A Multi-Disciplinary Review of the Potential Association between Closed-Suction Drains and Surgical Site Infection

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Abstract

Background: Despite the putative advantages conferred by closed-suction drains (CSDs), the widespread utilization of post-operative drains has been questioned due to concerns regarding both efficacy and safety, particularly with respect to the risk of surgical site infection (SSI). Although discipline-specific reports exist delineating risk factors associated with SSI as they relate to the presence of CSDs, there are no broad summary studies to examine this issue in depth.

Methods: The pertinent medical literature exploring the relationship between CSDs and SSI across multiple surgical disciplines was reviewed.

Results: Across most surgical disciplines, studies to evaluate the risk of SSI associated with routine post-operative CSD have yielded conflicting results. A few studies do suggest an increased risk of SSI associated with drain placement, but are usually associated with open drainage and not the use of CSDs. No studies whatsoever attribute a decrease in the incidence of SSI (including organ/space SSI) to drain placement.

Conclusions: Until additional, rigorous randomized trials are available to address the issue definitively, we recommend judicious use and prompt, timely removal of CSDs. Given that the evidence is scant and weak to suggest that CSD use is associated with increased risk of SSI, there is no justification for the prolongation of antibiotic prophylaxis to “cover” an indwelling drain.

THE BENEFITS OF SURGICAL DRAINAGE have been recognized since the time of Hippocrates [1–4]. As stated by Dougherty and Simmons in their extensive 1992 review of drainage tactics, drains serve to “prevent or evacuate accumulations of fluid or gas” [5]. Drains are placed commonly in the operative setting to prevent abscess or hematoma formation and are hypothesized to lead to surgical site infection (SSI) via external or luminal contamination and subsequent inward (retrograde) bacterial migration along the drain surface [6–8]. In contrast to passive (open) drains, closed-suction drains (CSDs) establish a pressure gradient between the wound and the external environment and empty into a sealed reservoir, and are believed to reduce the “risk of retrograde microbial contamination” [5]. Despite the putative advantages drains confer, the widespread utilization of post-operative drains has been questioned due to concerns regarding both efficacy and safety, particularly with respect to the risk of infection.

Likely as a result of this possible association, some surgeons prolong prophylactic antibiotic administration while drains remain in place (referred to commonly as “covering the drain”). However, in addition to the absence of sound

evidence supporting the practice, untargeted antibiotic administration alters patients’ normal flora and renders them susceptible to superinfection by resistant opportunistic organisms [5].

Although discipline-specific reports exist delineating risk factors associated with SSI as they relate to the presence of indwelling drains, there are no broad summary studies to examine this issue in depth. Given that the overall risk and pathogenesis of post-operative infection differs with each surgical discipline and anatomic location, herein we review the pertinent literature exploring the relationship between CSDs and SSI across multiple surgical disciplines.

Methods

A PubMed search of the English-language literature was performed using the search terms “surgical site infection,” “wound infection,” “drain,” or “risk factors.” Studies that evaluated drains as a potential risk factor for SSI or compared SSI rates among drain types or drainage tactics were eligible for inclusion. Studies in which only open drains were used

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were excluded. The references of relevant studies were evaluated similarly and included if appropriate.

Intra-abdominal

Hepatobiliary and pancreatic. Although less relevant in the laparoscopic era, drainage of Morison pouch following cholecystectomy (a clean-contaminated procedure) comprised the standard of care for a century since the procedure was first performed in 1882 [9, 10]. Despite the frequency with which it was performed, controversy existed as to whether or not routine post-operative drainage following cholecystectomy was beneficial [10–13]. Although initial studies focused on the relationship between open drains and post-operative morbidity [11, 12, 14], as CSDs increased in usage, their effect on morbidity was examined similarly.

Budd et al. [13] performed one of the first randomized controlled trials (RCT) to evaluate the effects of both open and CSDs on post-operative morbidity following open cholecystectomy. Three hundred patients were randomized to receive no drain, a Penrose drain to be removed on post-operative day (POD) three, or a CSD (Chaffin-Pratt sump), also to be removed on POD 3 if output was <50 mL on the previous day. Patients with acute cholecystitis, those who underwent common bile duct exploration, and those who underwent concomitant procedures such as appendectomy or liver biopsy were excluded. One patient in each drainage group developed peritonitis due to a undrained sub-hepatic collection. The overall SSI rate in this series was 2.3% (three in the Penrose group and four in the sump group); however, statistical analyses of these findings were not reported. Perioperative antibiotic administration was not discussed.

Lewis et al. [15] performed a similar RCT in which 494 patients who underwent elective open cholecystectomy were randomized to receive no drain (n=248), a Penrose drain (n=124) or a CSD (Hemovac®, [Zimmer, Inc., Warsaw, IN] n=122). Patients with acute cholecystitis or jaundice were excluded, as were patients who underwent concomitant common bile duct exploration or another gastrointestinal intervention. Drains were removed after 2 d if drainage was <20 mL/8 h. Cultures were obtained from the gallbladder lumen at the time of surgery, and from wound drainage if it developed. The overall SSI rate was ~3% (not different between drained and un-drained groups); 12% of gallbladder cultures were positive. Although *Streptococcus* spp. and *Enterobacteriaceae* were obtained most frequently from bile specimens, bile and wound drainage cultures were concordant in only three patients: *Staphylococcus* spp. were isolated most frequently from wound exudates. Of note, only 3% of patients received perioperative antibiotics in this series. Lewis et al. reported further a meta-analysis of 10 RCTs including 1,920 patients who underwent “simple, elective cholecystectomy,” the presence of a drain was found not to be a significant risk factor for SSI (odds ratio [OR] 1.4, 95% confidence interval [CI], 0.8–2.3; $p=0.77$). However, neither the type of drains used (open vs. closed), the microbiology of SSI, nor the antibiotic administration profiles were discussed in the meta-analysis.

Monson et al. [10] performed a RCT to examine the effect of post-operative CSDs on the incidence of sub-hepatic collection formation following open cholecystectomy. Patients were

randomized to undrained (n=58) or drained (n=54) groups. All patients received perioperative antibiotics. Patients assigned to the drained group received a ¼” diameter “high-pressure” (Portovac) suction drain, which was removed after 48 h or at the discretion of the surgeon. Seventy-two hours following surgery, all patients underwent abdominal ultrasonography to assess for the presence of sub-hepatic collection. Although there was a significantly higher incidence of collection in the drained group versus the undrained group (18% vs. 1.8%, $p<0.01$), “none of the collections was clinically significant” according to the authors [10], who offered two possible explanations for the increased prevalence of collections in the presence of a drain, including “failure of the drains to function” [10] (which they discounted given that all drains were patent upon removal), or a foreign-body reaction incited by the drain. The incidence of SSI was not different between groups (5% vs. 2%).

With the increased utilization of laparoscopic cholecystectomy, additional justifications for surgical drainage in the post-operative setting have been offered, including a potential reduction in shoulder pain by allowing for decompression of CO₂ insufflation [16]. Hawasli and Brown [9] performed a RCT of 100 patients undergoing elective laparoscopic cholecystectomy, who were randomized into drained and undrained groups. The SSI rate of zero in both groups argues against the need for drain placement following laparoscopic cholecystectomy, but the incidence of shoulder pain was not evaluated.

By contrast, in a meta-analysis of six RCTs by Gurusamy et al. [16] (one of which was the aforementioned study) comparing outcomes in patients who underwent laparoscopic cholecystectomy randomized to drained (n=361) or undrained (n=380) groups, the presence of a drain (including but not limited to CSDs) was associated with a significantly higher rate of SSI (OR 5.86, 95% CI 1.05–32.70).

As with drainage of Morison pouch following cholecystectomy, CSD of the sub-phrenic space following liver resection has been utilized traditionally in an effort to prevent the accumulation of bile, blood, or other fluids [10]. However, widespread application of CSD as standard practice has also been examined recently given concerns about potentially increased incidences of SSI, pulmonary complications, and post-operative pain.

Belghiti et al. [10] performed a RCT to examine the relationship between intra-peritoneal drains and post-operative complications following elective liver resection. Among 81 patients, those randomized to drainage (n=42) received two ¾” high-pressure CSDs in “the space left empty by removal of the liver parenchyma” [17]. All patients received 48 h of prophylactic parenteral antibiotics as well as prophylaxis of venous thromboembolic disease (VTE) with enoxaparin. When placed, drains were removed when output decreased below 100 mL/d. All patients underwent abdominal ultrasound on PODs 3 and 6. When noted, all fluid collections were drained and cultured. The authors reported a higher incidence of post-operative fever (>38.5° C after day two) in the drained vs. the undrained group (40% vs. 15%, $p=0.02$) but a higher incidence of abdominal pain requiring analgesia in the undrained group (2% vs. 18%, $p=0.05$). Furthermore, whereas there was a significantly higher incidence of sub-phrenic collection in drained patients (36% vs. 15%, $p=0.05$), the rates of hematoma, or serous, bilious, or infected

collections were not different. The authors pointed out that despite the presence of a drain, neither hematomas nor bile leaks were drained effectively, supporting the hypothesis that drains are “quickly surrounded by omentum and, thereby, isolated from the peritoneal cavity” [17]. Of interest, although the incidence of seroma following major resections was not different between groups, the authors reported a significantly higher incidence of seroma following minor resection in the drained group (32% vs. 4%, $p < 0.02$). This suggests that seroma accumulation was less a result of the procedure performed but instead was related to the presence of the drain itself (i.e., a foreign-body reaction). Culture of the collections drained percutaneously yielded *S. aureus* and *S. epidermidis* (skin flora, suggesting either contamination or infection ascending along the drain), as well as *Enterococcus faecalis* and *Escherichia coli*. However, neither cultures of the drain nor drain tubing were available for correlation.

In the RCT of 120 patients undergoing exploratory laparotomy for liver resection by Fong et al. [18], patients were randomized to drained or undrained groups. Drains were removed after a minimum of 4 d as long as drainage was non-bilious. The incidences of organ/space and superficial incisional SSI did not differ (5% vs. 0% and 3.3% vs. 6.7%, respectively). Furthermore, the presence of a drain was found not to predict any post-operative complication ($p = 0.7$).

In 2004, Petrowsky et al. [19] performed a meta-analysis of three RCTs (including the aforementioned two) evaluating prophylactic drainage following liver resection, which included 154 drained and 150 undrained patients. The presence of a drain was found not to be a significant risk factor for infected intra-abdominal collection (OR 2.83, 95% CI 0.82–9.71), biloma, or pulmonary complications.

Likewise, the placement of intra-abdominal drains following major pancreatic resection has comprised a routine aspect of this procedure since it was described originally in 1912 [20]. When used, drains are placed most commonly in the bilateral sub-hepatic spaces in proximity to the pancreatic and biliary anastomoses. Recent work has evaluated the necessity and safety of this practice. Conlon et al. [20] performed a RCT of 179 patients undergoing pancreatic tumor resection (139 pancreaticoduodenectomies, 40 distal pancreatectomies), in which patients were randomized at the time of surgery to drained ($n = 88$) or undrained ($n = 91$) groups. When utilized, 7 mm Jackson-Pratt CSDs (Bard Medical, Covington, GA, and others) were placed in the bilateral upper quadrants. Ninety-nine percent of patients received peri-operative antibiotics. The authors reported no differences in overall complication rates, the rates of incisional SSI (12.5% vs. 9.9%), organ/space SSI (6.8% vs. 6.6%), or intra-abdominal fluid collection (6.8% vs. 2.2%) in drained versus undrained patients. However, in aggregate, a higher incidence of intra-abdominal collections, abscesses, and fistulae (pancreatic and enterocutaneous) was observed in the drained group (21.6% vs. 8.8%, $p < 0.02$).

Although the majority of studies that evaluate CSDs following hepatobiliary and pancreatic procedures fail to identify the presence of a drain as a risk factor for SSI, none attribute any benefit to their use (Table 1). Furthermore, multiple studies suggest drains serve to incite a potentially detrimental foreign body reaction.

Hernia repair. Closed-suction drainage is utilized traditionally following open ventral incisional hernia repairs. Drains are suggested to reduce fluid and hematoma accumulation, factors believed to be implicated in hernia recurrence [21]. However, a Cochrane review published recently by Gurusamy et al. [21] found no published RCTs to exist for inclusion in the analysis. The literature for wound drainage following open incisional hernia repair consists entirely of non-rigorous observations.

As part of the 5,571 general surgery patients enrolled in the Israeli Study of Surgical Infection, Simchen et al. [22] reported a cohort of 1,487 patients who underwent hernia repair at multiple institutions (including inguinal, femoral, and ventral incisional hernia repairs; recurrent or incarcerated hernias were included). By uni-variate analysis, a trend toward a higher incidence of SSI was observed with the use of open- vs. CSDs (15.7% vs. 10.1%, $p = 0.115$), whereas the use of drains was significant by multi-variable analysis as an independent risk factor for SSI (relative risk [RR] 4.1, $p = 0.001$). However, there were differing temporal patterns of SSI incidence between drained and undrained groups; in the drained group, SSI was diagnosed through the 15th post-operative day, whereas SSI in the undrained group was apparent by the 9th post-operative day ($p < 0.001$). Also, Simchen et al. [22], reported a four-fold greater incidence of SSI in patients with drains in place for ≥ 4 d as compared to patients with drains indwelling for < 24 h, and a 13-fold greater incidence when compared to patients with no drains at all ($p =$ not reported). Neither the administration of antibiotics nor the placement of prosthetic mesh was analyzed, and the heterogeneity of hernia repair types and the inter-institutional variability in drain placement rates complicate the interpretation of these data.

Kaafarani et al. [23] performed a retrospective analysis of data collected prospectively from the Veterans' Affairs Ventral Incisional Hernia study, a RCT that compared the incidence of SSI following open vs. laparoscopic incisional hernia repairs. Surgical techniques were standardized, in that all open repairs received polypropylene mesh and all laparoscopic repairs received expanded polytetrafluoroethylene mesh (DualMesh[®], Gore Medical, Flagstaff, AZ). However, the decision to place a drain or not was at the discretion of the surgeon and occurred only during open repairs. The authors found that 79.0% of patients who ultimately developed a SSI had a drain in place, whereas only 49.3% of patients without SSI had a drain ($p = 0.021$). However, the duration of drainage was not different between SSI and non-SSI groups (5.0 ± 1.8 d vs. 4.6 ± 3.0 d, $p = 0.627$). Given that drain placement only occurred following open repairs and was discretionary, these findings are confounded by a higher degree of invasiveness (and therefore a higher risk of infection) in the open group.

There are no RCTs in the intra-abdominal surgery literature on which to base useful conclusions (Table 2). Furthermore, these studies fail to distinguish among different types of hernia repair, specifically those that include abdominal wall component separation, which involves the creation of substantially larger potential spaces.

Colorectal surgery

Prophylactic drainage is utilized routinely following colorectal anastomosis with intent to prevent post-operative leakage [24–29], to reduce its severity, or facilitate diagnosis

TABLE 1. CHARACTERISTICS OF HEPATOBILIARY AND PANCREATIC STUDIES EXAMINING THE RELATIONSHIP BETWEEN DRAINS AND SURGICAL SITE INFECTION

Authors	Year	Study type	Procedure	Drain type	Drained n (%)	Undrained n (%)	Duration of drainage	Perioperative antibiotic administration	SSI outcome	Cultures	Comments
Belghiti et al.	1993	RCT	Liver resection	CS x2	42 (51.9)	39 (48.1)	Removed when output <100 mL/d	100%	No difference between groups	Fluid collections detected with US on POD 3 and 6	Drained: increased incidence of fever, pain, and sub-phrenic collection
Budd et al.	1982	RCT	Open CCY	Open (Penrose) and CS (Chaffin-Pratt sump)	Open: 100 (33.3); Closed: 100 (33.3)	100 (33.3)	3 d ^b	–	Open: 3 (1.0); CS: 4 (1.3)	–	–
Conlon et al.	2001	RCT	Peri-pancreatic tumor resection	CS (Jackson-Pratt)	88 (49.2)	91 (50.8)	Discretion of surgeon	99%	Superficial: 12.5% vs. 9.9%, ^a p=NS; organ/space: 6.8% vs. 6.6%, ^a p=NS	–	–
Fong et al.	1996	RCT	Liver resection	CS (Jackson Pratt)	60 (50.0)	60 (50.0)	>4 d ^c	–	Organ/space: 5% vs. 0%, ^a p=NS; Superficial: 3.3% vs. 6.7%, ^a p=NS	–	Imaging for percutaneous collections only
Gurusamy et al.	2007	Meta-analysis	Laparoscopic CCY	CS ^d	361 (48.7)	380 (51.3)	–	–	Drain: OR 5.86 (95% CI 1.05–32.70) for superficial SSI; OR 3.41 (95% CI 0.14–84.53) for organ/space SSI	–	–
Hawasli et al.	1994	RCT	Laparoscopic CCY	CS (J Vac)	50 (50.0)	50 (50.0)	–	–	0	–	–
Lewis et al.	1990	RCT	Open CCY	Open (Penrose) and CS (Hemovac)	Open: 124 (25.0); closed: 122 (24.7)	248 (50.2)	2 d ^e	3%	3.3% vs. 2.4%, ^a p=NS	Gallbladder lumen and wound drainage	Cultures concordant in three patients
Monson et al.	1986	RCT	Open CCY	CS (Portovac)	54 (48.2)	58 (51.8)	2 d ^f	100%	5% vs. 2%, ^a p=NS	–	Drained: increased incidence of subhepatic collection
Petrowsky et al.	2004	Meta-analysis	Liver resection	CS	154 (50.7)	150 (49.3)	–	–	Drain: OR 2.83 (95% CI 0.82–9.71) for organ/space SSI	–	–

^aDrained vs. undrained.

^bIf output <50mL on the previous day.

^cIf drainage was non-bilious.

^dIncluding but not limited to closed-suction drains.

^eIf output <20 mL/8 h.

^fOr at the discretion of the surgeon.

CCY = cholecystectomy; CI = confidence interval; CS = closed-suction; NS = not significant; OR = odds ratio; POD = post-operative day; RCT = randomized controlled trial; SSI = surgical site infection; US = ultrasound.

TABLE 2. CHARACTERISTICS OF HERNIA REPAIR STUDIES EXAMINING THE RELATIONSHIP BETWEEN DRAINS AND SURGICAL SITE INFECTION

Authors	Year	Study Type	Procedure	Drain type	Drained n (%)	Undrained (%)	Duration of drainage	Perioperative antibiotic administration	SSI Outcome	Cultures	Comments
Kaafarani et al.	2010	Retrospective analysis of RCT	Laparoscopic vs. open hernia repair with mesh	-	41 (28.3; open repairs only)	104 (71.1)	Removed when output <25 mL/d	100%	Presence of a drain: 79.0% (SSI) vs. 49.3% (no SSI), $p=0.21$	-	Duration of drainage: 5.0 ± 1.8 d (SSI) vs. 4.6 ± 3.0 d (no SSI), $p=0.627$
Simchen et al.	1990	Cohort	Hernia repair	Open (60%) and CS (40%)	292 (19.6)	1195 (80.4)	-	-	Drain: RR 4.1, $p=0.001$; 15.7% (open) vs. 10.1% (CS), $p=0.115$	-	Overall SSI rate: 4.6%

CS=closed-suction; RCT=randomized controlled trial; RR=relative risk; SSI=surgical site infection.

of post-operative hemorrhage or anastomotic leakage [29]. Therefore, the majority of studies that evaluate the utility of CSDs following colorectal resection focus on whether CSDs affect the rates of either clinical or radiographic anastomotic leakage [25,27,30,31]. Studies that examine the effect of post-operative drainage on the incidence of incisional SSI following surgery of the colon and rectum are scarce by comparison [26,28,32,33].

An earlier prospective study to address this issue was reported by Simchen et al. [33], who included 403 patients undergoing colon surgery at a single institution in Jerusalem. All patients received peri-operative antibiotics, including 1–5 d of parenteral prophylaxis for elective cases, but bowel preparation was discretionary. The overall incidence of SSI in this series was relatively high (24.5%). Although the presence of an open drain was found to be an independent risk factor for SSI (OR 3.9, 95% CI 1.28–11.59), the presence of a CSD was not (OR 1.4, 95% CI 0.39–5.06). The duration of drainage was not discussed.

By contrast, Sagar et al. [28] performed a RCT of 145 patients undergoing emergent or elective colorectal resection with primary anastomosis to evaluate the relationships between the use of a drain and the duration thereof, and post-operative morbidity. Patients were randomized to receive no drain ($n=51$), or a CSD to be removed after 3 d ($n=47$), or 7 d ($n=47$). All patients received peri-operative parenteral antibiotics (range, 16 h–5 d) and mechanical bowel preparation. Three deaths were attributed to anastomotic dehiscence and sepsis, all of drained patients (two in the 7-d group). Furthermore, the incidence of “bad” outcomes including death and anastomotic dehiscence were higher in the seven-day drainage group compared with the un-drained group (12.8% vs. 2.0%, $p<0.02$). However, rates of complications including SSI (5.9% vs. 4.3% vs. 14.9%) and clinical or radiographic anastomotic leak did not differ among groups.

In a large RCT, Merad et al. [26] evaluated outcomes of 494 patients following colon surgery with pelvic anastomosis (distal to the sacral promontory) for either benign or malignant tumors, “specific or non-specific colitis,” or other benign disorders. Patients were randomized into drained and undrained groups, including strata for intra- and intra-peritoneal anastomosis. All patients received one dose of antibiotic prophylaxis and underwent mechanical and antibiotic bowel preparation. Drains were removed within 5 d post-operatively. Although this group did not report specific SSI rates, there was a 2.1% incidence of wound complications within 1 mo following hospital discharge. Complication rates and severity were identical between groups. The only complication attributed directly to the presence of a drain was one case of small bowel ulceration and enterocutaneous fistula.

Merad et al. [29] performed a similar RCT of patients undergoing elective colorectal resection with primary anastomosis at or above the sacral promontory. Patients were randomized to drained ($n=161$) or undrained ($n=156$) groups; drained patients were stratified by random allocation into open- (10 mm silicone tube) or CSD (14F, polyvinyl chloride) subgroups. Drains were removed by POD 5. All patients received one dose of antibiotic prophylaxis as well as mechanical and antibiotic bowel preparation. There were no differences in post-operative complication rates or severity between groups, nor were there differences in complication

rates between open- and CSD subgroups. One patient developed an intestinal fistula, again attributed to the presence of a drain.

Several meta-analyses address potential risk factors for SSI following colorectal surgery. Urbach et al. [24] performed a meta-analysis of four RCTs in which patients were randomized to prophylactic drainage ($n=223$) or no drainage ($n=188$) following colon or rectal anastomosis. Drains were left in place for up to 7 d. Although only two of the four included studies utilized CSDs, the presence of any drain did not confer additional risk of SSI (OR 1.70, 95% CI 0.87–3.30). Twenty clinical anastomotic leaks occurred in patients with drains in place (9.0%) compared with 12 in the undrained group (6.4%), only one of which resulted in the efflux of either purulent fluid or succus entericus via the drain itself, thus drawing into question the utility of leaving drains for the detection or treatment of anastomotic leakage.

In the meta-analyses of Jesus et al. [27] (re-published by Karliczek et al. [31]) of six RCTs including 1,140 patients underwent either prophylactic drainage ($n=573$) or no drainage ($n=567$) following colorectal surgery, multiple types of drains were included in the analysis (including but not limited to CSDs), as well as infra- and intra-peritoneal anastomoses. The presence of a drain was not associated with an increased rate of SSI (5.1% vs. 4.9%, 95% CI 0.60–1.76). No difference existed in the rates of clinical or radiological anastomotic dehiscence.

Pessaux et al. [34] performed a meta-analysis of RCTs (number unspecified) of 582 patients who underwent elective open sigmoidectomy for diverticulitis with primary anastomosis. The effects of both pre- and intra-operative risk factors on mortality; and overall, abdominal wall, intra-peritoneal, and extra-abdominal morbidities were assessed. The overall rate of SSI was 2.7%. Although post-operative drainage was not identified as a risk factor for any of the above-mentioned outcomes, the “absence of antimicrobial prophylaxis with ceftriaxone” was identified as the only risk factor for “abdominal” morbidity by multi-variable analysis (OR 2.0, 95% CI 1.1, –4.0; $p=0.003$). Additionally in a meta-analysis by Petrowsky et al. [19] of eight RCTs, including 717 drained and 673 undrained patients, the presence of a drain was not a significant risk factor for clinical leakage, SSI, or pulmonary complications.

In summary, the association between CSDs and SSI is well studied in colorectal surgery. In aggregate, the data fail to detect an increased incidence of SSI in the setting of closed-suction drainage, but also fail to attribute any specific benefit to the presence of a drain (Table 3).

Complicated appendicitis

Historically, the issue of trans-peritoneal drainage following appendectomy for perforated appendicitis has been controversial, particularly as it pertains to children. Some authors have suggested that, unlike in adult patients in whom intra-abdominal infections and drains are “walled off” effectively by omentum [35], this process is less effective in children [36]. Most early studies that examined the effects of open drains following appendectomy for complicated appendicitis demonstrate that drainage affords no added benefit in this setting, and is potentially detrimental.

Petrowsky et al. [19] performed a meta-analysis of four RCTs of 369 patients undergoing appendectomy for gangrenous or

perforated appendicitis, randomized to drained or undrained groups. The presence of a drain did not confer a significant risk of incisional or organ/space SSI (OR 1.75, 95% CI 0.96–3.19; OR 1.43, 95% CI 0.39–5.29, respectively).

The advent of laparoscopic appendectomy has raised concerns regarding a higher incidence of organ/space SSI therefrom, perhaps related to the acidic milieu of CO₂ pneumoperitoneum or dissemination of infectious material by high-pressure irrigation. Prophylactic drainage following laparoscopic appendectomy for complicated appendicitis has also raised concern [37]. To address this question, Allemann et al. [37] performed a case-control study of 130 patients who underwent laparoscopic appendectomy for complicated appendicitis (defined as “localized peritonitis, or the presence of purulence, fibrinous exudates, or abscess” [37]) with prophylactic drain placement and 130 matched un-drained control patients. However, the selection of an open- vs. a CSD was at the discretion of the surgeon (74% received an open drain, whereas 26% received a CSD). All patients received 5 d of standardized antibiotic therapy. All drains were removed 48 h after surgery if output was less than 50 mL/d. The authors reported a higher complication rate among drained patients (18.5% vs. 7.7%, $p<0.01$), as well as a higher incidence of abdominal wall abscess (3.1% vs. 0.8%, $p<0.01$). Although rates of specific complications were not reported for patients with open- versus CSDs, there was no overall difference in complication rates for these subgroups (Table 4).

Upper gastrointestinal surgery

Whether due to a higher incidence of diabetes mellitus, increased incisional dead space, prolonged operative times, or fat necrosis, the risk of SSI is increased for obese patients [38]. In a RCT performed by Shaffer et al. [38], 194 morbidly obese patients who underwent open gastric bypass (Roux-en-Y gastrojejunostomy with side-to-side jejunostomy) were randomized to receive either no drain ($n=92$) or a subcutaneous CSD ($n=102$). All patients received standardized antibiotic and VTE prophylaxis. One year into the study, the standard dose of cefazolin was increased from 1 g to 2 g. All drains were removed when drainage was less than 30 mL/24 h; none were irrigated. The overall SSI rate was 10.8%, not different between groups. Although *Staphylococcus* spp. and *Streptococcus* spp. were isolated most frequently from infected wounds when cultured (16/21), the prevalence and microbiology of drain contamination were not examined systematically. Neither the severity of infection nor the duration of post-operative hospital stay was different between groups. Not surprisingly, the increased cefazolin dose correlated temporally with a significant decrease in the incidence of SSI (Table 5).

Mixed-category series

Several mixed-category studies have been performed to identify risk factors for SSI, the majority of which are cohort studies rather than RCTs. In a classic early study to identify risk factors for SSI, Cruse and Foord [39] performed a cohort study of 23,649 patients undergoing clean, clean-contaminated, contaminated, and dirty neurosurgical, otorhinolaryngological, general surgical, urologic, peripheral vascular, plastic, orthopedic, and gynecologic procedures at a single Canadian institution. The overall SSI rate was 4.8%. Statistical analyses were not performed, but SSI rates in

TABLE 3. CHARACTERISTICS OF COLORECTAL STUDIES EXAMINING THE RELATIONSHIP BETWEEN DRAINS AND SURGICAL SITE INFECTION

<i>Authors</i>	<i>Year</i>	<i>Study type</i>	<i>Procedure</i>	<i>Drain type</i>	<i>Drained n (%)</i>	<i>Undrained n (%)</i>	<i>Duration of drainage</i>	<i>Perioperative Antibiotic Administration</i>	<i>Bowel Preparation</i>	<i>SSI outcome</i>	<i>Culture</i>	<i>Comments</i>
Jesus et al. and Karlczek et al.	2008, 2006	Meta-analysis	Colorectal surgery	Multiple types, including CS	573 (50.3)	567 (49.7)	-	-	-	5.1% vs. 4.9% ^a p=NS	-	-
Merad et al.	1999	RCT	Colonic surgery with pelvic anastomosis	CS (14F polyvinyl chloride)	247 (50.2)	245 (49.8)	≤5 d	100%	Mechanical and anti-septic: 100	-	-	Wound complication rate not different between groups (2.1%)
Merad et al.	1998	RCT	Colonic surgery with anastomosis at/above sacral promontory	CS (14F polyvinyl chloride: 82 (25.9) or open (10 mm silicon tube): 74 (23.3)	161 (50.8)	156 (49.2)	≤5 d	100%	Mechanical and anti-septic: 100	-	-	Wound complication rate not different between groups
Pessaux et al.	2003	Meta-analysis	Elective open sigmoidectomy with primary anastomosis	-	-	-	-	52.4%	Mechanical: 127 (21.8)	p=NS	-	-
Petrowsky et al.	2004	Meta-analysis	Colonic surgery	Open and CS	717 (51.6)	673 (48.4)	-	-	-	Drain: OR 1.41 (95% CI 0.87-2.29)	-	Clinical leakage rate not different between groups
Sagar et al.	1993	RCT	Emergent or elective resection with primary anastomosis	CS	94 (64.8)	51 (35.2)	3 d (n=47) or 7 d (n=47)	100%	Mechanical: 100	5.9% (no drain) vs. 4.3% (3 d) vs. 14.9% (7 d)	-	Higher incidence of death and anastomotic dehiscence in 7-day group
Simchen et al.	1984	Prospective cohort	Colonic surgery	Open and CS	Open: 165 (40.9); CS: 68 (16.9)	170 (42.2)	-	100%	At discretion of surgeon	Open: OR 3.9 (95% CI 1.28-11.59); CS: OR 1.4 (95% CI 0.39-5.06)	-	Overall SSI rate: 24.5%
Urbach et al.	1999	Meta-analysis	Colo-colonic or -rectal anastomosis	Closed suction in two of four studies	223 (54.3%)	188 (45.7%)	≥7 d	-	-	OR 1.70 (95% CI 0.87-3.30)	-	-

^aDrained vs. undrained.

CI= confidence interval; CS=closed-suction; NS=not significant; OR=odds ratio; RCT=randomized controlled trial; SSI=surgical site infection.

TABLE 4. CHARACTERISTICS OF STUDIES EXAMINING THE RELATIONSHIP BETWEEN DRAINS AND SURGICAL SITE INFECTION IN THE SETTING OF COMPLICATED APPENDICITIS

Authors	Year	Study type	Procedure	Drain type	Drained n (%)	Undrained n (%)	Duration of drainage	Perioperative antibiotic administration	SSI outcome	Cultures	Comments
Allemann et al.	2010	Case control	Laparoscopic appendectomy for complicated appendicitis	Open: 74%; CS: 36% ^b	130 (50.0)	130 (50.0)	48 h ^c	100%	Abdominal wall abscess: 3.1% vs. 0.8%, $p < 0.01$	-	Overall complication rate: 18.5% vs. 7.7%, ^a $p < 0.01$
Petrowsky et al.	2004	Meta-analysis	Open appendectomy for gangrenous/perforated appendicitis	-	SSI: 177 (48.0); organ/space infection: 137 (48.1)	SSI: 192 (52.0); organ/space infection: 148 (51.9)	-	-	Superficial SSI: 62.7% vs. 51.6%, ^a OR 1.75 (95% CI 0.96–3.19); organ/space infection: 27.0% vs. 19.2%, ^a OR 1.43 (95% CI 0.39–5.29)	-	-

^aDrained vs. undrained.^bDrain type selection was at the discretion of the surgeon.^cIf drainage was < 50 mL/d of clear fluid.

CI = confidence interval; CS = closed-suction; OR = odds ratio.

patients with clean undrained wounds vs. CSDs were 219/14,243 (1.53%) and 14/737 (1.90%), respectively ($\chi^2 p = 0.44$, had it been performed). Of note, whereas the SSI rate in the presence of a Penrose drain brought out via an adjacent "stab" incision was 2.4% (43/1,766), the incidence of SSI increased to 4.0% (52/1,299) when the drain was brought through the incision itself (OR 1.67, 95% CI 1.11–2.51, $p = 0.02$, had testing been performed). Furthermore, in the setting of open cholecystectomy ($n = 1,540$) (laparoscopic cholecystectomy had yet to be described), SSI rates in undrained, "stab drain," and "drain through incision" groups were 2.9%, 1.8%, and 9.9%, respectively. By contrast, there were no SSIs among post-cholecystectomy patients managed with a CSD. Antibiotic prophylaxis was not described. Although large, this study is heterogeneous and uncontrolled, which makes it largely of historical interest.

Twenty years later, as part of the aforementioned Israeli Study of Surgical Infections, Siegman-Igra et al. [40] analyzed potential risk factors for SSI when different portions of the gastrointestinal tract are entered during surgery (i.e., stomach, small bowel, and colon). Of the 813 patients included, 21.6% developed a SSI. When analyzed separately, SSI rates for colon, small bowel, and gastric procedures were 25.4% (115/452), 21.4% (25/117), and 14.8% (36/244), respectively ($p < 0.005$). Given that patients with active infections (dirty wound classification) were included in this series, only 505/718 (70.3%) potential candidates for antimicrobial prophylaxis (as opposed to therapy) actually received it. Although the presence of a CSD did not confer an increased risk of infection (OR 1.1, 95% CI 0.5–2.4), open drainage was a risk factor for SSI in all areas of the GI tract (OR 2.0, 95% CI 1.4–2.9, $p = 0.01$). However, antimicrobial prophylaxis was non-uniform and overall SSI rates were high, both of which confound the drawing of any conclusions from these data.

To identify potential risk factors for SSI in Bolivia, Soletto et al. [41] performed a cohort study of 372 patients who underwent 376 mixed-category (clean, clean-contaminated, and contaminated general surgery, colorectal, gynecologic, and orthopedic) procedures at a single public hospital. Drains were placed in 82 procedures (21.8%). However, neither the types of drain nor their indications were disclosed. The overall incidence of SSI was 12%. Prophylactic antibiotic administration occurred for only 48.4% of patients. *Enterococcus faecalis* (23.3%) and *S. aureus* (20.9%) were the most frequent wound isolates in the setting of SSI. The American Society of Anesthesiologists score, the duration of the surgical procedure, wound classification, and the presence of a drain (adjusted OR 1.09, 95% CI 1.11–3.52) were identified as independent risk factors for SSI. Drain microbiology was not reported. Similar to the above-mentioned studies, study heterogeneity, the low rate of antimicrobial prophylaxis, and lack of defined criteria for drain placement limit the utility of the study.

Lilani et al. [42] performed an observational study of 190 patients undergoing clean and clean-contaminated procedures at two hospitals in Mumbai. In this series, 17/190 patients were diagnosed with SSI (8.95%). Wound classification, the duration of preoperative hospital stay, and the duration of surgery were associated with the development of SSI. Furthermore, SSI rates were higher in drained versus undrained patients (22.41% vs. 3.03%, $p < 0.01$). The most common isolates from SSIs were *S. aureus* and *Pseudomonas aeruginosa*.

TABLE 5. CHARACTERISTICS OF UPPER GASTROINTESTINAL STUDIES EXAMINING THE RELATIONSHIP BETWEEN DRAINS AND SURGICAL SITE INFECTION

Authors	Year	Study Type	Procedure	Drain Type	Drained n (%)	Undrained n (%)	Duration of drainage	Perioperative antibiotic administration	SSI outcome	Cultures	Comments
Shaffer et al.	1987	RCT	Open gastric bypass	CS (subcutaneous)	102 (52.6)	92 (47.4)	Removed when output <30 mL/24 h	100%	10.8% vs. 10.9%, ^a p = NS	Infected wounds (16/21 cultured): <i>Staphylococci</i> and <i>Streptococci</i> most frequently isolated organisms	Temporal correlation between increase in cefazolin dose and decrease in incidence of SSI

^aDrained vs. undrained.

CS=closed-suction; NS=not significant; RCT=randomized controlled trial; SSI=surgical site infection.

However, as is commonplace in this literature, neither the profile of antibiotic prophylaxis, the rationale for drain placement, drain microbiology, nor the type of drain used was disclosed.

Arabshahi et al. [43] performed a prospective observational study of 910 patients undergoing general surgical procedures in four university-affiliated hospitals in Iran to identify risk factors for SSI. The overall SSI rate was 8.4%. The presence of a drain was identified as a risk factor for SSI (OR 2.2, 95% CI 2.0–2.4, $p < 0.0001$), as well as age ≥ 60 years, diabetes mellitus, tobacco smoking, obesity, and anesthesia and operative times. This study is limited by the same factors as the study of Lilani et al. [42].

Sangrasi et al. [44] performed a prospective study of 460 patients undergoing general surgical procedures at a university-affiliated hospital in Pakistan to quantify the incidence of and identify risk factors for SSI. The overall SSI rate was 13.0%. The incidence of SSI was significantly higher in drained patients compared with undrained patients (18.7% vs. 10.1%, $p < 0.05$). Age ≥ 50 years and wound class were also identified as risk factors for SSI. As with the aforementioned two studies [42, 43], neither the type of drain used, the rationale for drain placement (or lack thereof), the antibiotic administration profile, nor the microbiology of SSI was discussed.

In a large, multi-center study by Utsumi et al. [45] that was designed to evaluate age as a potential risk factor for SSI, 12,015 patients underwent open procedures including colorectal resection, appendectomy, gastrectomy, and cholecystectomy. The overall rate of SSI was 12.2%. The use of a drain was a risk factor for SSI following cholecystectomy (OR 5.24, 95% CI 1.22–22.45, $p = 0.026$), appendectomy (OR 3.21, 95% CI 2.02–5.13, $p < 0.001$), colectomy (OR 2.13, 95% CI 1.60–2.82, $p < 0.001$), and rectal resection (OR 3.12, 95% CI 1.67–5.84, $p < 0.001$), but not gastrectomy. Interestingly, antibiotic prophylaxis was not found to be protective against SSI, whereas the administration of multiple doses of antibiotics was found to be a risk factor for SSI following gastrectomy (OR 1.77, 95% CI 1.36–2.29, $p < 0.001$), both of which observations call into question the veracity of the authors' findings.

Baier et al. [46] reported a RCT of 200 patients undergoing laparotomy for procedures including esophageal, gastric, and colonic operations (patients who underwent herniorrhaphy and organ transplantation were excluded specifically, so as to ensure relative homogeneity of the subject population). Patients were randomized into drained ($n = 100$) and undrained ($n = 100$) groups. The overall SSI rate was 9.5%. Of these, 47.4% were in the un-drained group, whereas 52.6% were in the drained group ($p = \text{NS}$).

Pessaux et al. [47] performed a meta-analysis of three RCTs designed originally to examine the efficacy of antibiotic prophylaxis in non-colorectal abdominal surgery. Intra-abdominal and "intraparietal" (subcutaneous) drainage were considered as potential risk factors, although no distinction was made between "blade, tube, or other" [47]. Of the 4,718 patients included in the analysis, 191 patients (4.0%) were diagnosed with SSI. By multi-variable analysis, abdominal drainage was identified as a risk factor for SSI (OR 2.15, 95% CI 1.30–3.57). However, although multi-variable analysis failed to identify "parietal" drainage as a risk factor for SSI (including superficial and deep incisional SSIs tabulated in aggregate), it was found to be a risk factor for superficial incisional SSI only (OR 2.27, 95% CI 1.22–4.20). Of note,

“cutaneous closure” was protective against SSI in this series, which is perhaps surprising given the traditional practice of allowing wounds at risk for SSI to heal by secondary intention or delayed primary closure.

Rarely do studies of type seek to address the question of what constitutes a “safe” duration of drainage. Vilar-Compte et al. [8] performed one of the few studies to examine this issue effectively. The authors examined single-institution SSI rates over a range of clean, clean-contaminated, contaminated, and dirty surgical procedures. Among 3,372 consecutive procedures performed at a tertiary-care cancer hospital, the overall rate of SSI was 9.3%. Whereas the presence of a drain was not a risk factor for SSI by logistic regression analysis (OR 1.50, 95% CI 0.90–2.42, $p=0.11$), SSI risk was found to increase after 5–16 d and >16 d of surgical drainage (OR=1.84, 95% CI 1.02–3.31; OR=2.14, 95% CI 1.00–4.58; $p=0.04$, respectively). The most common organisms cultured from wounds in this series included *E. coli*, *S. aureus*, coagulase-negative *Staphylococcus*, *Pseudomonas* spp., enterococci, and other Enterobacteriaceae.

In the cohort study of Manian et al. [48] of 73,154 surgical procedures including orthopedic, gastrointestinal, vascular, gynecological, and spinal operations, the authors reported a univariate association between the presence of a surgical drain for >1 day and methicillin-resistant *S. aureus* (MRSA) SSI, although this relationship was non-significant by multivariable regression analysis.

Although cohort studies of varying size of gastrointestinal procedures suggest an association between CSDs and SSI, most are of poor quality; RCTs that assess this relationship are lacking (Table 6). Furthermore, mixed-category series such as these group together procedures that may have differing SSI profiles, thereby confounding their analysis.

Obstetrics and gynecology

Drains are placed following gynecologic procedures for reasons similar to those following other intra-peritoneal procedures, including the evacuation of hematoma [49] or seroma with intent to decrease the risk of infection [50]. Both obesity [51, 52] and the depth of subcutaneous tissue [51] have been demonstrated to correlate directly with SSI following gynecologic procedures. In addition, there is increased risk of SSI given entry into the female (clean-contaminated) reproductive tract.

Magann et al. [53] examined the effect of subcutaneous (i.e., multi-layer) sutured wound closure vs. subcutaneous drain placement on outcomes following cesarean section. Patients with ≥ 2 cm subcutaneous fat undergoing non-emergent cesarean section were randomized preoperatively to receive either simple skin closure only ($n=205$), closure of the subcutaneous tissues with a continuous absorbable suture ($n=191$), or a subcutaneous 7 mm Jackson-Pratt CSD ($n=194$). Although patients who required prophylaxis for Group B *Streptococcus* or bacterial endocarditis and those diagnosed with chorioamnionitis received an antibiotic preoperatively, all others received parenteral antibiotics upon umbilical cord clamping. No differences in the incidence of “wound disruption” (defined as “a hematoma, seroma, or infection that required the incision to be opened, evacuated, or irrigated and debrided” [53]) occurred among groups, whether each complication was analyzed individually or collectively.

Cardosi et al. [51] performed a similar, three-armed, RCT of 222 women with ≥ 3 cm of subcutaneous fat who underwent elective pelvic surgery via a lower midline incision, in which patients were randomized to subcutaneous CSD (15 F Jackson-Pratt) placement ($n=67$), suture re-approximation of Camper fascia ($n=78$), or skin closure only ($n=77$). All patients received 1–2 doses of parenteral antibiotic prophylaxis. Drains were removed when output decreased to 50 mL/24 h after a maximum of 4 d post-operatively. The overall wound complication rate was 15.3%, with no differences among groups (control 15.6%, suture 12.8%, drain 17.9%, $p=0.70$). The rates of cellulitis and wound disruption were also not different among groups (5.2% vs. 3.8% vs. 1.5%, $p=0.42$, and 11.7% vs. 7.7% vs. 14.9%, $p=0.60$, respectively). Furthermore, post-operative drainage was associated with a RR for wound complication of 1.15 (95% CI 0.55–2.39) and wound disruption of 1.28 (95% CI 0.55–2.95). Of note, body mass index (BMI) and depth of subcutaneous tissue were independent predictors of overall wound complications and wound disruption, respectively.

In Patsner’s [54] prospective, non-randomized series of 120 consecutive patients who underwent radical abdominal hysterectomy with bilateral pelvic lymphadenectomy for stage IB cervical cancer, the first 60 patients received bilateral Jackson-Pratt drains, whereas the remaining 60 were not drained. Drains were removed when output decreased below 100 mL/24h. All patients received antibiotic prophylaxis and underwent bilateral pelvic lymphadenectomy. Six patients in the drainage group (10%) developed a post-operative pelvic infection, defined as “a sustained temperature elevation above 101.5° F on or after post-operative day two accompanied by leukocytosis, pelvic tenderness with or without discharge, and in the absence of an extra-pelvic source of infection” [54], compared with two patients in the non-drainage group (3.3%). Statistical analysis was not performed. All patients underwent pelvic ultrasonography six weeks post-operatively to assess for occult lymphocele formation. Although there were no incidents of pelvic abscess in either group, four patients in the drained group developed a unilateral lymphocele, vs. zero in the undrained group. The authors hypothesized that “prolonged CSD may predispose patients to both pelvic infection and ‘lymphocyst’ formation by the presence of a foreign body” [54].

Benedetti-Panici et al. [49] performed a RCT of 137 consecutive patients to assess the effectiveness of drainage following pelvic or pelvic/aortic lymphadenectomy for gynecologic (ovarian, cervical, and endometrial) malignant neoplasia at two institutions in Rome. Patients assigned to the drained group ($n=68$) received two retroperitoneal low-pressure CSDs, which were removed when output was less than 50 mL/d. All patients received antibiotic and VTE prophylaxis. All patients at one of the two institutions ($n=110$) underwent weekly pelvic and abdominal ultrasounds to assess for the presence of lymphocele or ascites. Post-operative complications occurred more frequently in the drainage group (43% vs. 22%; RR 1.96, 95% CI 1.16–2.23, $p=0.01$), including lymphocele (58% vs. 25%, $p=0.0004$). Forty percent of patients in the drained group diagnosed with a lymphocele received that diagnosis with a drain still in place. No differences in the incidences of fever, pelvic abscess, or wound dehiscence occurred between groups. Not surprisingly, the incidence of asymptomatic free abdominal fluid was higher in

TABLE 6. CHARACTERISTICS OF MIXED-CATEGORY INTRA-ABDOMINAL SURGERY STUDIES EXAMINING THE RELATIONSHIP BETWEEN DRAINS AND SURGICAL SITE INFECTION

Authors	Year	Study Type	Procedure	Drain Type	Drained N (%)	Undrained n (%)	Duration of drainage	Perioperative Antibiotic Administration	SSI outcome	Cultures	Comments
Arabashi et al.	2006	Cohort	-	Not disclosed	310 (33.8)	608 (66.2)	-	-	Drain: OR 2.2 (95% CI 2.0-2.4, p<0.0001)	-	Overall SSI rate: 8.4%
Baier et al.	2010	RCT	Clean, clean-contaminated, contaminated, dirty	CS (Redon; subcutaneous)	100 (50.0)	100 (50.0)	48 h	-	52.6% vs. 47.4% ^a p=NS	100%	Overall SSI rate: 9.5%
Cruse et al.	1973	Cohort	Clean, clean-contaminated, contaminated, dirty	Open (Penrose) and CS	Penrose through adjacent stab incision: 1,766 (9.8); Penrose through wound: 1,299(7.2); CS: 737 (4.1)	14,243 (78.9)	-	-	1.90% (CS) vs. 1.53% (un-drained), p=0.44; 2.4% (Penrose adjacent to wound), 4.0% (Penrose through wound)	-	
Lilani et al.	2005	Cohort	Clean, clean-contaminated	Not disclosed	-	-	-	-	22.41% vs. 3.03% ^a p=0.00016	82.4% of SSI culture positive; <i>S. aureus</i> and <i>P. aeruginosa</i> most frequently isolated	190 patients included; Overall SSI rate: 8.95%
Manian et al.	2003	Retrospective cohort	-	Not disclosed	-	-	-	98%	MRSA SSI risk (vs. non-MRSA SSI) after drain > 24h: OR 1.9 (95% CI 0.92-3.89, p=0.78)	100%, MRSA, MSSA, and gram-negative bacilli most frequently isolated	Goal of study to determine RF for MRSA SSI; 73,154 patients included; overall SSI rate: 0.4%
Pessaux et al.	2003	Meta-analysis	Clean, clean-contaminated, contaminated	Not disclosed	Abdominal: 1,525 (32.3); "parietal": 832 (17.6)	2,361 (50.0)	-	-	Abdominal drainage for SSI: OR 2.15 (95% CI 1.30-3.57); "parietal" drainage for superficial SSI: OR 2.27 (95% CI 1.22-4.20)	100%	Overall SSI rate: 4.0%; cutaneous closure protective against SSI
Sangrasi et al.	2008	Cohort	Clean, clean-contaminated, contaminated, dirty	-	155 (33.7)	305 (66.3)	-	-	18.7% vs. 10.1% ^a p<0.05	-	Overall SSI rate: 13.0%
Siegmán-Igra et al.	1993	Cohort	Clean-contaminated, contaminated, dirty		Open: 343 (43.6); CS: 63 (8.0)	380 (48.3)	-	70.3%	CS: OR 1.1, (95% CI 0.5-2.4); open: OR 2.0 (95% CI 1.4-2.9, p=0.01)	-	Overall SSI rate: 21.6%

(continued)

TABLE 6. (CONTINUED)

Authors	Year	Study Type	Procedure	Drain Type	Drained N (%)	Undrained n (%)	Duration of drainage	Perioperative Antibiotic Administration	SSI outcome	Cultures	Comments
Soleto et al.	2003	Cohort	Clean, clean-contaminated, contaminated, dirty	Not disclosed	82 (21.8)	294 (78.2)	-	48.4%	Drain: adjusted OR 1.09 (95% CI 1.11–3.52)	75.6% of SSI culture positive; <i>E. faecalis</i> and <i>S. aureus</i> most frequently isolated	Overall SSI rate: 12%
Utsumi et al.	2010	Cohort	-	-	-	-	-	>80%	Drain following CCY: OR 5.24 (95% CI 1.22–22.45, p=0.026); appendectomy: OR 3.21 (95% CI 2.02–5.13, p<0.001); colectomy: OR 2.13 (95% CI 1.60–2.82 p<0.001); rectal resection: OR 3.12 (95% CI 1.67–5.84 p<0.001); gastrectomy: p=NS	-	12,015 patients included; overall SSI incidence: 12.2%; antibiotic prophylaxis not protective against SSI; multiple antibiotic doses a risk factor for SSI following gastrectomy
Vilar-Compte et al.	2000	Cohort	Clean, clean-contaminated, contaminated, dirty	Not disclosed	-	-	-	-	Drain: OR 1.50 (95% CI 0.90–2.42, p=0.11); Drain >5 and <16 d: OR=1.84 (95% CI 1.02–3.3, p=0.04); drain >16 d: OR=2.14 (95% CI 1.00–4.58, p=0.04)	<i>E. coli</i> , <i>S. aureus</i> , coagulase-negative <i>Staphylococci</i> most frequently isolated	3,372 patients included; overall SSI rate: 9.3%

^aDrained vs. undrained.

CCY=cholecystectomy; CI=confidence interval; CS=closed-suction; MRSA=methicillin-resistant *Staphylococcus aureus*; MSSA=methicillin-sensitive *Staphylococcus aureus*; NS=not significant; OR=odds ratio; RCT=randomized controlled trial; RF=risk factor; SSI=surgical site infection.

the undrained group (36% vs. 18%, $p=0.03$). As did Patsner, the authors hypothesized that the higher incidence of lymphocele in the drained group was due to the presence of a drain, "which may have acted as a foreign body" [49].

A meta-analysis by Gates et al. [50] of six RCTs including 1,581 females, comparing outcomes following cesarean section with or without post-operative drain placement, demonstrated no difference in SSI rates between groups (RR 0.90, 95% CI 0.58–1.38). Three studies included in this analysis also compared drainage with suture approximation of the subcutaneous fat, and also demonstrated no difference with respect to the rates of SSI (RR 0.70, 95% CI 0.42–1.44). However, multiple types of drains were utilized, not solely CSDs. Neither antibiotic administration, the microbiology of infection, nor overall SSI rates were discussed.

Therefore, evidence regarding the relationship between CSDs and SSI in the obstetrics/gynecology literature is conflicting (Table 7). Although drains are implicated repeatedly in the incidence of lymphocele, potentially due to induction of a foreign body reaction by the drain, there exists scant evidence to affirm this proposition.

General vascular surgery

Analyses of the association between drains and SSI in the vascular surgery literature are limited and offer conflicting results. Derksen et al. [55] performed a retrospective review of 140 consecutive patients who underwent common femoral endarterectomy to identify potential risk factors for SSI. The decision to place a drain was at the discretion of the surgeon and was independent of blood loss or operative duration. All drains were removed 24 h after surgery. In addition to a history of previous ipsilateral groin surgery, the presence of a surgical drain was an independent risk factor for SSI by multi-variable logistic regression analysis (OR 13.46, 95% CI 1.61–112.51 $p=0.016$), albeit with a wide CI. However, given that drain placement was discretionary, selection bias may be present.

Oz et al. [56] performed a RCT of 80 patients undergoing radial artery harvest prior to coronary artery bypass grafting, who were randomized to drained or undrained groups. The forearm fascia was left open in both groups so as to avoid compartment syndrome, and when used, drains were placed subcutaneously. An increase in patient discomfort was noted in the drained group, but there were no differences in the incidence of hematoma, neurological deficits, or infection rates. Therefore, although further studies are required, there is no firm evidence that drains confer additional SSI risk in the setting of general vascular surgery (Table 8).

Thyroid and parathyroid surgery

Cervical endocrine surgery is clean surgery with a low risk of infection [57], but wound drains are placed typically to avoid hematoma and resultant airway compromise [57, 58]. However, evidence regarding their association with SSI is conflicting.

In a retrospective review of 606 thyroidectomy and parathyroidectomy procedures in 582 patients by Tabagchali et al. [58], all patients underwent routine post-operative CSD placement during the first six years of the 14-year study period (drained group; $n=134$). However, in the last eight years of the study, drain placement was discretionary ("selective"

TABLE 7. CHARACTERISTICS OF OBSTETRICS AND GYNECOLOGY STUDIES EXAMINING THE RELATIONSHIP BETWEEN DRAINS AND SURGICAL SITE INFECTION

Authors	Year	Study Type	Procedure	Drain Type	Drained n (%)	Undrained n (%)	Duration of drainage	Perioperative antibiotic administration	SSI outcome	Cultures	Comments
Benedetti-Panici et al.	1997	RCT	Pelvic or pelvic/aortic lymphadenectomy	CS	68 (49.6)	69 (50.4)	Removed when output <50 mL/24 h	100%	Pelvic abscess: 0.0% vs. 3% ^a $p=NS$	-	Postoperative complications: 43% 22% ^a RR 1.96 (95% CI 1.16–2.23, $p=0.01$)
Cardosi et al.	2006	RCT	Pelvic surgery, ≥ 3 cm subcutaneous fat	CS (Jackson-Pratt)	67 (30.2)	155 (69.8)	Removed when output <50 mL/24 h ^b	100%	Cellulitis: 1.5% vs. 4.5% ^a $p=NS$; abscess: 6.0% vs. 2.6% ^a $p=NS$ Drainage: RR 0.90 (95% CI 0.58–1.38) "Wound disruption": 9.7% vs. 6.8% ^a $p=NS$	-	1,581 women included
Gates et al.	2010	Meta-analysis	Cesarean section	Not disclosed	-	-	-	-	-	-	-
Magann et al.	2002	RCT	Cesarean section, ≥ 2 cm subcutaneous fat	CS (Jackson-Pratt)	194 (32.9)	396 (67.1)	-	100%	-	-	-
Patsner	1995	Cohort	Radical abdominal hysterectomy with bilateral pelvic lymphadenectomy	CS (Jackson-Pratt; bilateral)	60 (50.0)	60 (50.0)	Removed when output <100 mL/24 h	100%	10.0% vs. 3.3% ^a $p=0.27$	-	-

^aDrained vs. undrained.

^bMaximum of 4 d.

CI = confidence interval; CS = closed suction; NS = not significant; RCT = randomized controlled trial; RR = relative risk.

TABLE 8. CHARACTERISTICS OF GENERAL VASCULAR SURGERY STUDIES EXAMINING THE RELATIONSHIP BETWEEN DRAINS AND SURGICAL SITE INFECTION

Authors	Year	Study Type	Procedure	Drain Type	Drained n (%)	Undrained n (%)	Duration of drainage	Perioperative antibiotic administration	SSI outcome	Cultures	Comments
Derkson et al.	2009	Retrospective review	Common femoral endarterectomy	CS	92 (65.7) ^b	48 (34.3)	1 d	100%	20.7% vs. 2.1%, ^a p=0.003; OR 13.46 (95% CI 1.61–112.51)	-	Venous bovine or prosthetic Dacron patch
Oz et al.	2006	RCT	Radial artery harvest	CS (Hemovac)	40 (50.0)	40 (50.0)	1 d ^c	-	2.5% vs. 2.5%, ^a p=NS	-	-

^aDrained vs. undrained.^bDrains were placed at the discretion of the surgeon.^cIf "drainage was low."

CI = confidence interval; CS = closed-suction; NS = not significant; OR = odds ratio; RCT = randomized controlled trial; SSI = surgical site infection.

group"; n=472). An overall SSI rate of 1% was observed, being 1.5% in the drained group and 0.8% in the "selective" group. All patients with SSI had CSDs emplaced ($p < 0.05$). However, there were three cases of airway compromise (0.5%), all of which occurred in patients with drains. Both of these findings are due potentially to selection bias given the lack of specified criteria for drain placement in the later years of the study.

By contrast, in the RCT by Schoretsanitis et al. [59], there was no difference in SSI rates among 200 patients undergoing elective thyroidectomy randomized to either drained (n=100) or un-drained (n=100) groups (4% vs. 2%, $p = \text{NS}$). Although drains were "removed 24 to 48 h post-operatively if the quantity of the drainage was less than 25 mL/24 h" [59], there was no comment on drain removal under circumstances of persistent drainage. Post-operative pain scores were significantly higher in patients who were drained (6.1 ± 1.2 vs. 3.5 ± 1.6 points, visual analog scale, $p = 0.001$).

Samraj et al. [57] performed a meta-analysis of 11 RCTs including 1,386 patients that compared outcomes following thyroid surgery with and without routine post-operative CSD placement. Patients who underwent parathyroid surgery or lateral neck dissection were excluded from the analysis due to the potential for increased tissue dissection. No differences were identified between groups with respect to either re-operation (RR 2.12, 95% CI 0.77–5.83) or SSI (RR 1.60, 95% CI 0.53–4.83) rates. Drains are therefore not a risk factor for infection in thyroid or parathyroid surgery, but neither do they confer any advantage by their placement (Table 9).

Skin and soft tissue surgery

Breast surgery. Although breast procedures are typically clean cases with a low risk of infection, the breast surgery literature contains among the most rigorous studies in exploration of the relationships between the presence and duration of CSDs and SSI. Not unsurprisingly, despite the relative plethora of RCTs, the results are also in conflict.

Corion et al. [60] performed a RCT in which 107 patients undergoing bilateral reduction mammoplasty were randomized to either drained (n=55) or undrained (n=52) groups. Antibiotic prophylaxis was not administered. Drains were removed when output decreased below 20 mL/d. There was no significant difference in complication rates between drained and undrained groups (40% vs. 23%, $p = 0.092$), including eight infections in the drained group (14.5%) and three in the undrained group (5.8%). Statistical testing of the difference in infection rates per se was not discussed ($p = 0.21$ by two-tailed Fisher exact test, had the authors done so), likely reflecting a Type II error.

Collis et al. [61] performed a study similar to the above-mentioned RCT, with the exception that all patients underwent unilateral drain placement following bilateral reduction mammoplasty and were randomized instead with respect to drain laterality. Drains were removed when output decreased below 30 mL/24 h. A higher rate of "abscess drainage" in the drained breast (2.0% vs. 0.7%) and "minor infection" in the undrained breast (3.3% vs. 2.7%) were observed, as well as one case of bilateral "major infection" (0.7%). However, the definitions of "minor" and "major" infection were not clear, nor were statistical analyses offered. No comment was made on antibiotic administration or the microbiology of infection.

TABLE 9. CHARACTERISTICS OF THYROID AND PARATHYROID STUDIES EXAMINING THE RELATIONSHIP BETWEEN DRAINS AND SURGICAL SITE INFECTION SURGERY

Authors	Year	Study type	Procedure	Drain type	Drained n (%)	Undrained n (%)	Duration of drainage	Perioperative antibiotic administration	SSI outcome	Cultures	Comments
Samraj et al.	2008	Meta-analysis	Thyroid surgery	CS	698	688	-	-	Drain: RR 1.60 (95% CI 0.53–4.83)	-	Reoperation rate not different between groups
Schorensanitis et al.	1998	RCT	Thyroidectomy	CS	100 (50.0)	100 (50.0)	24–48 h ^b	0%	4.0% vs. 2.0% ^a , p = NS	-	Postoperative pain score: 6.1 ± 1.2 vs. 3.5 ± 1.6 points, ^a p = 0.001
Tabaqchali et al.	1999	Retrospective review	Thyroidectomy and parathyroidectomy	CS	325 (53.6; 134 in "drain" group, 191 in "selective" group)	281 (46.4; all in "selective" group)	-	-	1.5% ("drain") vs. 0.8% ("selective"), p < 0.05	-	All patients with SSI had drains placed; 3 cases of airway compromise, all in patients with drains

^aDrained vs. undrained.^bIf output < 25 mL/24 h.

CI = confidence interval; CS = closed-suction; NS = not significant; RCT = randomized controlled trial; RR = relative risk; SSI = surgical site infection.

The relationship between post-operative drains and SSI has also been examined in the setting of breast oncologic surgery. In a case-control study of 77 patients with SSI and 221 matched control patients following a variety of procedures (e.g., local excisions; radical, modified-radical and skin-sparing mastectomies; axillary dissections) by Vilar-Compte et al. [62], the risk of SSI was found to increase after ≥ 19 d of drainage (OR 2.9, 95% CI 1.5–4.6 p=0.001). The reported rate of SSI, 38.0%, was considerably higher than reported typically. However, conversion of CSD systems to open drainage was commonplace in the outpatient setting, which could explain the high incidence of SSI. The bacteria isolated most frequently from infected incisions, in descending order, were *P. aeruginosa*, *Serratia* spp., *S. aureus*, and *S. epidermidis*. The authors attributed the high incidence of gram-negative pathogens to "high rates of flap necrosis and poor compliance with infection control practices" [62], an admission that calls into question the applicability of their results.

In a prospective cohort study by Felipe et al. [7] that compared SSI rates among 354 females who underwent breast cancer resection with concomitant axillary dissection, there was no difference in infection rates between patients with drains in place 7 d vs. 8–14 d (RR 1.15 for prolonged drainage, 95% CI 0.52–2.49, p=0.15). Although drains were in place for a median of 14 d, the authors did not comment on SSI rates among patients with drains in place for longer than 14 d. In addition, although the association between drain contamination (i.e., culture positivity) and SSI is not established in the literature, Felipe et al. [7] characterized the microbiology of the infections, which were caused by MSSA (70%), Enterobacteriaceae (22.5%), and *P. aeruginosa* (7.5%). Wound aspirate microbiology correlated with drainage fluid cultures in 33 of 40 cases (83%).

In a RCT by Dalberg et al. [63] designed to examine the relationships between the duration of axillary drainage and preservation of the pectoral fascia with seroma formation, 247 patients who underwent modified radical mastectomy were randomized to four arms (removal or preservation of the pectoral fascia, and removal of the drain within 24 h of surgery or when drainage decreased below 40 mL/24 h). Seroma was defined as "any clinically detected collection of fluid requiring aspiration in the axilla or anywhere along the skin incisions" [63] and infection as "any wound appearance that was treated by antibiotics" [63]. There was no difference in infection based on the duration of drainage (4.0% vs. 3.0%, p=0.70), although there was a significant increase in the incidence of seroma among patients whose drains were removed within 24 h (48.5% vs. 22.2%, OR 0.26 for prolonged drainage, 95% CI 0.14–0.39, p<0.001). Neither antibiotic prophylaxis nor microbiology was described (Table 10).

Plastic and reconstructive surgery

Objective analysis of the use of drains in the plastic surgery literature is relatively lacking. Plastic surgical procedures often involve large tissue dissections and creation of equally large potential spaces, and result in the frequent use of post-operative drainage.

A cohort study by Reid et al. [64] examined the outcomes of 73 plastic surgery patients who underwent CSD placement, finding that the incidence of "wound complications did not correlate with the duration of drain therapy" [64]. The authors

TABLE 10. CHARACTERISTICS OF BREAST SURGERY STUDIES EXAMINED THE RELATIONSHIP BETWEEN DRAINS AND SURGICAL SITE INFECTION

Authors	Year	Study Type	Procedure	Drain Type	Drained n (%)	Undrained n (%)	Duration of drainage	Perioperative antibiotic administration	SSI outcome	Cultures	Comments
Collis et al.	2005	RCT	Bilateral reduction	CS (Bellovac)	150 (100.0) unilaterally drained; left: 70 (46.7), right: 80 (53.3)	0 (0.0)	Removed when output <30 mL/24 h	-	Abscess drainage: 2.0% vs. 0.7% ^a , "minor" infection: 3.3% vs. 2.7% ^a	-	-
Corion et al.	2008	RCT	Bilateral reduction	-	55 (51.4)	52 (48.6)	Removed when output ≤ 20 mL for ≥ 24 h	0	14.5% vs. 5.8% ^a , p=0.21	-	-
Dalberg et al.	2004	RCT	Modified radical mastectomy	CS (Exudrain or Drevac)	247 (100.0)	0 (0.0)	Removed after 24 h; 99; removed when output <40 mL/24 h: 99	-	4.0% (24 h) vs. 3.0% (<40 mL/24 h), p=0.79	-	Seroma: 48.5% (24h) vs. 22.2% (<40 mL/24h), OR 0.26, (95% CI 0.14-0.39, p<0.001)
Felippe et al.	2007	Cohort	Cancer resection with axillary node dissection	CS	354 (100.0)	0 (0.0)	7 ^b -14 d	100%	7d vs. 8-14 d: RR 1.15 for prolonged drainage (95% CI 0.52-2.49)	POD7 and prior to removal; MSSA and <i>Enterobacteria</i> most frequently isolated	-
Vilar-Compte et al.	2004	Case control	Multiple, including local excision, radical-, modified-radical and skin-sparing mastectomy, axillary dissection	CS (Drenovac)	-	-	Removal guidelines not standardized	-	Duration of drainage ≥ 19 d: OR 2.9 (95% CI 1.5-4.6, p=0.001)	89.4% of SSI cultured: <i>Pseudomonas</i> and <i>Serratia</i> most frequently isolated	38.0% SSI rate for radical mastectomy; overall epidermolysis: 37.4%; flap necrosis: 23.9%; seroma: 25.6%

^aDrained vs. undrained.^bIf drainage was <50mL/day or on POD14, whichever came first.CI = confidence interval; CS = closed-suction; MSSA = methicillin-sensitive *Staphylococcus aureus*; OR = odds ratio; POD = post-operative day; RCT = randomized controlled trial; RR = relative risk.

reported an overall 9.6% “minor complication rate” (including but not limited to SSIs that resolved following antimicrobial therapy) (which might or might not meet contemporary definitions of superficial incisional SSI) and a 6.8% “major complication rate” (defined as “seromas, infections, or abscesses leading to a failed procedure or an open wound” [64]) (which could also include superficial incisional SSIs based on contemporary definitions), but did not delineate specifically the etiology of each complication. This study is also limited by discretionary antibiotic prophylaxis and failure to describe the microbiology of the “infections” they observed. Moreover, study heterogeneity with respect to the multiple types of operations over multiple anatomic locations included limits analysis.

Fatica et al. [65] performed a small retrospective case-control study of four patients who developed *S. aureus* SSI following clean cosmetic procedures and 12 non-infected control patients. No patient received antibiotic prophylaxis. The placement of a CSD was found to be a risk factor for SSI ($p=0.004$), but the small sample negates meaningful extrapolation of these data.

Scevola et al. [66] performed a retrospective review exploring the relationship between drain placement and seroma formation in both abdominal and breast sites following breast reconstruction with transverse rectus abdominis musculocutaneous (TRAM) or deep inferior epigastric perforator (DIEP) flaps. All patients received either one or two drains at each site. Intravenous antibiotics were administered perioperatively, converted to an oral regimen upon discharge and discontinued upon drain removal, which occurred at the discretion of the surgeon. Of the 768 procedures and 608 patients included, the incidence of infection was 2.3% in the one-drain group vs. 0.8% in the two-drain group ($p=0.1$). Similarly, following the 608 abdominal (donor site) procedures, there was no difference in infection rates (1.6% vs. 0.4%, $p=0.1$). Neither was use of prosthetic mesh (composition not specified) associated with an increase in SSI incidence. The authors concluded that, contrary to expectation, the use of two drains did not confer a higher risk of infection, but the absence of a undrained control group and excessively prolonged antibiotic prophylaxis are major design flaws.

In a retrospective cohort study by McCarthy et al. [67], surgical outcomes of 1,863 women who underwent 2,446 tissue expander/implant exchange procedures were compared between drained ($n=1,165$) and undrained ($n=698$) groups. All patients received perioperative antibiotics. Although not utilized typically for this type of procedure, drains were placed at the discretion of the surgeon and removed when output was below 30 mL/24 h. There was no difference in the overall infection rate (2.1% vs. 2.2%, $p=0.886$) or the rate of infection requiring prosthetic explant (0.7% vs. 0.4%, $p=0.585$) [68].

The present authors have performed recently a prospective analysis [68] exploring the relationship between CSDs, drain colonization, and SSI. Fifty-four plastic surgery patients and 101 drains were included in the study. Only drains that remained in place ≥ 5 d were included in the analysis. Patients underwent surgical procedures over all anatomic areas including the abdomen, chest, back, and groin/perineum. All patients received one or more doses of perioperative antibiotics. Drains were removed aseptically and cultured. Sixty-six drains (65.3%) were placed in the presence of prosthetic

material such as acellular non-crosslinked bioprosthetic mesh or metallic spinal hardware. Sixty-three percent of drains had positive cultures, including coagulase-negative *Staphylococcus* (24.8%), MSSA (8.9%), and *E. faecalis* (6.9%). Upon binary logistic regression, abdominal wall location (OR 3.14, 95% CI 1.35–7.32, $p=0.008$) was a risk factor for colonization. Location of an incision in the back (OR 0.37, 95% CI 0.15–0.90, $p=0.028$), and the use of prosthetic material (OR 0.17, 95% CI 0.06–0.54, $p=0.003$), and duration of post-operative antibiotics (OR 0.92, 95% CI 0.85–0.99, $p=0.039$) were protective against colonization. Curiously, drain colonization with *Micrococcus luteus* (a saprophytic gram-positive coccus that is part of normal skin flora) was found to be risk factor for SSI (OR 18.80, 95% CI 1.02–346.53, $p=0.048$), but the commensal nature of the organism and the wide confidence interval suggest that the result may be spurious. These results highlight that drain contamination does not herald clinical infection, and that culture of drain effluent does not inform clinical decision-making, and may even be misleading (Table 11).

An additional feature that distinguishes plastic surgical procedures from those of other surgical disciplines is the frequent dissection of large potential spaces at increased risk for collection formation, such as occurs with component separation or abdominoplasty. Therefore, given that none of the abovementioned studies clearly implicate drains as a risk factor for SSI per se, drains may be beneficial in the plastic surgery setting so as to reduce seroma formation and the potentially detrimental cosmetic consequences associated therewith, provided they are not “covered” by antibiotic administration.

Orthopedic surgery

In the realm of orthopedics, drains are placed commonly to prevent hematoma formation [2, 3, 69–71], owing to the difficulty in obtaining hemostasis of medullary bone [2, 4, 71, 72]. Accumulations of blood are believed to serve as a culture medium for bacteria [2, 4, 73] and a synovial irritant, resulting in joint effusion [71]. Despite the frequent use of post-operative drainage, studies evaluating the infection risk associated with CSDs in the orthopedic literature are conflicting.

In 1961, Waugh et al. [72] performed the first study to characterize the utility of CSD following orthopedic surgery. Among 200 case-matched drained ($n=100$) and non-drained ($n=100$) orthopedic patients, the authors analyzed the change in drain output over time and correlated their findings with drain and wound cultures. Antibiotic prophylaxis in this series was inconsistent, as only 35 patients in each group received antibiotics, which were then continued 3–5 d post-operatively. Drains were placed “for operations performed in areas where perfect hemostasis is difficult to achieve and a hematoma is likely to develop” [72], and removed when “drainage ceased or was negligible” [72], at which time the lumen of each catheter was swabbed for culture. There was one SSI in the drained group, which occurred in a patient with a drain in place for 65 h; drain and wound cultures from this patient grew identical *S. pyogenes* isolates. By contrast, there were three SSIs in the un-drained group. Although not different, this discrepancy prompted the authors to claim “a more benign and uncomplicated course can be anticipated if [drainage] is used” [72], thus providing justification, however specious, of the controversial practice of routine prophylactic

TABLE 11. CHARACTERISTICS OF PLASTIC AND RECONSTRUCTIVE SURGERY STUDIES EXAMINING THE RELATIONSHIP BETWEEN DRAINS AND SURGICAL SITE INFECTION

Authors	Year	Study type	Procedure	Drain type	Drained n (%)	Undrained n (%)	Duration of drainage	Perioperative antibiotic administration	SSI outcome	Cultures	Comments
Fatica et al.	2002	Retrospective case-control	-	CS (Blake)	6 (37.5)	10 (62.5)	-	0%	66.7% vs. 0.0% ^a p=0.004	-	-
McCarthy et al.	2007	Retrospective cohort	Tissue expander/ implant exchange	CS	1165 (62.5)	698 (37.5)	Removed when output <30 mL/d	100%	1.1% vs. 1.4% ^a p=0.447	-	-
Reid et al.	2003	Cohort	Abdomen, Chest/ Breast, Back, Other	CS (Clotstop)	73 (14.6)	427 (85.4)	Removed when output <30 mL/d	-	No relationship between SSI and duration of drainage	-	"Minor" complication rate: 9.6%, "major" complication rate: 6.8%
Reiffel et al.	2012	Cohort	Abdomen, Chest/Breast, Back, Groin	CS (Jackson Pratt)	54 (100.0)	0	≥ 5 d	100%	Drain colonization with <i>Micrococcus luteus</i> : OR 18.80 (95% CI 1.02–346.53, p=0.048)	All drains cultured: 63.4% positive; coagulase-negative <i>Staphylococcus</i> MSSA and <i>E. faecalis</i> isolated most commonly	Overall SSI rate: 5.6%
Secevola et al.	2002	Retrospective review	Breast reconstruction with TRAM or DIEP flaps	CS (Blake)	Breast site: 515 (67.1; 1 drain), 253 (32.9; 2 drains); Abdominal donor site: 126 (20.7; 1 drain), 482 (79.3; 2 drains)	0	Removed when output <30 mL/24 h	100%	Breast site: 2.3% (1 drain) vs. 0.8% (2 drains), p=0.1; abdominal site: 1.6% (1 drain) vs. 0.4% (2 drains), p=0.1	-	Antibiotics transitioned to oral regimen upon patient discharge until drain removal; increased seroma incidence at both sites with one drain (vs. two drains)

^aDrained vs. undrained.CI = confidence interval; CS = closed-suction; DIEP = deep inferior epigastric perforator; MSSA = methicillin-sensitive *Staphylococcus aureus*; OR = odds ratio; SSI = surgical site infection; TRAM = transverse rectus abdominis musculocutaneous.

TABLE 12. CHARACTERISTICS ORTHOPEDIC SURGERY STUDIES EXAMINING THE RELATIONSHIP BETWEEN DRAINS AND SURGICAL SITE INFECTION

Authors	Year	Study type	Procedure	Drain type	Undrained n (%)	Duration of drainage	Perioperative antibiotic administration	SSI outcome	Cultures	Comments
Bachoura et al.	2010	Retrospective review	Trauma-related procedures	Not disclosed	264 (11.8)	–	–	9.5% vs. 3.3, p<0.001; OR 2.3 (95% CI 1.3-3.8, p=0.004)	–	Additional RF for SSI: # operations, CHF, DM, site of injury (tibial shaft/plateau or elbow)
Cobb	1990	RCT	Repair of proximal femur fracture	CS	35 (50.0)	48 h	–	2.9% vs. 0.0%, ^a p=NS	–	–
Drinkwater et al.	1995	Cohort	THA or TKA	CS	92 (100.0)	<96 h	100%	–	Drain tip culture positivity not related to duration of drainage	–
Hsu et al.	2010	RCT	ORIF via Kocher-Langenbeck Approach	CS (Hemovac)	20 (51.3)	Removed when output <20 mL/8 h	100%	10.0% vs. 5.3%, ^a p=NS	–	–
Kleinert et al.	1997	Cohort	Hand surgery	Not disclosed	147 (6.0; clean-contaminated wounds)	–	23.2%	4.8% vs. 1.3%, ^a p=0.001; OR 2.7029, p=0.006	–	–
Parker et al.	2007	Meta-analysis	–	CS	1,305	–	–	1.9% vs. 2.4%, ^a RR 0.80 (95% CI 0.49-1.32), p=NS	–	Overall SSI rate: 1.5%
Parker et al.	2004	Meta-analysis	Hip or knee arthroplasty	CS	1,775 (50.1)	–	–	1.6% vs. 2.4%, ^a RR 0.73 (95% CI 0.47-1.14)	–	Transfusion requirement: RR 1.43 (95% CI 1.19-1.72)
Reilly et al.	1986	Retrospective review	TKA	CS	170 (56.9)	–	100%	“Wound problems”: 5.8% vs. 3.0%, ^a p=NS	14 wounds cultured, 1 grew <i>Enterococcus</i>	Drain group: a larger decrease in hemoglobin concentration, higher transfusion requirement
Sankar et al.	2004	Cohort	–	CS	1 drain: 96 (44.9); 2 drains: 118 (55.1)	Removed when output <100 mL/24 h	100%	Drain tip culture: sensitivity = 75%, specificity = 97%, PPV = 50%, and NPV = 99%	<i>S. aureus</i> most frequently isolated from drain tip and infected wound	–

(continued)

TABLE 12. (CONTINUED)

Authors	Year	Study type	Procedure	Drain type	Drained n (%)	Undrained n (%)	Duration of drainage	Perioperative antibiotic administration	SSI outcome	Cultures	Comments
Simchen et al.	1984	Cohort		Open and CS	Open: 23 (6.1); CS: 180 (47.9)	173 (46.0)		44.9%	Open: OR 4.6 (95% CI 3.8-6.5); CS: NS	-	Overall SSI rate: 4.8%
Tjeenk et al.	2005	RCT	Repair of proximal femur fracture	CS (Redon)	100 (50.0)	100 (50.0)	24h ^b	100%	8.0% vs. 13.0%, ^a OR 1.72 (95% CI 0.68-4.35), p = 0.36	-	-
Walmsley et al.	2005	RCT	THA	CS (Redivac)	295 (51.1)	282 (48.9)	24 h	100%	Superficial: 2.9% vs. 4.8%, ^a p = NS; deep, early (< 3 mo): 0.4% vs. 0.0%, ^a p = NS; deep, late (> 3 mo): 0.4% vs. 0.7%, ^a p = NS 1.0% vs. 3.0%, ^a p = NS	-	Transfusion requirement: 33.0% vs. 26.4%, ^a p = 0.042
Waugh et al.	1961	Case-control	-	CS	100 (50.0)	100 (50.0)	Removed when drainage was negligible	35.0%		Drain: <i>Pseudomonas</i> , coagulase-negative <i>Staphylococcus</i> , <i>Aerobacter</i> most frequently isolated Drain culture: 0.8% positive	All drains cultured
Weinrauch	2005	Retrospective review	THA or TKA	CS	387 (100.0)	0 (0.0)	24 h	100%	SSI: 5.2%; drain tip culture: sensitivity: 0%; specificity: 99.2% 3.0% (24 h) vs. 3.4% (48 h) vs. 7.1% (72 h), p = NS	Drain culture positivity did not correlate with SSI	
Willett et al.	1998	Cohort	THR	CS (Redivac)	120 (100.0)	0 (0.0)	24 h: 33 (27.5); 48 h: 59 (49.2); 72 h: 28 (23.3)	100%		Drain exit site, fluid, surface, and tract cultured: 5.8% positive; coagulase-negative <i>Staphylococcus</i> most commonly isolated; all wound cultures negative	Skin and a non-exit site culture positive for identical organisms

^aDrained vs. undrained.^bUnless output was > 500 mL/24 h.

CHF = congestive heart failure; CI = confidence interval; CS = closed-suction; DM = diabetes mellitus; NPV = negative predictive value; NS = not significant; ORIF = open reduction internal fixation; PPV = positive predictive value; RCT = randomized controlled trial; RF = risk factor; RR = relative risk; SSI = surgical site infection; THA = total hip replacement; TKA = total knee arthroplasty.

drain placement following orthopedic procedures. Since then, orthopedic studies addressing the same issue have yielded conflicting results.

Simchen et al. [74] performed a prospective, observational study of 376 patients who underwent orthopedic procedures at a single institution. The overall SSI rate in this series was 4.8%. By univariate analysis, both the presence of a drain and the presence of an open drain were identified as risk factors for SSI (OR 3.1, $p=0.04$; OR 11.7, $p=0.0001$, respectively), whereas the presence of a CSD was not. Only the presence of an open drain remained a significant risk factor by multivariable analysis. Antibiotic prophylaxis was not standardized nor was the microbiology of SSI discussed. Study heterogeneity, as some patients underwent solely soft tissue surgery, whereas others had insertion of a prosthesis, reduces the probative value of the study.

Hsu et al. [70] performed a RCT in which patients undergoing open reduction and internal fixation of an acetabular fracture via the Kocher-Langenbeck (posterior) approach were randomized to receive either two large Hemovac® drains (one beneath and one superficial to the fascia lata; $n=20$) or no drain ($n=19$). All patients received antibiotic prophylaxis, but VTE prophylaxis was initiated only following drain removal or on post-operative day three. Drains were removed when output was less than 20 mL/8 h or when "there was decreasing output by [post-operative day] five" [70]. Two cases of cellulitis (one per group) resolved with parenteral antibiotics. There were no other cases of SSI.

In a Cochrane meta-analysis by Parker et al. [75] of 21 randomized or quasi-randomized (i.e., the "method of allocating participants to a treatment (is) not strictly random; e.g., date of birth, hospital record number, alternation" [75]) studies of orthopedic procedures, the SSI incidence was 1.9% in patients with CSDs compared with 2.4% in patients without drains (RR 0.80, 95% CI 0.49–1.32, $p=NS$).

By contrast, in the cohort study by Kleinert et al. [76] of 2,458 patients undergoing hand surgery, the use of a drain was a risk factor for SSI (OR 2.70, $p=0.006$). However, their sole criterion for placement of a drain was wound classification as "clean-contaminated," an association that by definition confounds analysis of drains as an independent risk factor for SSI.

Bachoura et al. [77] performed a retrospective review of 1,611 patients who underwent 1,783 "trauma-related" procedures. Use of a wound drain (type not specified) was identified as a risk factor for SSI by multivariable analysis (OR 2.3, 95% CI 1.3–3.8, $p=0.004$). In addition, the number of operations, the presence of congestive heart failure or diabetes mellitus, and the site of injury (tibial shaft/plateau or elbow) were also identified as risk factors for SSI. The authors hypothesized that, given the complexity and heterogeneity of traumatic injuries, drain placement and multiple procedures might be a marker of more complex injuries, rather than an independent risk factor for SSI.

The orthopedics literature contains some of the few studies to examine the utility of routine drain-tip culture for the prediction of SSI or the relationship between the duration of drainage and the incidence of SSI. Sankar et al. [78] performed a prospective, observational study of all clean orthopedics procedures (200 patients, 332 CSDs) performed at a single institution in which a CSD was placed. All patients received antibiotic prophylaxis. Drain placement was discretionary.

Drains were removed when output decreased below 100 mL/24 h. Drain sites were prepared with povidone-iodine prior to drain removal, and a portion of the drain ("tubing") and 5 mL of drainage fluid were sent separately for culture. Wound fluid, when present, was also cultured. None of the 12 positive drain tubing cultures or seven positive drain fluid cultures occurred in the same patient. Fifty percent of patients with positive tubing cultures developed a deep incisional SSI, defined as "infections around the bone or implanted foreign materials" [78], with the same bacterial isolates yielded by drain culture (sensitivity = 75%, specificity = 97%, PPV = 50%, and NPV = 99%). This relationship was reported to be statistically significant (testing methodology and p value not given). Superficial incisional SSI occurred in one of seven patients with a positive drain fluid culture and one patient with a negative culture (sensitivity = 12.5%, specificity = 97%, PPV = 14%, NPV = 96.6%). However, this association was not statistically significant.

Total joint arthroplasty. Studies examining outcomes following arthroplasty with drain placement tend to focus on consequences of bleeding, including the need for dressing changes/reinforcement, changes in hemoglobin/hematocrit, and transfusion requirement. Although not always the case, SSI is evaluated most often as a secondary outcome.

Reilly et al. [3] performed a retrospective review of total knee arthroplasties by a single surgeon over a 10-year period, approximately seven years into which the once-routine placement of CSDs was discontinued. Of the 299 knees studied, drains were placed in 170 (56.9%). All patients received 48 h of antibiotic prophylaxis. Among the primary outcomes of this study was "wound problems," defined as "when cultures were taken of persistent wound drainage during the post-operative period" [3]. There was no difference in the incidence of "wound problems" in the drained vs. the undrained patients (5.8% vs. 3.0%). Only one of the 14 cultures taken (7.1%) was positive (*Enterococcus* spp.), but it is unstated whether the patient had a drain. There were no deep incisional SSIs. There were no differences in post-operative temperature elevation or range of motion. However, the drained group demonstrated a larger decrease of hemoglobin concentration and a higher transfusion requirement.

Walmsley et al. [4] performed a RCT of 552 patients undergoing 577 primary total hip arthroplasties. All patients received antibiotic and VTE prophylaxis. Patients were randomized to receive either no drain ($n=282$ hips) or a 3 mm Redivac drain (Orthopedic Equipment Co., Bourbon, IN) ($n=295$ hips). When placed, drains were removed 24 h post-operatively. There was no difference in infection rates between groups when stratified as superficial incisional, early deep incisional SSI (<3 mos), or late deep incisional SSI (>3 mo). As with the study by Reilly et al. [3], a greater number of hips required transfusion (according to a standardized transfusion policy) in the drained group (33.0 vs. 26.4, $p=0.042$).

In a meta-analysis by Parker et al. [2] of 18 studies including 3,495 patients and 3,689 incisions following elective hip or knee arthroplasty, there was no difference in SSI rates in patients with CSDs in place ($n=1,775$) versus patients with no drains ($n=1,765$) (1.6% vs. 2.4%, RR 0.73, 95% CI 0.47–1.14). Consistently, the authors also found a significantly higher transfusion requirement among drained patients.

To examine the relationship between the duration of drainage and the incidence of SSI, Willett et al. [73] performed a cohort study of 120 patients who underwent total hip replacement with CSD placement (Redivac). Patients were divided into three groups according to the timing of drain removal at 24 (n=33, group A), 48 (n=59, group B) or 72 (n=28, group C) h post-operatively. All patients received 12 h (three doses) of prophylactic antibiotic. Drains were removed using aseptic technique. Cultures were taken from four sites upon drain removal: The exit site, the "fluid content of the proximal portion of the drain (termed the deep aspirate)," [73] the external surface of the proximal 4 cm of the drain, and the walls of the drain tract. There were one (3.0%), two (3.4%) and two (7.1%) cases of SSI in groups A, B, and C, respectively. In two of these five cases (group not given) a deep aspirate culture was positive, but no organisms were isolated from the drain site or tract. In seven of 120 cases (five in group B and two in group C), both the skin and a non-exit site culture were positive for identical organisms, in three of which the same organism was isolated from all four loci. Coagulase-negative *Staphylococcus* was found in four of seven cases (likely a contaminant). The authors (over-) concluded that their study "re-affirms the risk of ingress of skin micro-organisms into the wound either by way of the drain or drain track with an increased rate of wound sepsis... if the drainage tube remains in situ more than 24 h," which is refuted objectively by the statistical result ($\chi^2=0.825$, $0.10 > p > 0.05$) [73].

To confirm the findings of Willett et al. [73], Drinkwater et al. [6] performed a prospective study at two institutions of 92 patients undergoing total hip or knee arthroplasty with CSD placement. Antibiotic and VTE prophylaxis was standardized. "Drains were randomly left in situ, some for up to 96 h" [6] but criteria used to determine the timing of removal were unspecified. Drains were removed using aseptic technique and both the exit sites and drain tips were cultured. At least one culture was positive from 29 patients (31.5%). Twenty-three drain tips from 19 patients (20.7%) were positive. Although only one of these drains was in place for <24 h, this was not statistically significant. The SSI rate and correlation between SSI and drain contamination were unreported.

Weinrauch [79] performed a retrospective study of 387 patients with 393 drains who underwent primary total hip or knee replacement at a single institution. All drain tips were cultured routinely following removal. All patients received prophylactic antibiotics, whereas ~50% of patients received antibiotic-impregnated polymethylmethacrylate cement at the surgeon's discretion. Drains were removed within 24 h of surgery and prior to discontinuation of antibiotic prophylaxis. Only three drains (0.8%) were culture-positive (coagulase-negative *Staphylococcus* and other skin flora) and did not correlate with the 20 patients who developed SSI, (sensitivity, zero; specificity, 99.2% for prediction of SSI).

Femur fracture. The placement of CSDs following femoral neck repair was first analyzed in 1961 [80] and has remained controversial ever since. As with other orthopedic procedures, drains are hypothesized to reduce the incidence of hematoma formation and thus subsequent infection or dehiscence [69].

Nearly 30 years later, Cobb et al. [80] performed a RCT of 70 patients undergoing repair of traumatic proximal femur

fractures, in which 35 patients were randomized to receive no drain and 35 patients received drains both adjacent to the metal implant and in the subcutaneous fat, all of which were removed after 48 h. There was only one SSI in this series, which occurred in a "doubly incontinent" patient with diabetes mellitus who was drained. Neither the microbiology of infection nor the administration of antibiotics was disclosed.

Tjeenk et al. [69] performed a similar RCT in which 200 patients undergoing repair of a proximal femur fracture were randomized to receive no drain (n=100) or a CSD (n=100). All drains were removed within 24 h unless output was >500 mL/24 h and all patients received one dose of parenteral antibiotic prophylaxis. The overall SSI rate was 10%, but did not differ between groups (8% drained vs. 13%, OR 1.72, 95% CI 0.68–4.35, $p=0.36$).

Therefore, despite the large number of orthopedic studies evaluating the relationship between CSDs and SSI, few are Class I data. None of the existing RCTs implicate drains definitively as a risk factor for SSI in the realm of orthopedics, or as beneficial for their reduction (Table 12).

Spine surgery

Closed-suction drains are used frequently in the setting of spinal surgery, as they are believed to reduce the incidence of post-operative hematoma, compression of the cauda equina, and resultant neurological defects [80–82]. The correlation between CSD and SSI has been examined in this literature, albeit with conflicting results. Brown et al. [81] performed a RCT of 83 patients undergoing extensive lumbar spine surgery, with randomization to either drained (n=42) or undrained (n=41) groups. When utilized, drains were placed overlying the dura mater. A zero incidence of both hematoma and SSI was reported in this underpowered study.

Ho et al. [82] performed a retrospective case-control study in which adolescent patients with idiopathic scoliosis who underwent posterior spinal fusion and instrumentation (PSFI) and developed a "delayed" SSI (n=36) were matched with randomly selected non-infected controls (n=90). All patients received antibiotic prophylaxis, but neither the timing nor the duration was associated with the development of delayed SSI. In contrast to the study of Brown et al., Ho et al. reported a significant increase the incidence of delayed SSI in patients who did not undergo drain placement (13.2% vs. 38.4%, $p=0.0005$). The authors reported this finding to maintain significance by multivariate logistic regression analysis, but the data were not reported. Duration of drainage was not evaluated.

By contrast, Chen et al. [84] performed a retrospective review of 195 patients who underwent elective posterior instrumented lumbar arthrodesis to examine the relationship between diabetes mellitus and SSI, as well as to delineate potential confounding factors. All patients were followed for a minimum of 12 mos. Despite a high overall SSI rate of 13.8%, drains were not a risk factor for SSI by univariate and multivariate analysis. However, both diabetes mellitus and higher estimated blood loss were found to increase the incidence of SSI. Duration of drainage was not discussed.

Kanayama et al. [83] performed a retrospective review of 560 consecutive patients who underwent single-level lumbar laminectomy to examine the effect of prophylactic drain placement on the rates of SSI and epidural hematoma. During

TABLE 13. CHARACTERISTICS OF SPINE SURGERY STUDIES EXAMINING THE RELATIONSHIP BETWEEN DRAINS AND SURGICAL SITE INFECTION

<i>Authors</i>	<i>Year</i>	<i>Study Type</i>	<i>Procedure</i>	<i>Drain Type</i>	<i>Drained n (%)</i>	<i>Undrained n (%)</i>	<i>Duration of drainage</i>	<i>Perioperative antibiotic administration</i>	<i>SSI outcome</i>	<i>Cultures</i>	<i>Comments</i>
Brown et al.	2004	RCT	"Extensive" lumbar spine surgery	CS	42 (50.6)	41 (49.4)	-	-	0%	-	-
Chen et al.	2009	Retrospective review	Posterior instrumented lumbar arthrodesis	-	-	-	-	100%	Drain: RR 1.843 (95% CI 0.822-4.135)	-	195 patients included; overall SSI rate: 13.8%; DM and EBL risk factors for SSI
Ho et al.	2007	Retrospective case-control	Posterior spinal fusion and instrumentation	-	73 (57.9)	53 (42.1)	-	100%	13.2% vs. 38.4%, ^a p = 0.0005	-	Cases: 36 patients with delayed (>6 mo) infection
Kanayama et al.	2010	Retrospective review	Single-level lumbar laminectomy	CS	298 (53.2)	262 (46.8)	Removed when output < 50 mL/d	100%	No difference in SSI rates between groups	-	-
Payne et al.	1996	RCT	Single-level lumbar hemi-laminectomy or decompressive lumbar laminectomy	CS	103 (51.5)	97 (48.5)	48 h	100%	1.9% vs. 1.0%, ^a p = NS	<i>S. aureus</i> and <i>Streptococcus</i> isolated	-
Rao et al.	2011	Retrospective case-control study	Posterior approach spinal fusion	CS	205 (86.1)	33 (13.9)	-	92.4%	Unit OR 1.6 per day drain present (95% CI 1.3-1.9)	MSSA and coagulase-negative <i>Staphylococcus</i> most frequently isolated	Cases: 57 patients with deep primary incisional SSI; male gender and higher BMI also risk factors

^aDrained vs. undrained.BMI = body-mass index; CI = confidence interval; CS = closed-suction; DM = diabetes mellitus; EBL = estimated blood loss; MSSA = methicillin-sensitive *Staphylococcus aureus*; OR = odds ratio; RCT = randomized controlled trial; RR = relative risk; SSI = surgical site infection.

the first two years of the five-year study, all patients received CSDs, and no patients received drains thereafter. Complicating the analysis further, all patients received a 5–7 day regimen of perioperative antibiotics during the first year, which was then shortened to a one-day regimen thereafter. However, the incidence of SSI did not change. Although there was reportedly no difference in the incidence of SSI between drained and undrained cohorts, the actual incidence of SSI was not reported. In addition, two patients in the drained cohort developed an epidural hematoma with transitory neurologic injury that resolved following surgical evacuation.

Payne et al. [85] performed a RCT in which 200 patients, who underwent “single-level lumbar hemi-laminectomy for herniated disc or decompressive lumbar laminectomy for degenerative stenosis,” [85] were randomized to receive a CSD placed beneath the lumbosacral fascia (n=103) or no drain (n=97). All patients received 48 h of antibiotic prophylaxis and all drains were removed on post-operative day two. Two patients in the drain group developed a SSI with gram-positive cocci and were treated successfully with oral antimicrobial therapy. One patient in the un-drained group developed a SSI requiring operative debridement and 10 d of parenteral antibiotics, followed by two weeks of oral antibiotics. The incidence of SSI was not different between groups (1.9% vs. 1.0%). In contrast to the study of Kanayama et al. [83], no patients developed neurologic deficits or hematomas of clinical importance in this series.

Rao et al. [86] recently performed a retrospective case-control study of 57 (3.6%) of 1,587 patients who underwent spinal fusion procedures via the posterior approach and developed deep incisional SSI (defined as “below the fascia”) to identify potential risk factors for SSI in this setting. Index cases were matched with non-infected controls (n=154) by calendar year of surgery only. In addition, there was no standardized drain removal criteria among the 11 surgeons included in the study. More than 90% of patients in each group received antibiotic prophylaxis timed appropriately. By multivariate analysis, the duration of CSD was found to be a significant risk factor for SSI (OR 1.6 per day drain present, 95% CI 1.3–1.9). Male gender and BMI were also identified as risk factors. Furthermore, subgroup analysis of only those patients who underwent procedures for the treatment of degenerative spinal disease identified the CSD duration as a risk factor (OR 2.1 per day drain present, 95% CI 1.6–3.1). Methicillin-sensitive *S. aureus* and coagulase-negative *Staphylococcus* were the pathogens isolated most commonly in this series, whereas the microbiology of drain colonization was not examined.

Thus, there is conflicting, largely retrospective evidence regarding an association between CSDs and SSI following spine surgery (Table 13). However, there are no studies in the spine literature that implicate the presence of a drain as a risk factor for SSI.

Cardiothoracic surgery

To date, the authors were unable to find analysis of the relationship between CSDs and SSI in the cardiothoracic literature. Although tube thoracostomy represents a similar modality of drainage, such tubes are of typically large caliber, do not require regular exposure of the system to the external environment for measuring of output volume, and serve the

functional purpose of maintenance of lung expansion following breach of the thoracic cavity.

Conclusions

Across most surgical disciplines, studies to evaluate the risk of SSI associated with routine post-operative CSD have yielded conflicting results. A few studies do suggest an increased risk of SSI associated with drain placement, but are usually associated with open drainage and not the use of CSDs. No studies whatsoever attribute a decrease in the incidence of SSI (including organ/space SSI) to drain placement. Drain-associated complications such as enterocutaneous fistula, post-operative pain, foreign-body reaction, and increased transfusion requirements have been reported. Until additional, rigorous RCTs are available to address definitively the issue, we recommend judicious use and prompt, timely removal of CSDs. Given that the evidence is scant and weak to suggest that CSD use is associated with increased risk of SSI, there is no justification for the prolongation of antibiotic prophylaxis to “cover” an indwelling drain.

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Author Disclosure Statement

None of the authors has competing financial interests to disclose.

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