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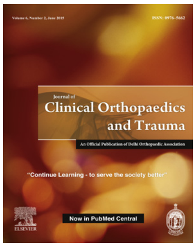

Original Article

Surgical site infection in orthopedic trauma: A case–control study evaluating risk factors and cost

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ABSTRACT

Background: With the shift of our healthcare system toward a value-based system of reimbursement, complications such as surgical site infections (SSI) may not be reimbursed. The purpose of our study was to investigate the costs and risk factors of SSI for orthopedic trauma patients.

Methods: Through retrospective analysis, 1819 patients with isolated fractures were identified. Of those, 78 patients who developed SSIs were compared to 78 uninfected control patients. Patients were matched by fracture location, type of fracture, duration of surgery, and as close as possible to age, year of surgery, and type of procedure. Costs for treatment during primary hospitalization and initial readmission were determined and potential risk factors were collected from patient charts. A Wilcoxon test was used to compare the overall costs of treatment for case and control patients. Costs were further broken down into professional fees and technical charges for analysis. Risk factors for SSIs were analyzed through a chi-squared analysis.

Results: Median cost for treatment for patients with SSIs was $108,782 compared to $57,418 for uninfected patients ($p < 0.001$). Professional fees and technical charges were found to be significantly higher for infected patients. No significant risk factors for SSIs were determined.

Conclusions: Our findings indicate the potential for financial losses in our new healthcare system due to uncompensated care. SSIs nearly double the cost of treatment for orthopedic trauma patients. There is no single driver of these costs. Reducing postoperative stay may be one method for reducing the cost of treating SSIs, whereas quality management programs may decrease risk of infection.

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1. Introduction

Surgical site infections (SSIs) account for over $3 billion in healthcare costs per year, with more than 150,000 new cases occurring annually in the US.[1] A large portion of these costs are attributed to longer hospitalizations, readmissions, and additional surgeries required for the treatment of infected patients.[2] The risk of developing surgical site infections (SSIs) varies tremendously, with orthopedic trauma demonstrating higher rates of SSI than many other surgical specialties.[3,4] However, since orthopedic trauma surgeons are currently reimbursed through a fee-for-service model, there has been little incentive to investigate the costs of treating SSIs among trauma patients. With the recent shift of our healthcare system toward a value-based system of reimbursement, treatment for patients who develop SSIs will potentially go uncompensated. In order to develop appropriate cost-cutting measures[5] and optimize care for high-risk patients, we will require the ability to measure the costs of SSI treatment,[6] identify the major factors driving these costs and investigate potential risk factors for infection.[7,8]

Although several studies have investigated the cost of treating SSIs in orthopedics,[2,9–17] most of these studies included only a small number of orthopedic trauma patients. Therefore, research related to SSIs for patients who sustain fractures and other trauma-related injuries remains limited. The few studies that have analyzed the cost of treating the wound or SSIs following orthopedic trauma only have focused on a specific type of injury and were conducted in other countries.[18,19] Currently, no study has provided a comprehensive analysis of the costs of treating SSIs among a large number of orthopedic trauma patients in the US.

Therefore, the aim of this study was to identify and categorize the costs of care related to SSIs among orthopedic trauma patients. By conducting a matched case/control analysis in which orthopedic trauma patients were matched with patients who did not develop an infection at a single-level I trauma center, we were able to (1) identify increases in costs for infected patients, (2) analyze the major drivers of these costs, and (3) analyze risk factors for SSIs in orthopedic trauma.

2. Methods

2.1. *Retrospective chart review*

Following institutional review board approval, all orthopedic trauma patients who underwent operative management of a fracture at our level I trauma center from January 1, 2005 to December 21, 2010 were identified using 37 Current Procedural Terminology (CPT code) codes (Appendix A). Through this search, 7338 orthopedic trauma patients were identified. A chart review was conducted to identify cases with isolated injuries, which were defined as single fractures requiring operative fixation with no other organ injury. Only patients between 18 and 90 years of age were included in the analysis. Patients who had multiple fractures or had incomplete patient charts were excluded from the analysis.

There were 1819 trauma patients found with isolated fractures between the ages of 18 and 90. Patient charts were reviewed for demographic information including age, gender, American Society of Anesthesiologist (ASA) score and current and previous smoking status. Medical comorbidities including myocardial infarction, cardiac dysthymia, atrial fibrillation, atrial flutter, congestive heart failure, heart block, cerebrovascular disease, bleeding disorder, chronic obstructive pulmonary disease, emphysema, renal insufficiency, dialysis dependency, cancer, and diabetes, were identified. Additional information on the injury was also collected, including whether or not the fracture was open or closed and the location of the fracture on the body. Details on the initial fixation surgery were recorded and included the type of surgery based on CPT code, duration of surgery, type of anesthesia administered (regional or general), and the occurrence of an intraoperative cardiovascular or respiratory event. Postoperative stay was measured as days from surgery to discharge. The incidence of complications including SSIs, non-union, hardware pain, and medical issues, was recorded for each patient. For patients with SSIs, patient charts were further reviewed to identify initial readmissions related to treatment for infection. Treatment included surgical intervention such as irrigation and debridement or antibiotic therapy. The overall length of stay (LOS) was calculated as the time from admission to discharge for the index surgery, and the time for hospitalization during the initial readmission, if required.

2.2. *Matching*

A total of 78 patients who developed SSIs were included as case patients in our study. These case patients were matched one-to-one with control patients who did not develop any complications. Past similar case/control studies[13,17,20] matched patients based on a National Nosocomial Infections Surveillance (NNIS) risk index score that was calculated using ASA score, type of wound, and surgical durations. Since ASA score is determined based on comorbidities, we decided to exclude this control in order to soundly assess the role of comorbidities in the risk of infection. Infected patients were matched to controls by fracture location, fracture type (open or closed) and duration of surgery (>2 h or ≤ 2 h). Patients with open fractures were matched based on the type of fracture (Gustilo grade of 1, 2, or 3). Patients were also matched as closely as possible based on age, year of surgery, and CPT code.

2.3. *Costs*

Hospital charges were obtained from our institution's financial services, and these charges represent the amount billed to patients for services and materials used for treatment during the initial hospitalization for their fracture and, if necessary, the initial readmission. The type of treatment provided during the initial readmission included administration of antibiotics, irrigation, and debridement and hardware removal. Overall costs were broken down into professional fees and technical charges. Professional fees included payment procedures and services performed by surgeons, anesthesiologists, and other health services staff. Technical charges included surgical materials, such as implants and other supplies, anesthesia, medications, radiographs, lab tests, and room and board. The sum of the professional and technical costs for initial hospitalization and readmission were defined as the overall costs of treatment.

2.4. *Statistics*

Data were coded and stored in Microsoft Excel (Microsoft Corp., Redmond, WA). Statistical analysis was performed to compare the difference in overall, surgical, and technical costs for patients with SSIs and uninfected controls using a Wilcoxon test. Within the professional fees category, differences in surgical, evaluation and management, and radiology fees were analyzed by grouping costs by CPT codes (Appendix B). Within technical costs, diagnostic and testing, surgical equipment (including anesthesia), room and board, and pharmacy costs were calculated and compared. Individual comorbidities, smoking status, and postoperative LOS were analyzed as potential risk factors for infection by conducting a chi-squared analysis. Statistical analysis was performed using SPSS (SPSS Inc., Chicago, IL).

3. Results

A total of 78 patients (4.3%) with SSIs and isolated orthopedic trauma injuries were matched to controls. 96% of matched pairs were within 10 years of age and 87% had their initial surgery within 2 years of each other.

Table 1 – Demographics.

	Case ($n = 78$)	Control ($n = 78$)
Age		
18–20	2 (3%)	2 (3%)
21–30	15 (19%)	11 (14%)
31–40	17 (22%)	17 (22%)
41–50	20 (26%)	21 (27%)
51–60	12 (15%)	16 (21%)
61–70	2 (3%)	2 (3%)
>70	10 (13%)	9 (12%)
Type of injury		
Closed	41 (53%)	41 (53%)
Open	37 (47%)	37 (47%)
Fracture grade		
0	53% (41)	53% (41)
I	10% (8)	10% (8)
II	19% (15)	19% (15)
III	9% (7)	10% (8)
IIIA	5% (4)	5% (4)
IIIB	3% (2)	1% (1)
IIIC	1% (1)	0% (0)
IIIA/IIIB	0% (0)	1% (1)
ASA class		
1	7 (9%)	7 (9%)
2	44 (56%)	40 (51%)
3	24 (31%)	25 (32%)
4	3 (4%)	6 (8%)
Location of fracture		
Acetabulum/hip	19 (24%)	19 (24%)
Upper extremity	5 (6%)	5 (6%)
Lower extremity	54 (69%)	54 (69%)

Table 1 compares demographics for our case and control groups. In terms of fracture type, both groups had 41 patients with closed fractures and 37 patients with open fractures. The majority of patients in both groups had an ASA class of 2. Both groups had 19 acetabulum/hip fractures, 5 upper extremity fractures and 54 lower extremity fractures (Table 1).

3.1. *Costs*

Infected patients incurred greater costs than uninfected patients in all categories of service ($p < 0.01$). The median cost for treatment during the initial hospitalization and readmission for an infected patient was $108,782, compared to $57,418 for treatment of an uninfected patient ($p < 0.001$). After further categorizing of the charges, median professional fees for an infected patient was $16,872 compared to $9493 for an uninfected patient ($p < 0.001$). Additional analysis of professional costs demonstrated that infected patients had significantly higher surgical fees ($13,475 vs. $8120) ($p < 0.001$), radiology fees ($718 vs. $524) ($p = 0.029$) and fees for evaluation and management ($1142 vs. $653) ($p < 0.001$). Technical costs were also significantly higher for infected patients ($90,374) than uninfected patients ($47,740). Further inspection of technical costs revealed that infected patients incurred double the costs for diagnostics and imaging ($10,718 vs. $6999), room and board ($5928 vs. $2742), surgical services ($39,502 vs. $21,874), and pharmaceuticals ($15,801 vs. $7091) ($p < 0.001$) than uninfected patients. The median LOS for the initial and secondary hospitalization of infected patients was 7 days compared to only 3 days for uninfected patients ($p < 0.001$) (Table 2a).

Furthermore, in order to compare the index hospitalization costs between the infected patients and uninfected patients, the median readmission costs (Table 2b) were subtracted from the costs calculated for the infected patients (Table 2c). In all cases, expect for diagnostics testing, index hospitalization costs were higher for the infected patients than the uninfected patients. The median professional costs for the index hospitalization of infected patients totaled to $12,508, whereas the median professional costs for uninfected patients were only $9493. Even though the groups were not significantly different, the initial hospital stay was more costly for patients with SSI than those who did not develop infections.

Table 3 shows the total costs for all infected patients compared to uninfected control patients. Over the 5-year period, the cost of treating the 78 patients with SSIs at our institution was $9,630,453. When compared to the cost of treatment for uninfected patients ($5,036,579), we found that the cost of treating SSIs across the 5-year period was $4,593,874. Over 80% of the costs for infected ($8,192,851) and uninfected patients ($4,178,324) were technical costs (pharmaceutical, room and board, and diagnostic) as opposed to professional fees ($1,437,602 and $858,255, respectively). Surgical materials and anesthesia had the greatest difference in costs between the infected patients and the control patients ($1,417,162).

3.2. *Risk factors*

None of the risk factors analyzed were found to be significantly different between the case and control patients. Both infected

Table 2a – Costs and LOS: index + readmission (case) vs. index (control).

	Case		Control		p
	Median	IQR	Median	IQR	
LOS	**7**	(4, 12)	**3**	(2, 5.8)	<0.001
Professional fees	**$16,872**	($10,637, $23,244)	**$9493**	($7960, $12,788)	<0.001
Surgical	**$13,475**	($9304, $19,690)	**$8120**	($6596, $10,229)	<0.001
Radiology	**$718**	($372, $2026)	**$524**	($176, $1782)	0.029
Evaluation and management	**$1142**	($550, $1943)	**$653**	($249, $922)	<0.001
Technical charges	**$90,374**	($50,213, $131,167)	**$47,740**	($35,602, $66,183)	<0.001
Diagnostic	**$10,718**	($5625, $24,327)	**$6999**	($1804, $18,024)	<0.001
Room and board	**$5928**	($3670, $15,732)	**$2742**	($1571, $5616)	<0.001
Surgical/implant	**$39,502**	($26,832, $55,328)	**$2,1874**	($17,138, $28,718)	<0.001
Pharmacy	**$15,801**	($8927, $25,470)	**$7091**	($5602, $9582)	<0.001
Total	**$108,782**	($61,841, $150,972)	**$57,418**	(43,333, $77,667)	<0.001

patients and uninfected patients stayed in the hospital for an average of approximately 3.5 days after their initial surgery (3.5 days and 3.6 days, respectively). Gender, smoking status, type of anesthesia administered and a history of medical comorbidities were not found to be significantly different between the infected and control groups. Both case and control patients were mostly men (65% infected and 68% uninfected) and had 10 current smokers in each group; 12% of infected patients had diabetes compared to 4% of uninfected patients, although this difference was not statistically significant (Table 4).

Table 2b – Costs and LOS: readmission costs.

	Case	
	Median	IQR
LOS	**3**	(0.25, 6.75)
Professional fees	**$4364**	($1629, 8508)
Surgical	**$3634**	($1371, $6964)
Radiology	**$70**	($0, $191)
Evaluation and management	**$448**	($0, $996)
Technical charges		
Diagnostic	**$4237**	($1124, $8578)
Room and board	**$3100**	($696, $6596)
Surgical/implant	**$11,445**	($4752, $22,020)
Pharmacy	**$7939**	($12,679, $19,502)
Total	**$31,141**	($13,183, $66,181)

Table 2c – Costs and LOS: index (case) vs. index (control).

	Case	Control	Higher index cost
	Median	Median	
Professional fees	**$12,508**	**$9493**	Case
Surgical	**$9841**	**$8120**	Case
Radiology	**$648**	**$524**	Case
Evaluation and management	**$694**	**$653**	Case
Technical charges			
Diagnostic	**$6481**	**$6999**	Control
Room and board	**$2828**	**$2742**	Case
Surgical/implant	**$28,057**	**$21,874**	Case
Pharmacy	**$7862**	**$7091**	Case
Total	**$77,641**	**$57,418**	Case

Table 3 – Total costs.

	Case	Control
Professional	$1,437,602	$858,255
Surgical	$1,156,035	$708,206
Radiology	$92,957	$72,572
Evaluation and management	$150,474	$62,708
Technical	$8,192,851	$4,178,324
Diagnostic	$1,339,788	$757,998
Room and board	$923,849	$405,008
Surgical/implant	$3,324,728	$1,907,566
Pharmacy	$1,736,657	$661,993
Total	$9,630,453	$5,036,579

Table 4 – Risk factors for infection.

Risk factor	Case	Control	p
Female gender	27 (35%)	25 (32%)	0.73
Myocardial infarction	1 (1%)	1 (1%)	1
Cardiac dysthymia	1 (1%)	5 (6%)	0.096
Atrial fibrillation	0 (0%)	2 (3%)	0.15
Atrial flutter	0 (0%)	1 (1%)	0.32
Congestive heart failure	2 (3%)	1 (1%)	0.56
Heart block	0 (0%)	1 (1%)	0.32
Cerebrovascular disease	1 (1%)	0 (0%)	0.32
Bleeding disorder	1 (1%)	0 (0%)	0.32
Chronic obstructive pulmonary disease	0 (0%)	1 14%)	0.32
Emphysema	0 (0%)	0 (0%)	1
Past smoker	3 (4%)	2 (3%)	0.65
Renal insufficiency	1 (1%)	1 (1%)	1
Dialysis dependent	0 (0%)	0 (0%)	1
Cancer	1 (1%)	1 (1%)	1
Diabetes	9 (12%)	3 (4%)	0.071
Current smoker	10 (13%)	10 (13%)	0.97
Intraoperative cardiovascular event	1 (1%)	0 (0%)	0.32
Intraoperative respiratory event	1 (1%)	0 (0%)	0.32
General anesthesia	76 (97%)	78 (100%)	0.15
Postoperative stay	3.5 (3.1)	3.6 (3.6)	0.9

4. Discussion

Our study demonstrates that SSIs nearly doubled the costs for treating isolated orthopedic trauma injuries. The actual costs of treating SSIs are most likely higher than our estimates as some infected patients may have required additional hospitalization and surgery beyond the initial readmission. When divided over the 5-year period of our study, the cost of treating SSIs ended up averaging almost $2 million per year. The major driver of these costs was the technical charges instead of the professional fees, which included pharmaceuticals, room and board, radiographs, laboratory procedures, and surgical equipment. In fact, pharmaceutical costs, which account for the cost of antibiotics, were nearly doubled for patients with SSIs ($15,801 for the case group compared to $7091 for the control group). Calderone et al. reported similar findings in patients who developed wound infections following lumbar fusion for spinal surgery. They concluded that technical charges may be the largest driver of costs in treating infections for orthopedic injuries.[14]

A few other studies have measured the cost of infection following orthopedic surgery in the US.[12,13,17] In a recent study of 59 infected patients, Whitehouse et al.[13] found that SSIs in orthopedics increase costs by 300% and prolong hospital stay by more than 2 weeks. Although these costs are higher than those reported in our study, only a small portion of their participants had fractures. Therefore, our results may indicate that the costs for treating an SSI may be less following trauma than other types of orthopedic procedures. Furthermore, our study only looked at the initial readmission for infections and therefore may have not included the costs of treatment for further readmissions required to treat the infection.

Only a few other studies have investigated the costs of treating infections among orthopedic trauma patients that sustained fractures of the hip or lower extremity. A study on patients with proximal femoral fractures in the U.K. found that LOS and costs following deep wound infection were about three times higher than they were for controls (80 days vs. 28 days).[18] Edwards et al.[19] also found that wound infections tripled overall costs and quadrupled LOS to 77 days for hip fracture patients in the U.K. The differences in our findings demonstrate how national healthcare reimbursement systems can strongly influence LOS and costs. As the US moves toward a value-based system of reimbursement, hospitals will face even more pressure to minimize LOS for surgical patients to prevent financial losses due to uncompensated care for SSIs.

A major driver of costs for infected patients in our study was increased LOS. When combining the LOS for both the index surgery and initial readmission, we found that patients with SSIs were hospitalized on average 4 days longer than uninfected patients and incurred almost two times the costs for room and board. Other studies have found similar results; for example, Lissovoy et al. conducted a nationwide study of seven different surgical procedures and found that SSIs increased mean LOS by 9.7 days for orthopedic surgery,[12] which was comparable to the number of days cited in other studies.[21] However, patients undergoing orthopedic trauma surgeries, including ORIF or hip arthroplasty, only composed a small component of these patients. The economic burden of SSIs most probably varies dramatically for patients with trauma injuries compared to those that have laminectomies, tumor resections, and other orthopedic procedures. Additionally, based on previous research and our own findings, this overall increased duration of hospitalization is most likely due to the need for additional surgery among patients who present with SSIs.[21]

Similar to other case vs. control studies, the majority of comorbidities analyzed were not found to be significant risk factors for infection, including smoking and diabetes.[19,21,22] Nevertheless, there was a considerably higher rate of diabetes in the infected group, 12% vs. 4%, but this was not significant ($p = 0.07$). Postoperative stay was also not found to be associated with SSIs, which has been demonstrated by previous studies. For example, Manian et al.[22] reported that a long postoperative hospital stay was not a significant risk factor for MRSA SSI and instead discharge to a long-term care facility and postoperative antibiotic treatment for more than 1 day increased the risk of MRSA SSI. On the contrary, other orthopedic studies have determined a correlation between length of hospital stay and SSIs[17]; however, other factors, such as age over 75, metastatic disease and congestive heart failure, have also been linked to increased LOS.[21]

Our findings from the risk factor analysis lead to several implications. For instance, changing hospital protocol to prevent SSIs in patients with longer than average LOS may not decrease infection rates. A study by Rowell et al. found that quality improvement programs, such as proper antibiotic administration, glycemic control, and no closure of contaminated wounds, reduced SSI. Interestingly, decreasing the LOS was not considered a valuable method to decrease the risk of infection.[7]

Our study is limited due to several factors. Because we used a retrospective design, we could only collect information about the patients of our institution that was available within the electronic medical records. Therefore, we were unable to control for differences in body mass index, as this parameter was missing from the medical record for the majority of our patients. With this in consideration, it is important to note that a near significant difference in the rate of diabetes between patients who developed an infection and those who did not ($p = 0.07$) may have biased the risk factors for SSI. Also, we only analyzed the initial readmission following the primary admission for surgical fixation. However, it is possible that patients who developed SSIs may have had more than one readmission. Therefore, our costs probably underestimate the true costs for treating infection. However, even prospective studies on this topic have limited the follow-up period for identifying readmissions from 30 days to 1 year. We were also limited by the number of factors that could be controlled due to the case/control design of the study; therefore, based on previous similar studies, we controlled the factors that would have the highest impact on cost. However, a variety of other factors, such as mechanism of injury, could have also played a role in increasing the costs of treating infection. When analysing the impact of LOS on the risk of SSI, there were several factors that could not be controlled for, including the time of the day of surgery (morning or evening), the time of the year of the surgery (weekend/holiday), as well as the difference in time to discharge for lower and upper extremity fractures, that would have biased the results. It was also difficult to find control patients matched to cases within a specific age and date of surgery or by the exact procedure performed. Finally, like many past studies, we used hospital charges to estimate costs for treating SSIs.[14,15,23,24] However, hospital charges are usually overestimates of the actual costs to the hospital for the services provided during treatment. We attempted to offset this limitation by using a matched case–control method so that the difference in charge to cost ratio was partially accounted for.[24]

This study is the first to provide a comprehensive analysis of the major costs and risk factors for SSIs across orthopedic trauma patients. In the current reimbursement model, hospitals and physicians are compensated for additional treatment required for infections. In a future global payment model, however, orthopedic trauma surgeons will be challenged to cover the costs of treating SSIs. Based on the findings presented, physicians must implement methods such as quality improvement programs to decrease the rate of SSIs. A prospective study that measures the actual costs of materials and services that hospitals incur when treating infected patients and focuses on specific anatomic regions would be able to better demonstrate the potential financial implications of SSIs in a changing healthcare landscape.

IRB approval

This study has approval from the Vanderbilt IRB.

Conflicts of interest

William Obremskey has been previously consulted for biometrics; provided expert testimony in legal matters, and received a grant from the Department of Defense. For the remaining authors, no conflicts of interest were declared.

Appendix A. CPT codes included in analysis

Acetabulum	
	27226
	27227
	27228
	27254
Lower extremity	
	27506
	27511
	27513
	27535
	27536
	27570
	27590
	27592
	27594
	27602
	27756
	27758
	27759
	27766
	27792
	27814
	28415
	28445
	28615
Upper extremity	
	23515
	23585
	23615
	24515
	24545
	24546
	24685
	25575
	25607

Appendix B. CPT codes and descriptions of categories of service

Service	CPT codes	Description
Surgery	10021-69990	All surgical procedures within ten body systems, including surgical packages and separate procedures
Radiology	70010-79999	Diagnostic imaging, including services performed by radiologists and radiology technicians
Evaluation and management	99201-99499	Consultations and services by physicians and other qualified professionals

Source: Marie A. Moisio (8 April 2009). *Medical Terminology for Insurance and Coding*. Cengage Learning.

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