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Effects of Operating Room Size on Surgical Site Infection Following Lumbar Fusion Surgery

HAROLD I. SALMONS, BS, MAYAN LENDNER, BS, SRIKANTH N. DIVI, MD, MYLES DWORKIN, BS, JAMES MCKENZIE, MD, DANIEL TARAZONA, MD, ZACHARY GALA BSE, YOVEL LENDNER, BARRETT WOODS, MD, DAVID KAYE, MD, JASON SAVAGE, MD, CHRISTOPHER KEPLER, MD, MARK KURD, MD, VICTOR HSU, MD, KRIS RADCLIFF, MD, JEFF RIHN, MD, GREG ANDERSON, MD, ALAN HILIBRAND, MD, ALEX VACCARO, MD, PHD, MBA, GREGORY SCHROEDER, MD

Rothman Institute at Thomas Jefferson University Hospital, Philadelphia, Pennsylvania

ABSTRACT

Background: Surgical site infections (SSIs) represent a devastating complication after spine surgery. Many factors have been identified, but the influence of operating room (OR) size on infection rate has not been assessed.

Methods: Two thousand five hundred and twenty-three patients who underwent open lumbar spine fusion at a single institution between 2010 and 2016 were included. Patients were dichotomized into large versus small groups based on OR volume. Bivariate logistic regression and a final multivariate model following a multicollinearity check were used to calculate odds of infection for all variables.

Results: A total of 63 patients (2.5%) developed SSIs with 46 (73%) in the larger OR group and 17 (27%) in the smaller OR group. The rate of SSIs in larger ORs was 3.02% compared with 1.81% in smaller ORs. Significant parameters impacting SSI in bivariate analysis included an earlier year of surgery, BMI $>$ 30, more comorbidities, more levels decompressed and fused, smoking, and larger OR volumes. Multivariate analysis identified BMI $>$ 30, Elixhauser scores, smoking, and increasing levels decompressed as significant predictors. Topical vancomycin was found to significantly decrease rate of infection in both analyses.

Conclusions: OR size (large versus small) was ultimately not a significant predictor of infection related to rates of SSIs, although it did show a clinical trend toward significance, suggesting association. Future prospective analysis is warranted.

Level of Evidence: 3.

Lumbar Spine

Keywords: infection, spine, fusion, size, operating room

INTRODUCTION

Surgical site infections (SSIs) remain a common and costly complication encountered during surgery.[1] According to the Centers for Disease Control and Prevention, SSIs may occur in 1% to 3% of all surgeries. Studies have shown that SSIs can increase hospital length of stay by 5 or more days and increase readmission rates by 600%.[2] SSIs also increase the incremental cost of care for both hospitals and patients. In a retrospective study reporting incremental hospital costs associated with adverse events following cervical spine fusion, the highest reported expense was managing complications from SSIs ($42 358).[3] They can cost hospitals up to $6,000,000 annually while subsequently reducing the patient's quality of life and increasing risk of neurologic injury, sepsis, or death.[2,4]

SSIs are especially devastating when associated with surgical procedures that require the use of permanent metal implants, such as in spine fusion surgeries. SSIs following lumbar fusion occur at a rate between 0.3% and 9%, and many different patient and surgical variables have been found to affect the infection rate.[5–10] However, the impact of environmental factors, such as operating room (OR) size, has not been fully elucidated in the scientific literature. A larger OR may have different environmental factors than a smaller OR with regard to increased door traffic, being more difficult to clean and having more participants in surgery.[11–13] As the size of the operating theater is a potentially controllable factor that may influence infection rate following spine surgery, the study of such an effect is warranted. This study aims to analyze the impact of OR size on the risk of SSI in patients who

underwent lumbar fusion surgery. We hypothesized that having a lumbar spine fusion in a large OR would increase the likelihood of infection.

MATERIALS AND METHODS

All patients undergoing 1- to 3-level open lumbar spine fusion with instrumentation at a high-volume, single institution between 2010 and 2016 were retrospectively reviewed. Patients over the age of 18 and operative levels between T12 and S1 were included. The decision on approach (posterolateral alone, transforaminal interbody fusion, or combined anterior/ posterior fusion) was individually determined by each surgeon. Standardized sterile draping and skin preparation with Povidone-iodine solution was used for each indexed case. Antibiotic prophylaxis for each case included cefazolin, vancomycin, or clindamycin, depending on patient-specific characteristics, including past allergic reactions to beta-lactam antibiotics or a history of MRSA as per institutional guidelines. Exclusion criteria included infection on presentation, lumbar fusions that involved greater than 3 levels, patients under the age of 18, and patients who underwent a staged anterior/posterior procedure if they were not done in the same OR.

Infection data were provided by the Institutional Infection Control Committee (ICC) at our institution. An SSI was classified by the ICC based on the Centers for Disease Control National Health Safety Network's (NHSN) definition applicable to each calendar year. Both superficial and deep incisional SSIs were included as defined by the NHSN. Patient demographics, including age, sex, race, body mass index (BMI), smoking status, and medical comorbidities as assessed by the Elixhauser score and the Charlson Comorbidity Index (CCI), were identified and recorded. Environmental and surgical variables, such as approach, revision status, use of topical vancomycin powder, number of levels decompressed and fused, number of levels with an interbody cage, duration of surgery (incision to closure), total case duration under anesthesia, presence of laminar flow in the OR, and total OR size were recorded. The OR size was calculated as room volume in cubic yards obtained from blueprints and subsequently dichotomized into 2 groups (large versus small). An OR was designated as small if it was below the mean OR size and large if it was greater than the mean OR size. The mean room volume was 187.6 yd^3. Of the 17 ORs analyzed, 9 fit the criteria for large (group A), and 8 fit the criteria for small (group B). Of note, 7 out of 9 large rooms used laminar airflow compared with only 1 out of the 8 small rooms.

Statistical Methods

Differences in demographic data were analyzed using a chi-square test or Fisher exact test for categorical variables and an independent *t* test for continuous variables. Preliminary bivariate logistic regression analyses with infection as the outcome variable were conducted to determine whether various surgical and patient background variables were significantly related to infection. A cutoff value of $P < .25$ as recommended by Hosmer and Lemeshow was used for inclusion of the variable in the final multivariate predictive model.[14,15] If 2 variables with significant multicollinearity were identified, only 1 of the variables was selected. The remaining predictors were entered into a final multivariate logistic regression. All analyses were conducted with the statistical package SPSS (IBM Corp, 2013, version 23).

RESULTS

A total of 2,523 patients were included in the study, with 1,568 patients who underwent surgery in large ORs (group A) and 955 patients who underwent surgeries in small ORs (group B). Gender, age, operative approach, vancomycin powder use, case duration, and surgery duration were significantly different between the 2 groups ($P < .05$; Table 1), while BMI was not significantly different. The total number of infections in the complete cohort was 63 (2.5%), with 46 in group A and 17 in group B (3.02% versus 1.81%, $P = 0.072$).

Bivariate logistic regression analysis assessing patient and surgical variables is shown in Table 2. Having an earlier year of surgery, BMI over 30, Caucasian race, being a current smoker, a higher Elixhauser score or CCI, lack of vancomycin powder use intraoperatively, an increasing number of levels decompressed and fused, and increasing OR volume were associated with an increased rate of infection ($P < .05$; Table 2). Posterior-only versus anteroposterior approach was not found to be a significant predictor of infection on bivariate analysis (odds ratio 0.877 [95% confidence interval (CI), 0.494, 1.558]; $P = .655$) and was therefore excluded from the final multivariate analysis. The presence of laminar flow in the OR was also not

Table 1. Demographic data for patients who underwent surgery in a small versus large operating room (OR).

	Group A (Large OR)	Group B (Small OR)	*P* Value
N (%)	1568 (62.1)	955 (37.9)	
Male gender (%)	681 (43.4)	464 (48.6)	.012[a]
Mean age (SD)	58.98 (13.11)	60.10 (12.81)	.037[a]
Mean BMI (SD)	30.77 (6.33)	30.51 (6.76)	.339
Infection (%)	46 (3.02)	17 (1.81)	.072
Posterior only (%)	967 (61.7)	851 (89.1)	< .001[a]
Vancomycin powder (%)	994 (63.4)	652 (68.3)	.013[a]
Case duration in minutes (SD)	320.75 (109.25)	282.78 (82.07)	< .001[a]
Surgery duration in minutes (SD)	245.67 (101.58)	210.21 (75.44)	< .001[a]
Revisions (%)	143 (9.1)	108 (11.3)	.075

Abbreviation: BMI, body mass index.
[a]Statistically significant ($P < .05$).

found to be a significant predictor of infection (odds ratio 0.846 [95% CI, 0.503, 1.423]; $P = .528$). In addition to the variables that came to significance on bivariate analysis ($P < .05$), the remaining predictors age over 65, sex, Caucasian race, number of levels with an interbody cage, total case duration (in room time), surgery duration, OR volume (yd^3), and large versus small OR size all met the threshold for inclusion into the final multivariate model ($P < .25$).

In the multicollinearity check, CCI was correlated with age ($r = .69$) and Elixhauser scores ($r = .48$), so CCI was excluded. The number of levels fused and decompressed were also correlated ($r = .60$); thus, the number of levels decompressed was retained since it carried more significance at the bivariate level ($P = .003$ versus $P = .006$). Case duration and surgery duration were also highly correlated ($r = .98$); thus, surgery duration was removed, as it was less significant at the bivariate level. However, due to borderline multicollinearity statistics causing an inflated conditioned index, case duration was also removed from the final model. Age and BMI were dichotomized because they generated large conditioned indices. Vancomycin use and year of surgery were also moderately correlated ($r = .61$). Given its greater importance to the study, vancomycin use was retained for the final model. The final multivariate model included the following predictors: age over 65, sex, Caucasian race, BMI over 30, smoking status, Elixhauser score, topical vancomycin powder use, number of levels decompressed, number of levels with an interbody cage, OR volume (yd^3), and OR size (large versus small).

Table 2. Bivariate logistic regression analysis of infection.

Predictor	Odds Ratio	95% CI	*P* Value
Year of surgery	0.791	0.690–0.907	.00 [a]
Age > 65	1.443	0.873–2.384	.152[b]
Gender (female)	1.358	0.812–2.273	.243[b]
BMI > 30	2.792	1.607–4.851	.000[a]
Caucasian	2.228	1.193–4.159	.012[a]
Current smoker	2.984	1.638–5.438	.000[a]
Elixhauser score	1.259	1.082–1.466	.003[a]
CCI	1.159	1.025–1.309	.018[a]
Revision	0.608	0.219–1.687	.339
Anterior/posterior versus posterior only	0.877	0.494–1.558	.655
Vancomycin used	0.474	0.287–0.783	.004[a]
Levels fused	1.564	1.136–2.154	.006[a]
Levels decompressed	1.439	1.127–1.836	.003[a]
Levels with TLIF cage	0.732	0.455–1.177	.197[b]
Case duration in minutes	1.002	1.000–1.004	.088[b]
Surgery duration in minutes	1.002	0.999–1.004	.130[b]
OR volume (yd^3)	1.000	1.000–1.019	.044[a]
Laminar flow	0.846	0.503–1.423	.528
OR size (A versus B)	1.668	0.950–2.926	.075[b]

Abbreviations: CI, confidence interval; BMI, body mass index; CCI, Charlson Comorbidity Index; OR, operating room.
[a]Significant variables ($P < .05$) that were considered for entry into final model.
[b]Variables ($P < .25$) that were also included in final multivariate model.

Table 3. Multivariate analysis of factors affecting the risk of developing SSI following lumbar fusion.

	Odds Ratio	95% CI	*P* Value
Age > 65	1.385	0.799–2.403	.246
Gender (female)	1.271	0.746–2.166	.378
BMI > 30	2.829	1.602–4.997	< .001[a]
Elixhauser score	1.196	1.002–1.428	.048[a]
Current smoker	3.469	1.961–6.137	< .001[a]
Levels decompressed	1.382	1.053–1.815	.020[a]
Vancomycin use	0.364	0.216–0.613	< .001[a]
OR size (A versus B)	1.009	0.999–1.018	.079

Abbreviations: CI, confidence interval; BMI, body mass index; OR, operating room.
[a]Statistically significant.

Results of the multivariate logistic regression analysis are shown in Table 3. OR size (group A versus group B) was not found to be significantly associated with surgical site infection with an odds ratio of 1.009 ([95% CI: 0.999, 1.018], $P = .079$; Table 3). However, having a BMI > 30 (odds ratio 2.829 [95% CI: 1.602, 4.997], $P < .001$), the presence of multiple comorbidities (Elixhauser) (odds ratio 1.961 [95% CI: 1.002, 1.428], $P = .048$), being a current smoker (odds ratio 3.469 [95% CI: 1.961, 6.137], $P < .001$), and increasing number of levels decompressed (odds ratio 1.382 [95% CI: 1.053, 1.815], $P = .020$) were found to be independent predictors of infection. Use of vancomycin powder intraoperatively was associated with a decreased rate of infection (odds ratio 0.364 [95% CI: 0.216, 0.613], $P < .001$).

DISCUSSION

SSIs remain one of the most significant challenges in health care today. SSI can negatively impact

quality of care, increase length of stay, and increase overall health care costs. Patient characteristics such as smoking status, age, BMI, and the presence of multiple comorbidities have been identified as risk factors for SSI.[16–18] However, operative and environmental variables, such as the OR itself, have become areas of major interest. The impact of unidirectional laminar airflow, the number of individuals participating in the procedure, and the climate maintained in the OR have become important considerations to reduce airborne organisms and infection risk.[19,20] To the authors' knowledge, however, there have been no peer-reviewed articles investigating the impact of the OR's size on surgical site infection. While there have been studies that demonstrated a direct correlation between the size of patient rooms and rates of infection, no study until now has examined this concept in the operative setting.[11]

In our study, there was a 2.50% incidence rate of SSI across the 7-year span of this cohort, which falls within with the infection rates described in the literature.[5–10] The difference in infection rate between large (group A) and small (group B) OR size was (3.03% versus 1.86%, $P = 0.072$). OR size (group A versus group B) was also not found to be a significant predictor on bivariate or multivariate logistic regression analysis ($P = .075$ and $P = .079$); however, the trend in P values suggests that there may be some clinical association. Possible causes of increased infection rates in larger rooms suggested by prior studies include increased difficulty in cleaning larger rooms, more people present in the OR, and increased door traffic.[11–13] However, a retrospective study by Wanta et al[21] showed no association of additional OR personnel to SSI for any of their subgroups (scrubbed surgical, non-scrubbed, or anesthesia). Additionally, a review by Alizo et al[22] found that airborne bacteria (a possible link between OR traffic to SSIs) were related to traffic flow but not to SSI incidence. Thus, while larger ORs often encourage more door traffic and personnel, the impact of these factors on SSI warrants future prospective study. On the other hand, protective factors may also exist in larger ORs. Larger areas may allow health providers more space opposed to being confined to a small room where the sterile field is more accessible to all participants.

The risk of developing an SSI varies greatly according to the type of procedure being performed, the specific clinical characteristics of the patient undergoing surgery, and the OR environment in which the surgery is performed.[12,23] The present study identified certain endogenous risk factors that increase the odds of infection. Having a BMI over 30, being a smoker, an increasing number of levels decompressed, and having multiple medical comorbidities were all shown to significantly increase the odds of infection following surgery ($P < .05$). These results correlate with the existing literature.[16–18,24–26]

Perioperatively, the use of vancomycin powder, presence of consistent unidirectional laminar airflow, and room temperature monitoring are important considerations, as they have been shown to influence infection rate in previous studies.[19,27] Temperature monitoring was not recorded in the present study, and laminar airflow was not found to significantly affect infection rates on bivariate analysis ($P = .528$). However, the use of vancomycin powder was found to significantly reduce SSIs in both bivariate and multivariate logistic regression analyses. This is consistent with a 2013 review by Kanj et al[28] that found the use of vancomycin both safe and effective at reducing SSIs in orthopedic procedures. This is likely in part due to its efficacy in treating *S. aureus*, which may be responsible for up to 48.6% of SSIs in orthopedic procedures and especially treating strains that are resistant to standard beta-lactams.[28]

The authors acknowledge several limitations to this study. Due to its retrospective nature, the study could not address and control for all patient or environmental confounders. Additionally, fully appreciating all perioperative variables that may have contributed to infection for each case was not possible. One possible confounding factor was that the use of intraoperative vancomycin powder varied with the year of surgery. While this was controlled for with the multicollinearity check prior to inclusion in the final multivariate model, there may have been other factors contributing to a change in practice over the study period, limiting our interpretation of vancomycin powder use. Additionally, the number of health care participants assisting with each case was unable to be determined due to the retrospective nature of this study. As this study was performed at an academic medical center, the number of participants varied on a case-by-case basis. However, the effect of the number of participants on airborne microbial count has

garnered mixed conclusions in prospective reports with some indicating no relation and others saying the 2 are correlated.[19,20] Furthermore, data for use of bone graft were unable to be obtained to determine whether the type of graft used, specifically rhBMP-2 or ICBG, contributed to an increased infection rate. Harvesting autologous ICBG requires a secondary incision, which could increase the potential for wound contamination. These data were unable to be accurately obtained due to inconsistent coding practices between providers for these procedures as well as the retrospective nature of this study. Finally, the study spanned a 7-year period in which minor changes to NHSN infection criteria occurred. These changes were minor adjustments to definitions but may have led to an underestimation of the total infection cases, as the earlier criteria were found to be less specific than the criteria toward the latter years of our study period.

In conclusion, we present the first report investigating the impact of OR size on surgical site infection. Although having lumbar spinal fusion surgery in a large versus a small OR was not significantly related to an increased risk of surgical site infection in our study, a trend toward significance in the data suggests there may be an underlying clinical association that could potentially be identified with a larger cohort. In the future, prospective study of the size of the OR on infection rate and the evaluation of OR environmental risk factors would be valuable.

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Corresponding Author: Mayan Lendner, BS, Rothman Institute, 925 Chestnut St, 5th Floor, Philadelphia, PA 19107. Phone: (215) 317-1321; Email: Mayan.lendner@gmail.com.

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