European Spine Journal (2023) 32:824–830
https://doi.org/10.1007/s00586-023-07547-1

ORIGINAL ARTICLE

Factors contributing to a longer length of stay in adults admitted to a quaternary spinal care center

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Received: 5 September 2022 / Revised: 30 December 2022 / Accepted: 16 January 2023 / Published online: 28 January 2023

Abstract

Background Longer hospital length of stay (LOS) has been associated with worse outcomes and increased resource utilization. However, diagnostic and patient-level factors associated with LOS have not been well studied on a large scale. The goal was to identify patient, surgical and organizational factors associated with longer patient LOS for adult patients at a high-volume quaternary spinal care center.

Methods We performed a retrospective analysis of 13,493 admissions from January 2006 to December 2019. Factors analyzed included age, sex, admission status (emergent vs scheduled), ASIA grade, operative vs non-operative management, mean blood loss, operative time, and adverse events. Specific adverse events included surgical site infection (SSI), other infection (systemic or UTI), neuropathic pain, delirium, dural tear, pneumonia, and dysphagia. Diagnostic categories included trauma, oncology, deformity, degenerative, and "other". A multivariable linear regression model was fit to log-transformed LOS to determine independent factors associated with patient LOS, with effects expressed as multipliers on mean LOS.

Results Mean LOS for the population (SD) was 15.8 (34.0) days. Factors significantly ($p < 0.05$) associated with longer LOS were advanced patient age [multiplier on mean LOS 1.011/year (95% CI: 1.007–1.015)], emergency admission [multiplier on mean LOS 1.615 (95% CI: 1.337–1.951)], ASIA grade [multiplier on mean LOS 1.125/grade (95% CI: 1.051–1.205)], operative management [multiplier on mean LOS 1.211 (95% CI: 1.006–1.459)], and the occurrence of one or more AEs [multiplier on mean LOS 2.613 (95% CI: 2.188–3.121)]. Significant AEs included postoperative SSI [multiplier on mean LOS 1.749 (95% CI: 1.250–2.449)], other infections (systemic infections and UTI combined) [multiplier on mean LOS 1.650 (95% CI: 1.359–2.004)], delirium [multiplier on mean LOS 1.404 (95% CI: 1.103–1.787)], and pneumonia [multiplier on mean LOS 1.883 (95% CI: 1.447–2.451)]. Among the diagnostic categories explored, degenerative patients experienced significantly shorter LOS [multiplier on mean LOS 0.672 (95%CI: 0.535–0.844), $p < 0.001$] compared to non-degenerative categories.

Conclusion This large-scale study taking into account diagnostic categories identified several factors associated with patient LOS. Future interventions should target modifiable factors to minimize LOS and guide hospital resource allocation thereby improving patient outcomes and quality of care and decreasing healthcare-associated costs.

Keywords Length of stay · Spine surgery · Factors · Adverse events · Diagnoses · Quality of care

Introduction

Longer hospital length of stay (LOS) has been associated with many undesirable consequences [1–4]. Prolonged LOS has been shown to increase healthcare costs and resource utilization [1, 3, 5]. It has also been associated with poorer patient outcomes and treatment related complications [1, 3, 6], increased patient morbidity and mortality [1], increased unplanned readmission following discharge [7, 8], and delays the initiation of rehabilitation efforts [9].

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LOS is commonly used as a surrogate marker of effectiveness, quality and efficiency of care delivered and a marker for hospital performance [2, 10, 11]. Patients undergoing spine surgery generally have longer average LOS than most patient populations [12], and also typically have more complicated health concerns as many are elderly, frail and have significant comorbidities affecting their quality of life [13, 14]. Additionally, with an actively aging population and persistent chronic illness comorbidity rates, average LOS will likely continue to lengthen [13, 15].

We have previously examined the trends of LOS over time at our institution [16], finding that the overall median LOS has not significantly changed over time between 2006 and 2019, while mean age has increased during this time. Additionally, in patients with degenerative pathology in particular, median LOS did increase over this period as well as the proportion of emergency admissions in this diagnostic group [16]. These results led us to thoroughly examine the specific factors that affected LOS among the same patient population as a follow-up study of our previously published work.

At a patient and organizational level, it is critical that we understand what factors are associated with changing LOS to combat any concerning trends. Understanding what factors are associated with lengthening LOS will help us predict patient outcomes and plan resource allocation. Not only will this allow us to have a more informed discussion with our patients about expectations and outcomes, but it allows for surgeons and administrators to implement customized changes in care at an organizational level and allows for implementation of Quality Improvement (QI) interventions at a care provision level. If factors associated with longer LOS can be identified then these can potentially be targeted with further work to maximize patient outcomes, optimize efficiency and quality of care and decrease costs.

A previous study has examined the factors associated with longer LOS among degenerative pathologies of the cervical spine [2]. Several other studies have examined factors associated with LOS; however, a thorough and large-scale study with a large sample size is lacking. Additionally, only a few studies have accounted for diagnostic categories in their analyses.

The main goal of this study was to examine factors associated with longer LOS in a large sample spanning 14 years. Secondarily, we aimed to examine the impact of diagnostic categories on LOS.

Methods

Study design

This study was a retrospective analysis of prospectively collected data from the registry of an academic quaternary spinal care center, serving a geographically diverse catchment area of over 5 million people. The study included data from 13,493 unique admissions between January 2006 and December 2019. Data from 2020 were excluded from the analyses as the COVID-19 pandemic affected nearly all aspects of hospital operations during that calendar year. We received ethics approval from the research ethics boards of our university and hospital. Patient consent was not required by our institutional ethics board as all patients have anonymized data collected prospectively in our study registry. Our study is a follow-up of our previously published work using the same patient population and dataset [16], however further analyzing factors impacting LOS that were previously not investigated to better understand why certain trends were observed in LOS over time.

Data collection

Patient LOS was defined as the number of calendar days from patient admission to the spinal care center to discharge from hospital. For every patient, a diagnostic category is assigned on admission by the admitting surgeon. This is then checked by experienced research staff to ensure accuracy of data. Any discrepancy in assignment is resolved by discussion between the surgeon and the research staff. Patient demographic and clinical information analyzed included patient age and sex, emergency vs elective admission, diagnostic category at admission (degenerative, deformity, oncology, trauma, other), ASIA Impairment Scale (AIS) as a continuous variable, operative vs non-operative management, operative duration, estimated blood loss, and the presence of one or more adverse events (AEs) during the hospital stay. Adverse events analyzed included the occurrence of surgical site infections (SSI), systemic and urinary tract infections (UTI), neuropathic pain, delirium, dural tear, pneumonia, and dysphagia. Adverse events were recorded using the rigorous, validated, and generalizable prospective SAVES system [17]. SAVES is a prospective, spine-specific, surgeon-led, peri-operative adverse event identification and reporting system. SAVES was developed and validated in Canada, has been utilized in more than 100 peer review publications, and is the adverse event reporting system of the Canadian Spine Outcomes Research Network.

Statistical analyses

Descriptive statistics (frequencies, means, medians, standard deviations [SDs], interquartile ranges [IQRs]) were computed on potential predictors of LOS, including age, sex, urgent/emergent admission, ASIA grade, operative procedure, mean blood loss, operative time, adverse events, and diagnostic category. Specific adverse events included surgical site infection (SSI), other infection (systemic or UTI

combined), neuropathic pain, delirium, dural tear, pneumonia, and dysphagia. Diagnostic categories included trauma, oncology, deformity, degenerative, and "other".

A multivariable linear regression model was fit on log-transformed LOS (in days) vs. the set of predictors. LOS required a natural log transformation to normalize the PRESS residuals in the linear regression model. Regression coefficients in the log-LOS model represent the additive effects on the natural log of LOS due to a one-unit increase in each predictor variable. To aid interpretation, exponentiated regression coefficients were computed from these as multipliers representing the multiplicative effect on LOS due to a one-unit increase in the predictor variables. For example, a multiplier of 0.5 indicates that a one-unit increase in the independent variable leads to a 0.5 multiplicative effect on the mean LOS (reduces it by half). For binary variables (such as patient sex or the presence of any adverse events), the multiplier indicated the multiplicative effect on LOS compared to the alternative (such as being male or having no adverse events). *P*-values < 0.05 were considered significant. R-squared was 0.614 for the fully adjusted multivariable model. We only included admissions with complete LOS and other variable data in the multivariable model. Model fit was assessed with normal quantile–quantile plots of the standardized residuals. All analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA).

Results

A descriptive summary of the predictors analyzed is listed in Table 1. Mean (SD) LOS was 15.8 (34.0) days. Median (IQR) LOS was 6.3 (12.6) days. Mean (SD) patient age was 53.3 (17.6) years. 40.2% of patients were female, 50.3% of admission were urgent/emergent, 13.9% admission were classified as AIS A-C, 86.0% of patients had an operative procedure (14.0% were non-operative), mean (SD) blood loss (× 100 mL) was 17.6 (34.1), operative time (SD) in hours was 2.7 (3.3), and 53.0% of admissions had at least one adverse event associated. Specific adverse events included surgical site infection (SSI) affecting 3.2% of admissions, other infection (systemic or UTI) affecting 17.0% of admissions, neuropathic pain affecting 20.8% of admissions, delirium affecting 13.5% of admissions, dural tear affecting 9.3% of admissions, pneumonia affecting 10.5% of admissions, and dysphagia affecting 5.0% of admissions. Of the diagnostic categories included, trauma represented 24.5% of admissions, oncology 10.4%, deformity 14.6%, and degenerative 34.0% (the rest were included as "other" and not listed in Table 1).

Table 2 lists the log-linear multipliers (95% CI) for predictors in the fully adjusted multivariable model. Factors significantly associated with longer LOS were advanced patient age with multiplier (95% CI) 1.011 (1.007–1.015) per additional year ($p < 0.001$), emergency admission 1.615 (1.337–1.951) when compared to scheduled admission ($p < 0.001$), ASIA grade 1.125 (1.051–1.205) per worse grade ($p < 0.001$), receiving operative management 1.211 (1.006–1.459) when compared to non-operative management ($p = 0.043$), and the occurrence of one or more AEs 2.613 (2.188–3.121) when compared to admissions without any AEs noted ($p < 0.001$). Significant AEs included postoperative SSI 1.749 (1.250–2.449) ($p = 0.001$), other infections (systemic infections and UTI combined) 1.650 (1.359–2.004) ($p < 0.001$), delirium 1.404 (1.103–1.787) ($p = 0.006$), and pneumonia 1.883 (1.447–2.451) ($p < 0.001$). Among the diagnostic categories explored, degenerative experienced significantly shorter log-LOS with multiplier 0.672 (0.535–0.844) compared to non-degenerative categories ($p < 0.001$).

Table 1 Descriptive summary of the predictors analyzed

Predictor	Overall cohort
Length of stay in days, mean (SD)	15.8 (34.0)
Patient factors	
Age in years, mean (SD)	53.3 (17.6)
Sex (female), n (%)	4284 (40.2)
Urgent/Emergent admission, n (%)	6787 (50.3)
ASIA impairment scale A-C, n (%)	1444 (13.9)
Surgical factors	
Operative management (vs conservative), n (%)	10,160 (86.0)
Estimated blood loss (x 100 mL), mean (SD)	17.6 (34.1)
Total operative time in hours, mean (SD)	2.7 (3.3)
Adverse events	
Presence of ≥ 1 adverse event, *n* (%)	3496 (53.0)
Surgical site infection (SSI), *n* (%)	156 (3.2)
Other infection (systemic + UTI), *n* (%)	825 (17.0)
Neuropathic pain, *n* (%)	1010 (20.8)
Delirium, *n* (%)	657 (13.5)
Dural tear, *n* (%)	402 (9.3)
Pneumonia, *n* (%)	510 (10.5)
Dysphagia, *n* (%)	242 (5.0)
Diagnostic factors	
Trauma, *n* (%)	3168 (24.5)
Oncology, *n* (%)	1347 (10.4)
Deformity, *n* (%)	1890 (14.6)
Degenerative, *n* (%)	4397 (34.0)

*Percentages are computed based on the available patient records for each predictor

Discussion

This large-scale study aimed to thoroughly examine factors associated with longer LOS. This is a follow-up to previously published work from our institution where trends in

Table 2 The effects of various predictors on patient LOS in fully adjusted multivariable log-linear model

Predictor	Multiplier [95% CI]	*p*-value
Patient factors		
Age (per additional year)	1.011 [1.007–1.015]	< 0.001*
Sex (female)	1.024 [0.887–1.182]	0.747
Urgent/Emergent admission	1.615 [1.337–1.951]	< 0.001*
ASIA impairment scale (AIS) (per worse grade)	1.125 [1.051–1.205]	< 0.001*
Surgical factors		
Receiving operative management	1.211 [1.006–1.459]	0.043*
Estimated blood loss (per additional 100 mL)	1.019 [0.995–1.043]	0.120
Total operative time (per additional hour)	1.007 [0.993–1.022]	0.317
Adverse events		
Presence of ≥ 1 adverse event	2.613 [2.188–3.121]	< 0.001*
Surgical Site Infection (SSI)	1.749 [1.250–2.449]	0.001*
Other infection (systemic + UTI)	1.650 [1.359–2.004]	< 0.001*
Neuropathic pain	1.085 [0.921–1.278]	0.330
Delirium	1.404 [1.103–1.787]	0.006*
Dural tear	0.963 [0.698–1.329]	0.820
Pneumonia	1.883 [1.447–2.451]	< 0.001*
Dysphagia	0.918 [0.653–1.291]	0.623
Diagnostic factors		
Trauma	1.038 [0.834–1.292]	0.739
Oncology	1.054 [0.792–1.403]	0.717
Deformity	0.777 [0.564–1.071]	0.124
Degenerative	0.672 [0.535–0.844]	< 0.001*

*Indicates significance

LOS were examined [16]. To our knowledge, this is the largest study over the greatest length of time, assessing factors associated with longer LOS in patients at a high-volume quaternary spinal care center. The main finding is that the occurrence of one or more adverse events had the strongest association with lengthening LOS in a very large cohort including all diagnostic categories. Secondarily, among the seven AEs analyzed, we found that the effects of surgical site infections, composite of systemic infections and UTI, delirium, and pneumonia had significant effects on LOS. Lastly, a degenerative diagnosis was associated with significantly shorter log-LOS in our sample. Other factors significantly associated with longer LOS (in order of effect) were urgent/emergent admission, operative procedure, AIS grade, and age.

Several other studies have been conducted within the past few years to investigate factors associated with prolonged hospital LOS in patients undergoing spine surgery. Factors identified include advanced age, female sex, a greater number of fused levels, longer operative duration, larger estimated blood loss (including the need for transfusion), postoperative complications, preoperative comorbidities, reoperations and the presence of certain operative or procedural factors (such as invasiveness, complexity, and approach) [1–3, 6, 7, 18–22]. Of the studies completed to date, many are small scale retrospective analyses of isolated factors, thus are not very reliable and are susceptible to significant confounding [3]. The present study with a large sample did not find that female sex, operative duration or estimated blood loss affected LOS significantly. Previous work has shown that pulmonary infections, SSI as well as UTI and deep wound infections, and neurological deficit are associated with longer patient LOS [23]. Even though SSI is not a common complication in our cohort, this is consistent with our findings. Worse AIS grade was also associated with LOS in our cohort. Early surgical decompression in patients with neurological deficits is understood to improve outcomes [24]; however, our data did not include operative timing in this study, limiting our ability to comment on neurological improvement.

A study by Kobayashi et al. [3] investigated predictors of prolonged LOS after lumbar interbody fusion in 1168 patients over 2 years. Age ≥ 70 years, American Society of Anesthesiologists (ASA) class ≥ III, open surgery, ≥ 3 fused levels, prolonged operative time and ≥ 500 mL estimated blood loss were predictors of prolonged LOS. Another study by Passias et al. [19] was conducted to determine predictors of hospital LOS in patients with cervical spondylotic myelopathy. Predictors included advanced age, ASA class, posterior approach and prolonged operative time. Additionally,

a study by Capua et al. [18] on adults after elective spine deformity surgery found that age ≥ 65 years, female sex, ASA class ≥ 3, operative time ≥ 4 h, and a variety of other procedural factors were predictors of non-home discharge and prolonged LOS. While these results do support some of our findings, specific procedural variables were either not reported in our databases or were found to not be associated with longer patient LOS. A study by Street et al. found a very high incidence of intra-operative and postoperative complications of spine surgery [25]. Therefore, large studies should focus on the effects of specific procedural factors on patient LOS and work to modify procedural techniques and thus intra-operative and postoperative complication rates to combat lengthy LOS after spine surgery.

Some of the predictors of LOS included in our model are inherent to the patient and are thus preexisting and have a limited ability to be modified. On the other hand, some of the factors were associated with the hospitalization period. Factors during the hospitalization that predict LOS include whether the patient received surgical intervention, and adverse events during their stay. Procedural factors may be modified, and adverse events prevented or managed effectively to combat lengthening LOS. Additionally, this knowledge allows us to assess the risks of surgery more accurately for individual patients, effectively obtain consent from patients, and allocate healthcare resources more appropriately. Future studies should examine the impact of specific procedural variables on LOS to make accurate recommendations on potential procedural modifications that may benefit patient care.

Our previous study found that median LOS and the proportion of emergency admissions increased over time in patients with degenerative pathology [16]. While our current study supports that emergency admission is associated with longer LOS than non-emergent admission, this trend is likely multifactorial. Firstly, our multivariable regression model, which accounts for factors including advanced age and emergency admission, suggests that patients with degenerative disease have a shorter LOS on average than patients classified as having other disease processes. In contrast, our previous study did not control for other variables that may confound the results with respect to diagnostic category. Thus, it is likely that as the population ages, so does the proportion of patients with significant frailty and comorbidities that may impact their ability to recover and increases the likelihood of developing AEs. These factors may lead to a prolonged LOS for degenerative patients [26]. Additionally, degenerative pathology may be quite heterogenous in a patient population, with vastly different AE rates and LOS values for each patient. The increased demand for spine surgery over time may have played a role in the increased proportion of emergent degenerative admissions, which may reflect the limited operating rooms available for patients who are often in need of elective surgery for months to years prior to presenting emergently [27]. While patients who are admitted electively are often prescheduled for surgery, those admitted urgently typically will need a full workup, imaging, and will need to wait for the next possible operative time, which can add to the LOS in these patients. Further studies should focus on interventions aimed at reducing the concerning LOS trends observed in patients with degenerative disease and enhancing the therapeutic resources available for these patients.

Our study analyzes the effect of various factors on LOS across many patient admissions, providing an event-level rather than a patient-level analysis. There was also a negligible number of patients readmitted within 12 months of initial discharge, reducing the likelihood that a future admission may be due to incomplete treatment of a previous pathology. The large, heterogenous sample of this study allows a more precise estimation of the effect of predictors on LOS and enhances the generalizability of the results. Additionally, both conservative and surgical management were assessed for a real-world representation of a busy spine service.

However, this study has important limitations. Firstly, we use a prospective, spine-specific tool (SAVES) for collecting data on AEs, and while it has been shown to be valid, reliable, and generalizable, it may not be applicable for all centers nor compatible with all other healthcare systems. The medical insurance system in other countries may also limit the generalizability of our data. Our analysis investigated the effects of specific AEs but did not investigate the cumulative effect on LOS of having multiple AEs. Since our data did not include precisely when in the admission the AE occurred, we were unable to determine if longer LOS caused an increased number of AEs to occur in certain patients. The analysis was retrospective in nature and thus has limitations inherent to this study design. While this study identified factors associated with longer patient LOS, future randomized studies could be conducted to test the efficacy of various QI interventions on reducing LOS. Reoperation and readmission data is beyond the scope of this manuscript but may be associated with LOS according to previous work [7, 8, 22, 28–30]. Additionally, we did not analyze preoperative comorbidities, living arrangement/social support network or specific procedural factors such as surgical approach, invasiveness or number of fused levels as this data was not available. Length of stay may also be confounded by external factors such as limited transportation means, which may delay discharge planning and lead to prolonged time in-hospital. Additionally, some patients may have been transferred to other facilities postoperatively, which wasn't considered in our model. The large variability in this study data manifested by a large SD and IQR decreases the precision of our results. However, this represents real-world data from a busy spinal care center where outliers and spread are inevitable. Lastly,

the in-hospital mortality rate was minimal; however, our model was limited by the inability to distinguish LOS ending in discharge from that ending in mortality. In the future, hospitals and healthcare systems will be able to implement new protocols and strategies to combat the effects of these factors, thus improving patient and community satisfaction.

Conclusion

We identified patient, surgical and organizational factors associated with longer patient LOS for adults undergoing elective and emergent spine surgery at a high-volume quaternary spinal care center. AE occurrence had the strongest association with LOS, especially pneumonia and infection. Additionally, degenerative disease was associated with shorter log-LOS than non-degenerative pathologies. Identifying modifiable factors that increase LOS provides opportunities for QI interventions at a care provision level. Understanding patient and disease factors that affect patient LOS allows for a more informed preoperative discussion with the patient. Future interventions can be targeted to maximize patient outcomes, optimize quality of care, and decrease healthcare costs.

Acknowledgements This work would not have been possible without the dedication and hard work of the staff of the Vancouver Spine Research Group.

Funding This work was funded by the Bob and Trish Saunders Spine Research Fund through The VGH and UBC Hospital Foundation.

Declarations

Conflict of interests No relevant competing interests have been declared by any authors.

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