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ORIGINAL ARTICLE

Incidence of surgical site infection following adult spinal deformity surgery: an analysis of patient risk

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Abstract Surgical site infection (SSI) following spinal surgery is a frequent complication and results in higher morbidity, mortality and healthcare costs. Patients undergoing surgery for spinal deformity (scoliosis/kyphosis) have longer surgeries, involving more spinal levels and larger blood losses than typical spinal procedures. Previous research has identified risk factors for SSI in spinal surgery, but few studies have looked at adult deformity surgeries. We retrospectively performed a large case cohort analysis of all adult patients who underwent surgery for kyphosis or scoliosis, between June 1996 and December 2005, by our adult spine division in an academic institution to asses the incidence and identify risk factors for SSI. We reviewed the electronic patient records of 830 adult patients. SSI was classified as deep or superficial to the fascia. 46 (5.5%) patients were found to have a SSI with 29 patients (3.5%) having deep infections. Obesity was found to be an independent risk factor for all SSI and superficial SSI ($P = 0.014$ and $P = 0.013$). As well, a history of prior SSI was also found to be a risk factor for SSI ($P = 0.041$). Patient obesity and history of prior SSI lead to increased risk of infection. Since obesity was related to an increased risk of both superficial and deep SSI, counseling and treatment for obesity should be considered before elective deformity surgery.

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Introduction

Surgical site infection (SSI) following adult spinal surgery is a frequent complication that has been reported to occur in 0.7–12.0% of patients and result in higher postoperative morbidity, mortality and health care costs [1–9]. SSI following spinal surgery has been estimated to increase health care costs by fourfold [10]. Over the last 30 years, rates of spinal surgery have increased significantly with a corresponding increase in number of cases of SSI [11]. As a result, SSI following spinal surgery is creating an increasing cost burden on our society making it important that we understand the risk factors for SSI so that infection risk can be minimized. Within the literature, different patient characteristics (age [12, 13], obesity [9, 14–18], diabetes [14, 19], presence of more than three co-morbid diseases [9], urinary incontinence [9], tobacco use [14], poor nutritional status [13, 20, 21], complete neurological deficit [22] and non-steroidal anti-inflammatory drugs use [23]) and operative characteristics (revision surgery [14, 15], posterior surgical approach [9], tumor resection [9], increased estimated blood loss [14, 20], prolonged surgical time [14] and multilevel surgery fusions extending to the sacrum [24]) have been identified as risk factors for SSI.

In general, surgeries performed for spinal deformities (scoliosis or kyphosis) are felt to be at higher risk for SSI than other spinal surgeries due to prolonged surgical times, larger blood loss, and larger number of levels fused [25–29]. However, few researchers have looked at this high risk group. Rihn et al. [30] reviewed 236 adolescent patients who underwent spinal surgery for adolescent

idiopathic scoliosis to identify specific risk factors for SSI and found 7 (3%) cases of SSI and described the treatment of these infections but did not identify any specific risk factors for developing SSI. Ho et al. [31] also reviewed adolescent idiopathic scoliosis patients and identified "significant medical history", receipt of blood transfusions and failure to use a postoperative drain as factors that increased risk of SSI but was limited by its population size. Other small studies in the literature have not been able to identify patient or surgical characteristics resulting in significantly increased risk for SSI [32–34]. To our knowledge, there have been no published studies describing the risk of SSI in adult patients who have surgery for kyphosis or scoliosis.

In this study, we performed a retrospective cohort analysis of all adult kyphosis and scoliosis patients ($N = 830$) who underwent surgery at our institution. Patient pre-operative characteristics, intraoperative surgical factors and postoperative patient outcome were reviewed. We will compare those patients identified with SSI the rest of the cohort and identify risk factors for SSI. Based upon any identified risk factors, protocols could be developed to try decrease the risk for SSI and thereby decrease patient morbidity, mortality and healthcare costs.

Materials and methods

Patients

After approval from the institutional review board, we used an administrative database to identify all consecutive admissions to the spine division of the adult orthopedic department in our institution between June 1996 and December 2005. All cases performed for the diagnosis of spinal deformity (kyphosis or scoliosis) were included. This resulted in 830 patients who had surgery performed by one of the five fellowship trained orthopedic spine surgeon. The electronic patient record for each patient, which includes all inpatient and outpatient laboratory results, radiographic results, all clinical outpatient notes, all operative notes and discharge summaries were reviewed by a physician and abstracted into an electronic database. All cases of possible SSI were re-reviewed by the senior author to confirm case identification and classification as superficial or deep.

Patient characteristics

Preoperative patient characteristics including age, gender, weight, presence of obesity (BMI > 30), co-morbidities, use of non-steroidal anti-inflammatory (NSAID) drugs, serum albumin level, serum protein level and serum white blood cell count were recorded. For later analysis, poor nutritional status was defined as serum albumin level <35 g/dl or serum protein level <60 g/dl. Total white blood cell count was low if less than 4,500 mm^{-3}. The number of previous spinal surgeries and the diagnosis of a previous spinal SSI were determined from preoperative clinical notes and prior operation notes.

Operative characteristics

During the inclusion period of our cohort, all surgical procedures were performed in the same block of operating rooms. Sterility and air handling characteristics remained unchanged and were monitored by our institutional infection control department. Standard surgical site preparation using DuraPrep® was performed in all cases. In case of iodine allergy, chlorhexidine scrub was utilized followed by an alcohol wash. In cases requiring hair removal, electric clippers were used. First generation cephalosporins were used in all cases except in the case of penicillin or cephalosporin allergies. Antibiotic prophylaxis began at least 30 min prior to skin incision was re-dosed every 4 h or 1,500 cc of blood loss during the procedure and dosed every 6 h for 24 h postoperatively. In cases of allergy, clindamycin was used when no metallic implants were placed and vancomycin was used when implant placement was planned. During review of the patient records, the following characteristics of the surgery were noted. Anatomic location (cervical, thoracic, lumbar and/or sacral), surgical approach (anterior, posterior or a combined anterior/posterior procedure on the same day or staged), type of surgery [decompression, fusion (instrumented or uninstrumented) and osteotomy], surgical estimated blood loss (EBL), number of levels fused and operative time were recorded. Operative time was categorized as 0–2 h, 2–5 h and greater then 5 h.

Outcome measurement

Within our study the primary outcome measurement was SSI. To identify those cases, the clinical notes, discharge summaries, re-admission summaries, all obtained cultures (intraoperative and postoperative) and culture outcome (Gram characteristics and culture results) of all 830 included patients were reviewed. The minimum follow-up period was 1 year. Clinical findings indicating wound infection were: fever, pain, erythema, swelling, warmth, tenderness to palpation and/or drainage [35]. Within our study, a SSI was defined as: any postoperative wound that required treatment with oral or intravenous antibiotics or surgical debridement. In cases of suspected deep infection, routine deep aspiration cultures would be performed. All

clinical SSI were categorized as to whether they were superficial to the fascia, deep to the fascia or both.

Statistical analysis

All analyses were performed using the Statistical Packages for Social Sciences® v15.0 (SPSS, Chicago, IL, USA). Binary logistic regression was used for continuous data and Cochran's and Mantel-Haenszels Chi-square tests were used in case of dichotomous data. Multivariate logistic regression was performed using variables with $P < 0.20$ in univariate analysis. P values were considered significant at $P < 0.05$.

Results

Eight hundred and thirty patients were eligible for inclusion in the current study. The mean age was 55.4 years (±16.1), and the majority of the patients were female ($N = 610$) (Table 1). Statistical analysis showed that age as a continuous variable was not a significant risk factor ($P = 0.523$). However, when age was categorized by decade it did showed to be a significant variability between decades (Table 2). Within our study group, 46 patients were identified as having a SSI with 29 patients having infections that extended deep to the fascia. The performed surgical procedures and it characteristics are summarized in Table 3. The lumbar (84%) and thoracic (75%) spinal regions were most frequently involved and posterior surgical approach was included in most cases (89.4%).

Table 1 Preoperative patient characteristics

	N^a	N^b	%
Gender	830		
Male		220	26.5
Female		610	73.5
Mean age (SD)		55.4 (±16.1)	
Co-morbidities	683		
Diabetes		55	8.1
Obesity		54	7.9
High blood pressure		259	37.9
Other cardiovascular pathology		105	15.4
Active tobacco use		128	18.7
NSAID		117	17.1
Previous surgery	734		
No		263	35.8
One surgery		183	24.9
Multiple surgeries		288	39.2
Previous SSI	695	38	5.5
Preoperative laboratory results			
Low preoperative protein	546	24	4.4
Low preoperative albumin	546	24	4.4

[a] Number of patients where presence of patient characteristic could be determined

[b] Number of patients' characteristic

Within our study group, 46 patients (5.5%) had SSI with 17 patients (2.0%) having superficial SSI and 29 patients (3.5%) having infections going deep to the fascia. Univariate analysis of this group showed that obesity ($P = 0.035$) and history of prior SSI ($P = 0.045$) significantly increased the risk of SSI. When age was categorized by decade, different decades were identified as a significant risk factor for postoperative wound infection (Table 2). Univariate analysis of operative characteristics did not show any significant factors (Table 4). Multivariate analysis, including the previously mentioned variables generated a weak model. The strength of the model increased when age as a variable was excluded. In our population, the surgical approach does serve as an indirect surrogate for age, since within our institution anterior/posterior same day procedures were performed in patients less than 60 years old, while staged procedures were performed in older patients. Performing forward and reverse stepwise regression obesity ($P = 0.014$), and history of SSI ($P = 0.041$) were found to be independent significant risk factors for SSI. Surgeries performed on the anterior and posterior spine on separate days ($P = 0.068$) had a tendency to be independent significant risk factor (Table 5).

Superficial SSI

Sub-analysis showed that 25 patients (3.0%) had a superficial SSI and 17 patients (2.0%) had an isolated superficial SSI. Univariate analysis showed that obesity was a significant ($P = 0.029$) risk factor for superficial SSI. Also, patients of 60–69 years ($P = 0.039$) and 70–79 years ($P = 0.033$) had a significantly higher risk for postoperative wound infection. However, multivariate analysis showed that only obesity ($P = 0.013$) was an independent significant risk factor for SSI (Table 6).

Deep SSI

Twenty-nine patients (3.5%) had a deep postoperative wound infection. During univariate analysis, no significant risk factors were identified. However, we performed a multivariate analysis using forward and reverse stepwise regression. During this analysis, we found that obesity ($P = 0.064$) and procedures performed anterior and posterior on separate days ($P = 0.063$) had the tendency to be independent significant risk factors (Table 7).

Table 2 Univariate comparisons of individual risk factors in patients with superficial or deep surgical site infection after spinal surgery

Preoperative characteristics	*N* with surgical site infection					
	Clinical infection		Superficial		Deep	
	N (rate)	*P* value	*N* (rate)	*P* value	*N* (rate)	*P* value
Gender		0.864		0.645		1.000
Male	11 (5.0%)		5 (2.3%)		7 (3.2%)	
Female	35 (5.7%)		20 (3.3%)		22 (3.6%)	
Mean age	54.0 (SD ± 16.1)		55.8 (SD ± 16.2)		55.8 (SD ± 16.3)	
Age (decade)						
2	3 (23.1%)		2 (15.4%)		1 (7.7%)	
3	1 (1.8%)	**0.021**	0 (0.0%)	0.997	1 (1.8%)	0.300
4	2 (3.1%)	**0.021**	0 (0.0%)	0.997	2 (3.1%)	0.445
5	9 (6.0%)	**0.037**	5 (3.3%)	0.063	4 (2.7%)	0.337
6	16 (8.8%)	0.109	8 (4.4%)	0.106	10 (5.5%)	0.741
7	7 (3.9%)	**0.009**	5 (2.8%)	**0.039**	5 (2.8%)	0.348
8	6 (3.8%)	**0.009**	4 (2.5%)	**0.033**	4 (2.5%)	0.309
9	2 (7.7%)	0.195	1 (3.8%)	0.236	2 (7.7%)	1.000
Diabetes	5 (9.1%)	0.366	2 (3.6%)	0.707	3 (5.5%)	0.458
Obesity	7 (13.0%)	**0.035**	5 (9.3%)	**0.029**	4 (7.4%)	0.142
NSAID	7 (6.0%)	1.000	4 (3.4%)	1.000	5 (4.3%)	0.790
High blood pressure	17 (6.6%)	0.623	12 (4.6%)	0.189	11 (4.2%)	0.682
Other cardiovascular pathology	7 (6.7%)	0.823	5 (4.8%)	0.378	4 (3.8%)	1.000
Active tobacco usage	8 (6.3%)	0.838	4 (3.1%)	1.000	5 (3.9%)	1.000
Low preoperative protein	2 (8.3%)	0.650	2 (8.3%)	0.234	1 (4.2%)	0.581
Low preoperative albumin	2 (8.3%)	0.651	2 (8.3%)	0.236	1 (4.2%)	0.582
Previous SSI	5 (13.2%)	**0.045**	3 (7.9%)	0.101	3 (7.9%)	0.138
Previous surgery						
None	12 (4.6%)		6 (2.3%)		7 (2.7%)	
One surgery	11 (6.0%)	0.498	6 (3.3%)	0.524	8 (4.4%)	0.952
Multiple surgeries	18 (6.3%)	0.385	10 (3.5%)	0.409	12 (4.2%)	0.920

Bold values indicate $P < 0.05$

Discussion

Surgical site infection after spinal surgery is frequently seen, and has been previously linked to length of surgical procedure as independent risk factors [36]. Patients undergoing surgery for scoliosis and kyphosis have prolonged surgical times compared to surgeries performed for other diagnosis. Therefore, it is important to identify variables that increase the risk for SSI in this high risk group so that strategies can be developed to minimize patient risk. The prevalence of SSI infection within our deformity patients was 46/830 (5.0%), this is consistent with the published literature [1–9], with 17 patients (2.0%) having isolated superficial SSI, and 29 patients (3.5%) having SSI that extended deep to the fascia.

Multiple risk factors for SSI have previously been identified. However, most studies have included a wide variety of patient diagnoses and have included relatively small numbers of patients. The limited sample size often limits the ability of these studies to analyze subgroups or identify potential confounding factors. We have previously reported [36] on risk factors for SSI in a large patient cohort ($N = 3174$). During that study, the diagnosis of deformity did have one of the higher risks of SSI. However, we did not perform a separate sub-analysis of this group. In our current patient population, patient obesity, a prior SSI and same day anterior/posterior surgery significantly increased SSI risk, while obesity played a key role in predicting superficial SSI.

The finding that obesity is an independent risk factor of SSI has previously been described in studies of spinal surgery patients [9, 14–17]. However, it has not been previously described within a population of deformity patients. During all of our analysis, neither patient weight nor BMI as a continuous variable was found to be a significant predictor of SSI. Only when patients were

Table 3 Operative characteristics

	N^a	N^b	%
Surgical location	830		
Cervical		69	8.3
Thoracic		625	75.3
Lumbar		698	84.1
Sacral		466	56.1
Approach	830		
Anterior		88	10.6
Posterior		441	53.1
A/P (staged)		133	16.0
A/P (same day)		168	20.2
Procedure	830		
Decompression		324	39.0
Fusion instrumented		816	98.3
Osteotomy		494	59.5
Fused levels	830		
0–1		28	3.4
2–4		242	29.2
>5		560	67.5
Surgery time (h)	830		
0–2		24	2.9
2–5		186	22.4
>5		620	74.7
EBL (l)	606		
<1		79	13.0
>1		527	87.0
Attending surgeon	830		
1		11	1.3
2		443	53.4
3		75	9.0
4		172	20.7
5		129	15.5

[a] Number of patients where presence of patient characteristic could be determined

[b] Number of patients characteristic

categorized as obese (BMI > 30) did the risk of SSI increase. In obesity the subcutaneous fat layer increases in thickness. This may result in the need for increased retraction forces during surgery to provide exposure. This increased force could lead to increased tissue necrosis and thereby an increased risk for SSI. Because of the increased subcutaneous tissue thickness, the obese patient is also at risk for the creation of dead space between the fascia and the skin stitches. This may be controlled by the use of a separate drain in this layer to prevent the development of dead space. Preoperative weight loss can also modify a patient's obesity but weight loss should be done in a balanced matter to prevent malnutrition which can increase the risk for SSI [13, 20, 21].

The history of previous SSI was also identified as an independent risk factor for SSI. This is consistent with the finding in literature for general spinal surgery [14, 15]. Within our study, there was no significant relation between the history of prior spinal surgery and SSI. Therefore, it is not the presence of old scar tissue alone that is responsible for the increased risk for SSI. It is only those cases with a prior infection in the surgical field that showed an increase risk of SSI. In theory, bacteria can lie dormant and encapsulated in the scar tissue following a SSI. Incising the scar tissue in a previously infected wound could release the dormant bacteria and seed into the new wound and lead to greater risk of a SSI. In cases of prior SSI, peri-operative antibiotics should be modified to cover any prior organism and treatment beyond the standard 24-h prophylaxis should be considered.

During analysis of deep wound infections, no risk factors were identified during univariate analysis. However, during multivariate analysis, surgeries performed anterior and posterior on separate days, and obesity was found to have a tendency to be independent significant risk factor. When surgeries performed on the anterior and posterior spine, are performed on separate days, the duration of each operative session will be less than if both surgeries are performed on the same day. One would expect that since each session is shorter that the risk of SSI would lessen since within the literature an increased operating time will result in significant increased risk for SSI [36]. However, when surgery is performed in a staged manner, the cases are typically performed 5–7 days apart and the patient is exposed to two anesthetics and a recovery period between the two surgeries. During this recovery it is typical for the patient to become mal-nourished which has been shown by other authors to significantly increase the infection risk in these staged procedures [21, 37]. In addition, in our institution, spinal surgeries were typically staged when patients who required anterior/posterior surgery were greater than 60 years old or were younger and had multiple co-morbid conditions. Hence, an increased risk of infection in this group could be expected. In these high risk patients, staging procedures over a longer period (several weeks) allowing nutritional recovery or use a parenteral hyperalimentation between the procedures might decrease the risk for SSI.

Limitation of this study

This study is limited by its retrospective nature. All information was obtained by reviewing electronic medical records and providers may vary in the completeness of their notes. This can result in missing data for some patient records, but fortunately our cohort is large enough to accommodate some missing data.

Table 4 Univariate comparisons of operative risk factors in patients with superficial or deep surgical site infection after spinal surgery

Preoperative characteristics	*N* with surgical site infection					
	Clinical infection		Superficial		Deep	
	N (rate)	*P* value	*N* (rate)	*P* value	*N* (rate)	*P* value
Fused levels						
0–1	2 (7.1%)		1 (3.6%)		1 (3.6%)	
2–4	12 (5.0%)	0.537	10 (4.1%)	0.887	9 (3.7%)	0.969
>5	32 (5.7%)	0.708	14 (2.5%)	0.727	19 (3.4%)	0.959
Approach						
Anterior	3 (3.4%)		1 (1.1%)		2 (2.3%)	
Posterior	25 (5.7%)	0.393	13 (2.9%)	0.352	17 (3.9%)	0.472
A/P (staged)	11 (8.3%)	0.159	7 (5.3%)	0.144	7 (5.3%)	0.285
A/P (same day)	7 (4.2%)	0.767	4 (2.4%)	0.504	3 (1.8%)	0.790
Procedure						
Osteotomy	29 (5.9%)	0.647	17 (3.4%)	0.416	19 (3.8%)	0.567
Decompression	15 (4.6%)	0.437	11 (3.4%)	0.679	9 (2.8%)	0.441
Localization of surgery						
Cervical	4 (5.8%)	0.788	1 (1.4%)	0.714	3 (4.3%)	0.727
Thoracic	33 (5.3%)	0.598	17 (2.7%)	0.479	21 (3.4%)	0.667
Lumbar	40 (5.7%)	0.683	23 (3.3%)	0.406	24 (3.5%)	0.797
Sacrum	25 (5.4%)	0.879	15 (3.2%)	0.838	16 (3.4%)	1.000
Surgery time (h)						
0–2	2 (8.3%)		0 (0.0%)		2 (8.3%)	
2–5	12 (6.5%)	0.759	7 (3.8%)	0.998	6 (3.2%)	0.236
>5	32 (5.2%)	0.599	18 (2.9%)	0.998	21 (3.4%)	0.217
EBL (l)						
<1	2 (2.5%)		2 (2.5%)		2 (2.5%)	
>1	26 (4.9%)	0.352	13 (2.5%)	0.972	15 (2.8%)	0.857
Attending surgeon						
1	1 (9.1%)		1 (9.1%)		0 (0.0%)	
2	27 (6.1%)	0.686	12 (2.7%)	0.240	17 (3.8%)	0.999
3	3 (4.0%)	0.467	1 (1.3%)	0.169	2 (2.7%)	0.999
4	6 (3.5%)	0.367	4 (2.3%)	0.218	4 (2.3%)	0.999
5	9 (7.0%)	0.794	7 (5.4%)	0.619	6 (4.7%)	0.999

Table 5 Multivariate logistic regression for postoperative wound infection

Risk factor	Odds ratio (95% confidence interval)	*P* value
Obesity	3.13 (1.26–7.75)	**0.014**
History of SSI	2.98 (1.05–8.50)	**0.041**
Staged (AP)	2.07 (0.95–4.52)	0.068

Bold values indicate $P < 0.05$

Table 6 Multivariate logistic regression for superficial postoperative wound infection

Risk factor	Odds ratio (95% confidence interval)	*P* value
Obesity	3.82 (1.33–10.97)	**0.013**

Bold values indicate $P < 0.05$

Table 7 Multivariate logistic regression for deep postoperative wound infection

Risk factor	Odds ratio (95% confidence interval)	*P* value
Staged (AP)	2.42 (0.95–6.18)	0.064
Obesity	2.93 (0.94–9.15)	0.063

Conclusion

In this retrospective cohort analysis, 830 adult patients underwent surgery for a spinal deformity (kyphosis/scoliosis). 46 patients (5.5%) developed a SSI, 17 patients (2.0%) having an isolated superficial SSI, and 29 patients (3.5%) having a deep SSI. Obese patients have an increased risk

for all types of SSI, while patients who had a prior SSI were at increased risk for recurrent SSI. An anterior/posterior procedure on the same day has a tendency to increase the risk for SSI. By understanding these findings, protocols can be developed to decrease the rate of SSI in this high risk population.

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