

Postoperative Anemia Predicts Length of Stay for Geriatric Patients Undergoing Minimally Invasive Lumbar Spine Fusion Surgery

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Abstract

Introduction: We hypothesize that postoperative anemia will predict length of stay (LOS) for geriatric patients undergoing minimally invasive (MIS) lumbar spine fusions. **Materials and Methods:** Patients who underwent MIS lateral and transforaminal lumbar interbody fusion between January 2017 and March 2018 at an academic tertiary care referral center were selected. Eighty-one patients were included. The primary outcome variable was LOS, measured in days. The predictors studied were preoperative hemoglobin (Hgb), postoperative day 1 Hgb, postoperative nadir Hgb, intraoperative Hgb decrement (preoperative Hgb-postoperative day 1 Hgb), perioperative Hgb decrement (preoperative Hgb-postoperative nadir Hgb), age, American Society of Anesthesiologists–Physical Status (ASA-PS) score, volume of perioperative intravenous (IV) fluids (IVFs), and number of levels fused. Simple linear regression and analysis of variance were used for statistical analysis. **Results:** In the present study, preoperative anemia was not associated with longer LOS ($P = .15$). Postoperative anemia was associated with longer LOS as both postoperative day 1 Hgb ($P = .05^*$) and postoperative nadir Hgb ($P < .0001^*$) predicted longer LOS. Greater intraoperative Hgb decrement did not predict longer LOS ($P = .36$); however, greater perioperative Hgb decrement predicted longer LOS ($P < .0001^*$). Older age ($P = .01^*$) and greater number of levels fused ($P = .03^*$) predicted longer LOS; however, a greater ASA-PS classification did not predict longer LOS. Greater IVF administration was associated with longer LOS ($P < .0001^*$). **Discussion:** Postoperative nadir Hgb ($P < .0001^*$) was more predictive of longer LOS than postoperative day 1 Hgb ($P = .05^*$). There is a perioperative Hgb decrement associated with longer LOS ($P < .0001^*$). Geriatric patients may be more susceptible to the potential contributors to Hgb decrement, including occult bleeding post-op and hemodilution from IVF administration. **Conclusion:** Postoperative anemia, perioperative decrement in Hgb, older age, greater number of levels fused, and greater total IVFs administered predict longer LOS. Understanding the impact of these factors on LOS is critical as these procedures increasingly move to the outpatient setting.

Keywords

length of stay, minimally invasive spine surgery, geriatric patients, lumbar fusion, postoperative recovery, anemia

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Introduction

In recent years, the association with longer length of stay (LOS) and cost and complication rates has garnered widespread attention across all specialties. Increasingly close attention is being paid to factors that predict LOS for patients undergoing spinal fusions. Longer LOS is associated with greater hospital costs, greater inpatient charges, and greater likelihood of postoperative adverse events.^{1,2} Adverse events can subsequently result in costly hospital readmissions.^{3,4} It is critical that we further our understanding of the factors leading to prolonged LOS.

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Preoperative anemia has been identified as a predictor of longer LOS, postoperative complications, and 30-day hospital readmissions for patients undergoing elective spine surgery.⁵⁻⁷ Older patients are more likely to be preoperatively anemic and more sensitive to intraoperative hemodilution.⁸

The impact of postoperative anemia on LOS has not been completely elucidated. A study from the Netherlands found that postoperative use of packed red cells in spine surgery patients increased LOS in the intensive care unit and ward; however, the patient sample was limited to those who had an intraoperative blood loss of 2 L or greater.⁹ The mean age (standard deviation) in this study was 55.1 (15.2). Their data suggest that older patients were more likely to have higher intraoperative and postoperative bleeding.

There are several relevant trends in modern spine surgery allowing more operations to move to the outpatient setting including in the geriatric population. Specifically, an increase in minimally invasive techniques allows for lower blood loss and in theory faster recovery. It is important to understand, however, that just because the external blood loss is low, there is likely significant occult blood loss with techniques such as lateral lumbar fusions and transforaminal lumbar fusions.

In this study, we sought to investigate the impact of postoperative anemia on LOS for minimally invasive (MIS) lateral and transforaminal lumbar interbody fusions using simple linear regression (SLR).

Materials and Methods

In a retrospective study, all patients who underwent MIS lumbar fusions between January 2017 and March 2018 at an academic tertiary care center and met the inclusion criteria were selected. The inclusion criteria were that patients underwent lateral lumbar interbody fusion (LLIF) and transforaminal lumbar interbody fusion (TLIF) with decompression and posterior spinal fusion of up to 4 levels within the specified time frame. All operations were performed using minimally invasive technique, working through small sequential incisions. Patients who underwent open procedures involving large or longitudinal midline incisions were not included in this study due to significantly higher expected blood loss. Additionally, patients had to have preoperative and postoperative complete blood counts (CBCs) documented in the electronic medical record.

One of 3 surgeons performed the operations. This study received institutional review board approval (Carilion Clinic, Roanoke, VA, Protocol #2581).

Demographic data collected were limited to age and gender. Perioperative data collected included diagnosis, surgical approach, number of levels fused, perioperative volume of intravenous (IV) fluids (IVFs) administered, American Society of Anesthesiologists–Physical Status (ASA-PS) score, preoperative hemoglobin (Hgb) level, postoperative day 1 Hgb, and postoperative nadir Hgb.

The primary outcome variable was LOS, measured in days. During the study period, at our institution, a CBC was ordered on each postoperative day. We defined postoperative day 1

Hgb as the Hgb value recorded during the first postoperative day, and postoperative nadir Hgb as the lowest Hgb value recorded over a patient's entire postoperative period. We defined intraoperative Hgb decrement as (preoperative Hgb-postoperative day 1 Hgb) and perioperative Hgb decrement as (preoperative Hgb-postoperative nadir Hgb). Simple linear regression models were made using preoperative Hgb, postoperative day 1 Hgb, postoperative nadir Hgb, intraoperative Hgb decrement, and perioperative Hgb decrement as the predictor variables and LOS measured in days as the outcome variable.

For a more thorough analysis of LOS, we also studied the relationship between patient age, number of levels fused, ASA-PS score, perioperative IVF administration, and LOS.

Simple linear regression models were made for age and perioperative IVFs administered. Analysis of variance (ANOVA) models were made for number of levels fused and ASA-PS, as these 2 variables are discrete rather than continuous. The outcome variable in each model was LOS, measured in days. No patient had hospital stay extended solely for the reason of low Hgb.

Of the 81 patients, one patient had a preoperative Hgb, but no postoperative Hgb value recorded. Intravenous fluid administration data were unavailable for six of 81 patients. Data available for these patients (ie, preoperative Hgb, age, number of levels fused, and ASA-PS) were utilized within the study, so these patients were not excluded from the study. We report additional data for these six patients in section "Results."

As an additional analysis, we analyzed the relationship between number of levels fused and perioperative Hgb decrement, and postoperative nadir Hgb using ANOVA.

Statistical Analysis

For the SLR analyses, the predictor variable (ie, preoperative Hgb, postoperative day 1 Hgb, etc) was the *x*-axis value and LOS was the outcome variable or *y*-axis value.

GraphPad PRISM 8 Software was used to analyze the SLR models. The output included a *P* value reflecting the probability of a significant linear relationship, the correlation coefficient or *R* value, and the *R*² value, which is the proportion of variance in the outcome variable predicted by the predictor variable. Relationships between the discrete predictors, number of levels fused and ASA-PS, and LOS were analyzed using 1-way ANOVA.

Results

Eighty-one patients who had undergone MIS LLIF/TLIF of up to 4 levels at an academic tertiary care center were included in the study, 26 were male and 55 were female. The average patient age was 62.8 years (range: 19-83). The mean number of levels fused was 1.65. The mean ASA-PS score for all patients was 2.54. Mean LOS for all patients was 2.8 days. More patients underwent LLIF (69) than TLIF (12). The most common preoperative diagnosis was lumbar stenosis. On average, patients

Table 1. Demographics and Introductory Data for Study Patients.

Demographic	Value
N	81
Mean age (SD)	62.8 (13)
Male	26
Female	55
Mean levels fused (SD)	1.65 (0.83)
Mean ASA-PS (SD)	2.54 (0.61)
Mean length of stay in days (SD)	2.8 (1.3)
MIS LLIF	68
MIS TLIF	12
Diagnosis	
Lumbar stenosis	63
Degenerative disc disease	5
Degenerative scoliosis	4
Other	9
Mean volume of perioperative IV fluids given (mL)	2762

Abbreviations: ASA-PS, American Society of Anesthesiologists–Physical Status; IV, intravenous; LLIF, lateral lumbar interbody fusion; MIS, minimally invasive spine; SD, standard deviation; TLIF, transforaminal lumbar interbody fusion.

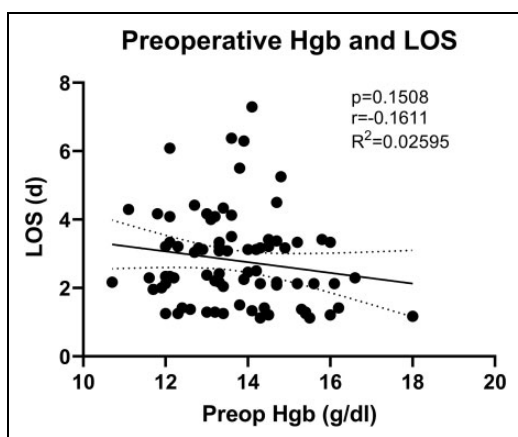


Figure 1. Lower preoperative hemoglobin was not associated with longer length of stay ($P = .1508$).

were administered 2762 mL of IVFs over the perioperative period. These data are depicted in Table 1.

Simple linear regression models were made setting preoperative Hgb, postoperative day 1 Hgb, and postoperative nadir Hgb as the predictor variable and LOS as the outcome variable. Preoperative anemia was not associated with a longer LOS ($P = .15$; Figure 1); however, lower postoperative day 1 Hgb was associated with longer LOS ($P = .05^*$; Figure 2). Lower postoperative nadir Hgb had stronger association with a longer LOS ($P < .0001^*$; Figure 3). We also analyzed postoperative nadir Hgb as cohorts, Hgb < 10 g/dL, Hgb 10 to 12 g/dL, and Hgb > 12 g/dL. Patients with postoperative nadir Hgb > 12 g/dL had the shortest mean LOS at 1.86 days. Patients with postoperative nadir Hgb < 10 g/dL had the longest mean LOS at 3.53 days ($P = .000126^*$; Figure 4).

Simple linear regression models were made setting intraoperative Hgb decrement (preoperative Hgb-postoperative day 1

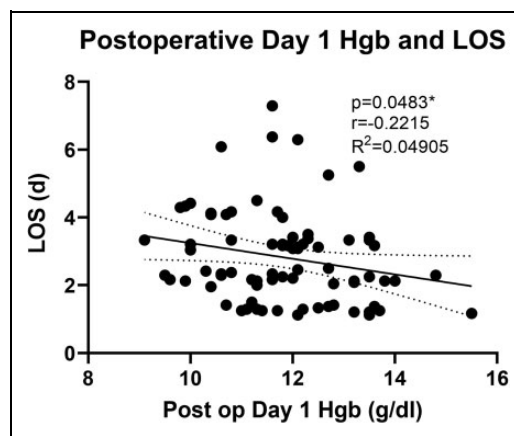


Figure 2. Lower post-op day 1 hemoglobin level was associated with longer length of stay ($P = .0483^*$).

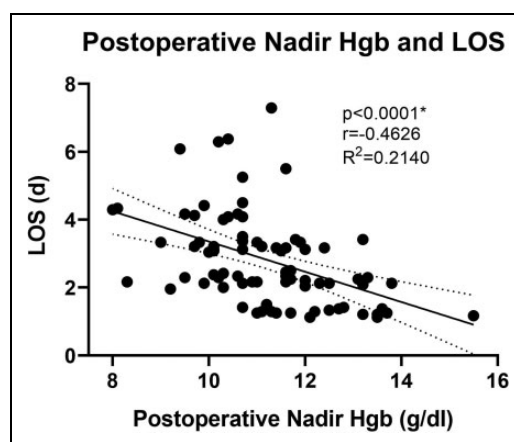


Figure 3. Lower postoperative nadir hemoglobin was significantly associated with longer length of stay.

Postoperative Nadir Hgb (g/dl)	N	Mean LOS (d)
<10	13	3.53
10-12	45	3.08
>12	22	1.86

Figure 4. Analyzing postoperative nadir hemoglobin (Hgb) using clinical thresholds of normal (Hgb > 12 g/dL), moderate anemia (Hgb = 10-12 g/dL), and severe anemia (Hgb < 10 g/dL), we find that patients with normal postoperative nadir Hgb had shortest length of stay ($P = .000126^*$).

Hgb) and perioperative Hgb decrement (preoperative Hgb-postoperative nadir Hgb) as the predictor variable and LOS as the outcome variable. Intraoperative Hgb decrement was not associated with a longer LOS ($P = .36$; Figure 5); however, a greater perioperative Hgb decrement was significantly associated with longer LOS ($P < .0001^*$; Figure 6).

Analysis of variance models were made setting number of levels fused and ASA-PS as the predictor variable and LOS as

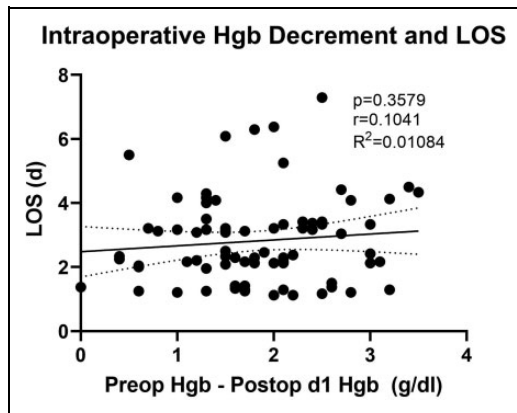


Figure 5. A greater intraoperative hemoglobin (Hgb) decrement, defined as the difference between the pre-op Hgb and post-op day 1 Hgb, was not associated with longer length of stay ($P = .3579$).

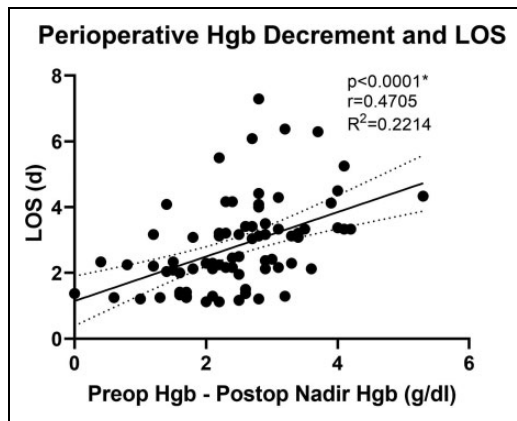


Figure 6. A greater perioperative hemoglobin (Hgb) decrement, defined as the difference between the pre-op Hgb and post-op nadir Hgb, was associated with longer length of stay ($P < .0001^*$).

ASA-PS	N	Mean LOS (d)
1 (No disease)	3	2.57
2 (Mild systemic disease)	33	2.58
3 (Severe systemic disease)	43	3.00
4 (Greater systemic disease)	2	2.90

Figure 7. American Society of Anesthesiologists–Physical Status score was not associated with longer length of stay ($P = .60$).

the outcome variable. Having a higher ASA-PS classification, indicating patients with more severe systemic disease, did not predict a longer LOS ($P = .60$; Figure 7). However, having greater number of levels fused did predict longer LOS ($P = .03^*$; Figure 8).

Finally, SLR models were made setting age and perioperative volume of IVFs administered as the predictor variable and LOS as the outcome variable. There was a clear relationship

Number of Levels Fused	N	Mean LOS (d)
1	43	2.47
2	25	3.35
3	10	2.68
4	3	3.91

Figure 8. Greater number of levels fused in surgery was associated with longer length of stay ($P = .03^*$).

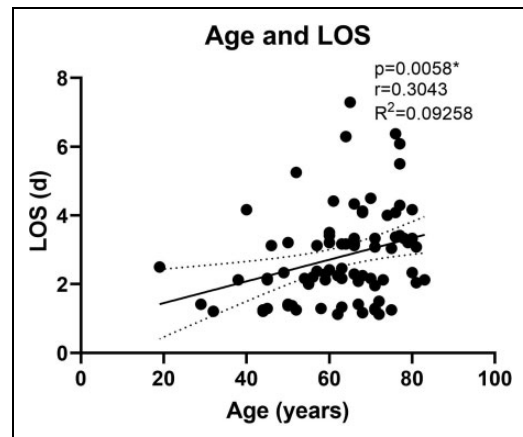


Figure 9. Increased age was associated with longer length of stay ($P = .0058^*$).

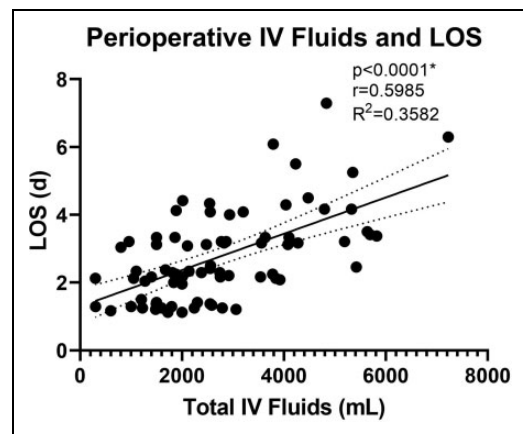


Figure 10. Greater perioperative intravenous fluid administration was associated with longer length of stay ($P < .0001$).

between increased age and longer LOS ($P = .0058^*$; Figure 9). Greater volume of IVFs administered was also significantly associated with longer LOS ($P < .0001^*$; Figure 10). Intravenous fluid data were unavailable for 6 patients. The mean LOS of these 6 patients was 3.1 days, while the mean LOS of the entire group was 2.8 days ($P = .70$). The mean number of levels fused of these 6 patients was 1.67, while the mean for the entire group was 1.65 ($P = .97$). The mean postoperative nadir Hgb for these 6 patients was 11.85 g/dL, while the mean for the entire group was 11.21 g/dL ($P = .24$). The mean age for these

Number of Levels Fused	N	Perioperative Hgb Decrement (g/dl)
1	43	2.19
2	24	2.76
3	10	2.61
4	3	3.87

Figure 11. There was an association between greater number of levels fused and greater perioperative hemoglobin decrement ($P = .003^*$).

Number of Levels Fused	N	Postoperative Nadir Hgb (g/dl)
1	43	11.46
2	24	10.99
3	10	11.19
4	3	9.43

Figure 12. There was no significant association between number of levels fused and postoperative nadir hemoglobin ($P = .08$).

6 patients was 64.7 years (range: 45-81), while the mean for the entire group was 62.8 years (range: 19-83; $P = .75$).

Figure 11 reports a significant relationship between greater number of levels fused and greater perioperative Hgb decrement ($P = .003^*$). Figure 12 reports that the relationship between number of levels fused and postoperative nadir Hgb was not significant ($P = .08$).

Discussion

Minimally invasive spine surgery has allowed increasingly complex procedures to be performed safely in the geriatric population with low complication rates and shorter LOS. In the present study, we seek to better understand factors related to LOS, specifically Hgb. While previous studies have documented an association between lower preoperative Hgb and longer LOS, in our study, lower preoperative Hgb ($P = .15$) was not found to predict longer LOS.⁵⁻⁷ The mean preoperative Hgb for all patients was 13.7 g/dL. Only 6 (7.4%) patients had a preoperative Hgb lower than 12.0 g/dL; therefore, preoperative anemia did not play a major role in this study despite the elderly study population with a mean age of 62.8 years.

Lower postoperative day 1 Hgb did predict longer LOS ($P = .05^*$). The postoperative day 1 Hgb level is the earliest postoperative Hgb recorded for patients and represents intraoperative blood loss and IVF administration. Geriatric patients may be more susceptible to blood loss during surgery as well as hemodilution from IVF administration compared to younger patients.¹⁰ Geriatric patients are often on anticoagulants or have slower clotting times, increasing their risk of higher occult blood loss during the intraoperative and postoperative phase.

Several prior studies have decisively shown that MIS fusions are associated with lower blood loss compared to open

spine fusions.¹¹⁻¹⁴ However, these studies measure estimated blood loss (EBL). Prior studies also show that hidden blood loss is underestimated and comprises a large percentage of the total blood loss in both MIS and open spine fusions.^{15,16}

In the case of lateral MIS lumbar spine fusions, the hidden blood loss likely represents occult blood loss into the retroperitoneal compartment. In posterior interbody and posterior-only MIS fusion, occult blood loss also occurs. Analyzing Hgb decrement in the intraoperative as well as postoperative phase instead of EBL alone accounts for this occult blood loss.

In our study, greater perioperative Hgb decrement and lower postoperative nadir Hgb were both associated with longer LOS ($P < .0001^*$). These data indicate a reduction or decrement in Hgb was occurring during the postoperative recovery period.

Greater perioperative IVF administration was associated with longer LOS ($P < .0001^*$) and is likely a major contributor to the postoperative Hgb decrement via hemodilution. Hemodilution is more than just a benign physical phenomenon and can result in dilutional coagulopathy, contribute to surgical bleeding, and necessitate blood transfusions.¹⁰ A study from the United Kingdom found that colorectal surgery patients receiving a greater volume of colloid boluses had greater intraoperative blood loss and higher transfusion rates.¹⁷ The mean patient age in this study was 66 years, emphasizing that elderly patients may be more susceptible to potential negative sequelae of hemodilution.

Randomized controlled trials of patients undergoing intra-abdominal surgery have shown that IVF restriction decreases LOS and complications. A randomized controlled trial of 152 patients undergoing intra-abdominal surgery by Nisanevich et al showed that patients in the IVF restriction group had a shorter LOS, experienced fewer complications, and maintained higher hematocrit and albumin concentrations compared to the group receiving normal IVFs.¹⁸ A randomized controlled trial of 172 patients undergoing colonic resection by Brandstrup et al showed that patients allocated to the restricted IVFs group experienced fewer complications.¹⁹

The relationship between greater perioperative IVF and longer LOS reported in Figure 10 may indicate that additional postoperative days are required to adequity volume resuscitate patients, making the perioperative IVF requirement a representation of the blood or intravascular volume loss occurring perioperatively. Alternatively, patients may be invariably receiving IVF for each day post-op based on institutional routine, making the relationship more of an association. The relationships reported in Figures 8 and 11, that greater number of levels fused was associated with longer LOS and greater Hgb decrement, respectively, suggest that perioperative IVF administration is likely goal-directed toward adequate volume resuscitation. However, within the data set, there may also be cases of invariable rather than goal-directed resuscitation, and these patients are especially susceptible to hemodilution. Figure 12 reports that there was no significant relationship between number of levels fused and post-op nadir Hgb level ($P = .08$). As prior studies show that Hgb decrement is one of the more

accurate indicators of true blood loss, Hgb decrement may also be a good indicator of patient under-resuscitation.¹⁵⁻¹⁶

Six patients did not have perioperative IVFs recorded. We sought to determine whether these 6 patients had characteristics that were appreciably different from the study group at large. These 6 patients had no statistically significant differences in mean age, LOS, number of levels fused, and postoperative nadir Hgb compared to the entire group.

We studied the relationship between age or ASA-PS classification, and LOS intending to quantify the effect of older age and comorbid conditions on LOS. Discharge planning is complex, multifactorial, and involves many stakeholders.²⁰ Postoperative stability, mobility, and coordination of resources such as transportation or rehabilitation are among the factors central to discharge planning.²¹ Literature shows that older patients with comorbid conditions are at higher risk of readmission and poor outcomes following discharge.²²

In our study, a greater ASA-PS score was not associated with longer LOS ($P = .60$). However, older age was associated with longer LOS ($P = .0058^*$). Although greater ASA-PS did not predict longer LOS per the model, a majority (53%) of the patients were elderly and had a classification of III, indicating severe systemic disease. A combination of preexisting disease conditions and logistical considerations related to older age may contribute to longer LOS for the geriatric population. A fine-tuned analysis of the interplay between statistically significant predictors of discharge, such as Hgb, and the actual discharge planning process is beyond the scope of this article. This is both a limitation and an excellent opportunity for future investigation.

Conclusion

Postoperative anemia was found to predict longer LOS for patients undergoing MIS LLIF or TLIF. Lower postoperative day 1 Hgb was significantly associated with longer LOS, and lower postoperative nadir Hgb was even more significantly associated with longer LOS.

Greater perioperative decrement in Hgb, greater number of levels fused, and greater perioperative volume of IVF administration were also associated with longer LOS, and these effects may contribute to postoperative nadir Hgb through occult blood losses post-op as well as hemodilution. Hemodilution is not necessarily a benign phenomenon and should be avoided. Older patients are likely more susceptible to occult blood loss as well as hemodilution, and older age predicted longer LOS in this study.

Cautious use of antifibrinolytics, IVF restriction, and careful soft-tissue dissection during surgical approach may elevate postoperative Hgb and reduce LOS for geriatric patients undergoing minimally invasive lumbar fusions.

Authors' Note

Data may be accessed on the Figshare repository.


Declaration of Conflicting Interests

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