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The Temporality of Deep Surgical Site Infection Rates Following Spinal Laminectomy and Fusion

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ABSTRACT

Background: Deep surgical site infections (dSSI) following spinal laminectomy and fusion are serious complications associated with poor patient outcomes. The objective of this study is to investigate the monthly and seasonal variability of dSSI rates following common spinal surgeries to investigate the "July effect," which refers to the alleged increase in adverse health outcomes due to new hospital trainees at the beginning of the academic year.

Methods: We performed a retrospective analysis of patients who had a dSSI following laminectomy (without fusion) or spinal fusion (with or without laminectomy) at a single large urban academic medical center between January 2009 and August 2018. The change in dSSI rate over the entire study period was calculated. The monthly and seasonal variability of dSSI were assessed using a Poisson regression model to assess for the presence of the July effect.

Results: A total of 7931 laminectomies and 14,637 spinal fusions were reviewed. The average dSSI rates following laminectomy and spinal fusion were 0.46 (SD, 0.47) and 1.26 (SD, 0.86) per 100 patients, respectively. The rate of dSSI following spinal fusion significantly decreased over the study period (rate ratio [RR] = 0.89, 95% CI 0.84–0.94, $P < 0.01$). With summer as the reference season, there were significantly lower dSSI rates following spinal fusions performed in the fall (RR = 0.62, 95% CI 0.39–0.98, $P = 0.04$). With July as the reference month, there was a significantly higher dSSI rate in April following spinal fusions.

Conclusion: The overall decrease in dSSI rate over the study period is consistent with previous reports. The monthly analysis revealed no significant differences in either procedure, calling into question the July effect.

Clinical Relevance: This study is relevant to practicing spinal surgeons and can inform surgeons about seasonal data regarding dSSIs.

Level of Evidence: 3.

Complications

Keywords: surgical site infections, laminectomy, spinal fusion, seasonal variability, monthly variability, yearly variability

INTRODUCTION

Despite the advances in prevention guidelines, surgical site infections (SSIs) remain a challenge in many orthopedic surgeries. While there is a volume of literature investigating the temporal variability of SSIs following hip and knee orthopedic procedures, SSIs are a significant complication across all subspecialties of orthopedic surgery, including spine surgery. SSIs can result in increased morbidity and mortality, hospital readmissions, and postoperative pain.[1–3] Based on the spine surgery literature, the rates of SSIs following procedures are variable, with a reported range of 0.5% to 20%.[4,5] Spine surgeries also contribute to the burden that SSIs place on the health care system. A cost analysis of spine surgeries determined that wound infections following various spinal procedures increased the average cost of care by $4067.[6]

Several patient and procedural factors are known to increase the risk for SSIs, including smoking, obesity, diabetes, malnutrition, hypoalbuminemia, increased operative time, and high personnel turnover.[7] Surgeons may decrease the risk of postoperative SSIs by having a thorough understanding of these risks and employing strategies to reduce them. While the relationship between several of these risk factors and SSI in patients undergoing surgical procedures has been well elucidated, the association of month of the year and seasonality with SSI warrants further investigation to support surgeons' recognition of these infections.[8] A possible cause of the temporal heterogeneity in SSI rates is the "July effect," which is the hypothetical increase in adverse health outcomes due to new hospital trainees at the beginning of the academic year.[9,10] This hypothesis is likely multifactorial. It may be due to the incoming surgical residents being unaccustomed to their clinical responsibilities and anxiety in starting a new role.

However, it could also be an organizational challenge in teaching trainees how to place orders, who to contact if a test is not done, and developing a culture that enables new residents to freely approach colleagues for assistance. In addition to the first-year interns, the July effect may represent the augmented operating room and patient management responsibilities of more advanced surgical residents.[11] Previous studies assessing the July effect have reported conflicting results.[10,12–14] The current study is based on the methodology of our previous study, in which we analyzed over 98,000 cases that included mostly all orthopedic surgical procedures. We reported that there was a significantly greater rate of deep SSI (dSSI) in the summer compared with the winter.[14] However, there was no significant difference in dSSI rate in July compared with other months.[14]

The present study examines the monthly and seasonal variability of dSSI rate following laminectomy and spinal fusion/revision fusion over a period of 116 months (9.67 years). Additionally, the change in dSSI rate over the study period was investigated. The purpose of this study was to determine the variability of dSSI in spine surgery as it relates to month and season of the year.

We hypothesized that there would be a difference in the dSSI rate following laminectomy and spine fusion between different months and seasons of the year, with a higher rate occurring during the summer in concurrence with the July effect. We also predicted that there would be a significant reduction in the dSSI rate following these procedures over the study period.

METHODS

Data Collection

All patients who underwent laminectomy (without fusion) or spine fusion/revision fusion (with or without laminectomy) surgery at our institution between January 2009 and August 2018 were reviewed. The data were obtained by retrospectively reviewing the prospectively collected dSSI database at a single, urban, academic medical center encompassing a specialty orthopedic hospital and a large multispecialty hospital. The prospective dSSI database was collected by our institution's Department of Hospital Epidemiology and Infection Control. Diagnosis of dSSI was made by attending physicians board certified in infectious disease according to the US Centers for Disease Control and Prevention's definitions.[15] Criteria for dSSI diagnosis were (1) that the infection appeared to be related to the operative procedure and occured within 30 to 90 days after the procedure; (2) that the infection involved deep soft tissues of the incision; and (3) at least 1 of the following: purulent drainage from the deep incision; a deep incision that spontaneously dehisces or is deliberately opened by a surgeon and organisms isolated from the deep soft tissues by a culture- or non-culture–based microbiologic methods and the patient has a fever, localized pain, or tenderness; and an abscess or other evidence of infection involving the deep incision that is found on direct examination, during reoperation, or by histopathologic or radiologic examination.[15] dSSI cases were assigned to the month and season in which the surgical procedure occurred. Seasons were defined as summer (June–August), fall (September–November), winter (December–February), and spring (March–May).

Statistical Analysis

Average total infection rates per 100 patients, as well as average dSSI rates stratified by procedure, were calculated over the entire study period to evaluate the dSSI rate during the study period. Poisson regression was used to evaluate the seasonal and year variability of dSSI rates while treating year as a continuous variable and 2009 as the baseline; summer was used as the reference season. Poisson regression was also used to evaluate the monthly variability of dSSI rates while controlling for the year to investigate the presence of the July effect. Rate ratio (RR) was obtained by the exponentiation of the coefficients from the Poisson regression model, and 95% CI was calculated. A P value less than 0.05 was considered statistically significant. All statistical analyses were performed using R statistical software.

A power analysis was used to determine the study's ability to detect significant changes in the dSSI rate in the seasons for each procedure studied. This analysis established that the study was underpowered to detect statistically significant differences between the fall and spring seasons in dSSI rate following laminectomy (fall $1-\beta = 0.44$, spring $1-\beta = 0.10$) and spinal fusion (fall $1-\beta = 0.40$, spring $1-\beta = 0.22$).

RESULTS

Laminectomy and spinal fusion procedures were reviewed between January 2009 and August 2018. A total of 7931 laminectomies and 14,637 spinal fusions were reviewed. The average infection following all procedures was 1.02 per 100 patients (SD, 0.61). The average rate of dSSI following laminectomies only was 0.46 per 100 patients (SD, 0.47), while the average rate

Table 1. Poisson regression for the effect of season on dSSI rates over time (laminectomy and spinal fusion/revision fusion).

Period	Patients (*n* = 22,568)	No. of dSSI (*n* = 225)	dSSI Rate (%)	Rate Ratio (95% CI)a	*P* Value
Overall	22,568	225	0.99	0.91 (0.87, 0.95)	**<0.01**
Season					
Summer (reference variable)	5868	66	1.12	---	--
Fall	5081	40	0.79	0.67 (0.45, 0.99)	0.05
Winter	5552	55	0.99	0.87 (0.61, 1.25)	>0.05
Spring	6067	64	1.05	0.94 (0.61, 1.25)	>0.05

Abbreviation: dSSI, deep surgical site infection.
Note: Boldface indicates statistically significant findings.
[a]Rate ratio obtained from Poisson regression.

of dSSI following spinal fusion and revision fusion was 1.26 per 100 patients (SD, 0.86). The total yearly infection rate significantly decreased over the study period while adjusting for season effect (RR = 0.91, 95% CI 0.87–0.95, $P < 0.01$; Table 1). The yearly rate of dSSI following laminectomy increased over the study period; however, the increase did not reach statistical significance (RR = 1.02, 95% CI 0.90–1.15, $P = 0.76$; Table 2). The yearly rate of dSSI following spinal fusion/revision fusion significantly decreased over the study period (RR = 0.89, 95% CI 0.84–0.94, $P < 0.01$; Table 3).

In the seasonal variability analysis with summer as the reference season while adjusting for year, there were no significant changes in the total infection rate following all procedures (Table 1). Similarly, there was no statistically significant difference in dSSI rate following laminectomy in the other seasons (fall RR = 0.65 95% CI 0.28–1.54; winter RR = 0.57, 95% CI 0.24–1.35; spring RR = 0.45, 95% CI 0.18–1.10; Table 2). However, there was a statistically significant reduction in the dSSI rate following spinal fusions/revision fusions in the fall compared with the summer (fall RR = 0.62, 95% CI 0.39–0.98, $P = 0.04$; Table 3). There was no statistically significant difference in the dSSI rate following fusion procedures in the other seasons (winter RR = 0.98, 95% CI 0.66–1.46; spring RR = 1.05, 95% CI 0.71–1.54; Table 3). While the dSSI rate following laminectomy decreased during the winter season over the study period while controlling for the year, the finding was not statistically significant (Table 2).

When analyzing the total dSSI rate following all procedures using July as the reference and controlling for the year, there was no statistically significant difference in dSSI rate as compared with any other months of the year (Table 4). The monthly analysis of dSSI following laminectomies yielded similar results, as there were no statistically significant differences in dSSI rates in any months when compared with July (Table 5). In the spinal fusion/revision fusion analysis, with July as the reference, no statistically significant difference in dSSI rate was found in other months (Table 6).

DISCUSSION

Season

The results of our study did not reveal a significant difference in dSSI rate following laminectomy and spinal fusion in the winter, spring, or fall as compared with the summer (Table 1). Although the results are not significant, there was a decrease in dSSI rate in each season when compared with summer as the reference. This downtrend is consistent with previous studies analyzing postoperative infection rate in spine surgery, both of which demonstrated that the highest infection rates are in the summer.[13,16] Our past study also showed that summer had a significantly greater rate of dSSI than winter in 98,068 cases.[14]

Analyzing data from a single tertiary referral institution over a 4-year study period, Gruskay et

Table 2. Poisson regression for the effect of season on dSSI rates over time (laminectomy).

Time Period	Patients (*n* = 7931)	No. of dSSI (*n* = 38)	dSSI Rate (%)	Rate Ratio (95% CI)[a]	*P* Value
Overall	7931	38	0.48	1.02 (0.90, 1.15)	>0.05
Season					
Summer (reference variable)	2088	15	0.72	---	--
Fall	1725	8	0.46	0.65 (0.28, 1.54)	>0.05
Winter	1952	8	0.41	0.57 (0.24, 1.35)	>0.05
Spring	2166	7	0.32	0.45 (0.18, 1.10)	>0.05

Abbreviation: dSSI, deep surgical site infection.
[a]Rate ratio obtained from Poisson regression.

Table 3. Poisson regression for the effect of season on dSSI rates over time (spinal fusion/revision fusion).

Period	Patients (*n* = 14,637)	No. of dSSI (*n* = 180)	dSSI Rate (%)	Rate Ratio (95% CI)[a]	*P* Value
Overall	14,637	180	1.23	0.89 (0.84, 0.94)	**<0.01**
Season					
Summer (reference variable)	3780	50	1.32	---	---
Fall	3356	29	0.86	0.62 (0.39, 0.98)	**<0.05**
Winter	3600	47	1.31	0.98 (0.66, 1.46)	>0.05
Spring	3901	54	1.38	1.05 (0.71, 1.54)	>0.05

Abbreviation: dSSI, deep surgical site infection.
Note: Boldface indicates statistically significant findings.
[a]Rate ratio obtained from Poisson regression.

al[13] reported a significant decrease in spinal surgery infection rate from fall to winter.[13] The same study also determined that the seasonal rate of infection peaked in the summer season.[13] Similarly, in a large, multicenter study associated with the Duke Infection Control Outreach Network, Durkin et al[16] found that the SSI rates following laminectomy and spinal fusion were highest in the summer season as compared with the rest of the year. A potential explanation for these differences is the seasonal variability of the most common infectious organisms in SSIs, including *Staphylococci*, *Streptococcus*, and *Enterococcus*.[7,16,17] Methicillin-resistant strains of *Staphylococcus aureus* (MRSA) are found in nearly 20% of spine SSIs, and numerous studies have reported significant increases in MRSA skin colonization and infections in the hot and humid months of summer.[17–20] Over the period in which this study was focused on (2009–2018), the average monthly temperatures in New York City during January and July were 38.5°F and 78.1°F, respectively. The relative humidity levels during January and July were 44.2% and 55.7%, respectively.[21,22] The climate disparity between the seasonal months as a cause for the difference in dSSI rates may be due to the increased number of bacteria in specific anatomic locations that have been observed with higher temperatures.[18,23] In a microbial ecology analysis of the human skin in various climates, McBride et al[18] analyzed the bacterial colonization of the human skin of individuals in varying climates based on temperature and humidity. The study reported that, in individuals from the high-temperature and high-humidity climate group, bacteria colonies were significantly larger from the back, axillae, and feet, when compared with the moderate-temperature, low-humidity environment. The large bacterial presence on the back may account for the increased spine surgery dSSI rate during the summer.

While seasonal analysis of laminectomies only also yielded no significant differences in dSSI rate, our results for spinal fusion/revision fusion demonstrate that there is a significant decrease in spinal fusion dSSI rate in the fall as compared with the summer when controlling for year (Table 3). While this is generally inconsistent with the seasonal variability literature, the rate of infection after spinal fusion has rates of 2% to 5%, whereas a laminectomy is approximately 1%.[19] The placement of instrumentation during spinal fusion further increases the infection risk due to possible growth of bacterial biofilms that enhance their growth and survival on spine implants.

Table 4. Poisson regression for the effect of month on dSSI rates over time (laminectomy and fusion/revision fusion).

Period	Patients (*n* = 22,568)	No. of dSSI (*n* = 225)	dSSI Rate (%)	Rate Ratio (95% CI)a	*P* Value
Overall	22,568	225	0.99	0.90 (0.86, 0.94)	**<0.01**
Month					
July (reference variable)	1882	21	1.12	---	---
January	2039	22	1.08	1.09 (0.60, 1.98)	>0.05
February	1895	17	0.89	0.91 (0.48, 1.73)	>0.05
March	2107	17	0.81	0.79 (0.42, 1.51)	>0.05
April	1944	22	1.13	1.35 (0.74, 2.45)	>0.05
May	2016	25	1.24	1.11 (0.62, 1.99)	>0.05
June	2052	23	1.12	1.05 (0.58, 1.90)	>0.05
August	1897	22	1.16	1.13 (0.62, 2.06)	>0.05
September	1642	16	0.97	1.04 (0.54, 1.99)	>0.05
October	1764	13	0.74	0.62 (0.31, 1.24)	>0.05
November	1675	11	0.66	0.82 (0.40, 1.70)	>0.05
December	1618	16	0.99	0.92 (0.48, 1.76)	>0.05

Abbreviation: dSSI, deep surgical site infection.
Note: Boldface indicates statistically significant findings.
[a]Rate ratio obtained from Poisson regression.

Table 5. Poisson regression for the effect of month on dSSI rates over time (laminectomy).

Period	Patients (n = 7931)	No. of dSSI (n = 128)	dSSI Rate (%)	Rate Ratio (95% CI)[a]	P Value
Overall	7931	128	1.64	1.02 (0.90, 1.15)	>0.05
Month					
July (reference variable)	766	7	0.91	---	---
January	590	1	0.17	0.15 (0.02, 1.26)	>0.05
February	674	3	0.45	0.46 (0.12, 1.76)	>0.05
March	784	1	0.13	0.15 (0.02, 1.21)	>0.05
April	678	2	0.29	0.39 (0.08, 1.90)	>0.05
May	704	4	0.57	0.63 (0.18, 2.15)	>0.05
June	734	4	0.54	0.53 (0.16, 1.82)	>0.05
August	672	4	0.59	0.68 (0.20, 2.31)	>0.05
September	550	4	0.73	0.78 (0.23, 2.65)	>0.05
October	625	1	0.16	0.17 (0.02, 1.38)	>0.05
November	550	3	0.55	0.83 (0.21, 3.20)	>0.05
December	604	4	0.66	0.71 (0.21, 2.45)	>0.05

Abbreviation: dSSI, deep surgical site infection.
[a]Rate ratio obtained from Poisson regression.

Month

Our study's findings do not indicate any monthly variability in SSI rate with July as the reference month following the analysis of both spinal procedures (Table 4). The same results were also found when observing laminectomies and the spinal fusion/revision separately (Tables 5–6). While monthly analysis in the spine surgery literature is limited to seasonal groupings (summer [June–August], fall [September–November], winter [December–February], and spring [March–May]), several other analyses in orthopedic surgery studies demonstrate conflicting findings.[23–26] These findings more consistently demonstrate that SSIs peaked in August. The July effect is a widely recognized term that is often used to explain diminished patient outcomes, including increased SSIs, in the summer months. This phenomenon suggests that the inexperience of new medical trainees and house staff early in the academic year is the cause of these worse patient outcomes.[9] Durkin et al's[16] study was conducted using data within a network of nonteaching community hospitals and found that the SSI rate following spinal laminectomy or fusion was higher in the summer months, which suggests the SSIs may be unrelated to the July effect.

Year

The total yearly dSSI rate following all procedures and yearly dSSI rate following only spinal fusion procedures significantly decreased during the study period (Tables 1–3). The lack of instrumentation in laminectomy-only cases would suggest the dSSI rate would significantly decrease, as the literature shows that instrumentation is a large risk factor for infections.[27–29]

However, there were no significant changes in laminectomy-only dSSI. This is likely related to the fact that the procedure has not changed much over the study period. In some cases, procedures transition from small open laminectomies to minimally invasive tubular laminectomies, which are now commonly used.[30] This could reinforce the fact that it is a challenge to minimize small procedures past a certain point.

Table 6. Poisson regression for the effect of month on dSSI rates over time (spinal fusion).

Period	Patients (n = 15,376)	No. of dSSI (n = 176)	dSSI Rate (%)	Rate Ratio (95% CI)[a]	P Value
Overall	15,376	176	1.14	0.88 (0.84, 0.93)	**<0.01**
Month					
July (reference variable)	1200	14	1.17	---	---
January	1150	22	1.91	1.49 (0.76, 2.94)	>0.05
February	1264	14	1.11	1.13 (0.54, 2.38)	>0.05
March	1323	15	1.13	1.16 (0.56, 2.41)	>0.05
April	1266	20	1.56	1.86 (0.94, 3.68)	**0.04**
May	1312	19	1.40	1.35 (0.68, 2.70)	>0.05
June	1355	19	1.36	1.34 (0.67, 2.66)	>0.05
August	1225	17	1.39	1.48 (0.73, 3.01)	>0.05
September	1092	12	1.10	1.17 (0.54, 2.53)	>0.05
October	1139	11	0.97	0.91 (0.41, 2.00)	>0.05
November	1125	6	0.53	0.76 (0.29, 1.98)	>0.05
December	1014	12	1.18	1.05 (0.49, 2.28)	>0.05

Abbreviation: dSSI, deep surgical site infection.
Note: Boldface indicates statistically significant findings.
[a]Rate ratio obtained from Poisson regression.

The total dSSI reduction was driven by the fusion/revision fusion dSSI improvement. This observed decrease in dSSI is consistent with the current literature.[14,31–33] Kolpa et al[31] found a significant reduction in infections following both laminectomy (4.5%–0.8%) and spinal fusion (11.8%–0.8%) over a 14-year period from 2003 to 2017. A similar study also reported a significant decrease in spinal instrumentation surgery reoperation due to SSI from 2004 to 2015, which may largely be a result of the significant reduction in MRSA identification in patients over the study period, which decreased from 37% to 20%.[32] This may suggest that more targeted therapeutic prevention of *S aureus* strains could help reduce the number of dSSIs following spine surgery. The greater awareness of other risk factors for SSI may also contribute to this reduction. As diabetes and obesity are associated with an increased risk of SSI following spinal surgery, proper preoperative optimization of these 2 factors, combined with dosage adjustment of prophylactic antibiotics, may lead to diminishing SSI rates over time.[34] Finally, at our institution, there were also specific SSI reduction strategies that were implemented during the study period. This included antibiotic prophylaxis against Gram-positive and Gram-negative organisms, intrawound vancomycin use, plastic surgery wound closure for complex cases, an increase in minimally invasive procedures, and a reduction in 3-column osteotomies.

Limitations

Our study has several limitations. As a retrospective review, there is potential for collection error and selection bias in the process of stratifying patients. As the data were collected exclusively from 1 large academic center, this may introduce sampling bias into our findings and would make it difficult to generalize to other hospital settings and populations. Second, the database used for this study only contained information about infection rate, depth of infection, and timing; therefore, this study analyzed only temporal factors associated with SSIs, and we were unable to investigate the effect of other predisposing risk factors for dSSI following laminectomy and spinal fusion. Third, data for some of the months for the specific infection were missing from the database, which may have reduced the confidence in that result. Fourth, as a retrospective study, we were unable to assess the effect of operative room and hospital climates at our institution. Additional studies looking at dSSI rates following laminectomy and spinal fusion should consider including patient and environmental factors such as diabetes, obesity, hospital humidity, and temperature of both the operative room and hospital, all of which are believed to influence dSSI rate. Fifth, the power analysis demonstrated that our study was underpowered, which was likely related to the overall infrequency of dSSI following spinal surgery. Future studies should investigate larger sample sizes across a variety of institutions with different practice types and ambient environments to further understand this important topic.

CONCLUSION

The results of this study show a significant decrease in total dSSI rate and dSSI rate following spinal fusion surgery over the nearly 10-year study period. While the July effect is a commonly used explanation for increased dSSI rates in summer months, the analysis revealed no significant differences, which warrant further investigation of this theory. A greater understanding of the seasonal trends of dSSI in spinal surgery can guide surgeons to develop and utilize preventive strategies to mitigate the large burden that dSSIs place on patients and the health care system.

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