Review Article

A narrative review of infection prevention techniques in adult and pediatric spinal deformity surgery

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Abstract: Spinal infections associated with pediatric and adult spinal deformity surgery are associated with postoperative morbidity and mortality along with elevated health-care costs. Prevention requires meticulous technique by the spine surgeon throughout the perioperative period. There is significant variability in the current practices of spinal deformity surgeons with regard to infection prevention, stemming from the lack of reliable evidence available in the literature. There has also been a lack of literature detailing the difference in infection rates and risk factors between pediatric and adult patients undergoing deformity correction surgery. In this narrative review we looked at 60 studies in the adult population and 9 studies in the pediatric population. Most of these studies of surgical site infections (SSI) in spinal deformity surgery have been performed in adult patients, however it is clear that the pediatric neuromuscular patient requires particular attention that we discuss in detail. This narrative review of the literature outlines evidence and compares and contrasts data for preventive strategies and modifiable risk factors to decrease rates of SSI in the pediatric and adult spinal deformity patient populations. In this review we discuss techniques relating to preoperative cleansing protocols, antibiotic administration, gentle soft tissue handling, appropriate closure, drain usage, and intraoperative technique itself to minimize EBL and operative time.

Keywords: Infection; prevention; adult; pediatric; spinal deformity; surgical site infection (SSI)

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Introduction

Spinal infections associated with pediatric and adult spinal deformity surgery are uncommon, but once encountered can cause substantial postoperative morbidity and mortality along with elevated health-care costs (1-4). The incidence of infection associated with spinal surgery overall ranges from less than 1% to 15% varying with procedure, patient population, and the use of instrumentation (1,4-6). One study demonstrated that spine infections after instrumented spondylodesis procedures were associated with a mean 29-day hospitalization and a mean hospital charge of $154,000 in addition to the average primary procedure cost of $103,143 (4,5). Other studies have reported average direct treatment costs ranging from $15,817 to $38,701 and increased costs up to 2.3 to 3.1 times greater for patients with surgical site infections (SSI) compared to patients without postoperative infection (6). Furthermore, surgery costs rise with delay of procedure from initial date of inoculation. Average hospital charges if implants were

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removed during the first subsequent procedure were found to be $81,828, compared to $101,590 if implants were removed within 3 procedures, and $674,292 if implants were removed after 4 or more procedures (7). Currently, there is no firmly established consensus for the management of implants during SSI. Risk factors for implant removal include vertebral pseudoarthrosis, hardware migration and/or loosening, delay of intervention with effective antibiotics, and chronic infection >90 days (8-10). The rate of postoperative SSI in spinal deformity surgery ranges depending on type: 4.2% for adult kyphosis, 2.1% for adult spondylolisthesis, and 3.7% for adult scoliosis (11). Similarly, in the pediatric population, the incidence of deep SSI varies by primary diagnosis: idiopathic spinal deformity (1.0%), neuromuscular (14.3%), syndromic (5.3%), congenital (5.7%), and kyphosis (0.0%) (12).

SSI associated with spinal deformity have a multifactorial etiology. There is significant variability in the current practices of spinal deformity surgeons with regard to infection prevention, stemming from the lack of reliable evidence available in the literature (13). Furthermore, the difference in infection rates and risk factors between pediatric and adult patients undergoing deformity correction surgery has not been explored in detail in the current literature. For the adult patient population some risk factors that have been identified include increased ASA classification (class III-IV), type of approach, and previous SSI infection (14-16). Some host factors that have been recognized specifically in the pediatric population include etiology such as adolescent idiopathic scoliosis (AIS) or neuromuscular scoliosis (NMS), Lenke curve classification, diabetes, obesity, and other comorbidities (2,3,17-19). SSIs significantly impact post-surgical morbidity and cost of care in adult and pediatric spinal deformity surgery. While there have been prior attempts to identify preventative strategies and risks factors, few practice guidelines exist. Despite advancements in surgical technique and infection prophylaxis, postoperative SSI remains one of the most common complications in spinal deformity surgery. This narrative review of the literature outlines evidence and compares and contrasts data presented for preventive strategies and modifiable risk factors in the pediatric and adult spinal deformity patient populations.

We present the following article in accordance with the Narrative Review reporting checklist (available at https://dx.doi.org/10.21037/jtd-21-10).

Methods

We performed a narrative review in April 2020 by searching the PubMed, Embase, and Cochrane databases. The search terms were scoliosis, scolio*, spine, spin*, infection, and infect*. Our specific PubMed search was: ("Scoliosis"(MeSH) OR scolio*) OR ("Spine"(MeSH) OR spin* OR spine*) AND ("Infection"(MeSH) OR infect*). Embase and Cochrane searches were modified from this PubMed search. Only studies that were prospective randomized control trials and retrospective review studies were included. Studies included were completed between 1995 and 2019. We reviewed 60 studies in the adult population and 9 studies in the pediatric population in full-text.

Results and discussion

Preoperative preparation

Pre-cleansing of the patient's skin before admission to the hospital has been shown to be an effective means of preventing SSIs. These measures typically consist of a shower regimen with chlorhexidine gluconate (CHG) (Hibiclens), povidone-iodine (Betadine), or skin wiping with CHG-impregnated cloths. Several studies have shown that preoperative chlorhexidine cloth use dramatically reduces the risk of periprosthetic infection in patients undergoing lower extremity total joint arthroplasty procedures (20,21). Some studies have reported SSI rates of up to 8.15 times higher for patients bathing with soap and water compared with CHG-impregnated cloths the night before and morning of admission (22). These findings have also been demonstrated across surgical subspecialties; patients showering twice (both evening and morning) with CHG compared with either lotion or betadine before elective coronary artery angioplasty procedures had significantly reduced surgical site staphylococcal colony counts at time of procedure (23). While no similar study currently exists in spinal surgery literature, pre-cleansing is a low risk intervention that allows the patients to become active contributors to their own care by reducing the microbial skin burden prior to hospital admission.

Preoperative skin preparation plays a major role in preventing postoperative infections in many types of surgery (24,25). The use of antiseptic solutions such as CHG and povidine-iodone (PVI) is standard practice in preoperative disinfection, but which one is optimal remains ambiguous in the literature (26). One study found that CHG and PVI were equally effective at eliminating the bacterial flora from the surgical site, but CHG showed a more favorable long-lasting effect for skin antisepsis (27). There has also not been a significant difference found between ChloraPrep™ (2% CHG and 70% isopropyl alcohol) or DuraPrep™ (0.7% available iodine and 74% isopropyl alcohol) in the amount of positive skin cultures after wound closure (28). When it is necessary to remove hair in the area of the surgical field, the existing evidence suggests that clipping is more effective in reducing SSI than shaving (29).

To date, no study has examined preoperative surgical site antisepsis or intraoperative irrigation specifically in pediatric spinal deformity surgery and it is unclear whether the results from the adult population can be applied.

Prophylactic antibiotic use

Antimicrobial prophylaxis with first-generation cephalosporin antibiotics such as intravenous cefazolin or cefuroxime is a standard practice in spinal surgery, however the specific combination, dose, dose timing, and length of treatment varies among institutions and practices (30). In the large body of literature available on this topic, there are relatively few treatment recommendations that are supported by high-level evidence (5). Gram-positive pathogens accounted for the majority of the inciting pathogens (82%), however gram-negative species have been found to account for 18–25% of the infections (11,12). The majority of SSI infections secondary to gram negative species occur in neuromuscular patients (12). A similar study looking at deformity correction surgery in NMS found that gram-negative bacteria were responsible for 60% of infections; 20% were gram-positive, and 20% involved both types (31). Thus, extended prophylactic antibiotic coverage for both gram-positive and gram-negative organisms may be indicated for patients with primary neuromuscular diagnoses.

A cohort study looking at 37 US children's hospitals found that 63% of hospitals used cefazolin alone for perioperative antimicrobial prophylaxis however broad spectrum gram-negative agent use (aminoglycosides, third or fourth generation cephalosporins, monobactams, quinolones) has increased over time as high as 52% of all NMS operations (32). Specific attention should be paid to the patient's comorbidities in making the final determination for antimicrobial prophylaxis. Patients with NMS diagnoses frequently have associated conditions requiring tracheostomies and gastrointestinal ostomies which may require extended coverage with vancomycin or broad gram-negative coverage (33,34).

Though intravenous administration of first-generation cephalosporin antibiotics within 1 hour before incision and continued for 24 hours postoperatively is generally considered the standard of care, conflicting data exist in the literature regarding the timing of antibiotic dosing and its effect on infection rate. Studies have shown an increased infection rate when these recommendations are not followed in both adult and pediatric populations (35-37). Despite these findings, there has been no evidence to support continuing antibiotics past 24 hours in both pediatric and adult patient populations. Takemoto *et al.* found that continuing perioperative administration of antibiotics for the entire duration that a drain is in place after spinal surgery did not decrease the rate of SSI compared with 24 hours of perioperative antibiotic coverage (38). Similarly, for pediatric populations there has been no difference in infection rates demonstrated between patients who had postoperative antibiotic ranging from <24 to >48 hours (35,39-41).

Routine use of intravenous vancomycin and ceftazidime with pulsatile lavage at time of closure for posterior spinal fusion in AIS patients has been associated with decreased rates of postoperative infection by 10 folds (42). Intravenous administration of vancomycin is associated with side effects such as nausea, vomiting, diarrhea, and rash (43). Rapid administration of vancomycin can also be associated with the constellation of symptoms known as "red man syndrome," which includes local pain at the infusion site, thrombophlebitis, hypotension, wheezing, dyspnea, urticaria, pruritis, and flushing of the upper body, though these can be resolved if the infusion is administered at a slower rate (44).

Local administration of vancomycin powder within the operative wound in adults during posterior spinal arthrodesis has gained popularity after a study by Sweet *et al.* who reported a 10-fold decrease in the infection rate with this practice (45). This study has since been supported by several others with similar results. A retrospective review evaluating 1,512 spinal surgery cases with the use of one gram of powdered vancomycin in the surgical site prior to wound closure found an overall postoperative deep infection rate of 0.99% (46). Other studies show no difference in infection rates between groups receiving intra-site vancomycin compared with control groups (1.61% *vs.* 1.68%, P>0.05) (47). A recent meta-analysis by Chiang *et al.* demonstrated that vancomycin is effective in the prevention of SSIs, deep incisional SSIs, and SSIs caused by *S. aureus* in multiple types of spine procedures (48). Local application of vancomycin powder into the surgical wound produces wound drug levels (128–1,457 µg/mL) several fold higher than has been documented with vancomycin elution from bone cement (15 µg/mL) (49). However, pediatric patients receiving intra-site vancomycin for spinal deformity surgery have not had any change in plasma drug concentration or creatinine with the application of 500 mg of intra-site vancomycin (50). Another study looking at thoracolumbar fusion procedures in adults found that after 2 g intra-site deposition of drug powder, plasma vancomycin was detectable on the first postoperative day, but was undetectable in 94% of patients by the second postoperative day (45). There are currently no recommendations on the dosage and timing of intra-site vancomycin application, nor are there guidelines for drug application on the deep fascial layers, supra-fascial layers, and on the bone graft. In most studies doses ranged from 500 mg up to 6 g, although most studies reported an average of approximately 1 g (51). The protective effect of intrasite vancomycin powder on the incidence of SSI has not been shown to increase rates of pseudoarthrosis in clinical studies (44,45). Additionally, fusion rates at a dose up to 10-fold higher than the weight-percentage equivalent of what is routinely used by surgeons has not been shown to inhibit spine fusion rates in rat posterolateral arthrodesis models (52).

Intra-site vancomycin powder has been associated with postoperative seroma formation in a recent observational single-institution study (51). A meta-analysis looking at a total of 6,701 patients who underwent treatment with intrawound vancomycin found an overall complication rate of 0.3% with complications involving nephropathy (1 patient), ototoxicity resulting in transient hearing loss (2 patients), supratherapeutic vancomycin exposure (1 patient), and culture-negative seroma formation (19 patients) (53). Despite these complications, it was determined that intra-site vancomycin use appears to be safe and effective for reducing SSIs with a low rate of perioperative and long-term morbidity. Furthermore, in cases with the powder applied directly onto the dura, no adverse events were noted (54).

Soft tissue handling

It has been suggested that stretch on soft tissues during spine surgery with retractors may lead to decreased perfusion in longer cases and an increased risk of SSI. In a series of 1,358 patients who underwent simple decompression and minimally invasive spinal fusion, superficial infections were found to have originated from problems associated with skin handling or closure (55). Longer operative times result in increased periods of tissue retraction and resulting tissue ischemia and necrosis (56). One strategy proposed to minimize the incidence of infections in longer cases is to frequently release tension on soft tissue retractors and frequently irrigate the wound with saline (57,58).

Estimated blood loss (EBL)

Increased EBL has been suggested to contribute to infection in multiple surgical disciplines including spine surgery for deformity and degenerative disease due to its association with longer operative times (59). Longer surgeries [2–5 hours (P=0.023) and 5 or more hours (P=0.009)] were found to be independent significant risk factors for deep SSI (14). Wimmer *et al.* also found that increased EBL and longer operative times in both anterior and posterior lumbar spinal fusion procedures are associated with increased SSI rates (60). Performing staged cervical, thoracic, and lumbar fusion procedures is associated with greater risk of SSI compared with performing both the anterior and posterior portion of the procedure on the same day (14). This is hypothesized to be due to the recovery period between the two surgeries, where the patient can become malnourished, which has been shown to significantly increase the infection risk (61). The increased infection risk due to surgical blood loss was demonstrated by Pull ter Gunne *et al.* who found that EBL greater than 1 liter was a statistically significant risk factor for SSI in patients undergoing spinal fusion (P=0.017) (58). Increased EBL can also lead to postoperative non-autologous blood transfusions, which have been shown to produce immunosuppression in patients, further increasing the risk of SSI (62).

Drain use

Closed suction wound drains are commonly used in orthopedic procedures to reduce hematoma and dead space formation while simultaneously providing a channel for wound drainage (63). Prophylactic closed suction drainage after spine surgery is the standard of care due to the potentially serious effects hematoma formation around the spinal cord. Drain duration >3 days after spinal fusion procedures has been identified as a risk factor for SSI in univariate analyses (3). More recently, a retrospective review supported this finding and cited an odds ratio of 1.6 per day that the drain was present postoperatively (64). This association may reflect greater drain output in patients who underwent more extensive procedures. Alternatively, drains may increase the risk of infection by causing local tissue inflammation and providing a direct route for bacteria to the surgical site (65). Bacterial colonization of closed suction drains increases over time (66). Studies have shown that SSIs are frequently caused by the same organisms isolated from the drain (a positive drain tip culture predicts wound infection in 50% of cases) (67). Drain removal typically depends on the amount of drain output (often <100 cc/day). More research is required to determine optimal drain duration and to compare the benefits versus risks of wound drains.

Closure and dressings

Wound closure is essential in preventing SSIs by restoring the patient's presurgical barrier between the surgical site and the contaminated skin flora. Before wound closure is undertaken, it has been demonstrated in literature that gentle pulsatile irrigation with detergent solution has resulted in lower infection rates while preserving the number of osteoblasts and osteoclasts in native bone (42,68). Alternatively, Cheng *et al.* demonstrated that the use of dilute Betadine solution resulted in no postoperative infections in a group of 208 patients compared with a 2.9% rate in 206 patients who did not have Betadine irrigation (69). Additionally, a thick layer of adipose tissue in obese patients creates a potential dead space layer with poor vascular perfusion and careful attention must be given to these closures (70,71).

A study comparing a relatively new closure method in long segmented fusions of 2-octyl-cyanocrylate (Dermabond) with surgical staples found that the use of 2-octyl-cyanoacrylate was associated with a lower rate of SSI despite having a cohort with more risk factors for SSI (72). For surgical dressings overlying wound closures, negative pressure wound therapy (NPWT) is associated with a significantly decreased risk of postoperative SSI compared with non-NPWT dressings such as xeroform, gauze, and Medipore™ tape in some studies (10.63% *vs.* 14.91%, P=0.04) (73,74). More recently, various slow-release silver dressings have shown to be comparable and superior to non silver impregnated dressings in reducing rates of superficial SSI (75,76). For large, complex spinal wounds with multiple prior surgeries, prior infection, or previous radiation therapy, closure with layered myocutaneous muscle flaps involving a plastic surgeon has resulted in improved outcomes with better soft tissue healing (77).

Conclusions

Spinal deformity surgeries are often complex and long in duration; a multi-faceted approach is required to decrease postoperative SSI rates including preoperative cleansing protocols, antibiotic administration, gentle soft tissue handling, appropriate closure, drain usage, and intraoperative technique itself to minimize EBL and operative time. SSIs in spine surgery are associated with significant postoperative morbidity and mortality and contribute to rising health-care costs.

Based on the most recent literature, several key practices may be incorporated at various steps throughout the process of spinal deformity surgery. This starts even before entering the OR with the patient performing pre-cleansing the night before surgery and the morning of. Once the patient arrives in the operating room, thorough preoperative prep should be performed with either CHG or iodine. Appropriate timing of antibiotics within 1 hour prior to skin incision, as well as sufficient gram-positive and gram-negative coverage, should be administered prior to incision. During the surgical approach, meticulous hemostasis will allow for decreased blood loss throughout the case which is critical in longer surgeries. The administration of tranexamic acid (TXA) throughout the case may be considered as well for hemostasis. Respecting soft tissues is critical throughout the entirety of the case; this includes subperiosteal dissection and gentle handling of soft tissues with frequent repositioning and releasing of retractors to prevent traction and necrosis. Following instrumentation, gentle irrigation and/or a betadine soak may be considered. The use of vancomycin powder within the wound may also be used at the end of exposure and prior to closure with minimal adverse effects. If a drain is used, pulling it within the appropriate amount of time postoperatively may help decrease infection as well, ideally by postoperative day 3; in more complex cases or revision cases a myocutaneous flap closure may help decrease tension and aid in wound healing. Lastly, one may consider a skin glue-type dressing in order to maintain wound integrity.

While most studies of SSI in spinal deformity surgery have been performed in adult patients, it is clear that the pediatric neuromuscular patient requires particular attention. Neuromuscular patients should regularly receive broad antibiotic coverage in addition to a first-generation cephalosporin. Additionally, neuromuscular patients often have challenging soft tissue closures; gentle handling throughout the case is critical, and one may consider a flap closure as well to ensure a tension-free closure to facilitate healing.

While relatively rare in occurrence, SSI can be devastating in spinal deformity patients. Prevention requires diligence by the spine surgeon preoperatively, at every stage of surgery intraoperatively, and postoperatively. This review summarizes current concepts in infection prevention for both the adult and pediatric spinal deformity patients, and provide areas in which further study is warranted to develop clear guidelines that can be widely adopted in the future.

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Footnote

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