Title

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Journal

Journal of the American Academy of Orthopaedic Surgeons, 27(6)

ISSN

1067-151X

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Publication Date

2019-03-15

DOI

10.5435/jaaos-d-17-00447

Peer reviewed

Published in final edited form as:
J Am Acad Orthop Surg. 2019 March 15; 27(6): e293–e300. doi:10.5435/JAAOS-D-17-00447.

Predictive Modeling for Geriatric Hip Fracture Patients: Early Surgery and Delirium Have the Largest Influence on Length of Stay

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Abstract

Background: Averaging length of stay (LOS) ignores patient complexity and is a poor metric for quality control in geriatric hip fracture programs. We developed a predictive model of LOS that compares patient complexity to the logistical effects of our institution's hip fracture care pathway.

Methods: A retrospective analysis was performed on patients enrolled into a hip fracture co-management pathway at an academic level-one trauma center from 2014–15. Patient complexity was approximated using the Charlson Comorbidity Index (CCI) and ASA score. A predictive model of LOS was developed from patient-specific and system-specific variables using a multivariate linear regression analysis; it was tested against a sample of patients from 2016.

Results: LOS averaged 5.95 days. Avoidance of delirium and reduced time to surgery were found to be significant predictors of reduced LOS. CCI was not a strong predictor of LOS, but ASA score was. Our predictive LOS model worked well for 63% of patients from the 2016 group; for those it did not work well for, 80% had post-operative complications.

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Conflict of Interest: The authors declare that they have no conflict of interest.

The study was approved by our ethical committee.

Conclusion: Predictive LOS modeling accounting for patient complexity was effective for identifying: 1) reasons for outliers to the expected LOS, and 2) effective measures to target for improving our hip fracture program.

Introduction

There are more than 300,000 geriatric hip fractures per year in the United States.[1,2] Patients with hip fractures face reduced mobility and independence after their injury and have an increased one-year mortality rate.[3,4] Early surgery and a prompt medical evaluation/optimization have been shown to reduce perioperative morbidity and mortality rates and improve outcomes[5–9]. Furthermore, Orthopedic-Geriatric co-management models have been shown to reduce morbidity, decrease length of stay (LOS), and lower hospitalization costs.[10–13]

As dedicated hip fracture co-management programs have evolved, inpatient outcome metrics have improved.[3,14] The most effective model, though, has yet to be determined.[7] Each hospital and healthcare system has unique nuances and logistical challenges that create barriers to implementing and improving hip fracture programs.[15–18] Additionally, variance among patient populations may prevent established models of co-managed care from being transferrable between similar types of institutions. Predictive modeling of care pathways can help healthcare systems better understand how variability affects patient throughput and outcomes.[19] However, the effect of hospital-specific predictive modeling in the hip fracture population has not been explored.

A multi-disciplinary care pathway for geriatric hip fracture patients was started in January of 2014 at the *****BLINDED FOR REVIEW*****, an academic level-one adult and pediatric trauma center and tertiary care center. Prior to the implementation of our geriatric fracture pathway (GFP), there were no defined guidelines or pathways for the care of this fragile patient population. Accordingly, our length of stay (LOS) averaged 8 days, well above published means in the United States. Since the start of our hip fracture program, we have made substantial, metric-proven improvements in our care of these patients.

Interim analyses of our care metrics found multiple positive effects of our pathway which includes: orthopedic-geriatric co-management, cohorting patients on an orthopedic surgery floor whenever possible, guidelines for pain control and delirium prevention/detection, early discharge planning, and delineating what is supposed to happen to patients during their hospital stay. After two years of data collection, we developed a predictive model of LOS and used it to try to understand the impact of patient medical complexity and delays to surgery on the actual LOS versus predicted LOS. Using our predictive model, we aimed to further understand what positively and adversely affected our care pathway in order to improve patient outcomes and care efficiency.

Methods

After obtaining institutional review board (IRB) approval, a retrospective review of the geriatric hip fracture database at [BLINDED] was performed. To be included in our hip fracture database patients had to be age 65 or older, and have an isolated hip fractures

(AO/OTA 31 A-C) sustained after a ground level fall (GLF). Patients meeting these criteria were eligible for participation in our geriatric fracture program (GFP). The GFP is a hip fracture pathway begins in the emergency department (ED). After the diagnosis of a hip fracture is made, patients enter the GFP pathway that guides the workup and care of the patients. It includes: pain control centered on acetaminophen and an iliofascial nerve block, specific imaging and lab tests, and family/patient education regarding hip fractures. An on-call hospitalist reviews the patient's chart and determines whether the patient should be admitted to the orthopedic service or an internal medicine service based on very clearly defined and mutually agreed upon criteria. Regardless of the admitting service, Orthopedic-Geriatric co-managed care ensues throughout the hospitalization.

Early medical optimization and early surgery are the initial goals of care. Patients are cohorted on the orthopedic floor whenever possible, where the staff – including nurses, physical and occupational therapists, discharge coordinators, and the managers of the unit - has been educated about their role in the GFP and participates in weekly multidisciplinary meetings. Geriatric pain protocols and a delirium detection/prevention program are used throughout the hospitalization. Internal fixation or arthroplasty is performed based on the fracture pattern, and all patients are weight bearing as tolerated post operatively on the injured extremity. Discharge planning and an evaluation by the acute rehabilitation service take place as soon as possible after admission.

Model Development

Patients who had their hip fracture operatively treated during calendar years 2014 and 2015 were used to develop our LOS predictive model. Our hip fracture database is prospectively collected and maintained using data automatically extracted from our hospital's electronic medical record system (Epic Systems, Verona, Wisconsin) and supplemented with retrospective chart reviews for data that cannot be automatically extracted. In this study, we excluded patients who had a fall while already admitted to the hospital, patients who had higher energy mechanisms of injury, and patients with any other significant injury (more than a soft tissue contusion). Patients who refused surgery or who were deemed too high-risk for surgery were also excluded. After the model was developed using patients from 2014 and 2015, data from the first 30 consecutive patients treated in early 2016 were used to test our predictive model and assess if it is a valuable tool to use for future quality improvement analyses.

Metrics

Core hip fracture data/metrics extracted automatically from EMR reports included: demographics, timing of care interventions, LOS, discharge disposition, admitting service and location, ASA score, and laboratory values. Cost data were obtained from another data system and merged into our registry. A delay to surgery (DTS) was defined as going to the operating room 2 or more midnights after presentation to our ED. We defined DTS this way because we do not routinely operate on hip fracture patients overnight and the time it takes for their medical evaluation and optimization makes surgery on the day of presentation nearly impossible. Therefore, one missed full daytime operative block represents a DTS. The Charlson Comorbidity Index (CCI) was used to score patients' pre-existing comorbidities. The complications we recorded were those defined by Liem et al. and the AO Trauma Network[20]. Delirium was assessed using the Confusion Assessment Method instrument (CAM), performed every 12 hours or whenever the patients' nurse detected a mental status change. For this study, any positive CAM was considered to signify the presence of delirium. All other complications were identified by a chart review and verified to have occurred during the hospitalization rather than being present on admission.

Building a Predictive Model of LOS

The primary purpose of creating a predictive LOS calculator was to improve our hip fracture care pathway and understand which controllable and/or uncontrollable factors influence the LOS of each patient. Accordingly, we included covariates that were both controllable and uncontrollable, as well as covariates that occur at different time points during hospitalization and may not be determinable on admission. Delirium was included in our predictive modeling because of its substantial rate of occurrence. All other in-hospital complications were excluded as a separate variable when we developed our model. This is because they are much less common and have a widely varying effect on patients' outcomes and LOS. Therefore, our model assumes a 19% complication rate (other than delirium) for each patient based on our average complication rate.

Statistical Analysis

The data were used to describe the characteristics of our patient population and guide the linear regression analysis that explored potential associations between clinical parameters and LOS. The variables that showed a statistically significant relationship to LOS and key demographic variables were added to the linear regression model to predict LOS. Even though successfully cohorting patients to our orthopaedic unit did not meet statistical significance in our unadjusted regression analysis, we chose to include this factor into our modeling because of its trend toward significance and essential role in our geriatric fracture program. The dependent variable, LOS, was skewed to the right owing to the influence of outliers, so we log transformed the values to meet normality assumptions of linear regression. We predicted log LOS for selected predictor values using the fitted regression equation. For ease of understanding clinical relevance, we exponentiated these values to yield the predicted geometric mean of LOS in days. Our statistical model was created using SAS statistical software (version 9.3, SAS, Carey, NC). The predictive calculator is available for download at SUPPLEMENTAL LINK.

Results

Between January 2014 and December 2015, 196 patients were entered in our hip fracture database. Of these, 177 patients fit the inclusion criteria for this study. 19 patients were excluded: 11 patients underwent non-operative management and 8 patients either had fracture patterns that were not AO/OTA 31A-C types or they bypassed the GFP pathway due to a delayed diagnosis of their hip fracture.

Supplemental Table 1 depicts the demographic and clinical profile of the patients included in this study. The majority of the patients (66.7%) were admitted to the orthopedic trauma surgery service, and 52.5% of patients were cohorted on the orthopedic floor. 54 patients (30.5%) had a delay to surgery (DTS). The mean LOS was 5.95 days, and the median LOS was 5.19 days, which reflects the 7% of patients who had 10-plus-day hospitalizations due to complications and/or refusing discharge to a skilled nursing facility (SNF). 83% of patients had Medicare Part A as their payer for the hospitalization, and 13% had either an HMO-contracted Medicare or an HMO/PPO as their payer. Four patients (2.3%) died during their hospitalization.

The results of the unadjusted regression analysis are shown in Table 1. Developing a complication or delirium during the hospitalization and the time to surgery were predictive of an increased LOS. An INR <1.5 on admission, ASA, and a CCI score <4 were also statistically significant and were predictive of a shorter LOS. Although not statistically significant, admission to our orthopedic unit – regardless of primary service – trended to lower LOS.

Multivariate Analysis

A multivariate analysis was performed to assess the independent effect of each covariate chosen for our predictive model. The variables chosen were: age, gender, time to surgery, ASA score, CCI score, INR on admission, admission to the orthopaedic unit (e.g. cohorting patients successfully), and occurrence of delirium during the hospitalization. The model had an R^2 of 0.20, indicating that 20% of variation in actual LOS could be measured by the variables included in the model. Nonetheless, time to surgery ($p < 0.01$) and the occurrence of even one episode of delirium ($p < 0.01$) were independent predictors of an increased LOS. (See Supplemental Table 2 for point estimates derived from the of multivariate multiple linear regression.) An elevated INR on admission, the effect of cohorting patients onto our orthopedic floor, and the ASA score also had trends showing an effect on the expected LOS calculation but were not statistically significant. Age, gender, and CCI were poor predictors of LOS. Table 2 shows an example of the applied predictive model to a theoretical “average” patient, as defined by the median LOS (5.19 days) in our cohort of patients.

Testing the Model

In order to assess the utility of our predictive LOS modeling, we compared the actual length of stay (aLOS) to the expected LOS for 30 patients who entered the hip fracture program between January and May 2016. One patient was excluded due to an inappropriate diagnosis for inclusion (bisphosphonate-associated femoral shaft fracture), and two had incomplete data. The aLOS was within the 95% confidence interval for 89% of patients. However, because of the wide range on the 95% confidence intervals, which averaged close to 10 days, we re-analyzed our results using the more clinically relevant LOS range of ±1.5 days (Figure 1). Using this criterion, 13 patients (48%) had an accurate prediction of their LOS and 4 (15%) had a smaller than predicted LOS. In sum, the model made reasonable predictions for 63% our patients. None of these patients had a post-operative complication other than delirium. Of the 10 patients (37%) who had a longer aLOS than predicted LOS ±1.5 days, all but two had a post-operative complication other than delirium (80%). This illustrated the substantial positive effect (i.e. increasing in value) on the LOS of any complication developing during the hospitalization.

Sub-analysis of Comorbidities (Charlson Index) and Delays to Surgery (DTS)

A stratified analysis using the reason for any DTS and the effect of pre-existing co-morbidities was performed for our 2014–15 patients. The CCI in isolation was a poor predictor of LOS in our model. However, patients with a CCI of 4 or greater averaged $3,966 more for their total cost of the hospitalization despite not having an increased post-operative complication rate.

DTS was associated with an increased complication rate and cost of hospitalization. When we analyzed the reasons for the DTS, we found that the reason for the delay mattered (Table 3). Delays due to medical evaluation/ optimization or a patient initially refusing surgery had an increase in LOS, hospital cost, and complication rate. A delay due to lack of operating room time was not associated with an increase in LOS, cost, or complication rate.

Discussion

Length of stay (LOS) can be used as a metric to evaluate the success of a geriatric hip fracture program since it may reflect the cost-effectiveness of care and the in-hospital complication rate. Simply averaging the LOS can mask the expected variability in this heterogeneous patient population and has been found to be an ineffective measure for determining successful patient management.[19,21] A tool that could be used to calculate an expected LOS for specific patients at an institution would help hip fracture centers improve patient care and provide more patient-specific quality control by allowing for accurate detection and analysis of outliers. We created a predictive calculator that estimates the expected LOS for a patient in our hip fracture pathway. It allowed us to identify what factors place patients at risk for prolonged hospitalizations, as well as those that predict a shorter LOS.

Our study has many limitations. First, the statistical power for our multivariate modeling is low due to the heterogeneity of the hip fracture patient population that ranges from high-functioning patients to minimally-ambulatory nursing home residents. We realized this while designing this study, but the value of using the results to focus our efforts made it worthwhile to pursue and use this predictive calculator. While the accuracy of our model is high, the precision of our expected LOS is low. To improve the clinical utility, we set a clinically relevant cutoff of within 1.5 days of our prediction as a “success”. This calculation enabled us to measure the effect of a post-operative complication on increasing the LOS in our 2016 group.

Additional limitations of our study include the retrospective data collection and the subjectivity in interpreting the cause(s) of any delay(s) to surgery. We attempted to mitigate the inaccuracies of retrospective data collection by confirming that all medical comorbidities were diagnosed prior to or at the time of admission for the hip fracture. All the complications we included in our analysis had to occur during the hospitalization, and any that were present at the time of admission were excluded. A DTS was most often caused by the need for medical optimization clearance or availability of an operating room. It was easy to determine the reason for the delay via a chart review because the daily orthopedic and medicine team progress notes discuss the delay since the implementation of our GFP.

Finally, in creating a model to predict LOS, we realize that there may be other variables we did not include included that can affect the predictive values. Specifically, hospital disposition is inherently tied to the LOS, and insurers differ in authorization processes for skilled nursing facilities. Our cohort, however, had Medicare Part A as the payor in 83% of patients. Because there was no other substantially common insurer, so we did not include the patient's insurance status in our modeling. While we do not anticipate this distribution of insurers to change, it is important to note this variable may substantially alter results in states and communities with different payor mixes.

There are very practical applications to institution-specific predictive modeling in geriatric hip fracture patients. First, it can provide patients and families with more specific expectations for the hospitalization. For example, a patient with an elevated INR on admission and an ASA score of 4 is expected to have an increased LOS; however, cohorting the patient to our orthopaedic floor and taking the patient to the operative room before the second midnight will improve the patient-specific predicted LOS. If patients and families ask about delirium, we can tell them not only our rate of patients who become delirious at some point in the hospitalization but quantify how that may change their predictive LOS.

Uncontrollable patient-specific variables set the initial framework for our LOS predictions when they present to the emergency room. Several of these variables have been previously reported to be associated with an increased LOS for hip fracture patients including: the ASA score,[22] medical comorbidities,[5] and the fracture pattern.[23] We did not include the fracture pattern in our modeling because all patients are treated with immediate weight bearing and there was no delay to care for arthroplasties compared with internal fixation at our institution. When we analyzed comorbidity scoring systems, the ASA score was an important predictor of LOS, but the CCI was not. This is a reflection of the intent of CCI to capture longer-term consequences of medical conditions, while the ASA score represents the immediate acuity of comorbid conditions. Prior studies determining that comorbidities are a risk factor for a longer LOS have not made this distinction.[5] CCI is a worthwhile metric to describe patient complexity that has cost implications and affects Medicare reimbursement, but it is a poor predictor of LOS and post-operative complications.

Another important application of predictive modeling is better quantifying the effect of hospital logistics on hip fracture patients. Factors including admissions on a weekend,[18] availability of arthroplasty surgeons,[24] admission to orthopedic versus general medicine services,[17] and admission to a geriatric unit[25] have all been shown to affect the LOS at various institutions. These conclusions represent hospital-specific findings and therefore may or may not be generalizable to other hospital systems. For example, the patients who present to our institution with elevated INRs (14%) are not routinely given rapid reversal agents. Obviously, a rapid reversal agent can change the effect of elevated INR on expected LOS.

In developing our GFP, we identified that a DTS and failure to cohort patients onto our orthopedic ward as important logistical targets for improvement. Interestingly, a subgroup analysis of the DTS group showed a difference between patients with operative delays due to medical clearance versus operating room availability (Table 3). While some reasons for delayed medical evaluation and optimization may be unsolvable, mandates for hastened medical evaluations have been shown to reduce the time to surgery and overall LOS.[9,26]

Our study showed a trend that a patient with an otherwise-average expected LOS successfully cohorted on our orthopedic floor, irrespective of what service admitted the patient, can expect a half-day decrease in the LOS. To our knowledge, this finding has not been reported for hospitals in the United States, which separate the acute hospitalization from the subacute rehabilitation period[25]. Our orthopaedic floor offers better care to geriatric fracture patients because the nursing and physical/occupational therapy staff are trained and used to taking care of orthopaedic patients. Additionally, the staff has received extra training in geriatric fracture patient care, and their managers take part in weekly quality improvement meetings where all of the geriatric hip fracture patients from the past week are discussed. This serves as a forum to improve communication, review patients with excessive delays to some aspect of their care, and discuss complications – it has also created “buy in” from this multidisciplinary group. Since our orthopedic floor has a limited number of beds and admits patients from other services and departments, we are competing for a finite resource. Our findings suggest that hip fracture patients would benefit from our hospital expanding the orthopedic floor and/or being prioritized for admission to the unit. Predictive modeling can display how the entire distribution of LOS would be expected to shift to the left if all of our patients were able to be cohorted to our orthopedic ward – a powerful tool to bring to hospital administrators.

Our predictive model was developed to focus our quality improvement efforts. When we applied our model to the first 30 patients of our 2016 cohort, we found that the impact of in-hospital complications on our expected LOS was substantial. Nearly every patient that exceeded our predictions by >1.5 days developed a complication other than delirium. Although the patients who had a delay to surgery for medical optimization were at a slightly higher risk for developing a complication, most complications seem to occur somewhat at random amongst the entire cohort. Moving forward, our geriatric fracture program will closely investigate which complications may be preventable and how best to limit prolonged hospitalizations when complications do occur. This will have major implications on reimbursement as Medicare transitions to a bundled payment structure.[27]

Our study is the first to examine the utility of a predictive LOS model to analyze the successes and shortcomings at a single-site Orthopedic-Geriatric co-management hip fracture program. Our model is imprecise, but it allows us to identify and analyze patients whose actual LOS deviates substantially from their expected LOS. It also lets us communicate better with patients and families when they ask how long they will be in the hospital and with hospital administrators when we show the value of additional resources for our hip fracture program. Most importantly, by understanding the individual “predictors” for longer or shorter LOS, we can target areas for improvement in our hip fracture program. We are not advocating that other centers to use our exact model; rather, our model serves as a prototype for other institution-specific predictive calculators that would allow similar targeted analyses to be performed. Future work will aim to improve the precision of our modeling and explore the relationship to risk adjustments that affect reimbursement as our geriatric hip fracture pathway continues to improve.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Disclosures of funding: Statistical analysis of the project was supported by the National Center for Advancing Translational Sciences, National Institutes of Health, through grant number UL1 TR001860. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH.

References

1. Braithwaite RS, Col NF, Wong JB, 2003 Estimating hip fracture morbidity, mortality and costs. J Am Geriatr Soc 51, 364–370. [PubMed: 12588580]
2. Sullivan KJ, Husak LE, Altebarmakian M, Brox WT, 2016 Demographic factors in hip fracture incidence and mortality rates in California, 2000–2011. J Orthop Surg Res 11.
3. Kates SL, 2016 Hip fracture programs: are they effective? Injury 47 Suppl 1, S25–27.
4. Gu Q, Koenig L, Mather RC, Tongue J, 2014 Surgery for Hip Fracture Yields Societal Benefits That Exceed the Direct Medical Costs. Clin Orthop Relat Res 472, 3536–3546. [PubMed: 25091223]
5. Lefaivre KA, Macadam SA, Davidson DJ, Gandhi R, Chan H, Broekhuyse HM, 2009 Length of stay, mortality, morbidity and delay to surgery in hip fractures. J Bone Joint Surg Br 91, 922–927. [PubMed: 19567858]
6. Giannoulis D, Calori GM, Giannoudis PV, 2016 Thirty-day mortality after hip fractures: has anything changed? Eur J Orthop Surg Traumatol 26, 365–370. [PubMed: 26943870]
7. Khan SK, Kalra S, Khanna A, Thiruvengada MM, Parker MJ, 2009 Timing of surgery for hip fractures: a systematic review of 52 published studies involving 291,413 patients. Injury 40, 692–697. [PubMed: 19450802]
8. McGuire KJ, Bernstein J, Polsky D, Silber JH, 2004 The 2004 Marshall Urist award: delays until surgery after hip fracture increases mortality. Clin. Orthop. Relat. Res 294–301. [PubMed: 15534555]
9. Uzoigwe CE, Burnand HGF, Cheesman CL, Aghedo DO, Faizi M, Middleton RG, 2013 Early and ultra-early surgery in hip fracture patients improves survival. Injury 44, 726–729. [PubMed: 23010072]
10. Kates SL, Mendelson DA, Friedman SM, 2010 Co-managed care for fragility hip fractures (Rochester model). Osteoporos Int 21, S621–625. [PubMed: 21058002]
11. Lau T-W, Fang C, Leung F, 2013 The effectiveness of a geriatric hip fracture clinical pathway in reducing hospital and rehabilitation length of stay and improving short-term mortality rates. Geriatr Orthop Surg Rehabil 4, 3–9. [PubMed: 23936733]
12. Swart E, Vasudeva E, Makhni EC, Macaulay W, Bozic KJ, 2016 Dedicated Perioperative Hip Fracture Comanagement Programs are Cost-effective in High-volume Centers: An Economic Analysis. Clin. Orthop. Relat. Res 474, 222–233. [PubMed: 26260393]
13. Dy CJ, McCollister KE, Lubarsky DA, Lane JM, 2011 An economic evaluation of a systems-based strategy to expedite surgical treatment of hip fractures. J Bone Joint Surg Am 93, 1326–1334. [PubMed: 21792499]
14. Basques BA, Bohl DD, Golinvaux NS, Leslie MP, Baumgaertner MR, Grauer JN, 2015 Postoperative length of stay and 30-day readmission after geriatric hip fracture: an analysis of 8434 patients. J Orthop Trauma 29, e115–120. [PubMed: 25210835]
15. Kates SL, O'Malley N, Friedman SM, Mendelson DA, 2012 Barriers to Implementation of an Organized Geriatric Fracture Program. Geriatr Orthop Surg Rehabil 3, 8–16. [PubMed: 23569692]
16. Collinge CA, McWilliam-Ross K, Beltran MJ, Weaver T, 2013 Measures of clinical outcome before, during, and after implementation of a comprehensive geriatric hip fracture program: is there a learning curve? J Orthop Trauma 27, 672–676. [PubMed: 23515124]

17. Greenberg SE, VanHouten JP, Lakomkin N, Ehrenfeld J, Jahangir AA, Boyce RH, Obremksey WT, Sethi MK, 2016 Does Admission to Medicine or Orthopaedics Impact a Geriatric Hip Patient's Hospital Length of Stay? J Orthop Trauma 30, 95–99. [PubMed: 26371621]
18. Ricci WM, Brandt A, McAndrew C, Gardner MJ, 2015 Factors Effecting Delay to Surgery and Length of Stay for Hip Fracture Patients. J Orthop Trauma 29, e109–e114. [PubMed: 25186844]
19. Marshall A, Vasilakis C, El-Darzi E, 2005 Length of stay-based patient flow models: recent developments and future directions. Health Care Manag Sci 8, 213–220. [PubMed: 16134434]
20. Liem IS, Kammerlander C, Suhm N, Blauth M, Roth T, Gosch M, Hoang-Kim A, Mendelson D, Zuckerman J, Leung F, Burton J, Moran C, Parker M, Giusti A, Pioli G, Goldhahn J, Kates SL, 2013 Identifying a standard set of outcome parameters for the evaluation of orthogeriatric co-management for hip fractures. Injury 44, 1403–1412. [PubMed: 23880377]
21. el-Darzi E, Vasilakis C, Chaussalet T, Millard PH, 1998 A simulation modelling approach to evaluating length of stay, occupancy, emptiness and bed blocking in a hospital geriatric department. Health Care Manag Sci 1, 143–149. [PubMed: 10916593]
22. Garcia AE, Bonnaig JV, Yoneda ZT, Richards JE, Ehrenfeld JM, Obremskey WT, Jahangir AA, Sethi MK, 2012 Patient variables which may predict length of stay and hospital costs in elderly patients with hip fracture. J Orthop Trauma 26, 620–623. [PubMed: 22832431]
23. Sund R, Riihimäki J, Mäkelä M, Vehtari A, Lüthje P, Huusko T, Häkkinen U, 2009 Modeling the length of the care episode after hip fracture: does the type of fracture matter? Scand J Surg 98, 169–174. [PubMed: 19919923]
24. Hagino T, Ochiai S, Senga S, Watanabe Y, Wako M, Ando T, Haro H, 2015 Efficacy of early surgery and causes of surgical delay in patients with hip fracture. J Orthop 12, 142–146. [PubMed: 26236117]
25. Taraldsen K, Thingstad P, Sletvold O, Saltvedt I, Lydersen S, Granat MH, Chastin S, Helbostad JL, 2015 The long-term effect of being treated in a geriatric ward compared to an orthopaedic ward on six measures of free-living physical behavior 4 and 12 months after a hip fracture - a randomised controlled trial. BMC Geriatrics 15, 160. [PubMed: 26637222]
26. Aqil A, Hossain F, Sheikh H, Aderinto J, Whitwell G, Kapoor H, 2016 Achieving hip fracture surgery within 36 hours: an investigation of risk factors to surgical delay and recommendations for practice. J Orthop Traumatol 17, 207–213. [PubMed: 26611677]
27. Centers for Medicare and Medicaid Services (CMS.gov): Notice of proposed rulemaking for bundled payment models for high-quality, coordinated cardiac and hip fracture care https://www.cms.gov/Newsroom/MediaReleaseDatabase/Fact-sheets/2016-Fact-sheets-items/2016-07-25.html. Accessed December 20, 2016

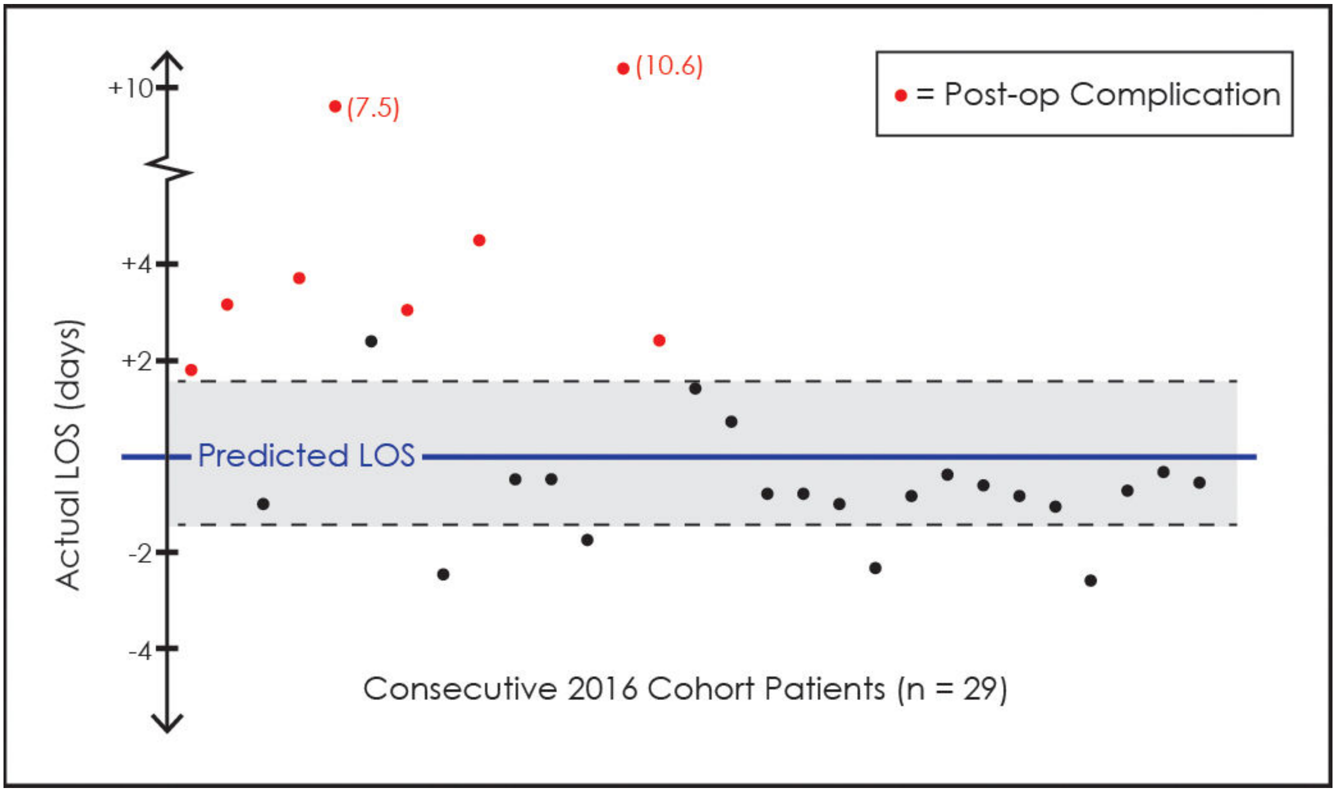

Figure 1.

Actual LOS of consecutive 2016 patients plotted against the predicted LOS value. The grey zone is ±1.5 days from the predicted LOS, chosen as a clinically relevant accuracy of our predicted modeling.

Table 1.

Unadjusted Regression Analysis of Length of Stay by Patient Demographics and Clinical Characteristics

Variable	Point Estimate	SE	p value	Average LOS
No complication	−0.4530	0.084	< 0.001 *	2.94
Midnights to surgery (base = 1)	0.1581	0.042	< 0.001 *	4.75
ASA Score (base = 3)	0.1971	0.062	0.002 *	4.93
No delirium	−0.1890	0.070	0.007 *	4.52
INR < 1.5	−0.2651	0.101	0.010 *	4.85
Charlson Comorbidity Index < 4	−0.1673	0.082	0.042 *	4.84
Cohorted to Ortho Floor	−0.1141	0.070	0.104	4.77
Age (base = 82)	0.0046	0.004	0.300	5.03
Gender Female	−0.0738	0.075	0.327	4.91

*Statistically significant p-value

Table 2.

Example of a predictive calculator showing the effect of covariates on the expected LOS.

Variable	Effect on LOS (days)	p-value
Age (each decade older than 82)	+ 0.14	$p = 0.56$
Gender (male)	+ 0.23	$p = 0.55$
Elevated INR (>1.5 on admission)	+ 0.99	$p = 0.08$
CCI score (4 or more)	+ 0.11	$p = 0.81$
Not Cohorted to Orthopedic Floor	+ 0.46	$p = 0.23$
ASA Score (one point increase)	+ 0.65	$p = 0.07$
Time to Surgery (each midnight)	+ 0.75	$p < 0.01$ *
Delirium (ever during hospitalization)	+ 1.07	$p < 0.01$ *

*Statistically significant p-value

Table 3.

Analysis of patients who had a delay to surgery (DTS) by reason

	All patients	Delay due to medical clearance	Delay due to OR availability	Delay due to patient initially refusing surgery
Number of patients	177	25	16	5
CCI = 4 or more	42 (24%)	10/25 (40%) $p = < .05$*	2/16 (13%) $p = 0.27$	1/5 (20%) $p = 0.84$
Post-operative complication rate (excluding delirium)	33 (19%)	8/25 (32%) $p = 0.06$	0/16 (0%) $p < 0.05$*	3/5 (60%) $p < 0.05$*
Length of stay (days)	6.0 ± 3.1	7.0 ± 2.9 $p < 0.05$*	5.3 ± 1.6 $p = 0.36$	9.2 ± 3.1 $p < 0.01$*
Average total cost of hospitalization	$33,495	$40,264 $p < 0.01$*	$31,443 $p = 0.48$	$44,882 $p < 0.05$*

*Statistically significant