details that influence SSI in these orthopedic specific wounds.
SENIC Risk Index & NNIS Basic SSI Risk Index

The major limiting factor of the NRC classification system is lack of intrinsic patient risk. A simple new index was developed during the Study on the Efficacy of Nosocomial Infection Control (SENIC) project. This SENIC project analyzed ten potential risk factors for SSI using multiple logistic regression analysis (Culver et al., 1991). The final model consisted of four risk factors: an operation that involved the abdomen; and operation lasting longer than two hours; an operation classified as either contaminated or dirty; and a patient having three or more diagnoses at time of discharge (Culver et al., 1991). Because these four risk factors had nearly equal regression coefficients (from 0.86 to 1.12), all were rounded to one, and the SENIC index consists of counting the number of risk factors present to produce a risk score for the patient (Haley et al., 1985). The fourth factor, a patient having three or more diagnoses at time of discharge, serves as a proxy for intrinsic patient risk, and helps to make the SENIC index a better predictor of SSI than the traditional NRC wound classification system (Culver et al., 1991). The SENIC risk index thus has increased usefulness for surveillance and control of surgical site infections.

The study performed by Haley et al. (1985) to develop the SENIC risk index used multiple logistic regression analysis to evaluate the efficacy of this new index. Of the four variables identified, the single best predictor was having an operation involving the abdomen (Haley et al., 1985). When compared to the traditional NRC wound classification system, the new SENIC risk index was found to have almost twice the predictive ability as calculated by the Goodman-Kruskal (G) statistic: 0.67 for the SENIC risk index and 0.36 for the NRC wound classification system (Haley et al., 1985). These findings suggest that using a multivariate risk index may increase the efficiency of surveillance and control of SSIs. However, limitations to
this study do exist. For example, the number of discharge diagnoses was taken from the face sheet or patient discharge summary; this may fail to account for complete patient complexity, complications during surgery that have an affect on outcome, or other significant events during the hospitalization. Incomplete recording could also lead to underestimation of number of diagnoses and actual complexity of the patient. Also, setting a standard two-hour time limit in the operating room does not account for difference in average length of procedures. Despite these limitations, the SENIC risk index again was a better predictor than the NRC risk index; in fact, it provided the strongest scientific evidence at that time for efficacy of the surveillance of SSIs, and set the stage for the development of the National Nosocomial Infections Surveillance (NNIS) Basic SSI Risk Index (Gaynes et al., 2001).

The NNIS System was established in 1970 when selected hospitals in the United States routinely began to report nosocomial infection surveillance data for use in a national database. The NNIS Basic SSI Risk Index was developed through the SENIC project and is composed of the following criteria: American Society of Anesthesiologists (ASA) score of three, four or five; wound class; and duration of surgery (Gaynes et al., 2001). The ASA score is in itself an index, and assesses overall physical status of the patient preoperatively. Duration of operation uses the 75th percentile of operation distribution for distinguishing between short and long cases. Each operation is scored and given a risk index value ranging from 0-3, and is applicable for 44 NNIS operative procedure categories (Gaynes et al., 2001). Orthopedic procedures include: limb amputation, spinal fusion, open reduction of fractures, hip prosthesis, knee prosthesis, laminectomy, other musculoskeletal, and other prosthesis (Gaynes et al., 2001).

The NNIS risk index was developed in order to adjust for differences in patient intrinsic risk as well as case mix. It has been evaluated in several studies and is accepted as a better
predictor of SSI than the original NRC wound classification system and SENIC risk index. In the previously mentioned study by Culver et al. (1991), surgical site infections rates ranged from 1.5 in 100 for patients with no risk factors, to a high of 13.0 per 100 for patients with all three risk factors present on the NNIS index; each additional risk factor was found to nearly double the risk of SSI. Gaynes et al. (2001) also set out to assess whether the NNIS index was effective at predicting risk of SSI based on strength of association between composite risk index and development of SSI using the Goodman-Kruskal (G) statistic. Overall, 34 of the 44 NNIS procedures had SSI rates that increased significantly (P < .05) with the number of risk factors based on the G statistic (Gaynes et al., 2001).

A separate prospective cohort study directly compared the SENIC index and NNIS risk index using stratified analysis and logistical regression to examine whether either index added explanatory information to the other; the NNIS risk index was found to add statistical significance to the SENIC index, however the opposite did not hold true (Delgado-Rodriguez, Sillero-Arenas, Medina-Cuadros, & Martinez-Gallego, d1997). The NNIS risk index was concluded to be the better index for discriminating and predicting intrinsic patient risk of SSI compared to the SENIC index (Delgado-Rodriguez et al., 1997). A final prospective cohort study, again using the G coefficient for correlation, found a higher NNIS risk index score associated with infection for both complex SSIs and any type of SSI, with values of G=0.52 (95% CI, 0.48-0.56) and G=0.49 (95% CI, 0.47-0.52) and P < .001 respectively (Anderson, Chen, Sexton, & Kaye, 2008). Anderson et al. (2008) concluded that stratifying SSIs using the NNIS risk index is a reasonable method to account for differences in case mix and intrinsic patient risk.
Currently, the NNIS basic SSI risk index is the best method for comparing SSI rates; however, when there is a combination of operative procedures, as in a multi-system trauma, the NNIS risk index is not useful (Gaynes et al., 2001). Certainly, additional important risk factors for specific procedures need to be identified and incorporated into more exclusive indices. It is also important to remember limitations to any index when comparing a cohort and control group and that the index may not properly adjust for case mix (Gaynes et al., 2001). Lastly, the general applicability of the NNIS risk index across a broad range of procedures is encouraging, but there remains room for improvement. Especially in the case of orthopedic trauma injuries, there are specific risk factors and procedures that should be developed into more specific specialty-driven risk indices. Only then will it be possible to appropriately predict risk of developing surgical site infection.
The Gustilo-Anderson classification system was developed in 1976 to categorize the severity of open fractures. It separates open fractures into Types I – III based on degree of soft tissue damage, mechanism of injury, configuration of the fracture, and extent of contamination (Gustilo, Merkow, & Templeman, 1990). In a Type I open fracture, the soft-tissue wound is less than 1cm, usually a puncture wound due to the spike of bone; these fractures are generally simple, transverse, or short oblique fractures with little comminution (Gustilo et al., 1990). Type II fractures consist of a wound 1 – 10cm in size, with no extensive soft-tissue injury; however, there is some degree of crushing injury, contamination, and comminution of the fracture (Gustilo et al., 1990). Lastly, Type III fractures have wounds greater than 10cm that have extensive damage to the soft-tissue, including skin, muscle, and neurovascular structures (Gustilo et al., 1990). There is also a significant amount of contamination in Type III fractures.

In 1984, the Gustilo-Anderson system was modified due to the increasing rate of Type III fractures observed, and because Type III fractures have the highest rates of infection at 24% (Gustilo, Mendoza, & Williams, 1984). Due to this high incidence of infection, correctly classifying fractures and preventing infection is a major clinical concern in Type III wounds. Type III fractures all result from high-energy trauma, and are further classified into IIIA, IIIB, and IIIC in order of worsening prognosis. Type IIIA injury wounds have adequate soft-tissue coverage despite extensive flaps or lacerations; Type IIIB lack adequate soft-tissue coverage and have periosteal stripping and bony exposure; Type IIIC are open fractures with any arterial injury requiring repair (Horn & Rettig, 1993).

Currently, the Gustilo-Anderson system is one of the most widely used classification schemes. Its primary purpose is to indicate need for soft tissue coverage and to minimize risk of
infection; it is important not only in the prognosis of the fracture, but also in determining hardware or fixation that can safely be used to stabilize the wound, selection of antibiotics, and managing the soft tissue injury. Open fractures are usually caused by high-energy trauma, particularly Type III fractures with 90% resulting from high-energy traumas (Gustilo et al., 1984). The incidence of infection in these injuries is directly correlated with degree of soft tissue damage as determined using this grading system. According to Gustilo et al., (1990) infection rates range from 0-2% for Type I fractures; Type II, from 2-7%; Type III overall from 10-25%; Type IIIA, 7%, IIIB from 10-50%, IIIC from 25-50%. In the prospective study of 82 Type III open fractures, Type IIIB and IIIC fractures had extremely high occurrence of infection and amputation compared to Type IIIA; infection rates were 52.0% and 41.7% with amputation in 16.0% and 41.7% of Type IIIB and Type IIIC fractures, respectively (Gustilo et al., 1984). Type IIIC fractures with arterial injury present the greatest challenge with amputation rates from 25-90% overall (Gustilo et al., 1984).

Because of its clinical utility and prognosis of a fracture, it is important that the Gustilo-Anderson classification be reliable. Gustilo has been tested and proven to be a consistent predictor of SSI. In a retrospective study, the Gustilo-Anderson classification was found by both univariate and multivariate analysis to be predictive of infection (Bowen & Widmaier, 2005). Specifically, a patient identified as Type IIIA, had IIIB, or IIIC was 7.85 times more likely (p = 0.001) to develop an SSI than a patient with a Type I or II fracture grade (Bowen & Widmaier, 2005). Host classification and location of the fracture were also prognostic of infection, but the Gustilo-Anderson classification remained the most influential tool in predicting SSI (Bowen & Widmaier, 2005). Lastly, the Gustilo-Anderson classification is beneficial because it is formulated from factors that predispose to most fracture complications, including infection,
delayed or nonunion, or amputation. These factors can occur individually or in combination and include: massive soft-tissue damage and periosteal stripping, wound contamination, compromised vascularity, and fracture instability (Gustilo et al., 1984). Because the incidence of infectious complications in open fractures can be significantly high, particularly in Type III fractures, any analysis for treatment and surveillance would be meaningless unless these factors are taken into consideration (Gustilo et al., 1984).

While the Gustilo-Anderson classification appears to be a consistent predictor of SSI, it does have limits to its application. On a broad scale, it simply is not the only predictor of SSI that must be taken into account. There are the intrinsic host risk factors and peri-operative and environmental risk factors that have been previously demonstrated as important in SSI risk. More specific of the classification itself, the sensitivity becomes limited as fractures become more severe; this was improved with addition of subgroups for Type III fractures, yet Gustilo-Anderson is still not entirely predictive of infection (Bowen & Widmaier, 2005). In addition, the Gustilo-Anderson classification lacks interobserver reliability. A study performed by Horn and Rettig (1993) tested interobserver reliability by having a group of 22 observers, both orthopedic residents and attending physicians, classify 10 open fractures based on photos and radiographs of the open wounds. The overall kappa value, or amount of agreement between observers, was 0.53 (Horn & Rettig, 1993). Specifically, the attending physicians in the study had a k-value of 0.63 and residents 0.49 (Horn & Rettig, 1993). While this is significantly greater than the probability of agreement, k of 0.2730, excellent agreement among observers requires a value of greater than 0.75; thus, agreement in this study was only found to be moderate (Horn & Rettig, 1993). Brumback and Jones (1994) also conducted a study on interobserver agreement of Gustilo-Anderson among 245 orthopedic surgeons via survey at three orthopedic specific conferences.
The surgeons were asked to classify twelve open fractures of the tibia on the basis of a series of videotaped case presentations. They found an average agreement of 60%, with over-all agreement for each fracture ranging from 42% to 94%, concluding again only moderate to poor agreement and reliability (Brumback & Jones, 1994).

Furthermore, this study only evaluates the agreement between the observers, and not agreement with a correct answer. The criteria for Gustilo-Anderson are simplistic, but they are also subjective, and no gold standard exists. Even in Type IIIC, a wound with vascular injury requiring repair, there is lack of objectivity because there are no universally agreed upon indications for repair of vascular injuries associated with fractures (Horn & Rettig, 1993). Because of this subjectivity, the Gustilo-Anderson classification has aspects that allow for poor reliability, such as no uniform method for documentation of wound size or degree of comminution (Bowen & Widmaier, 2005). This makes the Gustilo-Anderson classification more problematic and less beneficial for predicting SSI.
The Tscherne and Oestern classification is used for grading soft tissue injury in fractures. While in the United States the Gustilo-Anderson classification is the most widely accepted and utilized system, the Tscherne and Oestern classification is most popular in German speaking countries. According to this classification, fractures are separated into open and closed categories, each with four classes: grade zero to three for closed fractures, and grade I thru IV for open fractures. In closed fractures, a Grade 0 injury has minimal soft tissue damage with a simple fracture pattern, usually the result of an indirect injury to the limb, such as torsion (Sudkamp, 2007). A Grade 1 injury will have a superficial abrasion or contusion with a mild fracture pattern; grade 2 is a deep abrasion with skin or muscle contusion and severe fracture pattern, usually resulting from direct trauma (Sudkamp, 2007). Lastly, Grade 3 is a fracture with severe damage to underlying muscle with skin contusions (closed de-gloving) or a crush injury and may involve a compartment syndrome (Sudkamp, 2007).

For open fractures, the classification uses wound size, level of contamination, and fracture pattern to assign a grade. Grade I is an open fracture with a minimal puncture wound, negligible bacteria contamination and a low-energy fracture pattern (Sudkamp, 2007). Grade II injuries have small skin and soft tissue contusion, moderate contamination, and variable fracture patterns; all open fractures resulting from direct trauma are included in this group (Sudkamp, 2007). Grade III involves major soft tissue damage, heavy contamination, and often arterial or neural injuries (Sudkamp, 2007). Lastly, Grade IV wounds are fractures with either complete or incomplete amputation (Sudkamp, 2007).

The Tscherne and Oestern classification goes a step beyond the Gustilo-Anderson classification because it recognizes the difference and significance between open and closed
fractures, and gives each their own category accordingly. However, because closed injuries are frequently underestimated, Tscherne developed a more elaborate and detailed classification system called the Hannover Fracture Scale (HFS). Created in 1983, the HFS was developed from a retrospective analysis of approximately 1,000 open fractures of the upper and lower extremities (Sudkamp, 2007). The scale takes into account twelve details of the limb injury to formulate a checklist, including: fracture type, skin condition, underlying soft tissue damage, vascularity, neurological status, level of contamination, presence of compartment syndrome, time interval between injury and treatment, and overall severity of injury (Sudkamp, 2007). Soft-tissue damage includes three different scores: size of the wound, area of skin loss, and damage to deep soft tissues like muscle and tendons, to allow proper evaluation of superficial and deep injury (Sudkamp, 2007). The overall score is then used to guide general patient management and local treatment, and can be useful in estimation of possible complications.

Despite improvement in treatment protocols and grading systems in open fractures, osteitis remains a major complication in open fractures. Thus, a group of German researchers set out to investigate the primary factors responsible for cases of osteitis in open fractures. Over the course of eight years, 948 open fractures were treated at the Medical School in Hannover, Germany; 28 of these developed osteitis and were the basis for the study (Suedkamp et al., 1993). Of these 28 fractures, 19 were the result of a 297 (6.4%) retrospective case series that identified the most statistically significant and influential factors including: bone loss, deep soft tissue damage, primary contamination according to bacteriologic smear, occurrence of soft tissue infection, skin loss, compartment syndrome, ischemia, and fracture type (Suedkamp et al., 1993). In the prospective series of the study, nine of 651 fractures (1.4%) developed bone infection, a significant decrease in incidence of osteitis (Suedkamp et al., 1993). This decrease in infection
rate is thought to be due to a better understanding of various influencing factors and subsequent changes in treatment protocol. Many of these parameters overlap with items on the HFS, and echo the fact that severity of open fracture does result in different infection rates (Suedkamp et al., 1993).

Between 1994 and 1997 Krettek, Seekamp, Kontopp, and Tscherne (2000) reviewed all parameters of the Hannover Fracture Scale (HFS). The original HFS was found to have features that were not easy to assess at the time of initial surgery, like microbiological examination, and others that lost their significance with new advances in limb salvage (Krettek et al., 2000). The purpose of this study was to reduce the HFS to parameters that can be evaluated by the surgeon at the time of initial debridement, and that are still significant in prognosis; thus, making the new HFS ‘98 more relevant to modern fracture treatment. Their design was two-fold: first, a multivariant retrospective analysis of 182 open fractures was performed for each parameter to determine the predictive value; second, a prospective study was performed with a second group of 87 open long bone fractures, assigning both an original HFS value and a new Hannover Fracture Scale ’98 (HFS ’98) score to validate the new scoring system (Krettek et al., 2000). Sensitivity and specificity were calculated for the retrospective group using the original HFS, 0.82 and 0.99 respectively (Krettek et al., 2000). Score analysis then used receiver operating characteristic curves (ROC) to establish the optimal compromise between sensitivity and specificity, and to set a threshold or cutoff point for amputation (Krettek et al., 2000). Applying the new HFS ’98 to the retrospective group, sensitivity and specificity changed to 0.90 and 0.97, respectively (Krettek et al., 2000). Lastly, the HFS ’98 was applied to the prospective study group, and revealed a sensitivity of 0.82 and specificity of 0.99 (Krettek et al., 2000). The new scoring system now uses bone loss, skin injury, muscle injury, neurology, contamination,
deperiostation, local circulation, and systemic circulation as the eight parameters, and has a score threshold of equal or greater than 11 for recommended limb amputation. Overall, the new HFS ’98 has an accuracy of 0.97, greater or equal to the other limb salvage scores used in the study, including the original HFS, the Neurology, Ischemia, Soft tissue injury, Skeletal injury, Shock, Age of Patient Score (NISSSA) and the Mangled Extremity Severity Score (MESS) (Krettek et al., 2000). It was concluded that the HFS ’98 is a practical, standardized way of evaluating open fractures, but in terms of limb amputation, the decision process should be left to an experienced surgeon and the patient.

While mainly used and studied for predicting surgical complications like infection and limb salvage, wound classifications have also been somewhat evaluated for prediction of patient clinical and functional outcomes. The HFS ’98, along with other limb salvage scores, was reviewed in a prospective cohort of patients participating in the Lower Extremity Assessment Project (LEAP) for functional outcome after limb salvage. Injury severity was assessed with one of the five common limb salvage scores, and functional outcomes were measured using physical and psychosocial domains of the Sickness Impact Profile (SIP) at both six months and two years after successful limb reconstruction (Ly, 2008). Overall, the subjects SIP scores improved between the six and twenty-four months after hospitalization: physical SIP averaged 17.4 at six months and 9.5 at twenty-four months; psychosocial SIP decreased from mean of 12.1 at six months to 9.9 at twenty-four months (Ly et al., 2008). However, there is only limited association between injury severity scores and SIP outcomes, and the trends did not correlate in the expected manner. For example, the SIP outcomes were expected to increase with limb salvage score; however, at six months subjects with a MESS of less than two had a mean physical SIP of 21, subjects with MESS of between three and five had SIP mean of 17.4, and MESS between six and
eleven had mean SIP of 17.7 (Ly et al., 2008). This is in contrast to what was expected, an increasing SIP with increasing injury score. Thus, this study suggests no association between injury severity scores and functional outcome over time; and again, emphasizes that practitioners should use caution in interpreting wound and limb salvage scores when making patient care decisions.

Due to the lack of interobserver reliability in the Gustilo-Anderson classification and considerable amount of items in HFS ’98, a study performed by Yokoyama et al. (2009) set out to create a new scoring system for prediction of deep infection in upper and lower extremity fractures. This new scoring system hopes to create a more generalized scale that is still able to accurately and effectively predict occurrence of infection. In the initial analysis, a retrospective review was performed to evaluate the relationship between Gustilo’s grade and each of the eight items on the HFS ’98; this was carried out with 394 open fractures, using multivariate analysis (Yokoyama et al., 2009). This was done to ensure validity of the new system, and from these results significant items, based on P values and which correlated with Gustilo’s grade, were chosen for a second infection analysis that used categorical regression analysis (Yokoyama et al., 2009).

The new scoring system was developed using P values from the second infection analysis, and discrimination was evaluated using receiver operating characteristic (ROC) curves. The three new factors were found to have significant affect in the occurrence of deep infection on multivariate analysis: muscle injury (MI, p = 0.0001), wound contamination (WC, p = 0.0001), and local circulation (LC, p = 0.0001) (Yokoyama et al., 2009). Each of these three factors is assigned a score, 0-20, for a 60 total point scale with a cutoff point of equal or greater than 35 (p = 0.002); sensitivity, specificity, positive predictive value, and negative predicative
value in this cutoff point of the new score are 0.67, 0.92, 0.66, and 0.98, respectively (Yokoyama et al., 2009). While this scoring system may be useful for predicting occurrence of deep infection in open extremity fractures, and is perhaps easier to apply than the Gustilo-Anderson or HFS ’98, further prospective studies need to be performed to clarify validity of this scale. Minimally, this scale is another tool for surgeons to utilize when assessing infection risk in orthopedic trauma patients.
Discussion

Despite various advances in surgical procedures and technology, surgical site infections continue to be a cause of significant morbidity and mortality today. Surgical site infections remain the third most common nosocomial infection after urinary tract infections and pneumonia, and are the most common nosocomial infection in the surgical population at 38% (Anderson & Sexton, 2007). In addition, of all nosocomial infections in the elderly, SSIs account for 11% (Kaye et al., 2004). These infections lead to prolonged length of initial hospitalization, readmissions, additional surgical procedures, extended recovery time, and decreased quality of life for the patient, either temporarily or perhaps permanently. Patients who acquire an SSI have a 2.2 relative risk of death, and are 60% more likely to spend time in an intensive care unit (Mostofi et al., 2008).

Of the millions of operations performed each year in the United States, orthopedic procedures, along with cardiac procedures, continue to be the most common performed. The epidemiology of orthopedic surgery continues to change with the increased age of our population; of all orthopedic procedures, 39% are performed in those over the age of 65, and 34% are performed in those 45-65 years of age, majority being joint arthroplasty or fracture care (Berger et al., 2008). Falls are a common cause of trauma in older patients, with 33% of those over 65 having a fall each year in the United States (Jones et al., 1998). The incidence of fracture or other serious injury from even a simple fall from level surface to the ground is as high as 40% (Berger et al., 2008). While much of the fracture care that orthopedists provide will be related to falls in the elderly, severe trauma injuries will always exist.

Traumatic injuries, especially open fractures, are at more risk for development of SSI, mainly because of the associated soft tissue damage and contamination of the wound. Thus,
while intrinsic host risk factors and peri-operative risk factors are important, wound classification also plays an important role in helping predict the possibility of SSI. In fact, after age as an independent risk factor, wound class was the second most important independent risk factor (de Boer et al., 1999). It is important to identify soft-tissue wounds early to prevent chronic complications. In one study, the incidence of soft-tissue injury was high at 24%, but only 2% of patients developed chronic osteomyelitis; this can be attributed to early diagnosis and surgical debridement, and appropriate antibiotic therapy (Gustilo et al., 1984).

The goals of treatment in open fractures are preventing infection, healing of the fracture, and restoration of function to the extremity. Initial treatment of an open fracture often affects ultimate outcome, and thus a proper grading of the wound is paramount. There are various patient risk assessment scores and wound classification systems available for use in grading orthopedic trauma injuries. The purpose of this clinical review was to evaluate the current wound classification systems available, and if possible, to recommend one wound classification system specific to orthopedic trauma that could be used to effectively predict development of surgical site infections.

There are multiple risk assessment scores present in the literature and applied in the hospital setting for predicting patient morbidity and mortality. This clinical review looked specifically at several wound classification systems that could be applied to orthopedic trauma injuries. The NRC, SENIC risk index, and NNIS basic SSI risk index are all general wound classification systems that can be utilized for any surgical procedure. They were all found to be consistent predictors of SSI, however they have their limitations. The NRC traditional wound class fails to account for intrinsic patient risk. The SENIC index and NNIS basic SSI risk index were modified to factor in intrinsic patient risk and were superior to the NRC wound class,
however these grading systems do not take into account injury or procedure specific details that are important in orthopedic trauma injuries.

Two orthopedic specific wound classification systems, Gustilo-Anderson and the Hannover Fracture Scale-98, were then reviewed and evaluated for their predictability of SSI. These classification systems are superior to the previous wound classes because of their detail and specificity to orthopedic limb injuries; however, they have subjective components that lead to poor interobserver reliability. In addition, the HFS ’98 was not a good predictor of patient outcome. Most recently, a study set out to develop a new scoring system for orthopedic traumas with more generalized parameters, but that still accurately and effectively can predict SSI. This new scoring system may be easier to apply than the Gustilo-Anderson and HFS ’98, but still requires further prospective studies to validate its findings.
Conclusion

The majority of literature that exists for orthopedic trauma wound classification systems consists of retrospective and cohort studies. This is due to the nature of trauma injuries, and the need for immediate patient care, and inability to perform prospective, randomized trials. Prospective studies that have been performed took data that had already been collected and applied it to additional research models. Furthermore, there have been many important advances in the treatment of severe limb injuries over the last few decades; however, our classification systems and research are quite old and their utility in clinical practice is questionable. Most research studies that have been performed with these classification systems are 20 and 30 years old, far too old to be applicable today. Due to the constant and rapid scientific advances in surgical procedures and technology, updated research studies are necessary to further evaluate the current orthopedic wound classification systems.

At this time, the Gustilo-Anderson classification is the orthopedic specific classification largely used in the United States, while the Hannover Fracture Scale-98 is used in German-speaking countries in Europe. Based on the literature reviewed in this article, both are acceptable systems to use, but lack interobserver reliability. In all, the orthopedic wound classification systems should be used to help guide patient treatment, but should not be used as principal means for reaching decisions such as possible limb amputation. As always, clinical judgment and experience should first and foremost be taken into account.

Further research is warranted in this area of orthopedic trauma wound classification systems due to the increase of orthopedic procedures performed in the United States, and economic and clinical significance of surgical site infections. Surgical site infections can cause significant patient morbidity and mortality, and a classification system that can effectively
predict risk of developing an SSI, in order to help prevent it, would be beneficial to hospitals, surgeons, and most importantly, to patients.
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Abstract

Objective: To review current literature on surgical site infections in orthopedic trauma including: infection rates, risk factors, economic and clinical impact, and importance of wound classification systems in predicting complications. Methods: Searches were performed in PubMed, MEDLINE, and Cochrane library. Google Scholar was also utilized due to limited results for the orthopedic classification systems, which were developed in Germany. Results: Of the 44 references cited the majority were retrospective multivariate studies. Wound classification is considered a legitimate risk factor for infection, and several orthopedic wound classes exist in the literature. However, studies of these systems have found only moderate interobserver reliability, and there is a lack of recent and prospective research. Conclusion: A recommendation of orthopedic wound classification system cannot be made. However, existing classifications can help guide patient treatment decisions. Future research is warranted due to the clinical significance and impact of orthopedic surgical site infections.