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Preventing Surgical Site Infections in Emergency General Surgery: Current Strategies and Recommendations

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Abstract

Purpose of Review Surgical site infection (SSI) is a common post-operative complication that places significant burden on patients and healthcare systems. Patients undergoing emergency surgery are at an increased risk of SSI due to many patient factors and intra operative variables that are prevalent in emergency general surgery (EGS).

Recent Findings Surgeons utilize many different techniques during EGS cases to minimize the incidence of SSI. Data supporting wound protectors and routine wound irrigation are mixed, however, they are low-cost, low-risk options to help mitigate surgical site infections. There are several advantages to intra-operative normothermia and glucose control for the prevention of SSI, which have been studied in elective and emergent surgical populations. The management of contaminated general surgery wounds is controversial, but there is growing evidence to support the use of closed negative pressure wound therapy.

Summary This review provides a comprehensive, evidence based overview of perioperative recommendations for decreasing risk of surgical site infections and wound management strategies for contaminated general surgery wounds. Surgeons should be familiar with these techniques to help minimize the risk of surgical site infections and hasten the patient's recovery from surgery.

Keywords Surgical site infections · Wound vac · Primary closure · Negative pressure wound therapy

Introduction

Surgical site infection (SSI) is one of the leading causes of preventable morbidity and mortality. It is associated with prolonged length of stay and is responsible for up to 20% of all healthcare associated infections [1]. Superficial SSI occurs in 2–5% of patients undergoing in-patient surgery and is noted to be up to to 30% in patients undergoing contaminated abdominal surgery [2, 3]. Infections at the surgical site are known to place significant burden on the hospital system with substantial financial costs stemming from prolonged length of stay, further procedures, dressing needs, and frequent emergency room visits. The annual cost of SSI management has been estimated to reach up to $1.6 billion in hospital expenses alone [4]. Some have suggested that the cost may be as high $10 billion per year in the US [2]. Furthermore, potentially preventable SSI has been shown to increase charges by $27,000 per patient [5]. Up to 90,000 readmissions annually can be attributed to SSI with a reported $700 million in additional cost [2]. In colorectal literature, SSI have been shown to increase postoperative costs by 35.5% and hospital length of stay by as much as 71.7% [6]. Due to these burdens, prevention of surgical infections is an important aspect of providing quality, cost-efficient care and is the focus of many process improvement initiatives.

SSI prevention involves several modifiable patient risk factors and intra-operative techniques to help minimize exposure of the wound to contamination and infectious pathogens. Patient risk factors include achievement of normothermia and normoglycemia intraoperatively, which are known to decrease the risk of SSI [7, 8]. Intraoperative techniques include wound protectors and irrigation with saline or other sterile solution to help minimize wound exposure to contamination. Additionally, the use of negative pressure wound therapy (NPWT) for both primary and secondary wound closure has become an increasingly discussed topic with noted benefits including improved comfort and healing along with lower rates of infection and hematoma formation [9, 10]. The purpose of this article is to review current strategies

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of SSI prevention in EGS, including perioperative techniques and wound management strategies (see Table 1).

Intraoperative Infection-Prevention Strategies

Wound Protectors

Wound protectors have grown in popularity to reduce the risk of SSI. Wound protectors or wound edge protectors come in a variety of different styles. Protectors deploy a ring and thin transparent barrier that circumferentially attaches to the surgical wound promoting radial retraction and providing a barrier between the subcutaneous tissues and intra-abdominal contents. The goal of the wound protector is to keep the incision site free of contamination with any enteric contents or spillage and to limit exposure to both endogenous and exogenous bacteria. Surgeons find wound protectors advantageous because of their rapid set-up and ease of utilization in many wound sizes and depths.

Despite their popularity and intuitive design, literature supporting the use of wound protectors for SSI prevention is mixed. One of the earliest studies on the use of wound

Table 1 Summary of wound adjuncts

Strategy	Author	Summary of findings
Wound protectors	Nyström et al. [11]	Randomized control trial of 140 elective colorectal surgery patients; 10% SSI rate with the wound ring, 9% without
	Sookhai et al. [12]	Randomized control trial of 352 contaminated colon cases; 13% SSI with wound edge protector, 29% without
	Horiuchi et al. [13]	Randomized control trial of 354 nontraumatic GI cases; 0% SSI with wound protector, 8% without
	Edwards et al. [14]	Meta-analysis of 6 RCTs including 1008 GI and biliary cases; 45% SSI risk reduction with ringed wound protector
	De Pastena et al. [15]	Randomized control trial of 212 pancreatoduodenectomy cases; 7% SSI with dual ring wound protector, 7% without
	Pinkney et al. [3]	Randomized control trial 760 laparotomies; 24% SSI with wound protector, 25.4% without
	Muniandy et al. [16]	Randomized control trial of 200 open appendectomies; 8.4% SSI with wound edge protector, 7% without
Wound irrigation	Fu et al. [19]	Meta-analysis of 24 studies including all surgical cases; significant reduction in SSI with irrigation with an antibiotic solution (OR 0.48) or with proviodine-iodone (OR 0.40)
	de Jonge et al. [20]	Meta-analysis of 21 studies including open surgeries; significant reduction in SSI with incisional wound irrigation with aqueous povidone-iodine (OR 0.31) and no significant reduction with antibiotic irrigation (OR 1.16)
	Thom et al. [21]	Meta-analysis of 42 studies including open abdominal surgeries; lower risk of SSI with irrigation with antibacterial irrigation (OR 0.573)
	Mueller et al. [22]	Meta-analysis of 41 studies of open abdominal surgery; Significant reduction in SSI with incisional wound irrigation with saline, povidone-iodine or antibiotic solution (OR = 0.54) compared to no irrigation
	Ambe et al. [23]	Meta-analysis of 4 studies of open abdominal surgery; trend towards lower risk of SSI with saline irrigation, however, finding was not significant. Similar length of stay between irrigation and not irrigated
Normothermia	Flores-Maldonado et al. [39]	Prospective study of 290 surgical patients; Hypothermia was deemed to be a significant risk factor for SSI. 11% of patients with hypothermia developed SSI compared to 2% of normothermic patients
	Wong et al. [34]	Randomized control of 103 patients undergoing elective major abdominal surgery; perioperative systemic warming significantly decreased risk of SSI; 26% SSI rate for control compared to 13% for warmed patients
	Madrid et al. [7]	Meta-analysis of 67 studies of all surgery; Active body surface warming decreased risk of SSI from 13% to 4.7%
	Balki et al. [40]	Meta-analysis of 44 studies in noncardiac patients; active body warming significantly decreased the risk of SSI (OR 0.3)
Euglycemia	de Vries et al. [47]	Meta-analysis of 15 studies; significant risk reduction for SSI in patients who underwent strict glucose control < 150 mg/dl (OR 0.43)
	Yoneda et al. [48]	Retrospective study of 1612 patients undergoing gastrointestinal surgery; hyperglycemia shown to be an independent risk factor for SSI (OR 1.54)

protectors was done in 1984 by Nyström et al., who completed a two-center randomized control trial of 140 elective colorectal surgery patients with use of a wound ring drape [11]. The authors found no difference in infection rate with the use of the wound protection device in either clean or contaminated cases (10% with the wound ring and 9% without) [11].

Nystrom's findings were challenge by a 1999 single center randomize control trial of 352 patients by Sookhai et al., who found that wound edge protectors decreased the rate of infection in contaminated cases [12]. These results were further supported by another single center randomized control trial in Japan by Horiuchi et al., who looked at the use of the popular Alexis retractor in 354 nontraumatic gastrointestinal cases [13]. The Alexis retractor, manufactured by Applied Medical (Rancho Santa Margarita, CA USA), is a polyurethane wound retractor that is applied to the surgical wound following the incision and provides a tight seal around the wound edges. The study found a significant reduction in superficial SSI with the use of the wound protector (0% with the Alexis retractor and 8% without), which the authors contributed to the lack of bacterial contamination of the wound [13]. Additionally, a 2012 meta-analysis of 6 randomized control trials looking at the use of wound protectors in non-traumatic gastrointestinal and biliary surgery was published by Edwards et al. in the *Annals of Surgery*. The study found that wound protectors decreased the risk of wound infection by 45% [14].

More recent work by De Pastena et al. in 2020 looked at the role of a dual-ring protector in pancreaticoduodenectomies and found that, while safe and feasible, it did not in fact reduce superficial SSIs [15]. In an effort to provide further clarity to the benefit of wound protectors, a thorough multicenter randomized control trial of 760 patients at 21 UK hospitals, the ROSSINI Trial, was initiated [3]. The study examined laparotomy incisions, both in elective and emergency cases, and found no difference between the incidence of SSI in patients with or without a wound protector. This finding was consistent when looking at surgical site infections at different time points in recovery after surgery.

Interestingly, a study by Muniandy et al., in a 2021 randomized control trial of 200 patients who underwent an open appendectomy, a wound protector was not found to reduce the incidence of SSI; however, use of the wound protector for infected wounds was associated with an overall lower cost [16]. Although the data supporting wound protector use is mixed, they do provide other benefits with improved wound retraction at a marginal cost with limited patient risk and are frequently used in enhanced recovery pathways for elective surgery.

Wound Irrigation

Intra-operative surgical site wound irrigation is often practiced prophylactically among surgeons to prevent subcutaneous and deep infection. As many as 97% of surgeons report wound irrigation in an effort to prevent infection [17]. It has been traditionally thought that irrigating contamination from the wound will lower the risk of infection and expedite the healing process [18]. Contamination in the form of bacteria or foreign bodies can cause excess inflammation, which can lead to a dysfunction in collagen synthesis and the body's natural wound healing process. Wound irrigation has thus been argued to be an essential component of promoting the body's natural wound healing effects [18].

A recent meta-analysis done by Fu et al. found that irrigation with an antibiotic solution or with proviodine-iodone leads to lower surgical site infections rates when compared to no irrigation or irrigation with saline [19]. These findings would suggest the need to implement a new standard of care, however, the majority of the studies included in the meta-analysis were completed in either developing countries or in the 1980's, limiting the potential reach of the study's findings. Furthermore, several other meta-analyses have been done lately, which have reported a benefit of lavage with saline, anti-bacterial solution, or povidone-iodine solution [20–23]. Yet, these studies have also been limited by low-quality evidence with significant heterogeneity.

Due to the paucity of high quality evidence supporting wound irrigation, several international organizations have released recommendations on the topic, including the World Health Organization (WHO) [24], the Centers for Disease Control (CDC) [25], and the National Institute for Health and Care Excellence (NICE) [26]. The CDC provides a weak recommendation for washing the wounds with a diluted iodophore solution, while the WHO only recommends consideration of intraoperative wound washing, but the NICE guidelines in fact recommend against wound washing due to the lack of evidence [27].

Currently, there is a large multi-center randomized controlled trial ongoing, titled the "Intraoperative Wound Irrigation to prevent Surgical Infection after Laparotomy (IOWISI)" that is aimed at providing a more thorough examination of the potential benefit of wound irrigation with saline and an antiseptic polyhexanide-based solution [28]. The study aims to address the current short fall of high level of evidence for intra-operative wound irrigation. It will intriguingly be looking at the use of 0.04% polyhexanide solutions, (which has successfully been used in trauma and orthopedic surgeries) to saline and no irrigation prior to skin closure after laparotomy for visceral surgery. [29, 30] This study will hopefully provide a more thorough examination of the potential benefit of the use of wound irrigation as current data is heterogenous and fails to provide a thorough consensus as to the role of wound irrigation in preventing SSI.

Normothermia

Perioperative normothermia has been established as a core temperature greater than 36 °C [31, 32]. Hypothermia in the perioperative setting has long been known to increase mortality and complications [33]. Core body temperature is a constant combination of heat gained and heat lost. There are many factors that increase the perioperative heat loss and thus decrease core body temperature including, exposure to a cold operating room, introduction of anesthetics, and insensible heat losses [34]. The mechanisms through which hypothermia leads to an increased risk for SSI are multifactorial. Hypothermia induced vasoconstriction decreases the blood flow to the wound site, which lowers the amount of oxygen available for the healing tissues. This relative tissue hypoxia alters protein metabolism, decreasing wound healing and increasing the risk of wound dehiscence [35]. The relative tissue hypoxia due to vasoconstriction also reduces the action of neutrophils at the tissue bed by limiting the oxidative immune defense mechanism [36, 37]. Furthermore, hypothermia induced hypoxia reduces the activation of innate immune cells including the T-cell mediated host defense and targeted antibody production [34, 38].

Even just mild-hypothermia in the perioperative setting has been shown to be an independent risk factor for SSI with a relative risk of 6.3 [39]. A 2007 randomized control study of elective major abdominal surgeries demonstrated that the use of intraoperative warming techniques to prevent perioperative hypothermia leads to lower infection rates extending to 8 weeks postoperatively [34]. A 2016 Cochrane review by Madrid et al. found that active body surface warming to prevent incidental intra-operative hypothermia was demonstrated to reduce the risk of SSI from 13% to 4.7% [7]. Most substantially, a 2020 meta-analysis of 3976 patients undergoing noncardiac surgeries by Balki et al., demonstrated that perioperative active body warming significantly increased patient satisfaction and decreased wound infections with an odds ratio of 0.3 (95% CI 0.2–0.7) [40]. There are several ways to achieve intra-operative normothermia, including forced warm air, skin warming, and warmed intravenous fluids; all of which are crucial to preventing SSI.

Glucose Control

It has been well established that perioperative hyperglycemia leads to increased risk for surgical site infections, among other complications [8, 41–43]. Elevated glucose levels impact wound healing through several mechanisms including, impaired neutrophil function, overproduction of reactive oxygen species, free fatty acids, and inflammatory mediators [44]. Complications related to hyperglycemia are not limited to patients with diabetes and in fact, nondiabetic patients with perioperative hyperglycemia have double the risk for infections, re-operative interventions, and in-hospital deaths compared to those with diabetes [45]. Control of hyperglycemia with insulin management in the perioperative setting reduces complications, including wound infections, and decreases mortality [46].

A 2017 meta-analysis including 15 randomized control trials examining perioperative glucose levels, found that obtaining a glucose level < 150 mg/dL significantly reduced SSI [47]. These findings were instrumental in informing the guidelines published by the American College of Surgeons, which recommended a target glucose level between 110 and 150 mg/dL, in part for the prevention of SSI [1]. A recent study by Yoneda et al. in 2020, looked at the management of hyperglycemia in the prevention of SSI for non-diabetic patients undergoing gastrointestinal surgery [48]. In their study of 1612 patients, the authors found that persistent perioperative hyperglycemia, defined as a glucose level > 150 mg/dL, significantly increased the risk of SSI with an OR 1.54 (95% CI 1.03–2.31). The authors suggested that use of insulin post-operatively to maintain a blood glucose < 150 mg/dL is an important aspect of SSI prevention [48]. These conclusions were similar to those made in both the CDC guidelines and the International Critical Care guidelines on septic shock [25, 49] (see Table 2).

Management of Contaminated Wounds

Primary Closure

Primary wound closure inherently involves complete closure of the surgical wound at the completion of an operation with suture or staples. Primary closure, as opposed to delayed primary closure or closure by secondary intention, has the benefits of improved wound cosmesis, avoids the cost and pain of frequent dressing changes and wound management, and shortens hospital length of stay [50].

Some have suggested that there is no difference in infection rates between primary closure and delayed closure when looking at contaminated wounds [50–52]. Tsang et al., in looking at closure of contaminated open appendectomy wounds, reported there to be a 21% infection rate for those who underwent primary closure compared to 24% for delayed closure [51]. These findings would suggest that the use of primary closure would be appropriate for closure of contaminated wounds, however, the application of this data can be limited by the reality that the studies looked at wound closure in open appendectomies, a rare surgical procedure today. Other studies looking at open colectomies by Voyles [53] and Velmahos et al. [54] found there to be a significantly higher rate of SSI with primary closure. Volyes

Table 2 Summary of wound closure techniques

Strategy	Author	Summary of findings
Primary closure	Runcinski et al. [50]	Meta-analysis of 2532 patients with complicated appendicitis; primary closure patients had a 4.7% SSI risk and delayed closure patients had a SSI risk of 4.6% with no significant difference
	Tsang et al. [51]	A retrospective study of 63 patients of contaminated open appendectomy wounds; SSI rate of 21% with primary closure vs 24% with delayed closure
	Pettigrew et al. [52]	Randomized trial of 122 patients with perforated or gangrenous appendicitis; patients with primary closure had a 54% SSI compared to 18% for patients who underwent delated primary closure with topical ampicillin
	Voyles et al. [53]	Retrospective study of 62 patients who had open colectomies; patients with primary closure had a 56% rate of SSI compared to 19% for delayed primary or secondary closure
	Velmahos et al. [54]	A randomized control trial of studies of open colectomies; Primary closure had a 65% SSI rate compared to 36% for delayed primary or secondary closure. Primary closure was an independent risk factor for SSI (OR 5.5)
	Seamon et al. [55]	A multicenter retrospective study of 503 trauma laparotomy incisions with enteric injury; patients with primary wound closure had a SSI rate of 31.1%
	Pommerening et al. [57]	A retrospective study of 510 damage control laparotomies; patients with primary wound closure had an SSI rate 4 × higher than wounds closed with secondary intention
Delayed primary closure	Tang et al. [60]	A meta-analysis of contaminated abdominal surgical incisions; significant reduction in hospital length of stay with delayed primary closure compared to primary closure
	Cohn et al. [61]	A single center randomized control study; patients with delayed closure on post-operative day 4 had a SSI rate of 12% compared to a rate of 48% for delayed closure. Patients with delayed primary closure also had a reduction in hospital length of stay and cost
	Duttaroy et al. [62]	A randomized control trial of 81 patients with contaminated abdominal wounds; patients with primary closure had a SSI rate of 42.5% compared to 2.7% for delayed primary closure
	Bhangu et al. [63]	A meta-analysis of 8 studies of dirty or contaminated surgical wounds; delayed primary closure did not have a significant reduction in SSI compared to primary closure (OR 0.65)
	Siribumrungwong et al. [64]	A meta-analysis of 8 studies of contaminated abdominal surgical wounds; patient's with delayed primary closure did not have a significant difference in SSI compared to primary closure, but had an increased length of stay by 1.6 days
	Sato et al. [65]	A retrospective review of 15 patients with contaminated abdominal wounds after emergency laparotomy; patients with delayed primary closure on post-operative day 7 had a SSI rate of 4.5%
Closure via secondary intention	Condé-Green et al. [71]	A retrospective review of 56 patients undergoing open hernia repair with incision negative pressure wound therapy; closure of wounds by secondary intention had a significantly higher rate of wound complication compared to primary closure 63.6% vs 22%
	Braakenburg et al. [9]	A single center randomized control trial of 65 patients with surgical wounds; similar costs between use of negative pressure wound therapy for open abdominal wounds versus
	Regner et al. [76]	A retrospective study of 158 patients undergoing emergency celiotomy; patients managed via secondary intention with a negative pressure wound vac had a surgical site adverse outcome 22% of the time compared to 12% for primary closure

Table 2 (continued)

Strategy	Author	Summary of findings
Primary closure with incisional NPWT	Stannard et al. [77]	Case study of 4 patients who had negative pressure wound therapy applied to their wounds; all wounds healed well and were safe and cost effective
	Gomoll et al. [78]	Case study of 35 patients who had an incisional VAC placed after orthopedic surgery: VAC improved tissue edema, swelling, and decreased drainage
	Hyldig et al. [10]	Meta-analysis of 10 studies of standard open surgical incisions; patients with negative pressure wound therapy had a significant reduction in wound infection (RR = 0.54)
	Shiroky et al. [79]	Meta-analysis of 44 studies of any open surgery; Patients with negative pressure wound therapy had a 40% reduction in SSI compared to conventional dressings (RR = 0.61)

et al. reported the SSI rate to be as high as 56% for primarily closed wounds compared to only 19% for patients with delayed primary or secondary closure. Velmahos et al., in their randomized control trial, identified an increase from 36 to 65% with primary wound closure and identified primary closure to be an independent risk factor for SSI (OR 5.5).

More recently, the rate of SSI following primary closure has been examined in laparotomy incision by Seamon et al. in a 2013 multicenter retrospective study. In their study of trauma laparotomy incisions with enteric injury, primary closure was associated with an infection rate up to 31.1% [55]. This was significantly higher than the national rate of wound infection rates for emergency colon surgeries at 10.3%, which was reported by Dayama et al. in a 2017 retrospective study using the American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) database [56].

Furthermore, in the setting of damage control laparotomy, Pommerening et al. stated the risk of SSI in primary skin closure to be four times higher than healing by secondary intention [57]. The study used a stapled closure 1–2 cm apart for wounds that were closed and incisional packing with moist gauze for wounds left to close by secondary intention. Although the rate of SSI was significantly higher for patients with primary closure, 85% of patients who underwent primary closure did not develop SSI [57]. These findings suggest that while primary closure has a higher rate of SSI compared to closure by secondary intention, it may be appropriate for some patients to expedite post-operative healing and minimize burden of ongoing wound care.

Delayed Primary Closure

Delayed closure of wounds in an attempt to decrease surgical site infections has been a long discussed topic, with first reports in the literature by Hepburn in 1919, who described the use delayed closure for contaminated extremity wounds suffered during WWI [58]. By keeping the wound open initially, drainage of the wound site is possible along with decreasing the opportunity of microbial growth. In described practice, the wound is then closed on post-operative day 3–5, either under local or general anesthesia [59].

In a meta-analysis of incision closures in contaminated abdominal wounds by Tang et al., SSI and hospital length of stay was significantly reduced with delayed primary closure compared to primary closure of the surgical site [60]. A single center randomized control trial by Cohn et al. also demonstrated there to be a significant SSI reduction with delayed closure on post-operative day 4 vs primary closure (12% vs 48%) [61]. Hospital length of stay and hospital costs were similar in patients undergoing delayed primary closure versus those who underwent closure during the initial operation. Furthermore, Duttaroy et al. also examined delayed primary vs initial primary closure for patients with contaminated abdominal wounds with closure of the wound 3 days after wet-to-dry dressing [62]. The study found SSI infections to be as high as 42.5% for primary closure and as low as 2.7% for delayed primary closure.

Yet, in a conflicting systematic review in meta-analysis in 2013 by Bhangu et al., delayed primary closure was not found to be superior to primary closure in preventing surgical site infection, which was contrary to the author's initial hypothesis [63]. Additionally, in a 2014 study of contaminated abdominal wounds, Siribumrungwong et al. found that SSI rates did not significantly differ between primary closure and delayed primary closure, while delayed primary closure increased length of stay by 1.6 days [64].

In a 2022 study, Sato *et* al. looked at delayed primary closure with negative pressure wound therapy (NPWT) in patients with contaminated abdominal wounds following open intra-abdominal surgery [65]. The study included 22 patients who had fascial closure with negative pressure wound therapy for 7 days followed by wound closure with 3–0 nylon. The results of the study demonstrated an incisional SSI rate of 4.5%. These results are in comparison to a similar study done by Frazee and colleagues, which found the SSI rate to be 4.2% for laparotomy wounds managed open with NPWT [66]. However, in this study, the median time to wound healing was 48 days, compared to the 7 days for definitive closure seen in the study completed by Sato et al. The results of these studies are limited by their single-center nature and small patient population.

The data supporting delayed primary closure is heterogenous, which limits the ability to make definitive recommendations regarding the utility of this wound closure technique. There are likely some benefits of delayed primary closure in SSI prevention, however, these benefits must be weighed against the physical and financial burdens of leaving the patient's wound open during the initial operation and performing an additional procedure when the wound is ready for closure.

Secondary Intention With or Without Negative Pressure Wound Therapy (NPWT)

It has been widely established that primary closure in contaminated emergent general surgery cases is associated with increased morbidity compared to delayed primary closure or closure by secondary intention due to higher SSI rates [67]. Due to this known risk, many surgeons elect to leave the wound open, allowing the wound to heal by secondary intention with either wet to dry dressing or NPWT. Wet-to-dry dressings are the historic standard for managing contaminated wounds, with supporting data dating back to the 1960s [68]. The moisture from these dressings works to improve angiogenesis, promote breakdown of dead tissue and fibrin, and improves the interactions between growth factors and their target cells [69]. Despite these benefits, the wet to dry technique can cause significant physical, psychological and financial burdens on patients as they wait for upwards of a month for wound healing [70] Additionally, this technique is not without complications. Condé-Green et al. found wound complications (including skin dehiscence, skin/fat necrosis, infection, and seroma) to be as high as 63.6% with gauze dressing [71].

NPTW was first developed for open wounds in the 1990s in an effort to promote greater wound healing while waiting for a wound to close via secondary intention [72, 73]. NPTW works to decrease wound edema, thereby minimizing seroma formation, promoting angiogenesis and nutrient delivery. Additionally, the negative pressure and dressing changes provide a mechanical wound debridement [74, 75]. A randomized control trial by Braakenburg et al. examined the differences between traditional wet-to-dry gauze dressings versus NPWT for management of open wounds and found that overall costs were similar, but patient comfort was much higher with the use of NPWT [9].

NPWT has benefits, however, it does not completely eliminate the risk of surgical site occurrences (SSOs). In a study of 158 patients undergoing emergency celiotomy, Regner et al. found a 22% incidence of adverse wound events in patients who underwent traditional open wound management with NPWT [76]. This study also highlighted the time and financial hardships placed on these patients, with a median duration of vac therapy to be 33.8 days following celiotomy.

Healing by secondary intention allows for spontaneous drainage of the wound and mitigates the risk of trapping bacteria and microbes, however, there are several undesirable consequences of healing by secondary intention, such as a longer healing time and increased costs associated with dressing or wound vac changes. Leaving wounds to heal by secondary intention with our without vac therapy must be patient specific with thoughtful intention by the surgeon.

Primary Closure with Incisional Negative Pressure Wound Therapy (Prevena)

More recently, primary wound closure with incisional negative pressure wound therapy has gained attention in surgical literature. A handful of the first studies were published in the 2000s as observational studies and case reports describing the use of the negative pressure wound therapy over a closed incision site [77, 78]. It is thought that this technique provides the benefits of NPWT with evacuation of edema and promotion of angiogenesis. Additionally, this technique allows for primary wound closure, which is cosmetically advantageous for the patient and reduces the need of costly dressing changes. One commercially available system is the Prevena (KCI, St. Paul, Minnesota), which is a single-patient use, portable negative pressure device that delivers up to − 125 mmHg of pressure to a closed wound.

The evidence behind incisional vac therapy is growing. A 2016 meta-analysis by Hyldig et al. found that the addition of NPWT to a closed wound significantly reduces both wound infections and seromas [10]. Subsequently, a 2020 meta-analysis of over 5000 patients by Shiroky and associates found that there was a 40% decrease in surgical site infections with incisional NPWT compared to patients who underwent primary closure with traditional dressings [79]. The use of negative pressure wound therapy with primary wound closure has been adopted and shown to be beneficial for a variety of wound closures including in emergency celiotomies [80], lower extremity vascular bypass [81], liver transplant [82], breast reconstruction [83], among many others [84].

Conclusions

SSI remain incredibly expensive and cumbersome to patients. Throughout the course of modern surgery, surgeons have utilized a myriad of different techniques to close surgical wounds in an effort to limit or eliminate post-operative infections. Several intra-operative techniques have been developed to help reduce this risk, however, there is no clear consensus on which technique provides the most benefit.

SSI prevention in EGS is a critical part of every operation due to the complexity of these patients and high likelihood of bacterial contamination. As discussed, pre-operative variables, such as maintaining euglycemia and normothermia, play a significant role in minimizing SSI risk. Other intra-operative techniques, such as wound protectors and irrigation, may limit exposure of subcutaneous tissues to bacterial pathogens. The choice of wound closure technique in EGS should be carefully selected based on the patient and operation performed. Incisional closure with negative pressure wound therapy may provide the most benefit for the patient with improved healing time and decreased SSI risk, however, more studies on this topic are needed. With increasing scrutiny being placed on surgical outcomes, including EGS cases, surgeons must continue to be at the forefront of infection prevention strategies.

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••Of major importance

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