

Clinical Study

# Discharge to inpatient facilities after lumbar fusion surgery is associated with increased postoperative venous thromboembolism and readmissions

Sariah Khormae, MD, PhD\*, Andre M. Samuel, MD,  
William W. Schairer, MD, Peter B. Derman, MD, MBA,  
Alexander S. McLawhorn, MD, MBA, Michael C. Fu, MD, MHS,  
Todd J. Albert, MD

Hospital for Special Surgery, 535 East 70th St, New York, NY, 10021, USA  
Received 3 February 2018; revised 6 May 2018; accepted 30 May 2018

**Abstract**

**BACKGROUND CONTEXT:** Postdischarge care is a significant source of cost variability after posterior lumbar fusion surgery. However, there remains limited evidence associating postdischarge inpatient services and improved postoperative outcomes, despite the high cost of these services.

**PURPOSE:** To determine the association between posthospital discharge to inpatient care facilities and postoperative complications.

**STUDY DESIGN:** A retrospective review of all 1- to 3-level primary posterior lumbar fusion cases in the 2010-2014 National Surgical Quality Improvement Program registry was conducted. Propensity scores for discharge destination were determined based on observable baseline patient characteristics. Multivariable propensity-adjusted logistic regressions were performed to determine associations between discharge destination and postdischarge complications, with adjusted odds ratios (OR) and 95% confidence intervals (CI).

**RESULTS:** A total of 18,652 posterior lumbar fusion cases were identified, 15,234 (82%) were discharged home, and 3,418 (18%) were discharged to continued inpatient care. Multivariable propensity-adjusted analysis demonstrated that being discharged to inpatient facilities was independently associated with higher risk of thromboembolic complications (OR [95% CI]: 1.79 [1.13–2.85]), urinary complications, (1.79 [1.27–2.51]), and unplanned readmissions (1.43 [1.22–1.68]).

**CONCLUSIONS:** Discharge to continued inpatient care versus home after primary posterior lumbar fusion is independently associated with higher odds of certain major complications. To optimize clinical outcomes as well as cost savings in an era of value-based reimbursements, clinicians and hospitals should consider further investigation into carefully investigating which patients might be better served by home discharge after surgery. © 2018 Elsevier Inc. All rights reserved.

**Keywords:** Complications; Discharge destination; Disposition; Inpatient rehabilitation; Readmissions; Thromboembolism

FDA device/drug status: Not applicable.

Author disclosure: **SK:** Nothing to disclose. **AM:** Intellijoint (B), Ethicon (B). **WS:** Nothing to disclose. **PD:** Nothing to disclose. **AM:** Consulting: Intellijoint (B), Ethicon (B). **MF:** Nothing to disclose. **TA:** Zimmer Biomet (F), DePuy Synthes (F), JP Medical Publishers (B), Saunders/Mosby- Elseveir (B), Thieme (B), Gentis (D), Vital 5 Stock options (O), Bonovo Orthopedics Inc (D), Biomerix (D), InVivo Therapeutics (C), Spinicity (D), Crosstrees Medical (D), Paradigm Spine LLC (F), Invuity (C), ASIP (D), PMIG (D), Vertech (B), Nuvasive Nonfinancial Facet Link (B), Scoliosis

Research Society Nonfinancial United Health Care (A), PCORI (Past Grant Total) (F), Alan L. and Jacqueline B. Stuart Spine Research Center (Grant) (D).

\* Corresponding author. Sariah Khormae, MD, PhD, Hospital for Special Surgery, 535 East 70th St, New York, NY, 10021, USA. Tel.: (212) 606-1000.

E-mail address: [khormaees@hss.edu](mailto:khormaees@hss.edu) (S. Khormae).

## Introduction

Posterior lumbar fusion is one of the most common spine procedures, with more than 140,000 procedures performed in the United States in 2011 [1]. Between 1990 and 2001, the rate of lumbar fusion surgery in the US increased over 200% [2]. Posterior lumbar fusion often requires an intensive postoperative recovery period to manage care and complications, with previous studies reporting that up to 29% of patients require an extended length of stay of 5 or more days [3–5]. Patients are often discharged to inpatient facilities for additional rehabilitation and inpatient monitoring after their initial index hospitalization [6]. The discharge destination of patients after posterior lumbar fusion is an area of increasing study as it can reflect patients' preoperative health, alter their recovery, and influence over-all healthcare costs.

A recent Italian cost analysis study reported that the cost of a lumbar fusion procedure increased 200% between 2001 and 2010 [7]. Prior work in other orthopaedic subspecialties has shown that discharge destination after surgery is one of the most important drivers of increased cost. After total hip arthroplasty, postacute inpatient care can account for up to 36% of the total bundled costs of the index surgery [8]. Therefore in the arthroplasty community, there is a movement to facilitate discharge to home for both improved outcomes and decreased costs. This movement extends to all areas of medicine, including spine surgery, and it is important to understand whether all parts of a care episode, including discharge destination, offer good value [9,10].

Prior reports have looked at discharge destination after spinal fusion surgery and associated patient characteristics for nonhome discharge destination. Through multivariate analysis, female gender, increased comorbidity burden, intraoperative complications, operative complexity or operative time, and hospital length of stay were all predictive factors of a nonhome discharge destination [11–14]. However, these publications do not distinguish whether a non-home discharge destination is an independent predictor of postdischarge complications.

The current study presents a propensity-adjusted analysis to better isolate the relationship between discharge destination and postdischarge complications, independent of confounding patient specific factors. As a clinical trial of inpatient or home discharge destination after lumbar fusion is not logistically feasible, a retrospective propensity-adjusted study with adequate statistical power to control for preexisting confounding patient factors may provide valuable evidence to identify whether inpatient facility discharge destination is independently associated with higher complications. Using the large multicenter American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database, the purpose of our study was to determine the propensity-adjusted independent association between discharge disposition and short-term postdischarge outcomes [15,16].

## Patients and methods

### *Data source*

A retrospective review of the 2011–2014 American College of Surgeons NSQIP database was conducted. This database includes a systematic sampling of surgical patients from over 350 US hospitals with clinical data prospectively abstracted from operative reports, patient charts, and direct patient questionnaires. Patients are followed for postoperative complications and readmissions for 30 days after surgery, irrespective of discharge date [17,18].

### *Study population*

All patients undergoing 1- to 3-level primary posterior spinal fusion were identified in the database using the Current Procedural Terminology code 22612 (posterior or posterolateral fusion) or 22630 (posterior interbody fusion). The number of levels fused were identified by the presence of modifier codes 22614 (posterior or posterolateral fusion) and 22632 (posterior interbody fusion) for each additional level fused. Therefore, if the modified code is repeated more than 2 times, it indicates a fusion of >3 levels. Patients with more than 3 levels fused, and those with missing data on age, gender, height, and weight were excluded. In addition, emergency cases and those with nonclean wound classifications were excluded as well.

### *Variables, outcome measures*

Patient data collected from NSQIP included age, gender, height, weight, American Society of Anesthesiologists (ASA) score, anesthesia type, preoperative functional status (independent or nonindependent), medical comorbidities, discharge disposition, and 30-day complications. Body mass index (BMI) was calculated from patient height and weight, and stratified based on the World Health Organization classification. The medical comorbidities included congestive heart failure, previous percutaneous cardiac intervention, previous cardiac surgery, hypertension requiring medication, current smoker, dyspnea, congestive obstructive pulmonary disorder, currently on dialysis, stroke with or without deficits, diabetes, chronic corticosteroid use, and bleeding disorder. A modified Charlson Comorbidity Index (CCI) was calculated based on baseline comorbidities [19–21]. Discharge disposition is also reported in NSQIP and was categorized as either home or an inpatient facility. All complications reported in NSQIP were evaluated. These are each defined by strict criteria according to the NSQIP participant user file user guide and reviewed by specially trained NSQIP clinical data reviewers [17]. A composite outcome measure of “any complications” was also assessed including occurrence of any of the aforementioned complications.

Statistical analysis

Outcomes were compared between the home discharge and inpatient discharge populations using chi-square tests for categorical data and Student *t* tests for continuous data. To account for selection bias between the discharge destination groups, a propensity score model was used. This was defined as the conditional probability of a patient being discharged to continued inpatient care based on age, gender, obesity classification, modified CCI, preoperative functional status, ASA classification, number of levels fused, and the presence of any predischarge classifications. A multivariable logistic regression model was then adjusted using the propensity score to determine the independent association between discharge destination and our study outcomes. Finally, predictors of discharge to continued inpatient care were also determined using a second multivariable logistic regression, with nonhome discharge as the primary outcome.

All statistical tests were 2-tailed and conducted using SPSS 22 statistical software (IBM Corp., Armonk, NY, USA). Caused by multiple hypothesis testing in the current study, a Bonferroni correction was used to avoid type 1 error and determine the level of statistical significance for each hypothesis test [22].

Results

A total of 18,652 patients undergoing primary 1-, 2-, or 3-level posterior lumbar fusion were identified in 2010–2014 NSQIP. Of those cases, 55.3% were female, 11.6% were aged 75 or older, and 8.2% were obese class III (Table 1). In addition, 10.4% of patients had a modified CCI of 5 or greater and 48.4% had an ASA class of 3 or greater, 33.3% had multilevel fusions, 3.2% had a nonindependent baseline functional status, and 5.7% had a predischarge complication.

A total of 3,418 patients (18.3%) were discharged to inpatient facilities after their hospitalization. These patients were more likely to be female, older, functionally nonindependent, have higher BMI classifications, higher ASA class, greater modified CCI score, multilevel fusions, and suffer predischarge complications ( $p < .001$ ). After propensity score adjustment, none of these differences were statistically significant ( $p > .20$ , Table 1).

The over-all rate of postdischarge complications was 5.8% (Table 2). The most common complications were unplanned hospital readmissions (5.2%) and unplanned returns to the operating room (3.3%). All postdischarge complications occurred at higher rates in patients discharged to inpatient facilities in bivariate analysis. This difference was statistically significant ( $p < .001$ ) for all

Table 1  
Patient demographic characteristics, comorbidity burden, and predischarge complication rates by discharge destination, with propensity score adjustment

	All patients	Discharged to home	Discharged to inpatient facility	Unadjusted p value	Propensity-adjusted p value
Total	N=18,652	N=15,234	N=3,418		
Female gender	55.3%	52.8%	66.5%	<.001	.784
Age group (years)				<.001	.212
≤65	61.7%	68.2%	32.5%		
66–75	26.7%	24.1%	38.6%		
>75	11.6%	7.7%	29.0%		
Obesity classification				<.001	.880
Nonobese (≤29.9 kg/m <sup>2</sup> )	51.5%	52.5%	47.0%		
Obese I (30–34.9 kg/m <sup>2</sup> )	26.6%	26.6%	26.4%		
Obese II (35–39.9 kg/m <sup>2</sup> )	13.8%	13.4%	15.4%		
Obese III (≥40 kg/m <sup>2</sup> )	8.2%	7.5%	11.3%		
Modified CCI				<.001	.209
0–3	68.1%	74.7%	38.9%		
4	21.5%	18.6%	34.8%		
5+	10.4%	6.8%	26.3%		
Functional status				<.001	.809
Independent	96.9%	97.6%	93.4%		
Nonindependent	3.2%	2.4%	6.6%		
ASA classification				<.001	.597
1–2	51.6%	56.1%	31.7%		
3–4	48.4%	43.9%	68.3%		
Number of levels				<.001	.767
1	66.7%	69.4%	54.9%		
2	28.2%	26.0%	37.9%		
3	5.1%	4.6%	7.2%		
Any predischarge complication(s)	5.7%	4.2%	12.1%	<.001	.729

CCI, Charlson comorbidity index; ASA, American society of anesthesiologists.

Table 2  
Postdischarge complications by discharge destination

	All patients	Discharged to home	Discharged to inpatient facility	p value
Complication	N=18,652	N=15,234	N=3,418	
Any complication(s)	5.83%	4.81%	10.39%	<.001
Wound complications	1.94%	1.60%	3.48%	<.001
Septic complications	0.63%	0.47%	1.32%	<.001
Cardiac complications	0.12%	0.11%	0.18%	.278
Respiratory complications	0.24%	0.20%	0.41%	.026
DVT/PE	0.55%	0.43%	1.08%	<.001
Urinary complications	0.94%	0.66%	2.19%	<.001
Readmission	5.22%	4.59%	8.01%	<.001
Return to OR	3.30%	2.77%	5.65%	<.001
Death	0.08%	0.07%	0.12%	.322

DVT, deep vein thrombosis; PE, pulmonary embolism; OR, operating room.

Note: Using the Bonferroni correction, the level of statistical significance is 0.005.

complications except for respiratory complications, cardiac complications, and death.

In propensity-adjusted analysis, thromboembolic complications (odds ratio [OR] [95% confidence interval]: 1.79 [1.13–2.85]) had the greatest association with discharge to inpatient facilities (Table 3). In addition, after propensity-score adjustment, there was a statistically significant increase in odds of urinary complications (1.79 [1.27–2.51], and unplanned readmissions (1.43 [1.22–1.68]).

Finally, in multivariate analysis of predictors for discharge to an inpatient facility, all factors tested had statistically significant associations (Table 4). Patients aged older than 75 years had the strongest association with discharge to an inpatient facility (2.99 [2.68–3.34]), followed by pre-discharge complications (2.61 [2.27–3.01]), and modified CCI $\geq$ 5 (2.09 [1.85–2.36]).

## Discussion

The results of the current study showed that patients discharged to inpatient facilities had higher rates of all complications measured. After propensity score adjustment for

confounding factors, discharge to inpatient facilities was still associated with increased thromboembolic complications, urinary complications, and unplanned readmissions. Although there is no existing literature that may explain these findings, one hypothesis may be that the additional immobility associated with bed rest in a postacute care facility, and the exposure to other potentially sick patients increases the risk of both thromboembolism and infections.

Although urinary complications are usually easily managed and not severe, thromboembolic events can be a source of significant morbidity after spine surgery. In 1 large cohort of over 27,000 patients undergoing spine surgery, including anterior and posterior lumbar and cervical fusions, as well as stand-alone lumbar laminectomy and stand-alone lumbar discectomy, the overall venous thromboembolism (VTE) rate was 1%. However, among patients suffering from VTEs, the mortality rate was 5% compared with 0.3% over-all [23]. This study found that BMI $>$ 40, age $>$ 80 years, and longer operative time were independent predictors of deep vein thrombosis. Similarly, increased BMI, operative time, and male sex were independent predictors of pulmonary embolism (PE) [23]. Another large cohort study from Japan of over 47,000 spine surgery patients identified a pulmonary embolism rate of  $<$ 1%, but of those patients the mortality rate was 8% [24]. This study

Table 3  
Propensity-adjusted multivariable logistic regression for postdischarge complications, with adjusted odds ratios and 95% confidence intervals for patients discharged to nonhome facility vs discharged to home

Complication	Propensity-adjusted OR	95% CI	p value
<b>Any complication(s)</b>	<b>1.24</b>	<b>1.06–1.46</b>	<b>.009</b>
Wound complications	1.24	0.95–1.62	.113
Septic complications	1.10	0.71–1.73	.664
Cardiac complications	1.13	0.40–3.20	.825
Respiratory complications	1.28	0.62–2.63	.507
<b>DVT/PE</b>	<b>1.79</b>	<b>1.13–2.85</b>	<b>.014</b>
<b>Urinary complications</b>	<b>1.79</b>	<b>1.27–2.51</b>	<b>.001</b>
<b>Readmission</b>	<b>1.43</b>	<b>1.22–1.68</b>	<b>&lt;.001</b>
Return to OR	0.82	0.65–1.02	.079
Death	0.39	0.09–1.62	.195

DVT: deep vein thrombosis, PE: pulmonary embolism, OR: operating room.

Complications with a p value  $<$ 0.05 were highlighted in bold font.

Table 4  
Multivariable logistic regression for predictors of being discharged to non-home facility

Characteristic	OR	95% CI	p value
Age $\geq$ 75	2.99	2.68–3.34	<.001
Any pre-discharge complication(s)	2.61	2.27–3.01	<.001
Modified CCI $\geq$ 5	2.09	1.85–2.36	<.001
ASA $\geq$ 3	2.08	1.91–2.27	<.001
Nonindependent functional status	2.05	1.69–2.49	<.001
Female gender	1.84	1.69–2.00	<.001
Multilevel surgery	1.73	1.60–1.88	<.001
Obese III (BMI $\geq$ 40 kg/m <sup>2</sup> )	1.40	1.22–1.60	<.001

CCI, Charlson comorbidity index; ASA, American society of anesthesiologists; BMI, body mass index.

found that older patients (>70) and those with a diagnosis of trauma had higher risk for PE. The authors focused on a wide variety of spinal surgeries including anterior cervical fusion, posterior cervical fusion, and lumbar surgery with and without instrumentation [24]. In the current study, patients discharged to an inpatient facility after lumbar spine fusion had an over-all postdischarge thromboembolism rate of 1%, compared with 0.4% in patients discharged to home. Even after propensity-score adjustment for factors that may predispose patients to nonhome discharge, including BMI, sex, age, and comorbidity burden, this was associated with increased thromboembolic events, with an OR of 1.79. Of note, we combined deep vein thrombosis and PE into a rate of thromboembolic events, because clinical controversy still remains as to which entity is the more critical postoperative complication [25,26]. We also focused specifically on lumbar fusion surgery.

Discharge to inpatient facilities was also associated with increased 30-day readmissions. These patients had an overall readmission rate of 8% compared with 4.6% of patients who were discharged to home. Although this finding has not previously been found in spine surgery patients, a recent analysis of Medicare claims data revealed that after total knee arthroplasty discharge to both inpatient rehabilitation and skilled nursing facilities was associated with increased odds of both 30-day (OR: 1.44, 1.40) and 90-day (OR: 1.48, 1.45) readmissions [27]. This was after controlling for factors such as age, sex, race, disability, medical comorbidities, intensive care unit time, hospital length of stay, and previous admissions. In a similar propensity-adjusted study of 101,256 primary total knee arthroplasty cases from the NSQIP registry, continued inpatient care was independently associated with a 1.81 OR of readmissions as well [28].

In contrast to our results, a previous study of 34,000 patients reported that discharge to inpatient rehabilitation after elective spine surgery was associated with fewer postoperative readmissions [29]. However, this study did not differentiate between different types of spine surgery and included patients undergoing long thoracolumbar fusions, cervical fusions, or smaller lumbar decompressions. In the current study, patients underwent only 1-, 2-, and 3-level lumbar spine fusions. Thus, conflicting findings may result from differing patient populations with differing postoperative rehabilitation requirements.

In our current value-focused healthcare climate, postoperative readmissions are increasingly being used as a quality metric used to determine hospital and surgical reimbursements. As a result, a significant amount of research is now focused on risk factors for readmission. A recent study of over 2,000 patients undergoing elective posterior lumbar fusion found that the over-all rate of unplanned readmissions was 5%, and was associated with extended length of stay, diabetes mellitus, and bleeding disorders [30]. Another study of Medicare patients undergoing posterior lumbar fusion found that 3% were readmitted within 30 days and that this was associated with smoking,

chronic obstructive pulmonary disease, and obesity [31]. In addition, Niedermeier et al. reviewed 107 cases of single-level posterior lumbar fusion and found that in bivariate testing, discharge to inpatient rehabilitation was associated with increased age, obesity, medical comorbidities, and private insurance (compared with Medicare) [11]. Best et al. found that in a large cohort of over 1.9 million patients from the National Hospital Discharge Survey undergoing lumbar fusion for degenerative disc disease, nonhome discharge disposition was associated with age, inpatient complications, and a number of specific medical comorbidities, the strongest predictors being age  $\geq 65$  years and congestive heart failure [12]. Aldebeyan et al. found that of 15,000 patients undergoing posterior or anterior lumbar spinal fusion, 18% were discharged to a facility other than home [13]. A number of risk factors were associated with non-home discharge including older age, female sex, medical comorbidities, inpatient complications, length of stay, and levels of surgery, with ASA  $\geq 4$  and length of stay  $\geq 5$  days being the strongest risk factors.

Similarly, in the current study, several risk factors were associated with discharge to inpatient facilities. Although all risk factors tested were found to have an independent association with discharge to an inpatient facility, age >75 years had the strongest association with an OR of 2.99. Other risk factors included inpatient complications, medical comorbidities, female gender, multilevel surgery, and obesity. Although these are not novel findings with the existing body of research reviewed above, they do confirm that the risk factors included in the propensity score calculation and adjustment were appropriate. Therefore, in the primary analysis of the independent effect of discharge to inpatient facilities on postoperative outcomes, confounding factors predisposing to nonhome discharge to inpatient facilities were appropriately controlled.

Although many of these preexisting risk factors are not modifiable perioperatively, discharge disposition may be 1 factor associated with readmissions that can be modified, and the question emerges whether patients should be increasingly discharged home postoperatively. The costs and benefits of this have previously been demonstrated in the field of arthroplasty where home-based rehabilitation has been shown to cost USD 15,000 less than discharging the same patient to inpatient rehabilitation [32,33]. An extended inpatient length of stay of up to 5 additional days after total hip and total knee surgery has been shown cost-effective compared with inpatient rehabilitation [34,35]. Perioperative clinical care pathways and social work planning may also improve the rate of home discharge as well.

However, the question remains whether rehabilitation provides improved long-term outcomes in patients. This has yet to be shown after spine fusion surgery. However, studies have shown that patient outcomes are not worse with decreased use of inpatient rehabilitation. After incorporation of a bundled payments payment model at 1 academic medical center it was found that discharge to

postacute care facilities dropped from 40% to 30% with no increase in readmission [36]. Similarly a study across all inpatient admissions at 135 hospitals participating in a new bundled payment model found that hospitals vary significantly in regards to total costs per episode of care, but the largest driver for these differences was postacute care [37].

The current study is not without its limitations. First, NSQIP is a large national database that is subject to the same limitations found in all large datasets. Although NSQIP employs specially trained surgical clinical reviewers to prospectively collect data through conduct chart review and patient interviews and adheres to strict clinical definitions for medical comorbidities and inpatient complications, there remains a potential for data collection errors. This rate is expected to be low for NSQIP compared with other large national datasets, with only 2 of 30 data elements having >5% disagreement rate between reviewers and an over-all interrater disagreement rate of less than 2% [38]. Additionally, NSQIP performs quality control checks at participating institutions, and excludes and addresses areas of disagreement >5%. In addition, although propensity score adjustment was used to control for certain confounding factors, it is likely that additional confounding factors exist that could not be accounted for in a database study, including socioeconomic factors and home social support.

In conclusion, discharge to inpatient facilities after lumbar spine surgery is independently associated with increased thromboembolic complications, urinary complications, and 30-day readmissions, after propensity score adjustment to control for confounding factors documented in the literature. Although there certainly will be a subset of patients who require a higher level of continued inpatient care, our results suggest that further postoperative pathways that focus on increasing safe discharges to home when possible may result in both decreased complications and decreased costs, improving the societal value of lumbar fusion procedures.

## References

- [1] Singh K, Nandyala SV, Marquez-Lara A, Fineberg SJ. Epidemiological trends in the utilization of bone morphogenetic protein in spinal fusions from 2002 to 2011. *Spine* 2014;39:491–6.
- [2] Deyo RA, Gray DT, Kreuter W, Mirza S, Martin BI. United States trends in lumbar fusion surgery for degenerative conditions. *Spine* 2005;30:1441–5. discussion 1446–1447.
- [3] Basques BA, Fu MC, Buerba RA, Bohl DD, Golinvaux NS, Grauer JN. Using the ACS-NSQIP to identify factors affecting hospital length of stay after elective posterior lumbar fusion. *Spine* 2014;39:497–502.
- [4] Gruskay JA, Fu M, Bohl DD, Webb ML, Grauer JN. Factors affecting length of stay after elective posterior lumbar spine surgery: a multivariate analysis. *Spine J Off J North Am Spine Soc* 2015;15:1188–95.
- [5] Pumberger M, Chiu YL, Ma Y, Girardi FP, Mazumdar M, Memtsoudis SG. National in-hospital morbidity and mortality trends after lumbar fusion surgery between 1998 and 2008. *J Bone Joint Surg Br* 2012;94:359–64.
- [6] Kalanithi PS, Patil CG, Boakye M. National complication rates and disposition after posterior lumbar fusion for acquired spondylolisthesis. *Spine* 2009;34:1963–9.
- [7] Cortesi PA, Assietti R, Cuzzocrea F, Prestamburgo D, Pluderi M, Cozzolino P, et al. Epidemiologic and economic burden attributable to first spinal fusion surgery: analysis from an Italian administrative database. *Spine* 2017;42:1398–404.
- [8] Bozic KJ, Ward L, Vail TP, Maze M. Bundled payments in total joint arthroplasty: targeting opportunities for quality improvement and cost reduction. *Clin Orthop* 2014;472:188–93.
- [9] Burwell SM. Setting value-based payment goals—HHS efforts to improve U.S. health care. *N Engl J Med* 2015;372:897–9.
- [10] Sullivan R, Jarvis LD, O’Gara T, Langfitt M, Emory C. Bundled payments in total joint arthroplasty and spine surgery. *Curr Rev Musculoskelet Med* 2017;10:218–23.
- [11] Niedermeier S, Przybylowski R, Virk SS, Stammen D, Eiferman DS, Khan SN. Predictors of discharge to an inpatient rehabilitation facility after a single-level posterior spinal fusion procedure. *Eur Spine J* 2017;26:771–6.
- [12] Best MJ, Buller LT, Falakassa J, Vecchione D. Risk factors for non-routine discharge in patients undergoing spinal fusion for intervertebral disc disorders. *Iowa Orthop J* 2015;35:147–55.
- [13] Aldebayan S, Aoude A, Fortin M, Nooh A, Jarzem P, Ouellet J, et al. Predictors of discharge destination after lumbar spine fusion surgery. *Spine* 2016;41:1535–41.
- [14] Di Capua J, Somani S, Kim JS, Lee NJ, Kothari P, Phan K, et al. Predictors for patient discharge destination after elective anterior cervical discectomy and fusion. *Spine* 2017;42:1538–44.
- [15] Golinvaux NS, Bohl DD, Basques BA, Fu MC, Gardner EC, Grauer JN. Limitations of administrative databases in spine research: a study in obesity. *Spine J* 2014;14:2923–8.
- [16] Golinvaux NS, Bohl DD, Basques BA, Grauer JN. Administrative database concerns: accuracy of International Classification of Diseases, Ninth Revision coding is poor for preoperative anemia in patients undergoing spinal fusion. *Spine* 2014;39:2019–23.
- [17] American College of Surgeons National Surgical Quality Improvement Program. User Guide for the 2012 ACS NSQIP Participant Use Data. (2013).
- [18] Chapter 2: The Data Collection Process. ACS NSQIP: American College of Surgeons. in (2014).
- [19] Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis* 1987;40:373–83.
- [20] D’Hoore W, Bouckaert A, Tilquin C. Practical considerations on the use of the Charlson comorbidity index with administrative data bases. *J Clin Epidemiol* 1996;49:1429–33.
- [21] Bohl DD, Fu MC, Golinvaux NS, Basques BA, Gruskay JA, Grauer JN. The ‘July effect’ in primary total hip and knee arthroplasty: analysis of 21,434 cases from the ACS-NSQIP database. *J Arthroplasty* 2014;29:1332–8.
- [22] Dunn OJ. Multiple comparisons among means. *J Am Stat Assoc* 1961;56:52–64.
- [23] Schoenfeld AJ, Herzog JP, Dunn JC, Bader JO, Belmont PJ. Patient-based and surgical characteristics associated with the acute development of deep venous thrombosis and pulmonary embolism after spine surgery. *Spine* 2013;38:1892–8.
- [24] Masuda K, Chikuda H, Yasunaga H, Hara N, Horiguchi H, Matsuda S, et al. Factors affecting the occurrence of pulmonary embolism after spinal surgery: data from the national administrative database in Japan. *Spine J* 2012;12:1029–34.
- [25] Lachiewicz PF. Comparison of ACCP and AAOS guidelines for VTE prophylaxis after total hip and total knee arthroplasty. *Orthopedics* 2009;32:74–8.
- [26] Eikelboom JW, Karthikeyan G, Fagel N, Hirsh J. American Association of Orthopedic Surgeons and American College of Chest Physicians guidelines for venous thromboembolism prevention in hip and

- knee arthroplasty differ: what are the implications for clinicians and patients? *Chest* 2009;135:513–20.
- [27] Welsh RL, Graham JE, Karmarkar AM, Leland NE, Baillargeon JG, Wild DL, et al. Effects of postacute settings on readmission rates and reasons for readmission following total knee arthroplasty. *J Am Med Dir Assoc* 2017;18:367.e1–367.e10.
- [28] McLawhorn AS, Fu MC, Schairer WW, Sculco PK, MacLean CH, Padgett DE. Continued inpatient care after primary total knee arthroplasty increases 30-day post-discharge complications: a propensity score-adjusted analysis. *J Arthroplasty* 2017;32: S113–8.
- [29] Abt NB, McCutcheon BA, Kerezoudis P, Murphy M, Rinaldo L, Fogelson J, et al. Discharge to a rehabilitation facility is associated with decreased 30-day readmission in elective spinal surgery. *J Clin Neurosci* 2017;36:37–42.
- [30] Lee NJ, Kothari P, Phan K, Shin JJ, Cutler HS, Lakomkin N, et al. Incidence and risk factors for 30-day unplanned readmissions after elective posterior lumbar fusion. *Spine* 2018;43:41–8.
- [31] Puvanesarajah V, Nourbakhsh A, Hassanzadeh H, Shimer AL, Shen FH, Singla A. Readmission rates, reasons, and risk factors in elderly patients treated with lumbar fusion for degenerative pathology. *Spine* 2016;41:1933–8.
- [32] Ramos NL, Karia RJ, Hutzler LH, Brandt AM, Slover JD, Bosco JA. The effect of discharge disposition on 30-day readmission rates after total joint arthroplasty. *J Arthroplasty* 2014;29:674–7.
- [33] Ramos NL, Wang EL, Karia RJ, Hutzler LH, Lajam CM, Bosco JA. Correlation between physician specific discharge costs, LOS, and 30-day readmission rates: an analysis of 1,831 cases. *J Arthroplasty* 2014;29:1717–22.
- [34] Slover JD, Mullaly KA, Payne A, Iorio R, Bosco J. What is the best strategy to minimize after-care costs for total joint arthroplasty in a bundled payment environment? *J Arthroplasty* 2016;31:2710–3.
- [35] Slover JD. You want a successful bundle: what about post-discharge care? *J Arthroplasty* 2016;31:936–7.
- [36] Jubelt LE, Goldfeld KS, Chung W, Blecker SB, Horwitz LI. Changes in discharge location and readmission rates under medicare bundled payment. *JAMA Intern Med* 2016;176:115–7.
- [37] Das A, Norton EC, Miller DC, Chen LM. Association of postdischarge spending and performance on new episode-based spending measure. *JAMA Intern Med* 2016;176:117–9.
- [38] Shiloach M, Frencher SK, Steeger JE, Rowell KS, Bartzokis K, Tomeh MG, et al. Toward robust information: data quality and inter-rater reliability in the American College of Surgeons National Surgical Quality Improvement Program. *J Am Coll Surg* 2010;210:6–16.