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Applying Best Practices for The Prevention of Surgical Site Infection (SSI) and Reducing Risk Factors for Patients: Meta-Analysis Theoretical Review

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Abstract
This study aimed at providing a comprehensive range of evidence-based recommendations for interventions to be applied during the pre-, intra- and postoperative periods for the prevention of the surgical site infection SSI, while also considering aspects related to resource availability and values and preferences. An initial search identified more than 200 titles published in 2006-2017 as relevant for data extraction, the researchers dealt with the extracted information included study design and methodology, reported cumulative incidence and post-surgical time until onset of SSI, and odds ratios and associated variability for all factors considered in univariate and/or multivariable analyses. And then the study recommended the best producers for reducing the risk factors for patients by conducting the findings of the meta-analysis theoretical review.
Keywords: Surgical Site Infection, Risk Factors, Best Practices, Patients

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1.1 Introduction
Health care-associated infections (HAI) are acquired by patients while receiving care and represent the most frequent adverse event affecting patient safety worldwide.
In the Arab world, surgical site infection (SSI) is a commonly-occurring healthcare-associated infection, complicating 3-6% of surgeries in the Arab world hospitals. Increased morbidity and mortality are associated with SSI, ranging from wound discharge associated with superficial skin infection to life-threatening conditions such as severe sepsis. SSIs are responsible for an increased economic burden to healthcare systems, including additional postoperative hospital duration and costs (Korol, Johnston, Waser, Sifakis, Jafri & Kyaw, 2013).
Surgical site infections (SSIs) continue to challenge perioperative practitioners, as they are a significant source of patient morbidity and mortality, extended lengths of hospital stay, and increased health care costs. One of the goals for all patients undergoing an operative or invasive procedure is that they return from surgery free of infection; this is one of the perioperative nurse's biggest responsibilities, especially in today's dynamic health care environment (Anderson, Podgorny, Berríos-Torres, Bratzler, Dellinger, Greene & Kaye, 2014).
While advances have been made in infection control practices, including improved operating room ventilation, sterilization methods, barriers, surgical technique, and availability of antimicrobial prophylaxis, SSIs remain a substantial cause of morbidity, prolonged hospitalization, and death. SSI is associated with a mortality rate of 3.5% worldwide, and 75% of SSI associated deaths are directly attributable to the SSI (Awad, 2012).
Surveillance of SSI with feedback of appropriate data to surgeons has been shown to be an important component of strategies to reduce SSI risk7-10 . A successful surveillance program includes the use of epidemiologically-sound infection definitions and effective surveillance methods, stratification of SSI rates according to risk factors associated with SSI development, and data feedback (Magill et al., 2014).

Recent work by the World Health Organization (WHO) shows that surgical site infection (SSI) is the most surveyed and frequent type of HAI in low- and middle-income countries and affects up to one third of patients who have undergone a surgical procedure. Although SSI incidence is lower in high-income countries, it remains the second most frequent type of HAI in Europe and the United States of America (WHO, 2016).

Many factors in the patient's journey through surgery have been identified as contributing to the risk factors of SSIs. Therefore, the prevention of these infections is complex and requires the integration of a range of preventive measures before, during and after surgery. However, the implementation of these measures is not standardized worldwide. No international guidelines are currently available and inconsistency in the interpretation of evidence and recommendations among national guidelines is frequently identified (Harrop, Styliaras, Ooi, Radcliff, Vaccaro & Wu, 2012).

Surgical site infections (SSIs) are the most common nosocomial infections. These complications lead to revision surgery, delayed wound healing, increased use of antibiotics, and increased length of hospital stay, all of which have a significant impact on patients and the cost of health care. Such intraoperative factors as proper skin preparation, adherence to sterile technique, surgical duration, and traffic in the operating room contribute more to SSIs than do patient-related risk factors such as diabetes mellitus, obesity, and preexisting colonization associated with methicillin-resistant *Staphylococcus aureus*. Surgeons have a responsibility to understand the current evidence regarding the factors that affect the rates of SSIs so as to provide the highest level of patient care (Anderson, Podgorny, Berríos-Torres, Bratzler, Dellinger, Greene & Kaye, 2014).

1.2 Problem Statement

The Centers for Disease Control and Prevention's (CDC's) National Healthcare Safety Network (NHSN) definitions for SSI are widely used for public reporting, interfacility comparison, and pay-for-performance comparisons. SSIs are classified (see Figure 1) as follows:

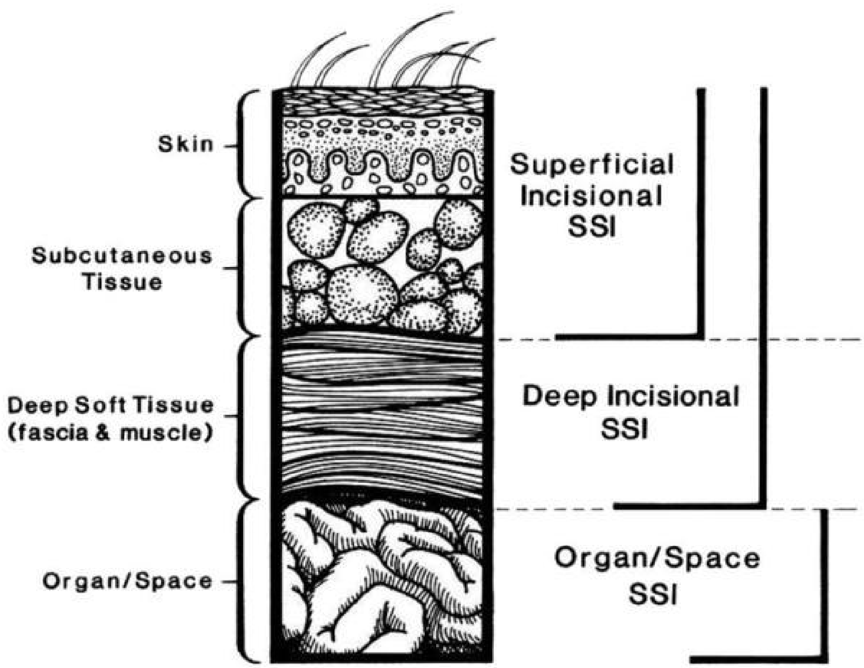

Figure (1): Classifications of the SSIs (sourse: Horan, Gaynes, Martone, Jarvis & Emori, 1992)

Recognition of risk factors frequently associated with SSI allows for identification of such patients with the greatest need for optimal preventive measures to be identified and pre-treatment prior to surgery.

The aim of this study is to provide a comprehensive range of evidence-based recommendations for interventions to be applied during the pre-, intra- and postoperative periods for the prevention of SSI, while also considering aspects related to resource availability and values and preferences.

An initial search identified more than 200 titles published in 2006-2017 as relevant for data extraction. Extracted information included study design and methodology, reported cumulative incidence and post-surgical time until onset of SSI, and odds ratios and associated variability for all factors considered in univariate and/or multivariable analyses.

Therefore, the problem statement of this study lies in the analyzing the implementation of the best practices for the prevention of surgical site infection (SSI) and then recommending the best producers for reducing the risk Factors for Patients by conducting a meta-analysis theoretical review.

1.3 Strategies to Detect SSIs

Numerous risk factors have been identified for the development of an SSI after surgery. These risk factors can be broadly separated into intrinsic (patient) factors that are modifiable or non-modifiable, as well as extrinsic (eg procedure, facility, preoperative, and operative) factors as shown in table (1).

Table (1): Surgical site infection (SSI) risk factors

Risk Factors		
Intrinsic (patient-related)	Non-modifiable	Increased age
		Recent radiotherapy
		History of skin or soft tissue infection
	Modifiable	Diabetes
		Obesity
		Alcoholism
		Current smoker
		Preoperative albumin
		Total bilirubin
		Immunosuppression
Extrinsic (procedure-related)	Procedure	Emergency
		Increasing complexity
		Higher wound classification
	Facility	Inadequate ventilation
		Increased operating room traffic
		Contaminated environmental surfaces
		Non-sterile equipment
	Preoperative	Pre-existing infection
		Inadequate skin preparation
		Inappropriate antibiotic choice, timing, and weight-based dosing
		Hair removal method
		Poor glycemic control
	Intraoperative	Longer procedure duration
		Blood transfusion
		Breach in asepsis
		Inappropriate antibiotic re-dosing
		Inadequate gloving
		Inappropriate surgical scrub
		Poor glycemic control

Source: (Ban, Minei, Laronga, Harbrecht, Jensen, Fry & Duane, 2017)

The following information identifies implementation strategies that can be used to prevent and reduce the risk for SSI. The implementation strategies are organized under 4 concepts: engage, educate, execute, and evaluate:

1.3.1 Engage

In the engagement phase, there needs to be clear and effective communication pertaining to the reasons why the SSI implementation strategies are important for patient care. Engagement of senior leadership, physician champions, infection preventionists, and multidisciplinary teams are examples of strategies necessary for initial implementation of a program to reduce SSIs. The following implementation strategies are described in the literature as being essential for the engagement process:

A. Obtaining support for SSI reduction from senior leadership. Senior leadership support is an important factor contributing to SSI rate decreases. Senior leadership is also critical for sustaining improvements over time. Senior leadership can include but is not limited to the hospital's board, president, chief operating officer, chief medical officer, and chief nursing officer (Thompson, Oldenburg, Deschamps, Rupp & Smith, 2011).
B. Obtaining highly engaged physicians as champions. Medical and surgical staff engagement is critical for SSI prevention activities and to champion SSI prevention throughout the hospital. Examples include

a physician leading an SSI prevention multidisciplinary team and a physician champion who provides education on strategies to reduce SSIs to other physicians and staff.

C. Use of multidisciplinary teams. Numerous studies and literature address the effectiveness of multidisciplinary teams to plan, develop, implement, and evaluate efforts to reduce SSIs. The key components of the team include preoperative, intraoperative, and postoperative management of the patient. Teams should include nursing, pharmacy, and physician champions (Wick, Hobson, Bennett et al., 2012).
D. Adopting evidence-based practices and guidelines. Several studies in the literature focus on the need for hospitals to adopt evidence-based practices and guidelines in an effort to decrease the risk of SSIs. The literature stresses that, although evidence-based interventions can reduce the number of SSIs and improve patient outcomes, implementation of these practices nationally occurs less frequently than is desirable (Alexander, Solomkin & Edwards, 2012).
E. Focus on a culture of safety. The literature supports the need for a culture of safety to successfully implement a program focusing on reducing SSIs. A culture of safety focuses on teamwork, technical processes, and promoting accountability for preventing SSIs throughout the continuum of care.

1.3.1 Educate

Education pertaining to practices to prevent SSIs is essential for senior leadership, physicians, nurses, and patients and families. The following implementation strategies describe the types of education that can impact SSI rates and who should be the focus of educational efforts.

A. Aligned and coordinated SSI education for licensed independent practitioners and staff. Multidisciplinary education for licensed independent practitioners (physicians and midlevel practitioners) and other practitioner staff (registered nurses) must be aligned and coordinated. The content of the education focuses on the continuum of the patient's care and execution of evidence-based practices to prevent SSIs.
B. One-to-one education of the surgeon when an SSI issue is identified. Provide one-to-one education when surgeons have elevated SSI rates and/or when appropriate preventive processes are not being adhered to. This education may be conducted by another surgeon, infection preventionist, quality office, or other qualified individuals. The education should be non-confrontational with an emphasis on understanding variation in practice rather than judgment. If lack of adherence to evidence-based practices is identified, then an action plan must be developed.
C. Education for senior leadership that describes the value and benefits of SSI reduction. Provide education to executive leadership regarding the value of reducing SSIs, including patient and fiscal outcomes.
D. Education for the surgical team on safety science. Provide education to licensed independent practitioners and staff involved in the care of surgical patients on the science of safety, including the principles of safe system design.
E. Specific SSI education for patients and families. Patient education for reducing SSIs is a major priority for any hospital focused on preventing SSIs. Education strategies such as pre-surgical classes, television education, and one-to-one education with the patient and family have been used successfully. Educational materials should be provided in multiple languages on the basis of the population served.

1.3.3 Execute

In the execution phase, the focus is on implementation strategies to reduce barriers and improve adherence with evidence-based practices and reduce the risk of SSIs, including (*a*) standardization of care processes, (*b*) creating redundancy or independent checks, and (*c*) learning from defects when an SSI occurs. As noted above, no consensus exists on the components of an effective bundle to prevent SSIs. Thus, individual hospitals must identify local deficits and create their own bundle.

A. Use a quality improvement methodology. Use of quality improvement methodology for designing and implementing a program leads to reduced rates of SSIs. Quality improvement methodologies include Lean Six Sigma, the Comprehensive Unit-Based Safety Program, and the Plan-Do-Check-Act model. Various performance improvement (PI) tools have been used, including dashboards, scorecards, and histograms, to display data.
B. Differentiate between adult and pediatric populations. Pediatric-focused evidence-based practices for reducing SSIs are lacking. Clinical interventions designed for the adult population cannot necessarily be transferred to the pediatric population. Hospital and pediatric surgeons must determine whether adult evidence-based interventions can be safely used with the pediatric population.[203]
C. Use of information technologies (IT). IT innovations can be used to simplify and standardize clinical documentation. IT and the electronic medical record can also be used for electronic surveillance,

electronic prompts, automatic stops for prophylactic antibiotic orders, and education. Education can be delivered to patients, families, and healthcare workers through different media, including the Internet and television.

D. Participation in a collaborative. Numerous studies have reported that participation in a collaborative can help reduce SSI rates in participating organizations. Collaboratives provide a mechanism for organizations to
   1. Utilize valid data, such as with the American College of Surgeons National Surgical Quality Improvement Program;
   2. Identify increased morbidity and mortality through comparisons to peer hospitals on a national basis; and
   3. Learn through the collaboration process.
E. Use of preoperative/postoperative order sets. Standardized order sets can be developed on the basis of evidence-based practices. The order sets should be approved by the medical staff and updated when the evidence-based practices change. The development of order sets is a labor-intensive process necessitating skills and expertise of several disciplines, including surgery, anesthesia, nursing, and pharmacy. All relevant disciplines should be educated in the use of the order sets.
F. Acting on identified SSI issues. When issues suspected of increasing the risk of SSI are identified, the hospital should take action to resolve the identified issues. Several hospitals conduct root-cause analyses with a multidisciplinary team to identify the cause of the issues and any lack of adherence in the evidence-based practices.
G. Establish a protocol for preoperative testing. Establish a protocol for procedure-specific preoperative testing to detect medical conditions that increase the risk of SSI. The protocol should focus on nutritional counseling if indicated, smoking cessation if indicated, preadmission infections, and reconciling medications with adjustments prior to surgery if indicated. If high-risk patients are identified through screening, alerts should be added to electronic medical records to ensure that all members of the perioperative team are aware of the high-risk condition(s).

1.3.4 Evaluate

In the evaluation phase, the focus is on the use of measurement and evaluation tools to determine the effectiveness of implementation strategies in the prevention of SSIs.

A. Use of performance improvement tools. Various PI tools can be used. PI tools include dashboards, scorecards, or histograms to display data. Additional PI tools can include root-cause analysis and failure modes and effects analysis.
B. Direct observation of evidence-based practices. As part of a hospital's SSI improvement activities, trained observers (eg, infection preventionists, educators, nurses, and physicians) should observe surgery to assure that evidence-based practices have been implemented in the operating room. Direct observation can also be conducted for hand hygiene and surgical hand antisepsis technique. This activity is used to educate and reinforce evidence-based practices with the operating room practitioners.
C. Longitudinal evaluation of SSI rates and compliance rates. Track the success of the SSI reduction program by evaluating SSI rates over time (ie, before, during, and after the program). If specific practices or processes are identified for improvement, evaluate the compliance with evidence-based practices related to these practices and processes. Feed these data evaluations back to frontline staff.

1.4 Prehospital interventions

Preoperative patient optimization topics include bathing and showering techniques, smoking cessation, whether long-term glucose control affects SSI risks, as shown in table (2).

1.4.1 Preoperative bathing and showering

Chlorhexidine (see figure 2) reduces the bacterial colonization of the skin, however, a recent Cochrane database systematic meta-analysis review of chlorhexidine vs placebo studies failed to demonstrate a corresponding decrease in SSIs with chlorhexidine bathing. Studies in this review included a highly variable surgical patient population, and no single standardized bathing process was used across all studies. Some research has shown that chlorhexidine needs to dry on the skin for maximal effect, which is a limiting factor in bathing. In a recent study by Edmiston and colleagues, a protocol of 2 to 3 sequential showers with 4% chlorhexidine gluconate with a 1-minute pause before rinsing resulted in maximal skin surface concentrations. Research is underway investigating the use of chlorhexidine-impregnated cloths to produce a more sustainable decrease in skin bacterial colonization to complement chlorhexidine bathing, but no high-quality studies have demonstrated a decreased SSI risk with these interventions (Edmiston, Krepel, Seabrook, et al., 2008).

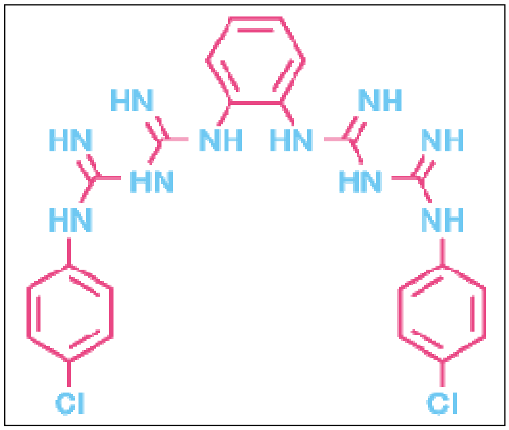

Figure (2): chemical formula of the chlorhexidine

1.4.2 Smoking cessation

Smoking has long been associated with an increased risk for SSI. The etiology of this phenomenon is complex, but is partially related to vasoconstriction of vessels in the surgical bed that leads to tissue hypovolemia and hypoxia. In addition, poor tissue perfusion impedes transport of nutrients and alters the immune response. The magnitude of this impact as reported by Durand and colleagues is particularly important in operations with implantation of mechanical devices and prosthetics (Durand, Berthelot, Cazorla et al., 2013).

Regardless of the type of surgery, current smokers are at the highest risk for SSI, and former smokers are at higher risk than an individual who has never smoked. As such, surgeons should counsel patients to completely refrain from smoking for a minimum of 4 to 6 weeks before elective surgery. Smoking cessation in this time period decreases SSIs and a host of other surgical complications (Moller, Villebro, Pedersen & Tonnesen, 2002). The American College of Surgeons patient education materials support the use of nicotine lozenges, nicotine gum, and medication to aid in smoking cessation.

Table (2): Prehospital Interventions

Guideline	Intervention
Preoperative bathing	Routine preoperative bathing with chlorhexidine (when not part of a decolonization protocol or preoperative bundle) decreases skin surface pathogen concentrations, but has not been shown to reduce SSI.
Smoking cessation	Smoking cessation 4 to 6 weeks before surgery reduces SSI and is recommended for all current smokers, especially those undergoing procedures with implanted materials. There is no literature to support cessation of marijuana and electronic cigarette use to prevent SSI, but cessation is recommended before surgery based on expert consensus.
Glucose control	Optimal blood glucose control should be encouraged for all diabetic patients; however, there is no evidence that improved Hgb A1C decreases SSI risk.

1.4.3 Glucose control

Data linking long-term blood glucose control and SSI risk have been conflicting. The study by Dronge and colleagues reported that an elevated Hgb A1c (marker of long-term glucose control) is associated with increased risk of postoperative infectious complications (Dronge, Perkal, Kancir, et al., 2006).

However, all subsequent studies where multivariate analysis included both Hgb A1c and perioperative glucose levels failed to demonstrate a correlation with Hgb A1c and SSI (Maradit, Lewallen, Mabry et al., 2015).

1.5 Hospital interventions

Hospital interventions covered include perioperative blood glucose control, hair-removal technique, skin preparation, surgical hand scrub, surgical attire, antibiotic prophylaxis, intraoperative normothermia, use of wound protectors, antibiotic-coated suture, glove and instrument use, wound closure techniques, topical antibiotics, supplemental oxygen delivery, and wound care practices in the hospital.

1.5.1 Glucose control

Management of perioperative hyperglycemia with insulin to obtain glycemic control is important to minimize the risks of SSIs. Kwon and colleagues showed a dose-response relationship between degree of glycemic control and SSI, with patients who maintained a serum glucose <130 mg/dL having the lowest SSI rate (Kwon, Thompson, Dellinger et al., 2013).

This effect is not limited to a specific field of surgery or to diabetics alone. The study by Ata and colleagues showed a correlation with blood glucose <140 mg/dL and lower SSIs in all general surgery patients, although not in vascular procedures. However, Kotagal and colleagues did demonstrate this benefit in vascular and other surgery (ie abdominal and spine), although their patient cohort included nondiabetics, and the target glucose level was lower at<125 mg/dL. This study also showed a greater risk from hyperglycemia in nondiabetics than in diabetics.

1.5.2 Hair removal

Factors related to patient preparation in the operating room have been examined, including hair removal. According to CDC, hair in the surgical site should only be removed if it will interfere with surgery. Shaving causes microscopic cuts and abrasions, resulting in disruption of the skin's barrier defense against microorganisms. As such, razors are no longer recommended, except in the scrotal area or scalp after traumatic injury. According to studies by Mangram and colleagues and Anderson and colleagues, clippers should be used instead of razors to remove hair, see figure (3: a, b).

Figure (3:a): Hair removal by razor (not recommended)

Figure (3:b): Hair removal by clippers (recommended)

1.5.3 Skin preparation

Although there is general agreement that a preparation solution of some kind is needed to scrub the surgical site, the active ingredient in the scrub solution is debated. Many randomized trials have compared chlorhexidine based with iodine-based antiseptics for preoperative skin preparation, however, most have been underpowered to detect differences in SSI rates. Overall, there is evidence that alcohol-based preparations are more effective in reducing SSI than aqueous preparations, and should be used unless contraindications exist. The rationale for alcohol-based solutions is rapid bactericidal effect, but this benefit is limited by its lack of persistent antimicrobial effect. The addition of iodine-based and chlorhexidine-based solutions prolongs bactericidal activity in alcohol-based preparations. Although many small randomized controlled trials have demonstrated superior decontamination of skin flora with chlorhexidine isopropyl alcohol compared with iodine-containing solution plus alcohol (in clean cases), no study has convincingly demonstrated the superiority of alcohol-containing chlorhexidine to iodine and alcohol skin preparations with regard to SSIs (Sidhwa & Itani, 2015).

1.5.4 Surgical hand scrub
Studies have shown that waterless chlorhexidine scrub is as effective as traditional water-based scrubs and requires less time. A recent systematic review concluded that there is overall low quality of evidence to support any one intervention over another. There is some evidence that alcohol scrubs reduce colony-forming units compared with aqueous scrubs, and that chlorhexidine gluconate scrubs reduce colony-forming units compared with povidone iodine scrubs, however, there is no evidence that lower colony forming units after surgical hand scrub are associated with lower SSI risk. The use of either a traditional scrub or a waterless chlorhexidine scrub is acceptable in accordance with each product's instructions (Tanner, Swarbrook & Stuart, 2008).

1.5.5 Surgical attire
The topic of surgical attire has been debated in recent years. Formerly acceptable practices, including home laundering of scrubs and use of cloth scrub hats, are no longer supported by Joint Commission and Association of Perioperative Registered Nurses policies. Unfortunately, there is a paucity of data to guide evidence-based practices in this realm. Many current guidelines reflect historical practices with intuitive infection-control benefits that are now firmly ingrained in surgical culture and patient-safety expectations. From a feasibility standpoint, it would be nearly impossible to test the effects of these practices on SSI. A task force convened by the ACS Board of Regents released new guidelines on surgical attire earlier last year. These guidelines reflect the ACS commitment to professionalism and are guided by common sense and evidence, whenever available.
The ACS guidelines recommend that clean and appropriate professional attire (not scrubs) be worn during all patient encounters outside the OR, and that OR scrubs should not be worn at any time outside the hospital perimeter (Board of Regents of the American College of Surgeons, 2016).

1.5.6 Topical antibiotic therapy
The use of various topical and local antibiotic therapy options for SSI reduction has been explored across many surgical subspecialties. Overall, there is a lack of high-quality data to support local and topical antibiotic therapy use to decrease SSI risk. These therapies include antibiotic irrigations, topical antimicrobial agents, antimicrobial-impregnated dressings, and wound sealants. Some studies even suggest that use of these agents can increase SSI risk, as described in a multicenter trial examining use of gentamicin-collagen sponges in colorectal surgery. There is some support in the literature for topical or local antibiotic use for specific procedures or patient populations. A recent systematic review found possible benefit for use in joint arthroplasty, cataract surgery, and possibly in breast augmentation and obese patients undergoing abdominal surgery (McHugh, Collins, Corrigan et al., 2011).

1.6 Post-hospital interventions
There is a paucity of informative research in the area of post-hospital interventions for the prevention of SSI. For example, there is almost no research on wound care in the post-hospital setting (Guideline 3.1). The majority of the literature covers methods of SSI surveillance after discharge. These results have shown that a substantial number of SSIs occur after discharge, and that SSI rates can be underestimated without formal surveillance. A recent study reported that when systematic 30-day follow-up is performed, as in NSQIP, compared with variable and primarily inpatient surveillance, as in National Healthcare Safety Network, that more infections are routinely found (Ju, Ko, Hall et al., 2015).
Unfortunately, no reliable methods have been described in the literature to identify SSI. Surveillance methods based on surgeon or patient questionnaires have poor sensitivity and specificity.1 Promising new methods of surveillance are being explored, many of which use smartphone technology to help patients send their surgeon daily photos or updates. Currently, most SSIs are identified via presentation to the emergency department or in outpatient clinic follow-up. Most superficial SSIs can be managed in the outpatient setting, but deep and organ space SSIs require readmission (Ming, Chen, Miller & Anderson, 2012).

1.7 Best practices for surgical site infection prevention
During the past decade, U.S. healthcare has entered a period of best practices bundling in which patient care actions that have been identified as improving outcomes have been grouped together. SSI reduction strategies have greatly benefited from this approach. Elective surgery patients, who may wait days or weeks between the decision to proceed with surgery and the actual date of surgery, are the optimal candidates upon whom to focus SSI prevention strategies. Rather than consider this interval time as an unnecessary delay, it should be viewed as

a window of opportunity to optimize the patient's resources and defenses against potential perioperative complications, as well as to ensure that the healthcare system is functioning at optimal level to protect the patient.

1.8 Conclusions

Surgical site infection risk depends upon a number of patient factors, including pre-existing medical conditions, amount and type of resident skin bacteria, perioperative glucose levels, core body temperature fluctuations, and preoperative, intraoperative and postoperative care. Therefore, it is difficult to predict which wounds will become infected. For that reason, caregivers should strive for early identification of patients with risk factors amenable to intervention to minimize the risk of wound contamination in all surgical cases and to support host defenses throughout the continuum of care. These and other well-researched interventions should be bundled together and considered integral components of the best practices care we must provide our patients every day.

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