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Spine Surgery: Longer Total Operating Room Duration Is Associated With Longer Hospitalization

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because protected health information was removed or de-identified in a HIPAA-compliant manner. No additional participant consent was required for this secondary analysis. Consent for publication is not applicable because the manuscript contains no identifiable participant information or images.

Spine Surgery: Longer Total Operating Room Duration Is Associated With Longer Hospitalization

Abstract

Purpose To evaluate the association between total operating room (OR) duration and postoperative length of stay (LOS) across a heterogeneous cohort of adult spine procedures.

Methods This retrospective cohort included 2,266 procedures. OR duration spanned entry to exit, and LOS spanned OR entry to discharge. Linear and logistic models adjusted for age, American Society of Anesthesiologists classification, documented fusion, and inpatient status. Prolonged LOS exceeded the cohort 75th percentile (>6.39 days). Sensitivity analyses addressed extreme LOS and preoperative hospitalization.

Results Median LOS was 3.90 days. In 2,265 complete cases, each additional OR hour was associated with 0.535 additional hospital days (95% confidence interval [CI], 0.360–0.709) and greater odds of prolonged LOS (odds ratio [OR], 1.26; 95% CI, 1.19–1.33; both $P<0.001$). Associations persisted in sensitivity analyses. Age was inversely associated with LOS ($\beta=-0.095$ days/year) and prolonged LOS (OR, 0.980/year; both $P<0.001$).

Conclusion Longer total OR duration was associated with longer hospitalization after adjustment for measured covariates. LOS included OR time, and the associations do not establish causation. The inverse age association was not evidence of a protective effect of age.

Keywords Spine surgery; Operating room duration; Length of stay; Prolonged hospitalization; Retrospective cohort; Perioperative outcomes

Introduction

Hospital length of stay (LOS) following spine surgery has implications for recovery, resource utilization, discharge planning, and costs. LOS varies with patient comorbidity, procedure type, postoperative complications, and surgical complexity. Identifying perioperative factors associated with hospitalization may help characterize anticipated recovery needs [1, 2].

Older age, higher American Society of Anesthesiologists (ASA) physical status classification, fusion procedures, and discharge barriers have been associated with prolonged LOS. Studies of lumbar interbody fusion and lumbar decompression demonstrate that LOS is multifactorial [3, 4]. However, findings from specific procedures or narrowly defined elective populations may not generalize to heterogeneous spine cohorts.

Operative duration is readily measured and may reflect procedural complexity, physiologic stress, and perioperative resource demand [3, 5]. Measuring hospitalization from the time of surgery separates it from preoperative inpatient care, which may reflect different clinical indications and acuity [6]. We evaluated whether total operating room (OR) duration was associated with postoperative LOS and prolonged hospitalization after adjustment for age, ASA classification, documented fusion, and inpatient status.

Materials and Methods

The hypothesis evaluated was that longer total OR duration is associated with longer LOS and greater odds of prolonged hospitalization after adjustment for measured covariates. The null hypothesis was no adjusted association with either outcome.

The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) framework guided manuscript preparation [7].

Study Design and Cohort

This retrospective cohort study used a perioperative electronic medical record database. Retained procedures were performed between January 2018 and July 2023. Available variables included age, ASA classification, recorded patient class, primary procedure descriptions, OR timestamps, and hospital admission and discharge timestamps.

Adult patients aged ≥18 years were identified using spine-related procedure terms, including spine, spinal, fusion, laminectomy, discectomy, decompression, ACDF, PLIF, TLIF, ALIF,

XLIF, foraminotomy, corpectomy, vertebral, cervical, and lumbar. Duplicate operative identifiers were removed. Procedures unrelated to conventional operative spinal surgery were excluded, including nonspinal procedures, spinal cord stimulator implantation or revision, intrathecal pain pump procedures, spinal angiography, lumbar drains or punctures, sacroiliac joint fusion, and vertebral biopsy or aspiration. Cases with missing OR duration, duration <2 hours, or duration ≥24 hours were excluded. The final descriptive cohort contained 2,266 procedures in 1,885 patients; repeat operations were retained as separate observations. Study size was determined by the eligible records in the available database; each observation was followed to hospital discharge.

Exposure and Covariates

Operative duration was defined as total recorded OR time from entry to exit. It therefore included in-room anesthesia care, positioning, preparation, and emergence in addition to the procedure itself. Incision and closure timestamps were not reliably available. Duration was analyzed continuously in hours and descriptively as 2 to <4, 4 to <6, and ≥6 hours.

Fusion was identified from terms indicating fusion or arthrodesis in the primary procedure description. Incomplete Current Procedural Terminology data prevented independent confirmation. Absence of a fusion descriptor was classified as no documented fusion, rather than confirmed absence of fusion. Inpatient status followed the recorded patient class. ASA classification was modeled as an ordinal numeric covariate; age was modeled continuously.

Outcomes and Statistical Analysis

Postoperative LOS was operationally defined as the interval from OR entry to hospital discharge, expressed in days. This excluded preoperative hospitalization but included time in the OR. Prolonged LOS was defined using the unrounded 75th percentile of the full descriptive cohort (6.3944 days, reported as >6.39 days).

Continuous variables were summarized as means and standard deviations or medians and interquartile ranges (IQRs); categorical variables were summarized as counts and percentages. The Kruskal–Wallis test compared LOS across duration categories. Multivariable linear regression estimated differences in LOS, and logistic regression estimated odds of prolonged LOS. Both models included OR duration, age, ASA classification, documented fusion, and inpatient status. Coefficients or odds ratios (ORs) and 95% confidence intervals (CIs) were

reported. Complete-case analysis excluded one procedure with missing ASA classification, leaving 2,265 observations in the primary adjusted models. Missing covariates were not imputed. Sensitivity analyses repeated the linear model after excluding LOS above the 95th percentile (>17.29 days) and after natural-log transformation of LOS. Linear and logistic models were also repeated among procedures performed within 24 hours of admission, retaining the full-cohort prolonged-LOS threshold. LOS and ASA classification were described across preoperative hospitalization categories of <1, 1 to <3, 3 to <7, and ≥7 days. Two-sided $P<0.05$ indicated statistical significance. The original analyses were performed in R.

ChatGPT (OpenAI) assisted with manuscript editing, formatting, consistency checks against the existing analysis exports, and preparation of figures from the existing cohort and models.

Results

Cohort Characteristics

The cohort included 2,266 procedures: 919 (40.6%) lasting 2 to <4 hours, 905 (39.9%) lasting 4 to <6 hours, and 442 (19.5%) lasting ≥6 hours. Mean age was 60.1±15.6 years, mean ASA classification was 2.72±0.60, and mean OR duration was 4.69±1.89 hours. Documented fusion was present in 1,200 cases (53.0%), and 2,131 (94.0%) were classified as inpatient. Mean LOS was 5.78±7.95 days and median LOS was 3.90 days (IQR, 2.12–6.39). Table 1 summarizes characteristics by duration category.

Documented fusion increased from 30.8% to 63.6% and 77.1% across the three duration groups. Inpatient proportions were 87.2%, 98.2%, and 99.8%, respectively. Median LOS increased from 2.25 days (IQR, 1.15–4.34) to 4.22 days (IQR, 2.92–6.49) and 6.04 days (IQR, 4.08–8.31; Kruskal–Wallis $P<0.001$; Figure 1).

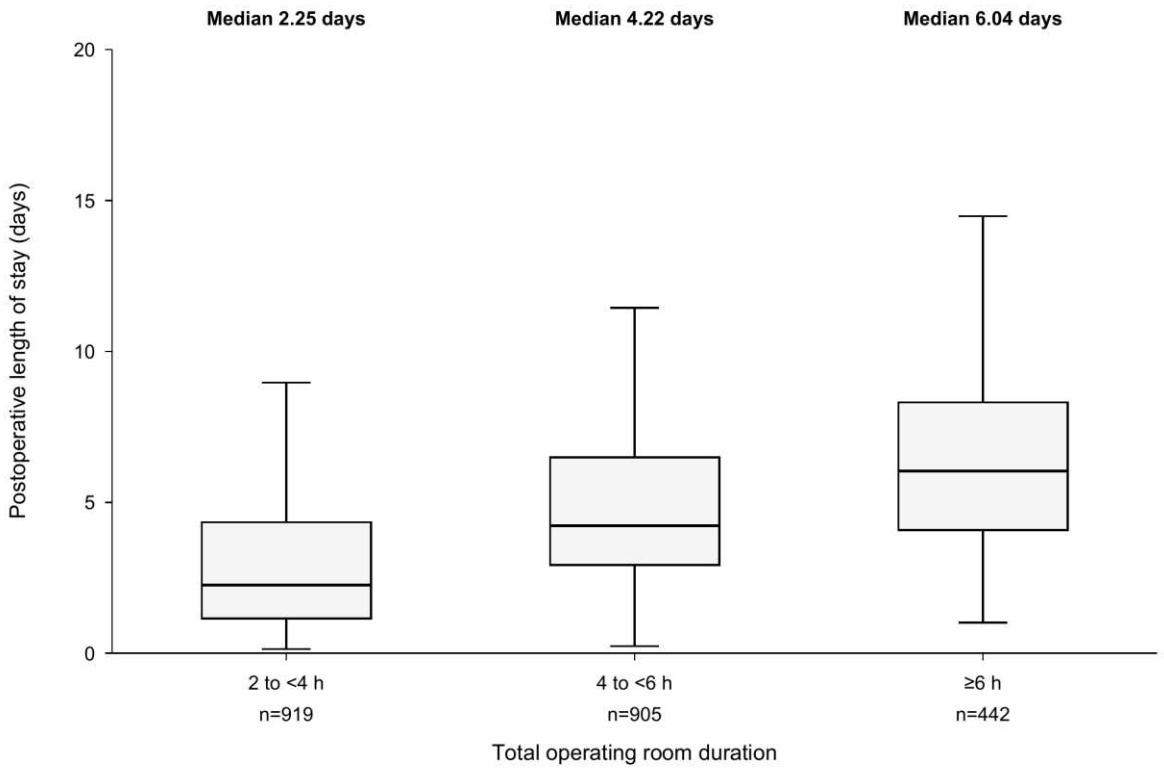


Fig. 1 Postoperative LOS by total OR duration. Boxes show medians and interquartile ranges; whiskers extend to the most extreme observations within 1.5 interquartile ranges. Outliers are omitted from display. All 2,266 cases were included in descriptive analyses

Adjusted Associations

Each additional OR hour was associated with 0.535 additional hospital days after adjustment (95% CI, 0.360–0.709; P<0.001; Figure 2). Documented fusion was associated with 1.21 additional days, each ASA class increase with 3.52 days, and inpatient status with 2.71 days. Increasing age was inversely associated with LOS (β=−0.095 days/year; 95% CI, −0.114 to −0.075; P<0.001). Full estimates are presented in Table 2.

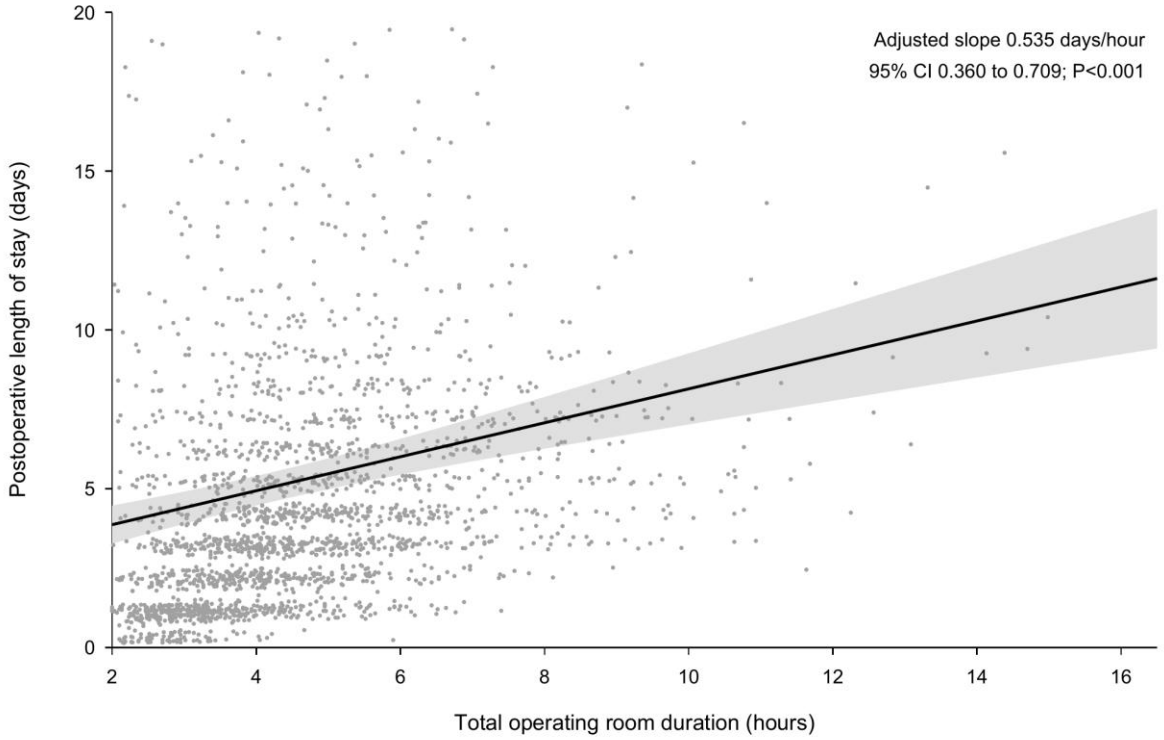


Fig. 2 Observed postoperative LOS with adjusted mean and 95% confidence band. Age and ASA classification are fixed at cohort means, documented fusion at no, and inpatient status at yes. Display is limited to 20 days; the model used all 2,265 complete cases

Prolonged LOS occurred in 567 procedures (25.0%). Each additional OR hour was associated with approximately 26% greater adjusted odds of prolonged LOS (OR, 1.26; 95% CI, 1.19–1.33; P<0.001). Documented fusion (OR, 1.52; 95% CI, 1.22–1.90) and ASA classification (OR, 2.63 per class; 95% CI, 2.17–3.21) were positively associated with prolonged LOS. Age showed an inverse association (OR, 0.980/year; 95% CI, 0.973–0.987; P<0.001). Inpatient status had a large, imprecise estimate (OR, 10.75; 95% CI, 3.35–65.64; P<0.001; Figure 3, Table 2).

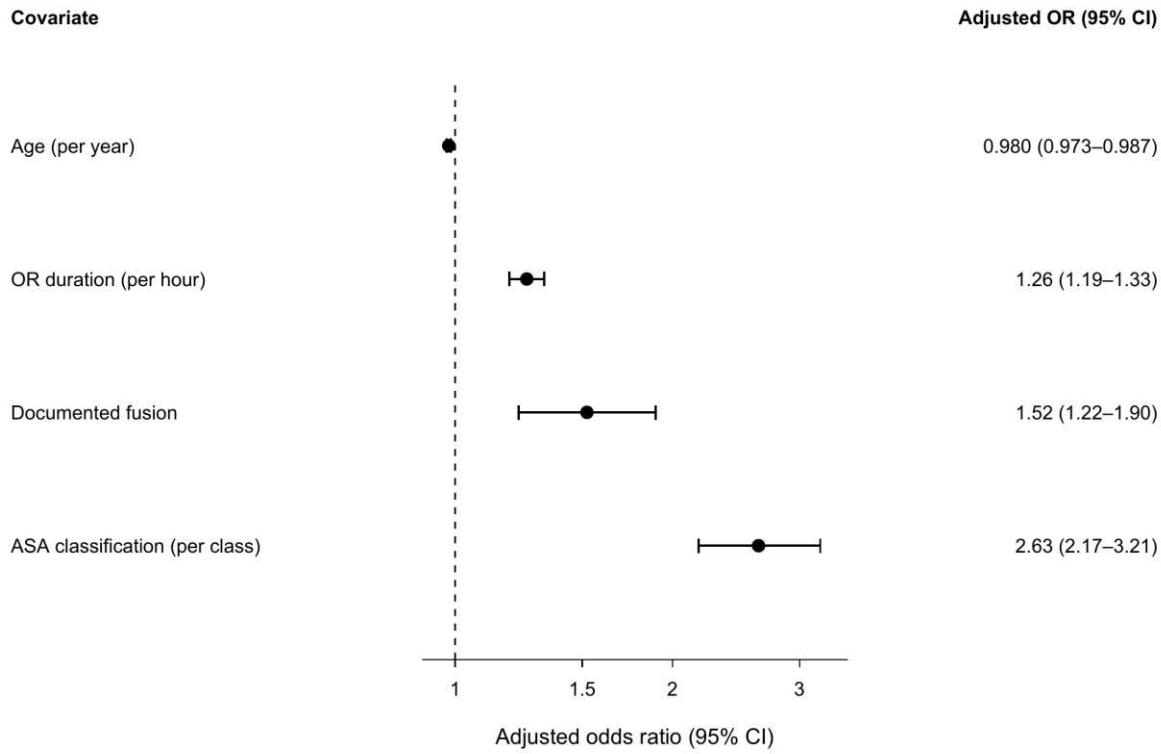


Fig. 3 Adjusted odds ratios and 95% confidence intervals for LOS exceeding 6.39 days. The complete-case model included OR duration, age, ASA classification, documented fusion, and inpatient status (n=2,265). Inpatient status is included in the model but omitted from the plotted estimates

Sensitivity and Preoperative Stay Analyses

Excluding LOS above the 95th percentile produced a smaller duration coefficient that remained significant (β=0.445 days/hour; 95% CI, 0.373–0.516; P<0.001). Natural-log LOS modeling also showed a positive association (β=0.123; 95% CI, 0.105–0.142; P<0.001; Table 3).

The early-surgery cohort contained 1,605 procedures, with 1,604 complete cases for adjusted models. Mean LOS was 4.27±4.86 days and median LOS was 3.19 days (IQR, 1.34–5.24); 276 cases (17.2%) exceeded the full-cohort prolonged-LOS threshold. Each additional OR hour was associated with 0.601 additional days (95% CI, 0.463–0.738; P<0.001) and greater odds of prolonged LOS (OR, 1.40; 95% CI, 1.29–1.51; P<0.001). The inverse age association with prolonged LOS was attenuated in this subgroup (OR, 0.993/year; 95% CI, 0.983–1.003; P=0.145).

Median LOS increased with longer preoperative hospitalization: 3.19 days for <1 day preoperatively, 5.47 days for 1 to <3 days, 6.12 days for 3 to <7 days, and 8.43 days for ≥7 days.

Mean ASA classification increased across these categories from 2.64 to 2.82, 2.97, and 3.18 (Table 4).

Discussion

In this retrospective cohort, longer total OR duration was associated with longer postoperative hospitalization after adjustment for measured patient and procedural covariates. Each additional OR hour corresponded to approximately 0.53 additional hospital days and 26% greater odds of prolonged LOS. The duration association persisted after exclusion of extreme LOS values, log transformation, and restriction to surgery within 24 hours of admission.

Longer OR duration may reflect technical complexity, greater tissue dissection, blood loss, anesthetic exposure, or recovery needs [5, 8, 9]. Phan et al. reported associations between longer operations and postoperative complications in adult spinal deformity surgery [8]. Systematic reviews across surgical specialties and a lumbar fusion study also link longer procedures with adverse events [10, 11, 12]. These findings support investigating OR duration as a marker of perioperative burden, while recognizing that different studies use different definitions of operative time.

The association remained after adjustment for age, ASA classification, documented fusion, and inpatient status. However, adjustment for these variables cannot establish that OR duration captures risk independently of all aspects of procedural complexity. The dataset lacked detailed indications and measures of operative extent. The observed increase in fusion and inpatient proportions across duration categories illustrates the substantial differences in case mix.

Increasing age was associated with shorter LOS and lower odds of prolonged hospitalization in the full cohort. This counterintuitive finding should not be interpreted as a protective effect of age. Patient selection and differences in operative complexity may contribute: selected older patients with neurogenic claudication may undergo a limited decompression without fusion, whereas younger patients may undergo more extensive procedures. Adjustment for binary fusion status does not capture decompression extent, number of levels, or revision complexity. Greater multidisciplinary involvement and earlier discharge planning for older patients could also contribute. These explanations were not directly investigated and remain hypotheses. The attenuation of the age association in the early-surgery logistic model further supports cautious interpretation.

LOS is affected by factors beyond perioperative morbidity. Adogwa et al. found that most patients with extended LOS after lumbar decompression and fusion lacked a documented postoperative complication, suggesting contributions from practice patterns and discharge factors [13]. Other spine cohorts demonstrate the importance of examining hospitalization alongside readmission and mortality [14]. In our cohort, longer preoperative hospitalization accompanied higher ASA classification and longer postoperative LOS. This pattern may reflect baseline acuity, medical optimization, or differences in surgical indication; it does not show that preoperative hospitalization itself caused a longer postoperative course.

The persistence of the duration association after excluding extreme LOS values suggests that the finding was not confined to the longest admissions. The smaller coefficient after truncation also indicates that extreme stays influenced the estimated magnitude. Restriction to early surgery reduces the contribution of prolonged preoperative inpatient care but does not identify a uniformly elective or low-acuity population.

Several limitations affect interpretation. The retrospective design precludes causal inference. Fusion classification relied on procedure descriptions, and incomplete coding prevented exclusion of concomitant fusion in cases without a fusion descriptor. Minimally invasive versus open approach could not be classified reliably. Number of levels, revision status, deformity correction, specific indication, blood loss, and intraoperative complications were unavailable for adjustment. Total OR time also includes workflow and anesthesia-related intervals that may vary independently of procedural complexity.

The LOS definition includes OR time, creating direct overlap between exposure and outcome. The estimates therefore describe hospitalization measured from OR entry and should not be interpreted as recovery time beginning at OR exit. Inpatient classification does not distinguish elective admissions from urgent care or medical optimization; its wide logistic CI warrants caution. Repeat procedures within patients and admissions were retained, and their correlation was not modeled, which may affect precision. Excluding procedures shorter than 2 hours limits applicability to shorter operations. Residual confounding and limited procedural detail also constrain generalizability.

OR duration may help frame postoperative resource needs, but clinical use requires validation beyond statistical association. Spine enhanced-recovery studies support evaluating structured

perioperative pathways [15, 16], whereas the present study did not test a discharge intervention or quantify incremental predictive performance. More detailed cohorts should evaluate OR-exit-based LOS and whether duration improves prediction beyond patient health, indication, and operative extent.

Conclusion

Longer total OR duration was associated with longer hospitalization measured from OR entry after adjustment for available covariates. Increasing age showed an inverse association with LOS in the full cohort. These associations do not establish causation or demonstrate a validated prediction tool.

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Table 1 Patient and Procedural Characteristics by OR Duration

Characteristic	Overall N=2,266	2 to <4 h n=919	4 to <6 h n=905	≥6 h n=442
Age, years, mean ± SD	60.1 ± 15.6	59.1 ± 16.2	61.8 ± 14.9	59.0 ± 15.5
ASA classification, mean ± SD	2.72 ± 0.60	2.58 ± 0.64	2.80 ± 0.57	2.85 ± 0.53
Documented fusion, n (%)	1,200 (53.0%)	283 (30.8%)	576 (63.6%)	341 (77.1%)
Inpatient, n (%)	2,131 (94.0%)	801 (87.2%)	889 (98.2%)	441 (99.8%)
Postoperative LOS, days, median [IQR]	3.90 [2.12–6.39]	2.25 [1.15–4.34]	4.22 [2.92–6.49]	6.04 [4.08–8.31]
Postoperative LOS, days, mean ± SD	5.78 ± 7.95	4.16 ± 6.87	6.25 ± 8.04	8.22 ± 9.05

OR, operating room; LOS, length of stay; ASA, American Society of Anesthesiologists; SD, standard deviation; IQR, interquartile range. Duration represents total OR entry-to-exit time. LOS is measured from OR entry to discharge. ASA data are available for 2,265 procedures overall and 918 in the 2 to <4-hour group. Other denominators are the column totals.

Table 2 Adjusted Associations With LOS and Prolonged LOS

Covariate	Linear β (95% CI)	P	Adjusted OR (95% CI)	P
OR duration, per hour	0.535 (0.360 to 0.709)	<0.001	1.257 (1.190 to 1.329)	<0.001
Age, per year	-0.095 (-0.114 to -0.075)	<0.001	0.980 (0.973 to 0.987)	<0.001
ASA classification, per class	3.518 (2.991 to 4.045)	<0.001	2.633 (2.174 to 3.206)	<0.001
Documented fusion, yes vs no	1.209 (0.559 to 1.858)	<0.001	1.523 (1.224 to 1.897)	<0.001
Inpatient status, yes vs no	2.711 (1.362 to 4.060)	<0.001	10.747 (3.353 to 65.644)	<0.001

LOS, length of stay; OR, odds ratio (in the model estimates) or operating room (in the covariate label); CI, confidence interval; ASA, American Society of Anesthesiologists. Both models include all listed covariates and 2,265 complete cases. Linear coefficients are differences in days. Prolonged LOS exceeds the unrounded cohort 75th percentile (6.3944 days). ASA classification is modeled numerically. Reference categories are no documented fusion and non-inpatient status.

Table 3 Sensitivity Analyses of the Association With OR Duration

Analysis	Adjusted model n	Linear β per hour (95% CI)	OR per hour (95% CI)
Exclude upper 5% of LOS	2,151	0.445 (0.373 to 0.516)	Not modeled
Natural-log LOS	2,265	0.123 (0.105 to 0.142)	Not modeled
Surgery within 24 hours	1,604	0.601 (0.463 to 0.738)	1.397 (1.293 to 1.513)

LOS, length of stay; OR, odds ratio (in the model estimates) or operating room (in the title); CI, confidence interval. Models adjust for age, ASA classification, documented fusion, and inpatient status. All displayed duration associations have P<0.001. The upper-5% analysis retains 2,152 procedures descriptively and 2,151 complete cases. Coefficients are in days/hour except for natural-log LOS. The early-surgery cohort contains 1,605 procedures descriptively; prolonged LOS uses the full-cohort threshold.

Table 4 Postoperative LOS by Preoperative Hospital Stay

Preoperative stay	n	Postoperative LOS days, median [IQR]	ASA classification mean±SD
<1 day	1605	3.19 [1.34–5.24]	2.64±0.58
1 to <3 days	382	5.47 [3.46–8.37]	2.82±0.62
3 to <7 days	208	6.12 [4.06–10.45]	2.97±0.64
≥7 days	71	8.43 [4.27–17.22]	3.18±0.46

LOS, length of stay; IQR, interquartile range; ASA, American Society of Anesthesiologists; SD, standard deviation. LOS is measured from OR entry to hospital discharge. ASA classification is available in 1,604 of 1,605 procedures in the <1-day group and in all procedures in the remaining groups. These comparisons are descriptive and do not establish an effect of preoperative hospitalization.