Late Week Surgery and Discharge to Specialty Care Are Associated with Higher Costs and Longer Lengths of Stay After Elective Lumbar Laminectomy

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Objective In a healthcare landscape where costs increasingly matter, we sought to distinguish among the clinical and nonclinical drivers of patient LOS following elective lumbar laminectomy—a common spinal surgery that may be reimbursed for with bundled payments—and understand their relationship with patient outcomes and costs.

Methods All patients ≥ 18 years undergoing laminectomy surgery for degenerative lumbar spinal stenosis within the Cleveland Clinic health system between 3/1/2016 and 2/1/2019 were included in this analysis. Generalized linear modeling was used to assess the relationship between day of surgery, patient discharge disposition, and hospital LOS, while adjusting for underlying patient health risks and other nonclinical factors, including surgical site and insurance.

Results A total of 1359 eligible patients were included in our analysis. Mean LOS ranged between 2.01 and 2.47 days for Monday and Friday cases, respectively. LOS was also notably longer for patients who were ultimately discharged to SNF or rehabilitation facilities. Prolonged LOS occurring later in the week was not associated with greater underlying health risks, yet it nevertheless resulted in greater costs of care: average total surgical costs for lumbar laminectomy were 20% greater for Friday compared to Monday cases and 24% greater for late versus early week cases that ultimately transferred to SNF or rehabilitation centers. A Poisson GLM model best fit the data and showed that comorbidity burden, surgery at a tertiary care center vs. community hospital, and incidence of any postoperative complication were associated with significantly longer hospital stays. Discharge to home health care and SNF/rehabilitation facilities and late week surgery were significant, nonclinical predictors of LOS prolongation, even after adjusting for underlying patient health risks and insurance, with LOS that were for instance 1.55 and 1.61 times longer for patients undergoing their procedure on Thursday and Friday compared to Monday, respectively.

Conclusions Late week surgeries are associated with prolonged LOS, particularly when discharge is to SNF or rehabilitation facilities. These findings point to opportunities to lower costs and improve outcomes associated with elective surgical care. Interventions to optimize surgical scheduling and peri-operative care coordination could help reduce prolonged LOS, lower costs, and ultimately give service line management greater flexibility over how to use existing resources as they remain ahead of health care reforms.

Keywords laminectomy; neurosurgery; elective surgical procedures; outcome assessment; health care; health care costs; length of stay; lumbar

SURGERIES account for a significant proportion of overall US healthcare expenditures: total costs per hospitalization have risen with costs per inpatient day,[1] and surgical admissions now account for 49% of all inpatient spending.[2,3] As the healthcare system rapidly evolves in an attempt to manage escalating expenditures and ever-growing demand, efforts to reduce unnecessarily long hospital lengths-of-stay (LOS) may help lower surgical costs and lessen burdens on providers and patients.

Toward this end, recent policy reforms have focused on reducing LOS with the objective of optimizing resource use. For instance, the 2018 Bundled Payments for Care Improvement (BPCI) Advanced program bundles payments to providers by healthcare episode, providing an incentive to redesign care, reduce LOS, and control costs.[4] The program covers 29 inpatient and 3 outpatient clinical episodes, including gastrointestinal, cardiac, orthopedic, and inpatient and outpatient spinal surgical procedures.[5]

To reduce waste rather than merely lower costs, such initiatives must incorporate robust evidence on the factors that influence the duration of hospital stays. For example, age and lower functional class may justify longer postoperative LOS if that means eventual, safe transfer out of hospital.[6,7] On the other hand, LOS may be equally impacted by factors unrelated to the health needs of patients. In the trauma setting, payer type and discharge destinations independently influence LOS.[8] For elective procedures, preoperative factors, including age, gender, and functional status have been found to affect LOS in international settings.[7] Descriptive studies have suggested that surgery location and day of surgery can also prolong LOS following elective orthopedic procedures.[9,10] Recent studies have reported similar findings in other surgical specialties, yet they may not adequately adjust for underlying health risks, account for postoperative outcomes and discharge disposition, or evaluate the economic impact from prolonged lengths-of-stay.[11,12] As payment systems change, failure to reliably distinguish among the clinical and nonclinical predictors of LOS, and understand their relationship with patient outcomes and costs, could have a palpable effect on clinical practice and provider reimbursement and create adverse incentives for care.

This may be particularly true for elective surgeries. For instance, elective lumbar laminectomy is routinely performed on an inpatient basis to treat symptomatic spinal stenosis. However, the procedure is increasingly performed by outpatient providers—such as ambulatory surgery centers—that may attempt to reduce perioperative surgical costs by limiting patient LOS,[13] though perhaps at greater risk of revision surgery and perioperative complications.[14] In the context of mounting economic pressures to limit LOS, it is increasingly important to develop an improved understanding of the impact from clinical and nonclinical factors on LOS, patient outcomes, and costs associated with elective surgical procedures.

The present study uses regularly collected hospital data to model the impact from clinical and nonclinical factors on patient LOS following elective lumbar laminectomy, a common surgical procedure that can be performed in both inpatient and outpatient settings and reimbursed for with bundled payments. By offering insights into the factors contributing to prolonged LOS, as well as their associated health and economic outcomes, this study helps to shed light on opportunities to optimize LOS in elective surgical settings.

Methods

Subjects and Procedure Selection

A retrospective review was performed for all patients ≥ 18 years undergoing elective lumbar laminectomy for degenerative spinal stenosis between March 1, 2016 and February 1, 2019 with an open or minimally invasive surgical technique. Data was obtained from all hospitals in Ohio that are affiliated with the Cleveland Clinic health system.

Degenerative stenosis of the lumbar spine is a common cause of disabling pain in the back and lower extremities that can safely and effectively be treated with surgical decompression via laminectomy.[15] Lumbar laminectomy is a relatively simple surgical procedure with a largely predictable hospital course. It is also commonly performed, with over 82,550 elective operations occurring in the US in 2012.[16]

Analysis

Generalized linear modeling (GLM) was used to examine the relationship between day of surgery and patient LOS, our dependent variable. Two candidate models were designed with and without patient discharge disposition and weekday of surgery; both adjusted for patient demographics (age, gender, race), weighted Elixhauser comorbidity scores, incidence of postoperative complications, as well as other nonclinical factors, including surgical site and insurance. Discharge planning may be affected by day of surgery and can impact patient LOS. One additional model therefore included an interaction term with patient discharge disposition as the mediator variable. Candidate models with the interaction term also considered all 7 combinations of demographic variables to adjust for underlying health risks and account for possible over-fitting.

Patient discharge disposition included home, home health care, and skilled nursing facilities (SNF) or rehabilitation facilities. All insurers covering study-eligible patients were included in our analysis. This included: private / commercial insurers, Medicare (Advantage, fee-for-service), worker's compensation, Medicaid, and others (e.g. self-pay). Our analysis took into account any postoperative complication, including cardiac (acute congestive heart failure, myocardial infarction) and pulmonary events (acute respiratory failure, pneumonia), as well as altered mental status, durotomy, and infection (C. difficile, UTI, or other). Surgical sites were classified as either a tertiary care center or community hospital, while early and late week surgeries were defined as those occurring on Mondays or Tuesdays and Thursdays or Fridays, respectively.

Length of stay can be represented as a nonzero, count variable. GLM models were therefore fitted with Gaussian and Poisson family functions. To account for potential over-dispersion of count data, Poisson regression with robust standard errors was used; a third Quasi-Poisson family function was also considered. To perform model selection, data were first randomly divided into training (80%) and testing (20%) subsets. 10-fold cross validation with a root mean square cost function was used to identify the model that best fit the training data and minimized the cross-validation error term. The best fitting model was then used to make predictions on test samples and estimate LOS residuals. A final classifier was then estimated by retraining the best fitting model on the entire dataset.

Total (direct + indirect) healthcare costs associated with each episode of care were obtained from hospital records and adjusted for inflation (2020 USD) by using the Producer Price Index for inpatient services from the US Bureau of Labor Statistics.[17] A chi-square test was used to

compare categorical sociodemographic characteristics of individuals undergoing lumbar laminectomy during each day of the week. Age, proportion of patients experiencing any postoperative complication, LOS, and adjusted total costs for care were compared across surgical day groups using a one-way ANOVA test. A Wald test was used to assess the significance of model predictor variables. Nagelkerke pseudo R^2 was also used to assess model performance. Statistical significance was defined at the $p \leq 0.05$ level. All statistical analyses were performed using R version 3.6.3 (The R Foundation, Vienna, Austria). This study was reviewed and approved by the institutional review board of the Cleveland Clinic.

Results

A total of 1359 patients met eligibility criteria and were included in this study (**Table 1**). The average age of treated patients varied throughout the work week and ranged between 64 years (Friday) and 68 years (Tuesday). There was no significant difference among surgical day groups in gender, race, or Elixhauser comorbidity score.

Patients who underwent their procedure on Tuesdays and Wednesdays more frequently received care at a tertiary care center, while those treated on Mondays were more likely to receive care at regional community hospitals. Among all surgical day groups, the greatest proportion of patients were insured with a private / commercial insurance plan, followed by Medicare fee-for-service. There was a statistically significant difference in the proportion of patients covered under each of the insurance plans. Tuesday operations also had the lowest proportion of patients covered under private/commercial insurance plans, while those occurring on Thursdays and Fridays were less likely to be covered by Medicare Advantage and fee-for-service plans.

There was no significant difference in the number of vertebral levels decompressed among surgical day groups. The incidence of any complication was consistently low, regardless of when operations took place. There was also no significant difference among surgical day groups in their discharge disposition.

Patients who underwent lumbar laminectomy late in the week had significantly longer hospital lengths of stay and costs (**Table 1**). Patients undergoing their procedure between Monday and Friday had a mean LOS of 2.01, 2.04, 2.16, 2.64, and 2.47 days, respectively. This effect was most notable for patients who were ultimately discharged to SNF or rehabilitation facilities.

Patients who underwent their procedure late in the week were associated with significantly higher total costs for their episodes of care, with average adjusted total costs that were 17.4% higher for Friday versus Monday cases. Patients who were discharged to SNF or rehabilitation and treated late in the week were also associated with an average adjusted total cost that was 21.5% greater than those who were discharged to SNF or rehabilitation but treated early in the week. Average surgical costs for late-week, SNF/rehabilitation discharges were also higher among all insurance subgroups.

Regression Analysis

Of the 27 candidate models that were considered, a Poisson GLM model best fit the data and resulted in the lowest estimate of error. When fitted onto the test sample, the final model had an

AIC of 855, a deviance of 134, and a Nagelkerke pseudo R^2 of 0.59 versus the null model. The mean difference between predicted and observed LOS also did not significantly differ from zero in any discharge disposition subgroup undergoing surgery early or late in the week.

Predicted lengths-of-stay for the test samples were longer for late week surgery patients who were discharged home and to SNF/rehabilitation, as well as for those who were discharged to home or home health care (**Fig. 1**). However, the difference in mean predicted LOS among patients undergoing their procedure late versus early in the week was far greater for those discharged to SNF/rehabilitation (1.46 days) compared to that of patients who were discharged home (0.31 days) or to home health care (0.46 days).

Retraining the best-fitting Poisson GLM model on the full dataset showed that comorbidity burden, surgery at a tertiary care center versus community hospital, and incidence of any postoperative complication were independently associated with longer hospital stays (**Table 2**).

Discharge to home health care or to SNF/rehabilitation, in particular, were significant predictors of longer LOS, even after adjusting for other covariates such as underlying health risks and insurance. Patients undergoing their procedure on Thursday or Friday were also found to have significantly greater likelihood of prolonged postoperative, in-hospital stays.

Discussion

Even as incentives to lower costs and improve patient outcomes evolve, it remains unclear what factors contribute to hospital LOS following elective surgical procedures. Our study uses regularly collected hospital data to assess the impact from clinical and nonclinical factors, including those related to surgical scheduling, on patient length of stay following lumbar laminectomy, a common elective surgical procedure that can be performed in both inpatient and outpatient settings and reimbursed for with bundled payments.

This study finds that hospital LOS following elective lumbar laminectomy is longer for patients who undergo surgery late in the work week. Patients treated on Mondays and Tuesdays have an average LOS of 2.01 and 2.04 days, respectively, indicating that their discharge usually occurs by the end of the work week. In contrast, LOS for those treated on Thursdays and Fridays is about 20%–30% higher, with average LOS of 2.64 and 2.47 days, respectively, pushing patient discharge into the weekend. Tuesday operations, and those occurring on Thursdays and Fridays, were less likely to be covered by private/commercial and Medicare Advantage and fee-for-service plans, respectively. However, this is unlikely to directly reflect insurer preferences—surgical scheduling often occurs in the clinic after treatment options have been discussed; it involves physicians, patients, and care coordinators; and it is designed to coordinate convenience to patients with provider availability. Indeed, late week surgeries were associated with prolonged LOS despite there being no significant difference in the number of levels decompressed, in comorbidity burden, or in the incidence of postoperative complications among patient groups. These findings also persisted even after adjusting for patient demographics, underlying health risks, surgical site, and insurance.

Discharge disposition also matters. After adjusting for potential confounders, we find that predicted lengths-of-stay are greater for patients who are scheduled for late-week surgeries, irrespective of whether they are discharged to home, home health care, or to SNF/rehabilitation facilities. However, the mean difference in LOS for early versus late week surgeries is far greater

for those being discharged to SNF/rehabilitation (1.46 days) compared to those who are discharged to home (0.31 days) or home health care (0.46 days). Efforts to reduce unnecessarily long LOS following elective surgical procedures may therefore have the greatest impact if they target late week surgery cases that are transferred to SNF or rehabilitation facilities.

LOS following elective lumbar laminectomy therefore only partially represents the health needs of patients. Postoperative LOS may instead often be influenced by nonclinical factors, including patient discharge disposition and logistics. Indeed, transfers to SNF/rehabilitation facilities can be delayed by difficulties in coordinating care with insurance companies.[18] There is also evidence to explain why such delays in patient discharge may be accentuated over the weekend. For instance, reduced hospital weekend staffing, including of occupational and physical therapists and social workers, results in poorer access to ancillary services,[19] and similar staffing challenges also exist at the subacute skilled nursing and rehabilitation facilities that receive patients.[20,21]

Unfortunately, hospital-level datasets, including our own, are not designed to explore the impact from social and logistical on LOS to great detail. For instance, datasets often lack information on social support, including from a spouse, as well as information on the auxiliary staff involved in hospital discharge and admission to outside, receiving institutions. Future studies should build on this analysis—perhaps with the use of qualitative or mixed methods—to explore how these factors, including auxiliary staffing at hospitals and specialty care facilities, contribute to LOS among late-week, postsurgical patients.

It nevertheless remains the case that late week surgery for lumbar laminectomy is associated with longer LOS. This is particularly true for patients who are discharged to skilled nursing or rehabilitation facilities. Besides likely worsening patient experience, prolonged LOS may have adverse financial consequences for payers, providers, and patients. At the extremes, we find that average total surgical costs for lumbar laminectomy cases occurring on Fridays are about 20% higher than those for cases that take place on Mondays. The average total surgical cost associated with patients discharged to SNF or rehabilitation late in the week was also 24% greater than those of patients treated early in the week. Average surgical costs were also higher for all insurance types, pointing to potential cost savings to providers irrespective of payer. Without any clear evidence of differences in pre- or postoperative health needs, these findings suggest that prolonged LOS among late week surgery cases, and particularly those transferring to SNF or rehabilitation facilities, contributes to unnecessary and potentially avoidable healthcare costs.

At the same time, we find little evidence to suggest that prolonged postoperative LOS improves health outcomes. Our study finds that the incidence of complications following lumbar laminectomy is low and unrelated to the weekday in which procedures take place. The likelihood of patient discharge to SNF/rehab facilities also did not differ across surgical day groups.

That said, another limitation of our study is that we cannot assess the impact from prolonged LOS and potentially greater intensity of in-hospital care on health outcomes occurring after discharge. In the cardiac literature, admission to hospital for myocardial infarction over the weekend and during evenings is associated with significantly greater odds of 30-day mortality.[22] In our case, while one could reasonably hypothesize that extended stays in hospital following elective lumbar laminectomy would reduce the risk of some complications occurring in the postdischarge setting, it could also increase the risk of other complications, such as nosocomial infection. While further research is needed to evaluate the long-term consequences of prolonged

LOS, our study finds no evidence to support the notion that patients fare better from prolonged LOS while they remain in hospital.

Moreover, our study is based on data from a single health care system. While the Cleveland Clinic is one of the largest academic hospital systems in the United States—with 18 hospitals in northeast Ohio alone—idiosyncrasies in patient case mix or healthcare delivery may limit this study's generalizability to other hospital systems. Additional studies should attempt to replicate this analysis in other settings to further explore this issue.

In summary, findings from our study suggest that hospital lengths-of-stay following elective spine procedures are prolonged by clinical and nonclinical factors, including day of surgery and discharge disposition. These findings point to opportunities to optimize the costs and outcomes of elective surgical care. For instance, our research group is studying the use of various technologies, including machine learning, to automate surgical scheduling and other clinical processes based in part on expectations of postoperative health needs. Such an approach may help identify surgical patients at greatest risk of requiring transfer to SNF or rehabilitation facilities, allowing providers to front-load these cases earlier in the week. Doing so may initially be disruptive to clinical operations, particularly considering surgical block time allocations. However, it could also help reduce prolonged lengths-of-stay, lower costs for patients and payers, allow providers to make more efficient use of surgical resources, and ultimately give service line management greater flexibility over how to use existing resources as they remain ahead of health care reforms. In a healthcare landscape where costs increasingly matter, such initiatives in surgical care are a worthwhile endeavor.

Conclusions

Hospital length-of-stay (LOS) following elective lumbar laminectomy is longer for patients who undergo surgery late in the work week, despite there being little evidence to indicate greater health needs among these patients. This effect appears to be particularly true for patients who are ultimately discharged to SNF or rehabilitation facilities. Indeed, after adjusting for potential confounders, predicted lengths-of-stay are greater for patients who are scheduled for late-week surgeries, irrespective of discharge disposition. However, the mean difference in LOS for early versus late week surgeries is far greater for those discharged to SNF/rehabilitation (1.46 days) compared to those who are discharged to home (0.31 days) or home health care (0.46 days). Prolonged LOS does not appear to result in improved in-hospital patient outcomes. It nevertheless results in greater costs of care, with average total surgical costs for lumbar laminectomy that are 20% greater for Friday cases compared to Monday cases and 24% greater for late versus early week cases that ultimately transfer to SNF or rehabilitation centers.

FUTURE DIRECTIONS

Our study points to opportunities to lower costs and improve outcomes associated with elective surgical care, notably by optimizing surgical scheduling and peri-operative care coordination. The use of predictive analytics during the surgical scheduling process could, for instance, help identify spine surgery patients at greatest risk of requiring transfer to SNF or rehabilitation facilities, allowing providers to schedule these cases earlier in the week. Such an approach may reduce prolonged hospital LOS, lower costs for patients and payers, allow

providers to make more efficient use of surgical resources, and ultimately give service line management greater flexibility over how to use existing resources as they remain ahead of health care reforms.

Disclosure

Acknowledgments

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Author Contributions

Conception and design: Salas-Vega, Winkelman, Grabowski. Acquisition of data: Salas-Vega, Winkelman, Habboub. Analysis and interpretation of data: Salas-Vega, Winkelman, Habboub. Drafting the article: Salas-Vega, Chakravarthy, Winkelman. Critically revising the article: Salas-Vega, Chakravarthy, Savage, Steinmetz, Mroz. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Salas-Vega. Statistical analysis: Salas-Vega, Winkelman. Administrative/technical/material support: Salas-Vega, Habboub, Savage, Steinmetz, Mroz. Study supervision: Salas-Vega, Grabowski, Habboub, Savage, Steinmetz, Mroz.

Table 1. Patient demographics and sample characteristics

	Monday	Tuesday	Wednesday	Thursday	Friday	p Value
No. of patients	366	229	279	242	243	
Patient characteristics						
Age, mean (SD)	65.40 (10.97)	68.04 (10.74)	66.13 (11.53)	65.22 (12.03)	63.70 (12.14)	0.001
Male	243 (66.4)	151 (65.9)	187 (67.0)	149 (61.6)	156 (64.2)	0.698
Race						0.155
Black	27 (7.4)	10 (4.4)	18 (6.5)	22 (9.1)	9 (3.7)	
Other	15 (4.1)	13 (5.7)	14 (5.0)	6 (2.5)	8 (3.3)	
White	324 (88.5)	206 (90.0)	247 (88.5)	214 (88.4)	226 (93.0)	
Elixhauser score*						0.800
0	83 (22.7)	54 (23.6)	78 (28.0)	59 (24.4)	62 (25.5)	
<0	235 (64.2)	139 (60.7)	167 (59.9)	143 (59.1)	141 (58.0)	
1–4	20 (5.5)	13 (5.7)	14 (5.0)	15 (6.2)	12 (4.9)	
≥5	28 (7.7)	23 (10.0)	20 (7.2)	25 (10.3)	28 (11.5)	
Provider & payer characteristics						
Insurance plan						0.041
Private/commercial	144 (39.3)	62 (27.1)	101 (36.2)	92 (38.0)	100 (41.2)	
Medicare Advantage	75 (20.5)	59 (25.8)	56 (20.1)	44 (18.2)	53 (21.8)	
Medicare FFS	118 (32.2)	91 (39.7)	104 (37.3)	84 (34.7)	68 (28.0)	
Workers' comp	3 (0.8)	2 (0.9)	5 (1.8)	2 (0.8)	8 (3.3)	

Medicaid	22 (6.0)	13 (5.7)	8 (2.9)	14 (5.8)	11 (4.5)	
Other	4 (1.1)	2 (0.9)	5 (1.8)	6 (2.5)	3 (1.2)	
Medical center						
Tertiary care	234 (63.9)	192 (83.8)	256 (91.8)	161 (66.5)	188 (77.4)	<0.001
Procedure & patient outcomes						
Vertebral levels treated, mean (SD)	1.79 (0.96)	1.72 (0.93)	1.68 (0.98)	1.73 (0.90)	1.77 (0.96)	0.709

Figure 1. Box-and-whisker plot depicting predicted lengths of hospital stay with respect to discharge disposition of patients surgically treated early or late in the week. Acute Rehab = acute rehabilitation center; Early Week = Monday + Tuesday + Wednesday; Late Week = Thursday + Friday.
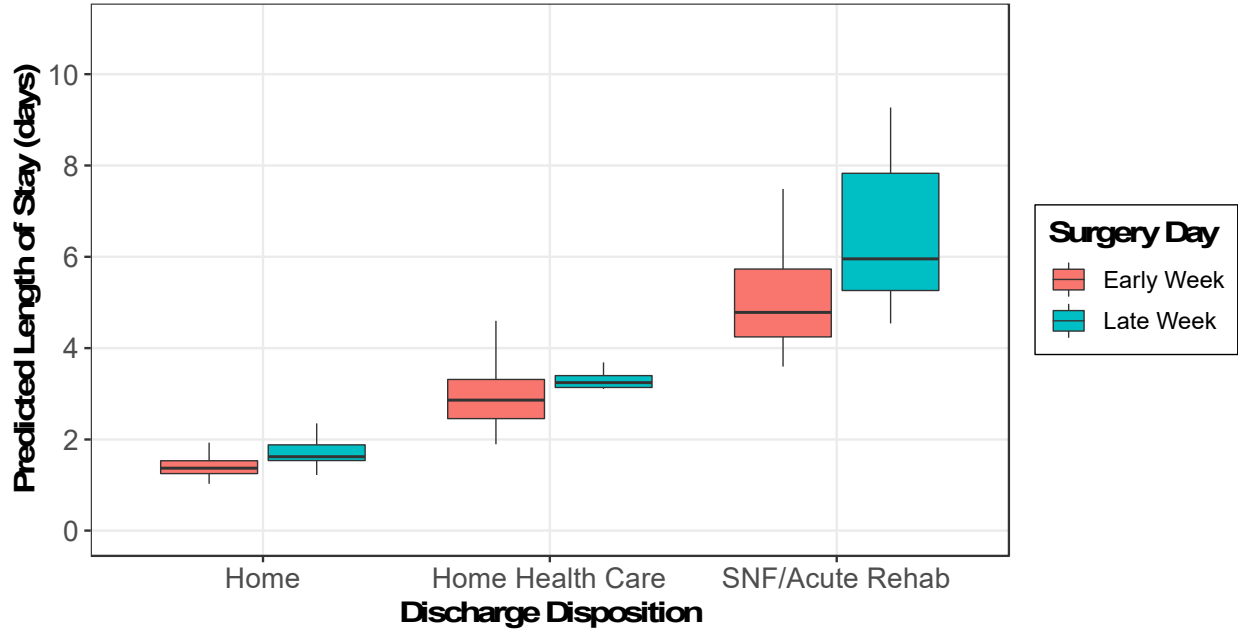
Table 2. Poisson regression-optimized model.

	Poisson Regression — LOS Exp (Est.)
(Intercept)	3.00*** (1.91, 4.70)
Age	0.96 (0.85, 1.09)
Gender	
Male	0.86 (0.71, 1.04)
Race	
Other	0.73 (0.44, 1.20)
White	0.78 (0.53, 1.15)
Center where surgery was performed	
Tertiary care	1.33* (1.05, 1.68)
Insurance	
Medicare HMO	1.21 (0.88, 1.68)
Medicare FFS	0.81 (0.64, 1.02)
Workers' Comp	0.81 (0.52, 1.28)
Medicaid	1.30 (0.89, 1.90)
Other	1.41 (0.63, 3.18)
Elixhauser score	
<0	1.42*** (1.22, 1.66)
1–4	1.50 (0.96, 2.33)
≥5	2.36*** (1.53, 3.63)
Surgical complication	
Any	3.31*** (2.30, 4.75)
Discharge disposition	
Home health care	4.83*** (3.69, 6.31)
SNF/rehabilitation center	49.58*** (26.86, 91.52)
Day when surgery was performed	
Tuesday	0.94 (0.73, 1.21)
Wednesday	1.09 (0.86, 1.37)
Thursday	1.55** (1.14, 2.12)
Friday	1.61*** (1.23, 2.11)
No. of patients	1359
AIC	5202.21
BIC	5316.93

Pseudo R^2	0.45