CLINICAL MANAGEMENT extra

Reducing Postsurgical Wound Complications: A Critical Review

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Barbara Delmore, PhD, RN, CWCN, MAPWCA, IIWCC-NYU • Senior Nurse Scientist • Center for Innovations in the Advancement of Care • NYU Langone Medical Center • New York, New York

Joshua Mitchell Cohen, BS • Medical Student • New York University School of Medicine • New York, New York

Daniel O'Neill, MD • Associate Director • Adult Offsite Anesthesiology Services • Assistant Professor of Anesthesiology • Department of Anesthesiology, Perioperative Care and Pain Medicine • NYU Langone Medical Center • New York, New York

Andy Chu, MS, RD, CDN, CNSC • Registered Dietitian • Food and Nutrition Department • NYU Langone Medical Center • New York, New York

Vinh Pham, MD, PhD • Assistant Professor • Department of Medicine • Division of Infectious Disease and Immunology • New York University School of Medicine • New York, New York

Ernest Chiu, MD, FACS • Associate Professor of Plastic Surgery • Director • Helen L. and Martin S. Kimmel Hyperbaric and Advanced Wound Healing Center • Hansjörg Wyss Department of Plastic Surgery • NYU Langone Medical Center • New York, New York

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GENERAL PURPOSE:

To provide information on risk factors for surgical site infections (SSIs) and actions to mitigate that risk.

TARGET AUDIENCE:

This continuing education activity is intended for surgeons, surgical teams, physicians, physician assistants, nurse practitioners, and nurses with an interest in skin and wound care.

LEARNING OBJECTIVES/OUTCOMES:

After participating in this educational activity, the participant should be better able to:

1. Identify modifiable risk factors associated with the development of SSIs.

2. Select steps to mitigate the risks for and morbidity from SSIs.

ABSTRACT

Given the current reimbursement structure, the avoidance of a surgical site infection (SSI) is crucial. Although many risk factors are associated with the formation of an SSI, a proactive and interprofessional approach can help modify some factors. Postoperative strategies also can be applied to help prevent an SSI. If an SSI becomes a chronic wound, there are recommended guidelines and strategies that can foster healing.

KEYWORDS: chronic wounds, surgical site infection, surgical site infection reduction strategies

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INTRODUCTION

The annual number of surgical procedures performed globally is growing, which emphasizes the need for proper management of postsurgical wounds. According to the Centers for Disease Control and Prevention's (CDC's) national report, there were more than 157,500 surgical site infections (SSIs) associated with inpatient surgeries in 2011.[1] This accounted for 31% of healthcare-associated infections among hospitalized patients. In addition, SSIs were associated with a 3% mortality rate and $10 billion in annual costs.[1] Although progress has been made in the improvement of postsurgical patient outcomes, further reduction in morbidity and mortality can be accomplished with proper preoperative and postoperative precautions. This is especially true for patients at high risk of wounds and SSIs, such as those with diabetes or irradiated tissues. In the current reimbursement system, avoiding these postsurgical complications and their progression to chronic wounds is paramount. This article highlights the preoperative, perioperative, and postoperative recommendations to reduce postsurgical wound complications. Included will be the scenario of the acute wound that becomes chronic and requires treatment.

SURGICAL SITE INFECTIONS

The SSI category includes superficial incisional SSI, deep incisional SSI, and organ/space SSI. The CDC's "Guideline for Prevention of Surgical Site Infection, 1999" describes the specific criteria required for an infection to be considered an SSI (www.cdc.gov/hicpac/SSI/table1-SSI.html). An SSI can occur up to 30 days postoperatively, or even a year later if an implanted medical device is associated with infection. To be considered an SSI, an infection must affect tissue manipulated during the surgery and show certain clinical or histologic signs, including purulent drainage or abscess.[2]

In 1 US study, SSIs in approximately 550 patients caused hospital profits to decrease by approximately $2.3 million.[3] This decrease resulted from multiple factors, including an increase in daily hospital charges, length of stay, and 30-day readmission rate.[3] In 2009, the World Health Organization announced that the minimization of SSIs was 1 of its "Ten Essential Objectives for Safe Surgery" (www.who.int/patientsafety/safesurgery/tools_resources/9789241598552/en/).

In March 2016, the CDC released the national and state healthcare-associated infections progress report based on data from 2014. The report provides national SSI data from acute care hospitals. In 39 surgeries selected by the CDC, breast surgery demonstrated the worst outcome in terms of the national standardized infection ratio—74% greater than the 2008 SSI national baseline. The only other procedure with a statistically significant increase in the national standardized infection ratio from 2008 to 2014 was appendix surgery, with an increase of 21%.[4] The reasons for this increase are not entirely understood.

PREOPERATIVE CONSIDERATIONS

Table 1 illustrates several preoperative risk recommendations for decreasing SSIs.

Smoking

Decreases in tissue oxygen concentration can be measured after only 1 cigarette.[5] In a wound, tissue ischemia inhibits all phases of normal healing. Hypoxia directly impairs primary healing and also increases the chance of wound infection because of negative effects on bactericidal neutrophils.[6,7] Although the mechanisms of how smoking causes tissue hypoxia are not fully understood, studies suggest that carbon monoxide and carcinogenic toxins such as nicotine are not conducive to healing. The morphologic changes that carbon monoxide causes in fibroblasts lead to alterations in collagen metabolism that affect the tensile strength of the wound.[5,8] Nicotine may cause the release of catecholamines, resulting in peripheral vasoconstriction, increased blood viscosity, and further hypoxia.[5,9] Recent studies have suggested that nicotine replacement therapy does not increase the risk of healing-related complications. However, nicotine in doses higher than that used in nicotine replacement therapy can increase the risk of skin flap necrosis.[10,11]

In 2014, the US FDA published regulations for e-cigarettes and warned that there is not enough information to know the potential risks or benefits associated with their use.[9] The American Heart Association stated that there is not enough evidence for healthcare providers to counsel patients to use e-cigarettes as a smoking cessation aid.[12] A US study showed a significant alteration in platelet activation, aggregation, adhesion, and inflammation after exposure to e-cigarette extracts of variable nicotine concentrations.[13]

Table 1.
PREOPERATIVE RISK RECOMMENDATIONS FOR DECREASING SURGICAL SITE INFECTIONS

Risk	Mechanism	Recommendation	Level of Evidence	References
Smoking	Tissue hypoxia due to CO and carcinogens	Smoking cessation at least 4 wks before and after an operation	I	5–11,13–16
	Release of catecholamines leading to peripheral vasoconstriction and increase in blood viscosity	Introduction of programs to increase awareness and access to smoking cessation resources	IV	
Diabetes	Impairment in vasculogenesis due to increase in ROS Deficiencies in collagen deposition, fibroblast migration, and granulation tissue formation	HbA_{1c} ≤7.0% *or* HbA_{1c} ≤8.0% for patients with a history of significant hypoglycemia	IV	17–22,24,26,29
Obesity	Impairment in tissue oxygen perfusion due to large diffusion barrier and restriction in capillary proliferation	Healthy weight reduction prior to surgery Evaluation of comorbidities including diabetes Nutritional and exercise education	I	30–32
Malnutrition	Nutrients needed for angiogenesis and collagen synthesis	Albumin and prealbumin levels are *not* considered an accurate measure of malnutrition	I	21,34–43
	Vitamins A, C, and E help protect against cellular oxidative destruction	Nutritional consult may be necessary during presurgical management	II	
Chemotherapy	Disrupt angiogenesis and fibroblast function and increase in rate of SSIs	Understand cellular mechanism of specific chemotherapeutic being used	I	34,44
Radiation	Soft tissue fibrosis, ulceration, and vessel rupture	HBOT has shown benefit for optimization of oxygen supply to irradiated tissues	I	44,45
	Overexpression of inflammatory cytokines impair proliferative phase of wound healing	Surgical planning for replacement of irradiated tissue if there is tissue breakdown	I	
Infection	Increase in cytokines and proteases can degrade the extracellular matrix	Treat preexisting infection with appropriate antibiotics	I	34,56,57,156
		Give appropriate prophylactic antibiotics within 60 min before surgical incision if no infection PATOS	I	

Abbreviations: CO, carbon monoxide; HbA_{1c}, glycated hemoglobin A; HBOT, hyperbaric oxygen therapy; PATOS, present at time of surgery; ROS, reactive oxygen species; SSI, surgical site infection.

The American College of Surgeons recommends smoking cessation at least 4 weeks before and after surgery to reduce the rate of wound complications.[9] One study confirmed a reduction in endothelial injury and dysfunction after only 4 weeks of smoking cessation.[11] In addition, a meta-analysis of the effects of short-term preoperative smoking cessation on postoperative complications found a significant risk reduction in wound-healing complications for patients who quit more than 3 to 4 weeks before surgery, compared with current smokers.[14]

Patient education regarding smoking cessation needs improvement. A study of patients' awareness of the surgical risks of smoking showed only half of those surveyed were aware that continued smoking increases surgical risks; more than half were never advised to quit before their surgeries.[15] A "Stop Smoking Before Surgery" program in Canada has shown that patients who received smoking cessation education prior to surgery were more likely to have reduced or quit smoking before surgery.[16]

Diabetes: Glycemic Control

The negative effect that diabetes has on wound healing is multifactorial. There are deficiencies in growth factor production, angiogenesis, collagen deposition, fibroblast migration,

and granulation tissue formation.[17] Hyperglycemia increases inflammation, activates blood coagulation, and leads to impairment in vasculogenesis due to an increase in reactive oxygen species.[18] This hypoxic environment potentiates the dysregulation in wound healing.[18] Therefore, patients with diabetes have a greater risk of SSI development compared with patients without diabetes.[19]

This elevated risk has clinical implications, as more than 15% of patients with diabetes develop diabetic foot ulcers, and 80% of those eventually lead to amputations.[17] However, SSIs did not occur in patients with well-controlled diabetes, glycated hemoglobin A (HbA_{1c}) of less than 7.0%, but did occur in more than 35% of patients with uncontrolled diabetes, HbA_{1c} of 7.0% or greater.[19] The American Diabetes Association and the American Association of Clinical Endocrinologists Diabetic Guidelines recommend an HbA_{1c} of 7.0% or less and HbA_{1c} of 6.5% or less, respectively, for all nonpregnant adults with diabetes. One exception is the patient with a history of significant hypoglycemia, whose HbA_{1c} target should be kept at 8.0% or less.[20]

Preoperative HbA_{1c} is more important than serum glucose because it is a reflection of long-term glucose control as acute hyperglycemia can be caused by metabolic stress and illness. Glycemic control 30 to 60 days before surgery is beneficial to perioperative outcome.[21,22] Elevated preoperative HbA_{1c} level is associated with a higher postoperative glucose level[23,24] and is suggested to predict a higher rate of infections, myocardial infarction, and mortality after surgery.[25,26] It is also associated with increased wound infections and overall 30-day morbidity in vascular surgery,[27] an almost 3-fold increase in infectious complications after major colorectal surgery,[23] higher incidence of major complications and minor infections after cardiac surgery,[28] and increased odds ratios for 30-day wound complications following arthroplasty.[29]

Obesity

Obesity is a significant healthcare issue today, and an increasing number of patients are undergoing bariatric surgery and direct surgical excision to decrease body mass index. Unfortunately, obesity is associated with impairment of cutaneous wound healing, fascial dehiscence, SSIs, and vascular problems—due to the disproportionate increase in adipose tissue compared with capillary density, as well as increased levels of fibrosis, which restrict capillary proliferation. The blood vessels in these individuals are also larger, decreasing oxygen perfusion due to the large diffusion barrier.[30]

Obese patients have an increased cardiometabolic demand. If the heart cannot sufficiently perfuse peripheral tissues, ischemia can result.[31] Patients with a body mass index of greater than 50 kg/m^2 have an increased risk of perioperative complications.[32] These patients should be evaluated for diabetes, and nutritional education and exercise counseling are recommended. However, the American Society for Metabolic and Bariatric Surgery updated its position in 2016 on insurance-mandated preoperative weight loss requirements and no longer supports preoperative weight loss because of lack of evidence on postoperative outcome.[33]

Malnutrition

Wound healing is a complex process that requires appropriate nutritional support. Carbohydrates and proteins are needed for angiogenesis, capillary formation, fibroblast proliferation, and collagen synthesis. Arginine is important in immune and endothelial function, and glutamine stimulates many of the processes in the inflammatory phase of wound healing. Vitamins A, C, and E are potent antioxidants that protect against cellular oxidative destruction.[34]

Although nutritional evaluation is critical for the surgical inpatient, there is no single definitive marker for adult malnutrition according to the American Society for Parenteral and Enteral Nutrition.[35] Albumin and prealbumin levels are no longer considered an accurate measure of malnutrition because of low reliability.[36] A diagnosis of malnutrition must include at least 2 of the following 6 characteristics: insufficient energy intake, weight loss, loss of subcutaneous fat, loss of muscle mass, fluid accumulation, and decreased functional status (measured by grip strength).[35] A nutritional consult may be necessary during presurgical management. In the postoperative period, patients need 30% to 50% more calories and 50% more protein than they do at rest.[37] One randomized controlled trial (RCT) showed that an oral nutritional supplement improved healing of pressure injuries in patients who were not malnourished.[38]

Malnutrition impairs the immune system by weakening the function of neutrophils, macrophages, monocytes, and lymphocytes in the complement system.[39] Concerns for malnourished patients undergoing surgery include increased mortality, increased postsurgical hospital stay, increased intensive care unit admissions, poor wound healing, central line–associated bloodstream infections, SSIs, and other infectious complications.[21,39] A diagnosis of malnutrition significantly increased odds of infection after lumbar spine fusion.[40] A high nutrition risk score (high risk of malnutrition) was associated with higher occurrence of postoperative complication, including SSI in gastrointestinal surgery.[41]

Preoperative malnutrition is a potentially modifiable risk factor.[42] A 2-question screening tool, the Canadian Nutrition Screening Tool, was recently developed to determine patients at risk of malnutrition. In 1 study, the Canadian Nutrition Screening Tool had a sensitivity of 73% and specificity of 86%.[43] This tool can be used and implemented into electronic medical records for earlier recognition of malnourished patients.[43]

Chemotherapeutics and Radiation

Chemotherapeutic drugs have many mechanisms that inhibit pathways critical to wound repair. Vascular endothelial growth factor inhibitors disrupt angiogenesis; patients taking these drugs tend to have significant wound healing problems. Many alkylating agents inhibit fibroblast function, resulting in delayed wound healing. Chemotherapeutics also weaken the immune system, increasing the risk of SSIs. Corticosteroids are frequently given to patients with cancer to decrease tumor pain and resulting inflammation; however, steroid therapy has significant implications in wound healing dysregulation.[34,44]

As radiation is more frequently used as a neoadjuvant and adjuvant therapy for cancer treatment, the wound healing implications have become more apparent. Clinically, soft tissue fibrosis, ulceration, and vessel rupture may occur. Radiation results in an overexpression of inflammatory cytokines, which can impair the normal inflammatory and proliferative phases of wound healing. Molecular changes are seen in keratinocytes after radiation, and collagen deposition is disorganized because of dysfunction in matrix metalloproteases.[44] It is critical to optimize blood and oxygen supply to these irradiated tissues to prevent complete wound breakdown. Hyperbaric oxygen therapy (HBOT) has shown some success as a potential treatment for irradiated wounds.[45] However, if the tissue is deemed unsalvageable, surgical planning may be necessary to replace irradiated tissues with skin grafts and flaps.

Anticoagulation

Anticoagulation is commonly used for the prevention of venous thromboembolism and stroke in certain procedures. While venous thromboembolism can lead to life-threatening pulmonary embolisms, infections, and wound breakdown, anticoagulation also has risks. It can lead to bleeding-related wound complications, such as tissue breakdown and infection. In fact, studies looking at prophylactic anticoagulation in various surgeries found that SSIs were associated with heparin use, as compared with no prophylaxis or warfarin use.[46,47] It is imperative to balance the benefit-risk ratio of prophylactic anticoagulation and carefully monitor the international normalized ratio to reduce the risk of infection and other adverse events.

Infection

The role of bacterial infection and biofilm in persistent wounds and delayed wound healing has been examined.[48,49] Animal models have shown that biofilm is associated with increases in local proinflammatory cytokines such as interleukin 1 and tumor necrosis factor α.[50,51] This proinflammatory state is believed to be associated with alterations in the balance of local matrix metalloproteases and their inhibitors at the wound, leading to degradation of the tissues and prolongation of wound recovery.[52,53] Human studies have shown evidence of such increased activity of matrix metalloproteases in chronic leg ulcers.[54,55]

For elective surgical cases, an infection detected preoperatively typically results in surgery postponement. In cases where infection is present, but the procedure cannot be delayed, optimal management of the infection is crucial to reduce the risk of subsequent SSI. Patients may be on antibiotics at the time of surgery, which may be continued through the procedure and postoperatively. For elective cases where there is no preexisting infection, prevention of SSI includes prophylactic antibiotics.

Antibiotics

For those with previously infected wounds prior to surgery, microbiologic studies should be used to guide definitive antimicrobial treatment that would be continued through the procedure.[56] When microbiologic data are not available, treatment of the preexisting infection should follow local guidelines based on local antimicrobial susceptibility data.

The use of prophylactic antibiotics immediately before incision in patients with no preexisting infection has been shown to reduce SSI rates. The recommendations to use antimicrobial prophylaxis are based on complex considerations, including the costs and potential morbidity associated with SSI versus prophylaxis. The overall goal is increasing patient safety without creating unnecessary overusage of antimicrobials.[57]

Prophylactic antibiotics should be administered within 60 minutes prior to surgical incision. Antimicrobial doses are weight-adjusted for children and for obese adult patients. Intraoperative redosing of antibiotics is needed if the procedure lasts longer than 2 half-lives of the particular antibiotic. It is not recommended to continue antibiotic prophylaxis beyond 24 hours postoperatively because there is no evidence of benefit.[57]

PERIOPERATIVE CONSIDERATIONS

Table 2 shows perioperative recommendations for decreasing SSIs.

Hair Preparation

Perioperative hair removal from an incision site is a common practice; however, some providers believe it can cause SSIs and should be avoided. A 2011 Cochrane review found no statistically significant difference in SSI rates when comparing hair removal with no hair removal.[58] There was also no statistically significant difference in SSI rates when comparing hair removal the day of surgery with the day before surgery. Within the hair removal group, however, there was a statistically significant increase in SSI rates when hair was removed by shaving rather than clipping. One explanation is microtrauma to the epidermis and

Table 2.
PERIOPERATIVE RECOMMENDATIONS FOR DECREASING SURGICAL SITE INFECTIONS

Consideration	Recommendation	Level of Evidence	References
Shaving patients	Hair removal by clipping rather than shaving	II	58
Perioperative hypothermia	Maintenance of perioperative core body temperature >36.0° C (96.8° F) Use of active body surface warmers to reduce rate of SSIs	I I	63–67
Perioperative hypovolemia	Prevention of hypovolemia by using specific hemodynamic goals during fluid management Best perioperative fluid management strategy is still up for debate	I	68,69
Vasopressor use	Use vasopressors to combat anesthesia-induced hypotension, when deemed necessary	II	70–72
Oxygen use	Supplemental oxygen is recommended intraoperatively and in the postoperative period	I	73–78
Tissue closure	Limit tension on the skin during closure to prevent wound breakdown Sutures coated with antimicrobial products can reduce rate of SSIs	I I	80,84
Surgical drain usage	Surgical drains protection against SSIs is dependent on surgery type	II–IV	85–90

Abbreviation: SSI, surgical site infection.

subsequent microorganism colonization following razor use.[58] More research is needed to better assess the association between perioperative surgical site hair removal and SSI development.

Surgical Site Preparation and Aseptic Technique

Surgical site preparation with perioperative skin antiseptics is a mainstay of any surgery to reduce the risk of SSIs. The most common types used are alcohol-based, iodine-based, or chlorhexidine gluconate-based. All 3 solutions are effective against gram-positive and gram-negative bacteria. The alcohol-based solutions work most rapidly.[59] While the quality of evidence was low, a 2015 Cochrane review comparing the different types of perioperative skin antiseptics showed evidence of a lower rate of SSIs following use of 0.5% chlorhexidine in methylated spirits compared with the use of alcohol–based povidone-iodine solutions.[60]

Excellent aseptic technique and proper sterilization of surgical instruments are critical in minimizing the risk of SSIs. Breaks in sterile technique do happen, so it is important to recognize them immediately and take the proper steps to resterilize the surgical field.[61] One study performed in the United Kingdom found a link between SSIs and poststerilization contamination of surgical instrument sets.[62] Timely audits should be performed to verify that proper sterilization technique is being upheld.

Temperature Management

Unintentional perioperative hypothermia, defined as a core body temperature of 36.0° C (96.8° F) or less, can increase the rate of SSIs, impair wound healing, and even cause death.[63] In a 2009 study, a community hospital showed that implementation of a perioperative normothermia protocol was successful in decreasing unintentional perioperative hypothermia during colorectal surgeries. The acceptable operating room temperature range used in this protocol was 20° C to 25° C (68° F–77° F).[64] More recently, hospital systems have implemented active body surface warming (ABSW) systems in operating rooms, such as forced-air warming and fluid warmers, to prevent inadvertent perioperative hypothermia.[65] This includes the use of fluid warmers during perioperative blood transfusions.[66] A recent Cochrane review comparing patients placed on ABSW system with control subjects showed a 64% relative risk reduction in the rate of SSIs in the ABSW group. This study confirmed the importance of perioperative normothermia; however, it did not determine which specific ABSW system was most effective.[67]

Hemodynamic Stability and Fluid Management

Intraoperative fluid management to achieve normothermic hemodynamic stability is a primary goal of every surgery. Hypovolemia and hypervolemia decrease tissue perfusion and can lead to organ failure. Hypovolemia can result from a preoperative dehydrated state and perioperative blood loss; hypervolemia can result from inadvertently high fluid administration.[68] Many different perioperative fluid therapies have been used to prevent these problems. A 2012 meta-analysis compared goal-directed therapy, guided by hemodynamic goals, with liberal fluid therapy. They both involved large amounts of perioperative fluid administration, compared with restrictive fluid therapy, but have very different effects on perioperative outcomes. Patients receiving liberal therapy had an increased risk of pneumonia and prolonged length of stay. This study stressed the importance of specific hemodynamic goals during fluid management, but there is still uncertainty if

goal-directed therapy is superior to restrictive fluid therapy.[69] Although the best perioperative fluid management strategy is debated, the importance of euvolemia cannot be understated.

Vasopressors are commonly used intraoperatively by anesthesiologists to counterbalance the anesthesia-induced vasodilation, with the goal of maintaining cerebral and coronary perfusion pressures without promoting tissue ischemia. Many surgeons are wary of the detrimental effects vasoconstriction can have on tissue perfusion and wound healing; however, it is important to understand that low cardiac output can impair wound perfusion.[70]

A study conducted on patients during childbirth showed that strict use of vasopressors was important in maintaining optimal tissue perfusion. The researchers evaluated the fetal pH, as an index of tissue perfusion, following the use of vasopressors if systolic blood pressure dropped below a certain percentage of a determined baseline. The fetal pH values after tight control of systolic blood pressure with vasopressors were superior to the fetal pH values in laboring patients allowed to be hypotensive.[71]

In a recent meta-analysis, the impact of intraoperative vasopressor use on patients undergoing free tissue transfer reconstruction was examined.[72] There was no statistically significant difference in the incidence of flap failure or flap complications between the group who received intraoperative vasopressors and the group who did not.[72] Although vasoconstriction may be concerning to the wound, the top priorities are the brain, heart, liver, and kidneys.

Supplemental Oxygen

Oxygen consumption is needed for energy metabolism, collagen maturation, acceleration of vasculogenesis, and antimicrobial action.[73,74] Multiple meta-analyses have shown a statistically significant reduction in SSIs following perioperative oxygen administration; however, 1 study suggested a benefit in only specific patient subgroups (general anesthesia and colorectal surgery).[75,76] In 2 separate double-blind randomized trials, researchers compared the effect of 30% and 80% inspired oxygen given during colorectal surgery and 2 to 6 hours postoperatively. There was a significant decrease in SSI risk for the groups receiving 80% inspired oxygen.[77,78] Prolonged use of high inspired oxygen concentration (Fio_2) can cause oxygen toxicity; this is most common in patients with acute respiratory distress syndrome who exceed an Fio_2 of more than 60% after 24 hours.[79]

Tissue Closure

Skin is a very complex material that has nonlinear, anisotropic, and viscoelastic behaviors. The collagen and elastin fibers in the dermis contribute to these incredible properties. When skin is stretched, the elastin fibers are the first to respond. Once they are fully stretched, the collagen fibers align with the direction of force and resist deformation. Any further stretch will cause damage to the skin. Large amounts of tension on the skin during closure of a wound can result in wound breakdown, decreased circulation, and, ultimately, skin necrosis.[80] Thus, when tension-relieving surgical techniques of local tissues are not sufficient, other methods of closure should be evaluated, including skin flaps or grafts.[81]

Skin closure methods vary among surgery types and are largely based on surgeon preference. In a single-institution study comparing infection rate following spinal surgery closure with skin glue, 2-octyl-cyanoacrylate, or staples, there was increased rate of infection with staple closure.[82] Many orthopedic surgeries are closed with staples. A meta-analysis comparing hip and knee surgeries closed with sutures or staples found no statistically significant difference in infection rates.[83] There are many different suture types that have varying rates of infection, and many sutures are coated with antimicrobial compounds to reduce infection rates. A 2016 meta-analysis of RCTs comparing triclosan-coated sutures with uncoated sutures found a significant reduction in SSIs when using the coated sutures. This risk reduction, however, was seen only in abdominal surgeries and surgeries with prophylactic antibiotic use. There was not a significant risk reduction in cardiac, breast, or surgeries without prophylactic antibiotic use.[84]

The use of prophylactic surgical drains has become a controversial topic because of patient discomfort and a potential increase in infection risk with use. A number of RCTs and cohort studies have been conducted on the topic, but the findings on SSI risk following surgical drain placement are contradictory. The following studies showed that there is no significant benefit of postsurgical wound drains following gastrectomy,[85] laparoscopic cholecystectomy,[86] pancreatic surgery,[87] breast cancer surgery,[88] and reduction mammoplasty.[89] A 2016 RCT found that subcutaneous placement of closed suction drains was protective against SSIs after colorectal surgery.[90]

Duration of Procedure

Multiple studies have found a correlation between SSI rates and prolonged operative times.[91–94] In a study of more than 100,000 general and vascular surgical cases, Daley et al[91] determined that procedures taking more than 95% upper confidence standard time limit for a specific procedure had significantly greater organ-space SSIs. They recommended that procedures be carefully planned to minimize time in the operating room.[91]

POSTSURGICAL CONSIDERATIONS

Wound Healing

In general, there are 3 possible wound healing responses.[95,96] A wound can be closed through (*a*) primary intention from

approximation of the edges, (*b*) secondary intention where granulation and epithelialization needs to occur, or (*c*) tertiary intention by using an advanced modality and/or topical treatment with eventual closure by approximation, grafting, or a flap.[95] Surgical wounds are considered acute wounds and heal through primary intention unless dehiscence or a chronic wound occurs. In this instance, healing will occur through a secondary- or tertiary-intention process. This response process is in tangent with the wound healing phases.

The healing process is accomplished via sequential and overlapping processes. The concept of the wound healing phases dates back centuries, but in the mid-1700s John Hunter was credited with better defining the wound repair processes.[97] The phases of wound healing include the inflammatory phase, the proliferative phase, and the remodeling phase. A wound follows a normal trajectory of healing as it follows 4 physiologic events of hemostasis, inflammation, repair, and remodeling that eventually culminates to scar formation (scar remodeling).[95,98] The first 2 phases of the healing process are accomplished in approximately 21 to 30 days,[98,99] but healing is faster when there is an approximation and suturing.[100] The final phase of remodeling may take 1 to 2 years to be completed.[95,101] The wound matures via intermolecular cross linking between the collagen fibers. The maximal tensile strength of the wound is approximately only 80% of the original skin and peaks approximately 2 months after the wound is created.[102]

The time each phase takes can differ or be delayed because of certain patient characteristics.[102] In addition, acute wounds and chronic wounds can differ in the number of events a wound may encounter based on level of tissue affected and/or the time it may take a wound to proceed through these stages.

Partial-Thickness Wounds

The postsurgical wound can also be called an acute wound.[100,103] Primary intention is a reparative process where the wound bed edges are approximated by suturing, stapling, or gluing together to create a close proximity. This reparative process involves little or no contraction, helping to hasten the healing time.[96] When approximation and suturing are used to achieve wound healing via primary intention, the inflammatory phase lasts approximately 4 days.[102] After hemostasis is achieved, venules in the wound bed dilate and allow leukocytes, neutrophils, enzymes, and other cellular elements to migrate into the wound to fight microbes and promote healing. The influx and action of these inflammatory constituents are clinically seen as the 4 cardinal signs of inflammation.[102]

If the acute surgical wound is partial thickness and involves only the epidermis, it will heal through a regeneration process and does not require the synthesis and deposition of collagen.[104–106] While the upper dermis can heal by regeneration, generally in the adult patient, wound contraction and scarring occur as part of the healing process as it does in the deeper dermal and hypodermal layers.[106,107] In partial epithelial wounds, the healing process begins within 24 to 48 hours, with new epidermis usually around day 6 or 7.[104,108,109] The subsequent proliferative phase can last approximately 6 weeks and involves the synthesis of collagen from fibroblasts, which leads to an increase in tensile strength in the wound. It also allows for a new network of blood vessels to replace the ones damaged in the wounding process.[102]

Full-Thickness Wounds

An acute full-thickness wound heals by a granulation process or scar formation and involves the deeper dermal and tissue layers.[98,105] Therefore, full-thickness wounds require all 3 wound healing phases and all 4 physiological events of hemostasis, inflammation, repair, and scar remodeling.[95,98]

An effective healing process includes the correct moisture balance atmosphere because it favors migration and matrix formation, thus accelerating healing through an autolytic debridement process.[103] Using pig models, earlier work by Geronemus and Robins[101] in the acute wound healing process found that a moist wound environment heals more than 40% faster than a wound exposed to air. Similarly using pig models, later work by Winter[110] supported these findings. Winter[110] found that the epithelial resurfacing process in partial-thickness wounds that were allowed to heal in a moist environment did so 2 to 3 days sooner than did those wounds that were allowed to dry out and form a scab.[110] A dry wound bed creates negative wound healing consequences as it (*a*) increases the healing time because at this point the keratinocytes must "burrow" under the crust and matrix for reepithelialization to occur; (*b*) leads to tissue dehydration, cellular death, and diminished angiogenesis and growth factors; and (*c*) increases formation of necrotic tissue.[111]

Quicker reepithelialization occurs if the cells can migrate over viable, nutrient-rich tissue and an intact extracellular matrix. From an important patient perspective, moist wound healing can reduce wound pain or tenderness and produce better cosmetic outcomes.[103] Dressings that offer protection and a balanced moisture environment will foster proper wound healing.

Suture Line Care

If the acute wound is in the form of a suture line, current recommendation for care of the postsurgical wound is to provide protection over the suture line.[112] With the onset of a surgical incision, the body begins the healing process immediately.[95,105] This normal healing or "knitting" process takes up to 48 hours

before a natural barrier is formed.[95,113,114] There are many ways to protect the suture line. Primary surgical dressings are used as a "physical barrier" to protect the surgical site until the continuity of the skin has occurred. They can also absorb exudate from the wound, keeping it dry and clean and preventing bacterial contamination from the external.[114] A recent Cochrane review showed no statistically significant differences between primary surgical dressings removed at less than 48 hours versus primary surgical dressings removed at more than 48 hours. These findings come with caution as this review was based on 3 RCTs, so the quality of evidence is considered low.[114]

The traditional surgical dressing cover is gauze and tape or gauze with a transparent dressing. If saturated before 48 hours, or if there is increasing drainage, it should be changed to avoid 2 issues: (1) the gauze sticking to the suture line and possibly causing trauma to newly formed tissue when removed[115] and (2) to decrease the chances of possible bacterial contamination during a time when the tissue has not fully completed the initial healing process.[104,108,109] Dressings over closed wounds should be removed or changed if they are wet or if the patient has signs or symptoms of infection, such as fever or unusual wound pain. When the dressing is removed, the wound should be evaluated for signs of infection.

Clinicians must also care for the periwound skin. Nonsilicone tapes or transparent film dressings could cause additional skin damage if care is not used when removing the tape or transparent dressing. Moisture-associated skin damage can occur under transparent dressings or allow the periwound skin to be exposed to excess drainage, thus necessitating additional wound care. Transparent dressings have no absorbent capacity and can create more moisture damage. Gauze is not highly absorbent and can result in periwound damage if moist or if pulled away from the skin when drainage is dry.[116,117]

Surgeons may choose not to apply anything directly to the suture line, whereas others may apply topical antibiotics or petrolatum. The application of a topical antibiotic is controversial, with many favoring the use of petrolatum. A meta-analysis by Saco et al[118] revealed that there was no statistically significant difference in the incidence of postsurgical infection when using a topical antibiotic versus petrolatum in the outpatient setting. Other concerns regarding topical antibiotics use include that they (*a*) may increase the rates of antibiotic resistance, given the minimal amount of mutation required to confer nonsusceptibility to some antimicrobials[118–121]; (*b*) tend not to be broad spectrum[121]; (*c*) have known allergens that may cause additional skin injuries[122]; and (*d*) do not have the ability to debride necrotic tissue, which makes them less than ideal for a choice in a real wound treatment scenario.[119] If the situation calls for an optimal moist wound environment for healing, then petrolatum has a better ability to provide this ideal environment than a topical antibiotic and a less expensive proposition. Considering these factors, it has been recommended that the use of topical antibiotics on postsurgical wounds be reconsidered in practice.[118–120] Recent guidelines found that there was insufficient evidence to use topical antibiotics in the prevention of SSIs routinely.[123]

In cases where a patient may be at a higher risk of postsurgical infection, such as an uncontrolled diabetic, the use of oral antibiotics may be considered. This approach should be determined by individual case, as the evidence on this strategy is moderate.[119] Instead, some surgeons use more advanced topical treatments, including composite dressings. Antimicrobial dressings with silver or polyhexamethylene biguanide may be more commonly chosen in cardiovascular, neurosurgery, and orthopedic cases, especially when hardware or medical device implants have been inserted or because of the general nature of the surgical procedure or patient history and/or presentation. Some of these dressings include the term "surgical" in their name. The antimicrobials in these dressings are long acting and designed for a longer wear time. These dressings allow the suture line to not be disturbed so frequently, thus possibly decreasing bacterial contamination or trauma. They also provide greater absorption than plain gauze. The adhesive borders to these dressings are made of materials such as silicone or genetically modified hydrocolloid that are less aggressive to the surrounding skin and minimize skin damage.[117,124] Draining suture lines present with cover dressing issues because transparent film dressings, gauze, and nonadherent ("nonstick") pads have limited absorbent capacity and may create more pain to the patient as compared with the more advanced, absorbent topical treatments.[116,117]

Surgical wounds that are left open to heal by secondary intention, such as abscesses, require wound care that addresses the wound bed characteristics.[115] Typically, these wounds require proper but gentle packing. Gauze dressings should be avoided for many reasons, including that they (*a*) can cause trauma to healthy granulation tissue, thus impeding healing; (*b*) can leave remnants in the wound bed and inhibit healing; (*c*) may not be as absorbent when there is increased drainage, thus slowing the healing process and/or creating periwound skin damage; and (*d*) cause pain to the patient.[116,117,119,125] Nonwoven gauze is usually made of synthetic materials and has less absorbency, but is less adherent. Traditional woven gauze is 100% cotton and may have more absorbency, but may leave more fibers in a wound bed.[116] Although there are a plethora of gauze-alternative topical treatments reporting on their effectiveness in the literature, only a few have been evaluated using RCTs.[126] Given the characteristics of gauze and the literature, it may be more prudent to use an advanced topical treatment to hasten healing and provide

Figure 1.
TOPICAL TREATMENT SUGGESTIONS BASED ON CHRONIC WOUND BED CHARACTERISTICS

Wound Bed Has:	Consider:	
	Granulation Tissue and/or Necrotic Tissue	**Bioburden/Infection?***
Dry	-Wound gel	-Wound gels with silver, PMHB
Slough/Eschar	-Moistened plain hydrofiber/alginate -Selective enzymatic debrider (moisten debrider with a wound gel, or saline on gauze or hydrofiber/alginate)	-Medical-grade honey -Sustained-released iodine -Moistened silver hydrofiber/alginate
Moist Granulation Tissue	-Collagenase -Hydrofiber/Alginate	-Wound gels with silver, PMHB -Medical-grade honey -Sustained-released iodine -Slightly moistened silver hydrofiber/alginate
Slough/Eschar	-Collagenase -Medical-grade honey	-Wound gels with silver -Medical-grade honey -Sustained-released iodine -Slightly moistened silver hydrofiber/alginate
Overly Moist	-Hydrofiber/alginate -Foam dressing (if wound bed flat)	-Hydrofiber/alginate with silver -Foam dressing w/silver, PHMB (if wound bed flat)
Stalled Dry w/Granulation Tissue	-Moistened collagen -Selective enzymatic debrider (moisten debrider with a wound gel) -Wound gel -NPWT (for moderate-deep/cavity wound)	-Moistened collagen with silver/PHMB -Wound gels with silver, PHMB
Dry w/Necrotic Tissue	-Selective enzymatic debrider (moisten debrider with a wound gel) -Wound gel -NPWT (for moderate-deep/cavity wound)	-Wound gels with silver, PMHB (gels cannot debride highly necrotic wound beds) -Consider use of silver-impregnated dressing
Moist	-NPWT (for moderate-deep/cavity wound) -Sustained-released iodine	-Consider use of silver-impregnated dressing

*Only antibiotics treat infection; topical treatments only control bacteria on wound surface.[115, 119, 121]

Abbreviations: NPWT, negative pressure wound therapy; PHMB, polyhexamethylene biguanide

patient comfort.[116,117,119,125,126] Figure 1 outlines various advanced topical treatments and their best use based on wound bed characteristics.

Many studies have tried to evaluate the effectiveness of wound dressings for preventing SSIs. In 2014, a Cochrane review examined RCTs comparing alternative wound dressings with a wound with no dressing. All of the trials included in this study were at unclear or high risk of bias. The review concluded that there is insufficient evidence to support whether covering surgical wounds with a dressing reduces the risk of SSI or whether 1 wound dressing is more advantageous than another. Wound dressings should be chosen based on their cost and management of symptoms.[127]

A surgical wound that is initially left open with the intent to be closed by tertiary intention will also require use of a topical treatment until surgical closure can occur. If there is a cavity wound, products that are used as fillers or in rope foam are generally the best option. Some surgeons use negative-pressure wound therapy (NPWT) as a "bridge" to subsequent closure involving primary or reconstructive closure.[128,129]

When dehiscence is possible in an acute full-thickness surgical wound, strategies such as NPWT may be used to help prevent a surgical acute wound transitioning to a chronic wound. Appropriate NPWT devices and associated dressings can be used along the suture line to avoid dehiscence. The surgeon may choose this option based on several criteria: patient

comorbidities such as obesity, diabetes, or steroid use; type of surgery such as traumatic wounds or joint replacements; and/or indications such as edema or congestion.[130] Binders historically have been used after abdominal surgery as a means to prevent seroma formation, provide pain relief, and/or assist with mobility. Rothman et al[131] performed a systematic review and found the evidence was inconclusive regarding prevention of seroma formation and limited to the types of operations included in the research.

Addressing the Postsurgical Wound That Becomes Chronic

After 4 to 6 weeks, a surgical wound that has not healed and no longer resembles a suture line is considered a chronic wound. A chronic wound occurs because of a healing process failure that has stalled at the inflammatory phase. It lacks the hemostasis period that promulgates an acute healing process.[102,115,132] Prolonged time in the inflammatory phase delays the collagen synthesis process, as this process does not occur until the inflammatory phase is complete.[132] After addressing the cause of the prolonged inflammatory phase, such as treating infection and/or necrotic tissue debridement, the collagen synthesis in the proliferative phase will progress.[115,119]

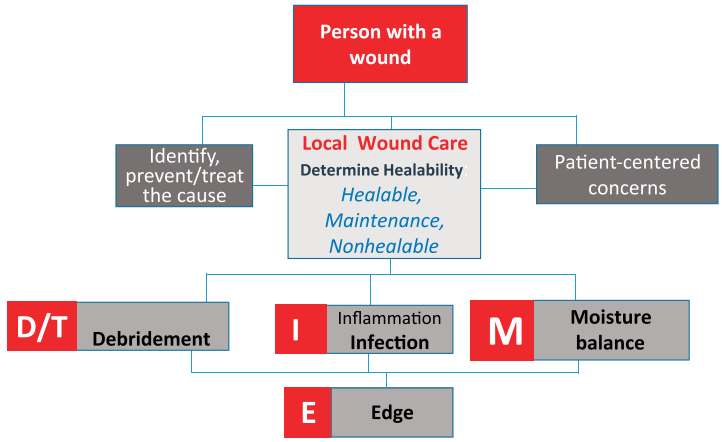
When a wound becomes chronic, it should be treated according to its characteristics using advanced topical treatments or therapies as required. In some cases, the use of normal saline wet-to-dry dressings may have led to a chronic wound because they did not support the true wound healing environment, increased wound temperature loss, and delayed healing.[115] If a chronic wound continues to be treated with normal saline wet-to-dry dressings, the potential for increased bacterial contamination will persist.[99] Wet-to-dry dressings should be used only when true debridement is required because of slough and eschar on the wound bed.[99,116,119] This type of dressing is not selective, so healthy tissue may be sacrificed along with the devitalized tissue. Therefore, using a wet-to-dry dressing on healthy granulation tissue can cause injury or reinjury when the dressing is removed, increase bleeding, increase bacterial contamination, and cause pain to the patient. This type of dressing does not offer moisture balance as recommended by research.[99,101,110] In cases where true debridement is required to decrease bioburden, antiseptics (eg, Dakin solution) are a better choice than saline because they can better address the bacterial bioburden and the nonviable tissue in the wound bed.[121] Dakin solution at a lower concentration will have less collagen degradation.[133,134]

Evidence shows that a well-hydrated wound surface helps expedite healing and allows any topical treatment to be more productive, such as in its debridement or antimicrobial delivery properties.[109,111,115] In the past, the costs of wet-to-dry dressings have been compared with alternative dressings. The findings are generally the same: wet-to-dry dressings can increase costs because of slower healing times and labor.[99,135–137] With the advent of advanced topical treatments, the comparison of wet-to-dry dressings has abated since the number of advanced topical treatments has grown.

To improve patient care outcomes, various guidelines are available to assist the clinician in approaching chronic wound care management in a comprehensive, evidence-based manner using a patient-centered concern approach.[6,115,119,138,139] Some of the more common examples are the Wound Bed Preparation model, DIME (***d***ebridement/devitalized tissue, ***i***nfection or inflammation, ***m***oisture balance, and wound ***e***dge preparation/wound depth), and TIME (***t***issue, nonviable or deficient; ***i***nfections/inflammation; ***m***oisture imbalance; ***e***dge of wound, nonadvancing or undermined).[6,103,115,119,140] These guidelines may be seen with some variations or a combination of these models. For example, the TIME mnemonic was initially published in 2003 and since then has been revised for accuracy,[103,140] including a version that adds the concept of hypoxia correction called TIMEO_2.[6] The essential key principles behind these guidelines are as follows: identify the wound etiology and address any underlying issues, determine if the wound is healable, assess the wound bed characteristics to ensure that the appropriate topical treatment is applied, consider an interprofessional team approach, and ensure that this process always considers patient-centered concerns as this aspect is one of the determinants in the healing process.[115,119,138] Figure 2 is an example of a combined guide using the Wound Bed Preparation/DIME paradigm to foster successful and evidence-based chronic wound healing.

The patient characteristics and physiology of chronic and acute wounds differ.[141,142] It is important to understand that the nutritional needs of a typical patient with a chronic wound are not the same as the ones with trauma.[141] Trauma patients tend to be younger, healthier, hypermetabolic, well nourished, and resilient, whereas patients with chronic wounds tend to be older, with multiple comorbidities, hypometabolic, and often chronically malnourished and fragile.[141] Therefore, medical nutrition therapy of an acute wound is different than that of a chronic wound. Nutritional assessment should be part of the routine wound management evaluation for patients with chronic wounds.[142] This is important because of the high prevalence of malnutrition in this population in both developed and developing countries.[141,142] Despite the physical appearance, obese patients may also suffer from protein calorie malnutrition because malnutrition can be masked by the appearance of obesity.[141]

Figure 2.
WOUND BED PREPARATION 2014



Modified from Sibbald, Goodman, Krasner, et al. Special consideration in wound bed preparation 2011: An update. Adv Skin Wound Care 2011;23:415-36.

Adequate calories, protein, and micronutrients are needed in patients under metabolic stress or recovering from surgery. Vitamin C plays a role in collagen metabolism and inflammation.[141] When malnutrition is suspected or confirmed, intake of a multivitamin and 250 to 500 mg vitamin C twice daily is recommended in addition to increased calorie (30–40 kcal/kg of body weight per day) and protein needs (1.25–2 g/kg of body weight per day).[141,142] Vitamin A supplementation (20,000 IU daily for 2 weeks) may also be recommended for patients on chronic steroids because it can reverse the inhibitory effects of chronic steroids on wound healing. Arginine and glutamine supplementation may be beneficial only if calories and protein intakes are adequate.[141]

Chronic Wound Bed Issues

Figures 3 to 6 illustrate cases where a surgical wound became a chronic wound. Chronic wounds may "stall" despite a standardized approach and optimal topical treatment. Several factors may cause this problem, which necessitates a reevaluation of the wound and may require the use of more advanced modalities such as NPWT, collagens, human skin grafts, or HBOT. For healing to continue in a stalled wound, it should be determined if the underlying condition such as infection was identified.[115,119] A wound assessment may reveal necrotic tissue that requires debridement. Debridement may be critical and should be considered to control infection and the inflammatory effect caused by the presence of dead tissue that will further prolong wound healing.[97,103,115,132]

Infection needs to be treated systematically, and bioburden should be treated topically. There are mnemonics or guidelines that help to distinguish between critical colonization and infection. Well-published examples are the mnemonics NERDS (nonhealing, exudate increase, red + bleeding, debris, and smell) and STONEES (size is bigger, temperature, Os[probes, exposed], new breakdown, exudate, erythema/edema, and smell).[115,119,143] It is important to remember that topical antimicrobial dressings will not treat an infection, as the antimicrobial property can penetrate only a few millimeters.[121] Only systemic antibiotics can treat infection, and

Figure 3.
POSTSURGICAL WOUNDS

The patient is a 25-year-old woman with a medical history significant for tobacco use with wound dehiscence following breast reduction.

Figure 4.
POSTSURGICAL WOUNDS

A 30-year-old woman with full-thickness skin loss following nevus removal toward the left lower abdomen.

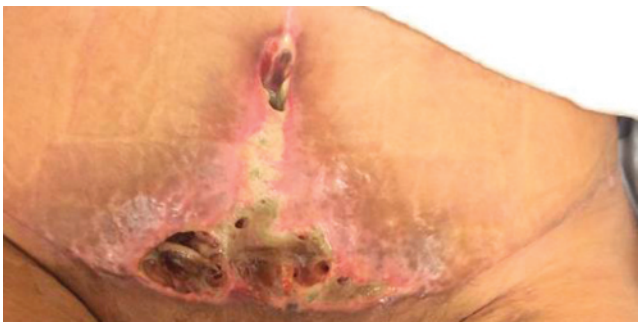
topical antimicrobial dressings should be used as a complement to address the wound surface bioburden when it exists.[119,121]

Another sign of a stalled wound is the "edge effect." The edge effect occurs when the epithelium does not migrate over the wound base, giving the wound edge a steep, "cliff-like" appearance.[119] This condition requires attention and advanced modalities to correct so that the wound can heal. Advanced or active modalities that may be required in this scenario may be growth factors, skin substitutes, NPWT, HBOT, or skin grafting.[115,119] When using any advanced modalities, note that they will be successful only if debridement is part of the treatment as needed. Hyperbaric oxygen therapy can be used as an advanced treatment modality after compromised or failing flaps. When a wound bed is in a state of hypoxia, HBOT can deliver intermittent oxygenation to wound beds that are hypoperfused and help to reinitiate the wound healing cascade.[144]

Choosing the Correct Topical Treatment

Topical treatments should not be used lightly or indiscriminately. Clinicians may try to use a "one-size-fits-all" approach rather than consider the wound bed characteristics for the proper topical treatment. For example, does the wound bed have granulating tissue or nongranulating tissue? Is the wound bed wet or dry? Are slough and/or eschar present? What can be visualized will dictate the appropriate topical treatment (Figure 1).

Figure 5.
POSTSURGICAL WOUNDS



A 40-year-old woman with full-thickness skin loss following abdominoplasty.

Figure 6.
POSTSURGICAL WOUNDS

A 54-year-old woman with cellulitis of a right supraclavicular flap donor site.

FINANCIAL IMPLICATIONS

Earlier in this article, the authors discussed the financial consequences of an SSI. It has been noted that an estimated 60% of SSIs are preventable.[145] Because of these facts, SSIs have become a pay-for-performance metric for which quality improvement efforts have been created.[123] On October 1, 2008, the Centers for Medicare & Medicaid Services determined that hospitals would no longer receive additional payment for cases that were hospital-acquired conditions as an attempt to address "never events."[146] In fact, SSIs were 1 of the first 8 conditions that were part of this ruling.[147]

In 2011, to achieve the triple aim of better health, better healthcare, and reduced expenditures, the Centers for Medicare & Medicaid Services began an initiative called Bundled Payments for Care Improvement. The intent of this initiative is for providers to work toward higher quality and coordinated care with a subsequent lower cost to Medicare.[148] For example, the provider or joint providers are reimbursed for care provided along the continuum that begins in the acute care setting, such as a surgical procedure. The care covered under Medicare Parts A and B is within 30, 60, or 90 days after an acute care hospital depending on the diagnosis.[149] If the surgical outcomes are ideal, then the received payment is more favorable. However, if there are issues with the surgical outcomes, in addition to poor patient outcomes, the provider may lose funds.

Recent publications relay some successes in care-coordinated programs associated with specific clinical episodes associated with a diagnosis-related group condition or surgery.

In the case of a surgical diagnosis, there is a heavy emphasis on presurgical planning, especially concerning discharge disposition.[150,151] Efforts around bundling care have also resulted in SSI reductions.[152–154]

The cost of chronic wounds has been estimated in the billions.[138,155] When reviewing the US Wound Registry, Fife and Carter[138] found that nonhealing surgical wounds were the largest category. This further highlights the need to ensure the proper prevention of an SSI and proper care of the suture line postoperatively. Fife and Carter[138] also found that comorbid conditions, such as diabetes, the need for systemic antibiotics, renal failure, immunocompromised state, and current smoking, increased the cost to heal a chronic wound.

CONCLUSIONS

The etiology of SSIs is multifactorial and requires a team approach to address issues that can lead to their occurrence. The team should consider all modifiable and nonmodifiable risk factors in the preoperative setting. Preparation ahead of surgery can help avoid an SSI and conversion to a chronic wound that necessitates more intensive treatment. Should a chronic wound develop, adherence to a wound bed preparation framework is recommended. A cohesive, interprofessional team can achieve successful outcomes in a timely matter.

PRACTICE PEARLS

- The etiology of SSIs is multifactorial. There are modifiable risk factors that the surgeon and team can address in the perioperative setting to help decrease SSIs.
- Appropriate perioperative evaluation, monitoring, and corrective action can help prevent SSI development.
- Proper primary intention wound closure care that considers the nature of the surgery and patient characteristics can help prevent an SSI.
- If a chronic wound develops, an approach that considers wound bed characteristics, patient-centered concerns, and an interprofessional team will foster successful wound healing.
- Given the current reimbursement and financial constraints when an SSI develops, it is paramount to optimize patient care in the presurgical environment.

Note: The 155 references for this article are available online only as Supplemental Digital Content 1, http://links.lww.com/NSW/A1.