

The effect of patient age on discharge destination and complications after lumbar spinal fusion

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ABSTRACT

Age is an important patient characteristic that has been correlated with specific outcomes after lumbar spine surgery. We performed a retrospective cohort study to model the effect of age on discharge destination and complications after a 1-level or multi-level lumbar spine fusion surgery. The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database was used to identify patients who underwent lumbar spinal fusion surgery from 2013 through 2017. Perioperative outcomes were compared across ages 18 to 90 using multivariable nonlinear logistic regression controlling for pre-operative characteristics. A total of 61,315 patients were analyzed, with patients over 70 having a higher risk of being discharged to an inpatient rehabilitation center and receiving an intraoperative or postoperative blood transfusion. However, the rates of the other complications and outcomes analyzed in this study were not significantly different as patients age. In conclusion, advanced-age affects the discharge destination after a one- or multi-level fusion and intraoperative/postoperative blood transfusion after a one-level fusion. However, age alone does not significantly affect the risk of the other complications and outcomes assessed in this study. This study will help guide preoperative discussion with advanced-aged patients who are considering a 1-level or multi-level lumbar spine fusion surgery.

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1. Introduction

Age has been shown to affect both positive and adverse clinical outcomes after treatment for various disease processes [1–3]. In particular, age has a significant effect on the treatment of spine disease; not only regarding what treatment is selected for a patient of a specific age but also the likelihood of favorable outcomes after treatment. Lumbar spine fusion surgery has been used for decades to treat spine pathologies such as spinal fractures and defects that result in instability and spinal deformity, radiculopathy from degenerative disc disease, or multiple recurrent disc herniations which have failed to resolve after conservative management. The goal of lumbar spine fusion surgery is to immobilize a part of the spine, often in conjunction with a decompression of the neural elements to restore physiologic function, reduce pain, and maintain proper alignment of the spine. Thus, spine surgeons weigh these goals for a successful outcome against the potential risk of an unintended outcome. Given that age has been shown to affect the risk of adverse outcomes after surgical intervention [4,5], surgeons

have utilized the age of a patient when considering surgery for a particular patient as well as the extent of the procedure. This concept was illustrated by a study that showed that spine surgery decision-making for younger patients was driven by an increased coronal plane deformity; while the decision-making was driven by pain and disability in older patients [6]. Such variation in treatment plans based on age highlights the importance of understanding the effect of age on the number of fusion levels and postoperative complications or unfavorable outcomes. This interaction has been explored in the literature; however, these studies either have a small sample size, do not assess the change in complication rate over all adult ages, or include a mix of patients who have had instrumentation or decompression alone. Thus, when a surgeon utilizes age as a condition in their decision-making, it is influenced by their preference, clinical experience, and subjective impression.

The correlation between age and complications have been described for elderly patients who underwent deformity correction surgery. One retrospective study of 46 patients who were 60 years of age or older and underwent a thoracic or lumbar arthrodesis procedure consisting of 5 levels or greater reported a 37% overall

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complication rate [7]. Another retrospective study of 34 patients over the age of 65 who underwent an adult deformity correction surgery with an average of 6.7 levels fused reported a 17% overall complication rate [8]. Other similar studies in patients over 65 who have undergone deformity correction surgery report an overall complication rate ranging from 15% to 71% [9,10]. Moreover, older patients may have an even higher risk of complication as Acosta et al. showed that patients between the age of 75 and 83 who have undergone 5 to 15 levels of deformity correction have a 62% rate of perioperative complication [11], including myocardial infarction, pneumonia, pulmonary embolism, deep wound infections, and stroke. However, a study that matched cohorts of patients older and younger than 65 years of age who underwent deformity correction surgery found no differences in complications between these two groups [12]. These studies show a trend towards a higher complication rate in older patients; however, they are relatively small cohorts and have a high variance in complication rate between studies. Also, these studies strictly discuss patients who have undergone adult deformity correction surgery, which is typically a much more extensive surgery involving at least 4 levels and thus is not generalizable to all lumbar fusion spine surgeries.

Other studies that specifically describe the complication and readmission rates in patients of different age groups after any type of posterior lumbar spinal surgery have highly variable findings. While some report no difference in complication rate for patients older than 65 [13], others report complications rates ranging from 7 to 27% for patients older than 70 years of age [14–17]. Though informative, these studies include a heterogeneous cohort of patients who underwent fusions and decompression alone. Also, many of these studies analyze a relatively small cohort of patients. Thus, they do not fully illustrate the interaction between complication rates and age in patients who have undergone one-level lumbar spine fusion surgery.

There is some evidence that older patients are more likely to be discharged to an inpatient rehabilitation center [18] or have an unplanned readmission [18–21] after spine surgery. However, the correlation between age, complications, and discharge destination is not fully understood and has not been fully described. Also, the surgeon's operative preference, clinical impression of the patient's frailty [22,23], and assessment of the patient's comorbidities also contribute to what procedure is offered to a patient. Thus, identifying the relationship between age and the rate of complications or discharge destination could help guide the preoperative planning and discussion with patients before a planned lumbar fusion procedure. We aim to identify this relationship and address the following questions:

- How does age relate to complications, hospital readmissions, and discharge destination?
- Do multilevel fusions have a higher complication rate, hospital readmission rate, or discharge to inpatient rehabilitation centers compared to one-level fusions across all ages?

2. Material and methods

2.1. Study population

Data were obtained from the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database and spanned 2012 to 2017. The data from the NSQIP is released annually, and it is composed of de-identified demographic and clinical data from patient medical charts from 716 hospitals nationwide in the United States. The patients included in the database are randomly selected from all the surgical cases done at that hospital and tracked for 30 days postoperatively. A set number of

complications are recorded by a trained surgical clinical reviewer [24]. We specifically identified patients who underwent arthrodesis procedures as annotated by their Current Procedural Terminology (CPT) codes. Thus, those patients with specific CPT codes indicating that they had undergone a lumbar fusion procedure (22533, 22534, 22558, 22585, 22612, 22614, 22630, 22632, 22633, 22634) were selected for analysis.

2.2. Outcomes

Outcomes were selected based on specific complications recorded within the NSQIP. We selected the following as an unfavorable outcome: discharge to an inpatient rehabilitation center (Home, Rehab), return to the operating room (OR) within 30 days of the initial operation (Yes, No), unplanned hospital readmission (Yes, No), and total hospital length of stay in days. We select the following as complications due to the surgery: perioperative blood transfusion (Yes, No), any vascular event such as a cerebral stroke or myocardial infarction (Yes, No), Urinary Tract Infection (UTI) occurrences (Yes, No), and Deep Vein Thrombosis (DVT) or Pulmonary Embolism (P.E.) occurrences (Yes, No).

2.3. Intervention

Patients were selected based on the CPT codes assigned to their corresponding surgery. Patients who underwent procedures labeled with the CPT codes 22533, 22558, 22612, 22630, and 22633 as their principle code without any other code for an additional level were selected as one-level lumbar fusion procedures. On the other hand, procedures with + 22534, +22585, +22614, +22632, +22634 were selected as multi-level lumbar fusion procedures.

2.4. Covariates

We also consider the following covariates: age, sex (Female, Male), ethnicity (Hispanic, not Hispanic) race (American Indian or Alaska Native, Asian, Black or African American, Native Hawaiian or Pacific Islander, Caucasian and Unknown), height (inches), weight (pounds), operational time (minutes), current smoker (Yes, No), American Society of Anesthesiologists (ASA) classification (No Disturb, Mild Disturb, Severe Disturb, Life Threat, None assigned), history of diabetes (Insulin, No, Non-Insulin), history of dyspnea (At rest, Moderate Exertion, No), preoperative functional status (Independent, partially independent, totally independent, Unknown), dialysis treatment (Yes, No), history of disseminated cancer (Yes, No), history of Chronic Obstructive Pulmonary Disease (COPD) (Yes, No), history of Congestive Heart Failure (CHF) (Yes, No), history of hypertension (Yes, No), history of renal failure (Yes, No), history of steroids use (Yes, No), weight loss (Yes, No), bleeding disorder (Yes, No), preoperative transfusion (Yes, No) and calendar year (from 2012 to 2017).

2.5. Statistical analysis

Descriptive statistics, percentages, mean and standard deviations were computed to describe characteristics of the study population. Chi-square and Fisher's exact test for binary and categorical variables and the Wilcoxon rank-sum test for continuous variables were used to evaluate the marginal relationship between one-level and multilevel fusion. Multivariable nonlinear logistic regression models were used to assess the effect of fusion levels, age, and their interactions on the aforementioned binary outcomes (discharge to home vs. inpatient rehab, return to the OR, hospital readmission, perioperative blood transfusion, any vascular event, UTI occurrences, DVT/PE occurrences). The total length

Table 1
Study population.

	Total No. 61,315	One-level fusion No. 58,416	Multilevel fusion No. 2,899	P-value
Age	60 (± 14)	60 (± 13)	57 (± 17)	< 0.0001
Sex (Female)	33,300 (54%)	31,652 (54%)	1,648 (57%)	0.005
Ethnicity				< 0.0001
No	53,873 (88%)	51,405 (88%)	2,468 (85%)	
Unknown	4,349 (7%)	4,027 (7%)	322 (11%)	
Yes	3,093 (5%)	2,984 (5%)	109 (4%)	
Race				< 0.0001
American Indian or Alaska Native	308 (1%)	291 (0.5%)	17 (0.6%)	
Asian	865 (1%)	803 (1%)	62 (2%)	
Black or African American	4,845 (8%)	4,597 (8%)	248 (9%)	
Native Hawaiian or Pacific Islander	146 (0.2%)	139 (0.2%)	7 (0.2%)	
Unknown/Not Reported	4,275 (7%)	3,910 (7%)	365 (13%)	
Caucasian	50,876 (83%)	48,676 (83%)	2,200 (76%)	
Weight	191 (± 45)	192 (± 45)	175 (± 47)	< 0.0001
Height	66 (± 4)	66 (± 4)	65 (± 4)	< 0.0001
Operational time	210 (± 111)	205 (± 106)	305 (± 157)	< 0.0001
ASA class				< 0.0001
No Disturb	1,792 (3%)	1,687 (3%)	105 (4%)	
Mild Disturb	29,173 (48%)	28,075 (48%)	1,098 (38%)	
Severe Disturb	28,927 (47%)	27,362 (47%)	1,565 (54%)	
Life Threat	1,349 (2%)	1,223 (2%)	126 (4%)	
None assigned	73 (0.1%)	69 (0.1%)	4 (0.1%)	
Current smokers (No)	48,871 (80%)	46,513 (80%)	2,358 (81%)	0.025
Diabetes				< 0.0001
Insulin	3,445 (6%)	3,313 (6%)	132 (5%)	
No	50,740 (83%)	48,242 (83%)	2,498 (86%)	
Non-Insulin	7,130 (12%)	6,861 (12%)	269 (9%)	
Dyspnea				0.058
At rest	171 (0.3%)	158 (0.3%)	13 (0.4%)	
Moderate exertion	3,259 (5%)	3,124 (5%)	135 (5%)	
No	57,885 (94%)	55,134 (94%)	2,751 (95%)	
Preoperative Functional Status				< 0.0001
Independent	59,769 (97%)	57,067 (98%)	2,702 (93%)	
Partially Dependent	1,144 (2%)	1,008 (2%)	136 (5%)	
Totally Dependent	93 (0.1%)	51 (0.1%)	42 (1%)	
Unknown	309 (1%)	290 (0.5%)	19 (0.7%)	
Dialysis (Yes)	122 (0.2%)	112 (0.2%)	10 (0.3%)	0.083
Disseminated Cancer (Yes)	336 (1%)	264 (0.5%)	72 (2%)	< 0.0001
History of COPD (Yes)	2,861 (5%)	2,721 (5%)	140 (5%)	0.65
History of CHF (Yes)	175 (0.3%)	164 (0.3%)	11 (0.4%)	0.29
History of Hypertension (Yes)	33,986 (55%)	32,586 (56%)	1,400 (48%)	< 0.0001
History of Renal Failure (Yes)	31 (0.05%)	28 (0.05%)	3 (0.1%)	0.18
History of Steroid use (Yes)	2,520 (4%)	2,373 (4%)	147 (5%)	0.01
Weight loss (Yes)	166 (0.2%)	140 (0.2%)	26 (0.9%)	< 0.0001
Bleeding disorder (Yes)	886 (1%)	812 (1%)	74 (3%)	< 0.0001
Transfused (Yes)	134 (0.2%)	100 (0.2%)	34 (1%)	< 0.0001
Calendar year				< 0.0001
2012	5,303 (9%)	4,973 (9%)	330 (11%)	
2013	7,402 (12%)	6,910 (12%)	492 (17%)	
2014	9,301 (15%)	8,828 (15%)	473 (16%)	
2015	11,384 (19%)	10,886 (19%)	498 (17%)	
2016	13,353 (22%)	12,813 (22%)	540 (19%)	
2017	14,572 (24%)	14,006 (24%)	566 (20%)	

P-values are obtained by using Chi-square and Fisher's exact test for binary and categorical variables and Wilcoxon rank sum test for continuous variables

of hospital stay in days was modeled by using multivariable non-linear regression. To better model the relationship between age and the outcomes, we plugged into the models, both linear and nonlinear terms for age. Odds Ratios, mean differences, and 95% confidence intervals were computed from these models. The Odds Ratio is defined as the odds of an unfavorable outcome or complication in a group of patients divided by the odds in a different group of patients. For instance, if we consider the odds among those with One-level fusion divided by the odds among those with Multilevel fusion, then an Odds Ratio below 1 means that One-level fusion is less harmful than Multilevel fusion, *i.e.*, the odds for Multilevel fusion are higher than those for One-level fusion.

Conversely, an Odds Ratio above 1 means that One-level fusion is more harmful than Multilevel fusion. An Odds Ratio above 1 for

the interaction between fusion levels and age means that when increasing age, the risk of One-level fusion increases. An Odds Ratio below 1 indicates that when increasing age, the risk of One-level fusion decreases. The mean difference is the difference in means between two groups of patients. For instance, if we consider the mean difference of total length of hospital stay of One-level fusion versus Multilevel fusion, a negative mean difference means that Multilevel fusion patients stay longer. The same models were used to predict complications and unfavorable outcomes probabilities and means. A p-value below 0.05 was considered statistically significant. Data analysis was done by using R version 3.5.1 and RStudio (Integrated Development for R. 2015. RStudio, Inc., Boston, MA)

Table 2

Overall major and minor complication data.

Complication	Number of Patients (%)
Perioperative Blood Transfusion Occurrence	7589 (12.4%)
Return to the Operating Room (OR)	2076 (3.4%)
Urinary Tract Infection	1017 (1.7%)
Superficial Surgical Site Infection	635 (1.03%)
Deep Surgical Site Infection	421 (0.69%)
Wound Dehiscence	179 (0.3%)
Deep Vein Thrombosis	497 (0.81%)
Pulmonary Embolism	366 (0.6%)
Stroke/CVA	99 (0.16%)
Myocardial Infarction	219 (0.36%)
Cardiac Arrest	95 (0.15%)
Failure to Wean to Extubate	212 (0.35%)
Postoperative Renal Insufficiency or Failure	174 (0.28%)
Mean Length of Hospital Stay after 1 Posterior Lumbar Fusion Surgery	
1-level	3.75 days
Multilevel	6.9 days

3. Results

3.1. Overall results

Table 1 summarizes study population (n = 61,315) characteristics across fusion levels. Overall, the majority (54%) were female, Caucasian (83%), non-smokers (80%), with no diabetes (83%), and an independent preoperative functional status (97%). <1% of patients had dialysis or disseminated cancer, history of CHF, history of renal failure, weight loss, bleeding disorder, or were transfused. Five percent of the overall population had a history of COPD, while more than half (55%) had a history of hypertension. The volume of patients enrolled in the NSQIP database increased over the years, from 9% in 2012 to 24% in 2017. Overall, the mean age was equal to 60 (± 14), the mean weight (pounds) 191 (± 45), the mean height (inches) 66 (± 4), and the mean operational time was (minutes) 210 (± 111). Multilevel fusion patients were statistically significantly younger, more likely to be female, smaller in weight and height, with higher operative time, more likely to have disseminated cancer, less likely to have a history of hypertension, history of steroid use, weight loss, bleeding disorder, and being transfused compared with one-level patients. There were also statistically significant differences between fusion levels groups in ethnicity, race, diabetes, ASA class, preoperational functional status, and calendar year. Table 2 reports the overall major and minor complications within the dataset. The most common complications were all minor events, such as perioperative blood transfusions (12.4%), return to the operating room (3.4%), and urinary tract infections. Major complications such as myocardial infarction (0.36%), cardiac arrest (0.15%), and wound dehiscence (0.3%) were low within this dataset.

3.2. Age, fusion levels and their interactions on complications and discharge destination

Table 3 reports the estimated Odds Ratios for the aforementioned binary outcomes, the regression coefficient for the mean length of total stay, and their 95% confidence intervals (CI) for fusion levels, age, and their interactions. One-fusion level patients are significantly less likely to have bleeding occurrences (Odds Ratio = 0.171, CI=(0.116;0.251)), and on average, they stay at the hospital one day and a half less compared to patients with multilevel fusion (Mean difference = -1.325 , CI = (-1.847 ; -0.803)). No statistically significant differences were found between one-level and multilevel fusions for discharge destinations other than home,

Table 3

Results for complications and Discharge Destination.

Fusion levels: if the odds ratio is statistically below 1, or the mean difference is negative, then One-level fusion is less harmful than Multilevel fusion with respect to complications and discharge destination.		
Outcome	Odds Ratio	95% Confidence Interval
Discharge to an Inpatient Rehab	0.756	(0.467;1.224)
Return to the Operating Room (OR)	1.379	(0.686;2.774)
Hospital Readmission	1.571	(0.796;3.1)
Perioperative Blood Transfusion*	0.171	(0.116;0.251)
Vascular Event (CVA or MI)	0.383	(0.053;2.769)
UTI Occurrences	0.797	(0.265;2.4)
DVT/PE Occurrences	0.765	(0.158;3.689)
Mean difference		
Hospital Length of Stay*	-1.325	(-1.847 ; -0.803)
Age: if the odds ratio is statistically above 1 or the mean difference is statistically positive, then older patients are more at risk of complications and discharge destination.		
Outcome	Odds Ratio	95% Confidence Interval
Discharge to an Inpatient Rehab	0.978	(0.964;0.994)
Return to the Operating Room (OR)	0.973	(0.951;0.995)
Hospital Readmission	0.988	(0.968;1.008)
Perioperative Blood Transfusion	0.996	(0.983;1.01)
Vascular Event (CVA or MI)	1.001	(0.931;1.075)
UTI Occurrences	0.967	(0.933;1.002)
DVT/PE Occurrences	1.013	(0.962;1.068)
Mean Difference		
Hospital Length of Stay	-0.031	(-0.047 ; 0.015)
Interaction between fusion levels and age: if the odds ratio is statistically above 1 then when age increases, One-Level fusion is more harmful compared with Multilevel fusion with respect to complications and discharge destination (see top-left-panel of Fig. 1 for clarification).		
Outcome	Odds Ratio	95% Confidence Interval
Discharge to an Inpatient Rehab	0.997	(0.99;1.005)
Return to the Operating Room (OR)	0.993	(0.982;1.004)
Hospital Readmission	0.993	(0.983;1.004)
Perioperative Blood Transfusion*	1.018	(1.012;1.024)
Vascular Event (CVA or MI)	1.008	(0.979;1.038)
UTI Occurrences	1.001	(0.984;1.018)
DVT/PE Occurrences	1.001	(0.977;1.026)
Mean Difference		
Hospital Length of Stay	-0.008	(-0.017 ; 0.001)

* indicates statistically significance at the 0.05 level.

return to the OR, hospital readmission, any vascular event, UTI occurrences, and DVT/PE occurrences. When increasing age, the risk of discharge not to home, unplanned readmission, bleeding occurrences, any vascular event, UTI occurrences, and DVT/PE occurrences increased (Table A1). There was a statistically significant interaction between fusion levels and age on bleeding occurrences, suggesting that among younger patients with one-level fusion, the risk of bleeding occurrences is significantly lower than multilevel fusions, while the risk becomes not significant when increasing age. This relationship can be easily seen in the top-left plot of Fig. 1, in which predictions of bleeding occurrences are plotted across the age distribution, from 18 to 90 years old. Similarly,

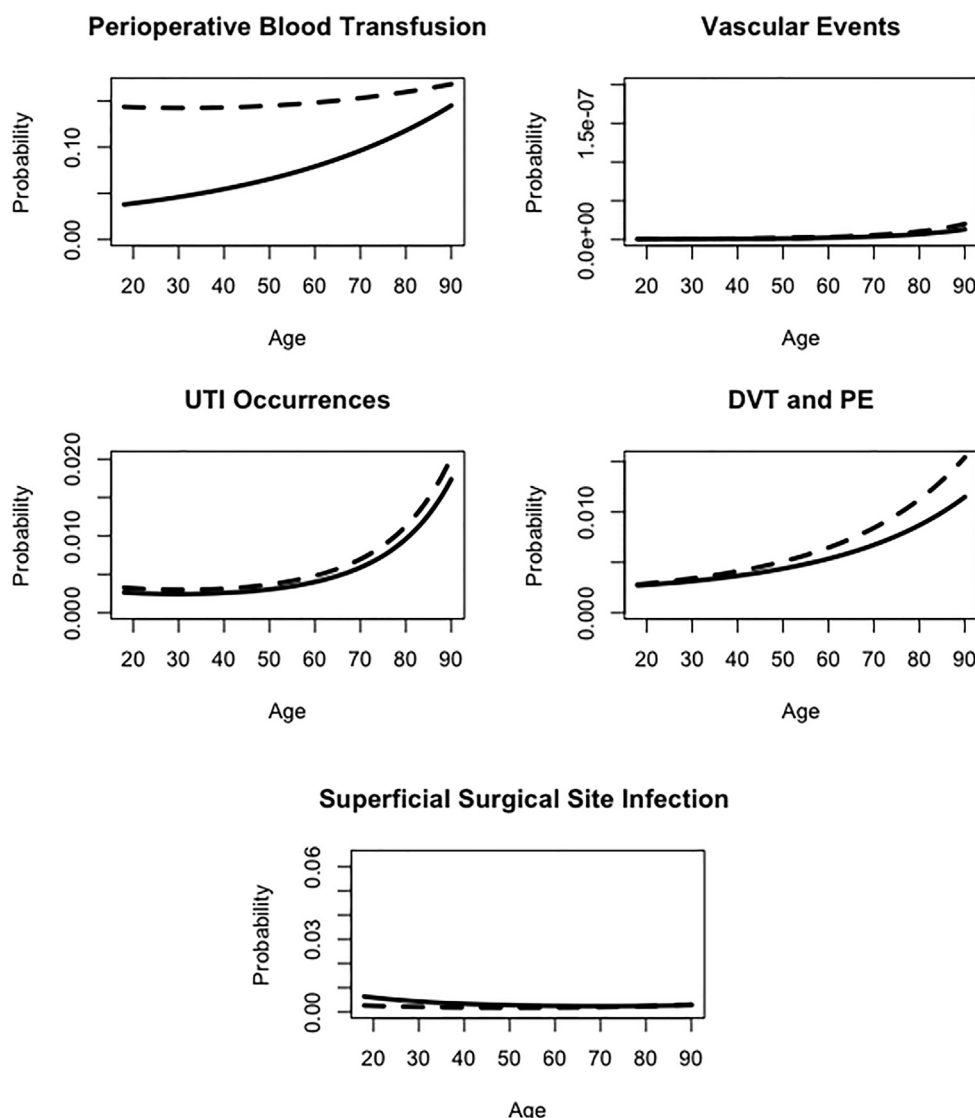


Fig. 1. Predicted probability of perioperative blood transfusion (top-left panel), a vascular event such as a cerebral stroke or myocardial infarction (top-right panel), Urinary Tract Infection (UTI) occurrences (middle-left panel), Deep Vein Thrombosis (DVT) or Pulmonary Embolus (P.E.) (middle-right panel), and superficial surgical site infection. The dashed line represents “multilevel” fusion, solid line “one-level” fusion.

predictions of complications and discharge destination across the age distribution for one-level and multilevel fusions are shown in Fig. 1 and Fig. 2.

4. Discussion

The relationship between age and unfavorable outcomes and complications following one- or multilevel lumbar spinal fusion surgery is gaining critical importance; especially as the U.S. population older than 65 years of age is projected to more than double from 46 million today to over 98 million by 2060 and projected to rise to nearly 24% of the U.S. population from 15% [25].

In our study, we show that the probability of receiving an intraoperative/postoperative blood transfusion gradually increases as a patient's age after one-level surgery. This is likely due to older patients showing vital signs and physical exam changes consistent with volume depletion more readily than younger patients. More specifically, as a person ages, they develop decreased baroreflex

sensitivity, decreased alpha-1-adrenergic vasoconstrictor response to sympathetic stimuli, decreased parasympathetic activity, decreased renal salt and water conservation, increased vascular stiffness, and reduced left ventricular diastolic filling [26]. Thus, clinicians are more likely to transfuse one or two units of packed red blood cells in older patients because they are more likely to observe low blood pressure, tachycardia, or pale pallor/clammy/cold skin from low intravascular blood volume. Second, the prevalence of coronary artery disease is higher in patients older than 65 [27]. Clinicians are sensitive to keeping the hemoglobin higher in patients with coronary artery disease, given the risk of demand ischemia-related cardiac events in patients with coronary artery disease [28–30]. Though a patient receiving a blood transfusion after lumbar spine surgery is not a complication, it is a potentially concerning event that should be discussed with any patient over the age of 65 who will undergo a one-level fusion. On the other hand, we found no association between age and intraoperative/postoperative blood transfusions after multilevel lumbar spinal fusions. This is likely due to the larger opening needed for multi-

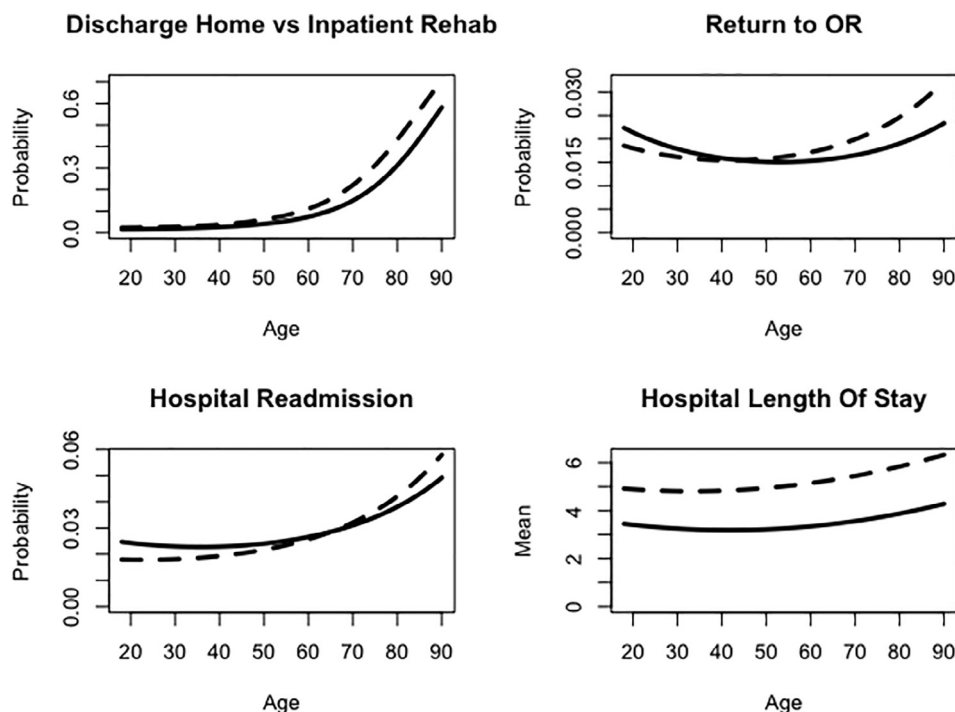


Fig. 2. Predicted probability of discharge to home versus an Inpatient Rehabilitation Center (top-left panel), return to OR (top-right panel), and hospital readmission (bottom-left panel), and predicted mean of total length of hospital stay across age, from 18 to 90. The dashed line represents “multilevel” fusion, solid line “one-level” fusion.

level spinal fusion and, thus, a higher intraoperative and postoperative blood loss associated with these procedures. In other words, age had no effect on blood transfusion events for multilevel fusions because blood loss is higher for these procedures irrespective of the patient's age; the NSQIP database does not track the number of blood units transfused, so this is considered an “all-or-none” event.

Similar to blood transfusion events, we identified that patients over the age of 65 are significantly more likely to be discharged to an inpatient rehabilitation center after their lumbar spine surgery. Similar findings have been shown in patients older than 75 compared to those between 65 and 74 after deformity correction surgery [31]. This finding has significant implications for older patients as they have been shown to have longer lengths of stays at inpatient rehabilitation centers and incur high costs compared to younger patients [32]. Additionally, a prolonged stay at an inpatient rehabilitation center is associated with an increased rate of complications, which were not captured within the 30-day postoperative period of the NSQIP, such as delayed wound infections, sacral decubitus ulcers, delayed DVT/PEs, and death [33].

Unsurprisingly, patients who underwent a multilevel surgery had, on average, a 2 day longer length of stay compared to those who underwent one-level surgery. However, there was no significant change in length of stay based on the patient's age for either one-level or multilevel surgery. In addition, we found no difference in the risk of unplanned readmissions after discharge between one-level and multilevel spine fusion surgery. Though there was a trend towards older patients having higher rates of unplanned readmission, this was not statistically significant. These results are consistent with results published by Kalagara et al., who reported a mean age of 64.7 for patients readmitted versus 62.3 for a patient not readmitted after a laminectomy [20]. Similarly, the probability of returning to the OR was not significantly different between one-level and multilevel surgery and did not change based on the patient's age.

However, there is no correlation between age and number of levels fused for UTIs, DVTs, a vascular event (e.g., strokes, myocardial infarction, or cardiac arrest). The risk of having a vascular event or UTI began to increase with an inflection point at 70-year-old; however, this trend was not found to be statistically significant. There is also a continuous, linear increase in DVT occurrences by age irrespective of the number of levels fused; however, this trend was also found not to be statistically significant. The lack of significance may be due to the relatively low events of UTIs (1017, 1.7%), DVTs (497, 0.008%), and vascular events (318, 0.005%) in our cohort population of 61,315 patients.

Our results for the marginal probability for a UTI, vascular event, and DVT are lower than previously published studies; however, our patient cohort is large, multi-institutional, and encompasses both 1-level and multilevel lumbar fusion surgeries. For lumbar surgery for patients older than 80 years-old, Saleh et al. reported a 0.60% P.E. rate, 0.68% vascular event rate, which is consistent with the marginal increased rate of these complications seen in the patients older than 80 years-old in our study. For multilevel deformity surgery, Acosta et al. reported a 2 P.E.s (9.5%), 2 M.I.s (9.5%), and 1 CVA (4.8%), while reporting a 62% complication rate in a cohort of 21 patients between the 75 and 83 years old who underwent deformity corrections ranging from 5 to 15 levels [11]. Daubs et al. reported 1 MI and 2 P.E.s from a group of 46 patients between 60 and 85 years-old who underwent 5- to 16-level fusion while reporting a 20% overall complication rate [7]. Other studies report similarly low rates of vascular events and DVT/PEs after lumbar spine fusion surgery [8].

Our study did not include complications such as dural tear/cerebrospinal fluid leak, postoperative transient or permanent neurological deficit, and deep surgical site infection. The complications analyzed in the present study were limited to those collected by the NSQIP; the database does not record dural tears/cerebrospinal fluid leaks and neurological deficits. Additionally, deep surgical site infections are an uncommon event within 30-days of a lumbar

spine operation and thus were very rare within our cohort of patients. This is also applicable to any complications that are infrequent events within the first 30-days postoperatively, such as pseudoarthrosis. Lastly, the database does not include information on the severity of spinal disease or any specificity regarding the number of levels fused greater than 2. This limits the specificity of analysis regarding those patients who undergo 2-level fusion procedures versus those who underwent 15-level fusion procedures, a very wide range of invasiveness.

5. Conclusion

Presently, most of the spine literature on the age-related variability of complications and unfavorable outcome rates of patients after lumbar fusion surgery does not assess these risks across the entire adult age distribution but instead focuses explicitly on patients of advanced age. Our study broadens the scope and characterizes how age affects the probability of specific complications over the entire adult age range and assess how that probability gradually changes as patients age. Specifically, patients over the age of 70 have a higher risk of being discharged to an inpatient rehabilitation center and receiving a perioperative blood transfusion. However, the rates of the other complications analyzed in this study were not significantly different in patients between 18 and 90 years old.

6. Key points

- As patients age, the risk of return to the operating room, hospital readmission, or increased length of hospital stay does not significantly increase with age.
- Patients over the age of 70 have a significantly higher risk of being discharged to an inpatient rehabilitation after a one-level or multilevel posterior lumbar fusion surgery
- Patients over the age of 70 have a significantly higher risk of receiving a perioperative blood transfusion after a one-level posterior lumbar fusion surgery.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jocn.2021.07.006>.

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