Thirty-Day Morbidity Associated with Pelvic Fixation in Adult Patients Undergoing Fusion for Spinal Deformity: A Propensity-Matched Analysis

Parth Kothari¹ Sulaiman Somani¹ Nathan J. Lee¹ Javier Z. Guzman¹ Dante M. Leven² Branko Skovrlj³ Jeremy Steinberger³ Jun Kim¹ Samuel K. Cho¹

¹Department of Orthopaedic Surgery, Icahn School of Medicine at Mount Sinai, New York, New York, United States
²Department of Orthopaedic Surgery, SUNY Health Science Center at Brooklyn, Brooklyn, New York, United States
³Department of Neurosurgery, Icahn School of Medicine at Mount Sinai, New York, New York, United States

Address for correspondence Samuel K. Cho, MD, Department of Orthopaedic Surgery, Icahn School of Medicine at Mount Sinai, 5 East 98th Street, Box 1188, New York, NY 10029, United States (e-mail: samuel.cho@mountsinai.org).

Abstract

Study Design   Retrospective study of prospectively collected data.
Objective   To determine if patients undergoing spinal deformity surgery with pelvic fixation are at an increased risk of morbidity.
Methods   The American College of Surgeons National Surgical Quality Improvement Program is a large multicenter clinical registry that prospectively collects preoperative risk factors, intraoperative variables, and 30-day postoperative morbidity and mortality outcomes from ~400 hospitals nationwide. Current Procedural Terminology codes were used to query the database between 2010 and 2014 for adults who underwent fusion for spinal deformity. Patients were separated into groups of those with and without pelvic fixation. Univariate analysis and multivariate logistic regression were used to analyze the effect of pelvic fixation on the incidence of postoperative morbidity and other surgical outcomes.
Results   Multivariate analysis showed that pelvic fixation was a significant predictor of overall morbidity (odds ratio [OR] = 2.3, 95% confidence interval [CI]: 1.7 to 3.1, p = 0.0002), intra- or postoperative blood transfusion (OR = 2.3, 95% CI: 1.7 to 3.1 p < 0.0001), extended operative time (OR = 4.7, 95% CI: 3.1 to 7.0 p < 0.0001), and length of stay > 5 days (OR = 2.1, 95% CI: 1.5 to 2.8, p < 0.0001) in patients undergoing fusion for spinal deformity. However, fusion to the pelvis did not lead to additional risk for other complications, including wound complications (p = 0.3191).
Conclusion   Adult patients undergoing spinal deformity surgery with pelvic fixation were not susceptible to increased morbidity beyond increased blood loss, greater operative time, and extended length of stay.
Introduction

Adult spinal deformity (ASD) is a challenging spinal disorder due to its complex presentation and treatment.\textsuperscript{1–3} Surgical treatment is most commonly spinal fusion, though the surgeon must take into account several factors that vary by patient and deformity characteristics.\textsuperscript{4,5} Particularly challenging is the extension of long fusions to L5–S1 for several reasons. Long fusion constructs to this area, which are often necessary for correction of both sagittal and coronal plane deformities, have a high rate of pseudarthrosis. The large lever arms and cantilever forces created by long constructs produce high mechanical stress at the construct’s base. Furthermore, the sacrum and the S1 and S2 pedicles in particular are quite cancellous and potentially osteoporotic in the elderly ASD patient. When these risks are present, pelvic fixation may be indicated to improve the stability of the construct base and maintain the surgical correction of deformity until fusion is achieved.\textsuperscript{6–8}

Given the increasing incidence of spinal deformity in the United States,\textsuperscript{1–3} understanding the potential complications of surgical intervention is important. In particular, pelvic fixation has not been well studied. Previous studies generally do not adequately assess the additional risk pelvic fixation adds to spinal fusion surgery. In the recent literature, pelvic fixation has been associated with higher infection rates, longer operating times, longer length of stay, and higher rate of blood loss. However, these studies were small, single-center studies.\textsuperscript{9–11} Furthermore, these studies considered pediatric patients with neuromuscular scoliosis, not ASD. Other studies on pelvic fixation have considered the differences in complications between different techniques for extension to the pelvis.\textsuperscript{12–14} Others have been noncomparative investigations, focusing solely on outcomes.\textsuperscript{15–17}

To our knowledge, no study has used a large, multi-institutional database to describe the risk profile for pelvic fixation in patients who undergo fusion for ASD. In this study, the ACS-NSQIP database was used to investigate the effect of pelvic fixation adjunct to spinal deformity surgery on 30-day morbidity and mortality in adults.

Materials and Methods

Data Source

The ACS-NSQIP was originally created as a quality improvement initiative for the Veteran's Administration (VA) health system in 1994. It has since expanded to the private sector after its initial success in the VA system.\textsuperscript{18,19} Details of the ACS-NSQIP (www.acsnsqip.org) have been described before, and its use has been well established in the surgical literature. It is a validated outcomes registry that allows assessment of 30-day risk-adjusted surgical morbidity and mortality to provide feedback to participating hospitals.\textsuperscript{20}

The database consists of more than 150 preoperative, intraoperative, and 30-day postoperative variables that are collected prospectively from the medical records and operative reports among other sources by on-site surgical clinical reviewers. Data is gathered through the entirety of the 30-day postoperative period, including patients discharged within this period or treated on an outpatient basis.\textsuperscript{20}

Data Collection

The ACS-NSQIP database from 2010 to 2014 was used in this study. Adult patients (≥18 years) undergoing spinal fusion for deformity were identified based on Current Procedural Terminology (CPT) codes 22802, 22804, 22810, and 22812. CPT codes 22843, 22844, 22846, or 22847 were included to capture long, multilevel fusions (Table 1). Patients undergoing pelvic fixation in addition to fusion were identified using CPT code 22848. To reduce the risk of confounding variables, we excluded cases with missing preoperative data; emergency cases; patients with a wound class of 2 (clean wound but within the respiratory, alimentary, genital, or urinary tracts), 3 (contaminated), or 4 (infected); patients with an open wound on their body, current sepsis, current pneumonia, or prior surgeries within 30 days; cases requiring

| CPT       | Description                                                                                      |
|-----------|-------------------------------------------------------------------------------------------------|
| 22802     | Arthrodesis, posterior, for spinal deformity, with or without cast; 7 to 12 vertebral segments  |
| 22804     | Arthrodesis, posterior, for spinal deformity, with or without cast; 13 or more vertebral segments|
| 22810     | Arthrodesis, anterior, for spinal deformity, with or without cast; 4 to 7 vertebral segments     |
| 22812     | Arthrodesis, anterior, for spinal deformity, with or without cast; 8 or more vertebral segments  |
| 22843     | Posterior segmental instrumentation (e.g., pedicle fixation, dual rods with multiple hooks and sublaminar wires); 7 to 12 vertebral segments |
| 22844     | Posterior segmental instrumentation (e.g., pedicle fixation, dual rods with multiple hooks and sublaminar wires); 13 or more vertebral segments |
| 22846     | Anterior instrumentation; 4 to 7 vertebral segments                                              |
| 22847     | Anterior instrumentation; 8 or more vertebral segments                                           |
| 22848     | Pelvic fixation                                                                                 |

Abbreviation: CPT, Current Procedural Terminology.
cardiopulmonary resuscitation prior to surgery; patients undergoing a nonelective procedure; and cases with diagnoses of cervical spine trauma or injury or neoplasm of the spine.

Propensity-Score Matching
Propensity-score matching allowed for reduction of the risk of selection bias within this population. This reduction was particularly important as the pool of patients with pelvic fixation was small (n = 415) and the number of patients without pelvic fixation was much larger (n = 3,233). Propensity scores were assigned to patients in each cohort (with or without pelvic fixation) based on several preoperative factors including patient demographics, operative information (primary posterior versus primary anterior approach, osteotomy, bone graft, intervertebral device insertion, and total relative value units [RVUs]), and preoperative comorbidities. The process of matching was 1:1 and performed by selecting one patient from the pelvic fixation cohort and matching the patient with one in the non–pelvic fixation cohort with the closest propensity score. Comparisons for postoperative morbidity and mortality were conducted only on the matched cohorts. Propensity-score matching has been well described in the literature.21–25 Matching was performed using R Software (Vienna, Austria, http://www.R-project.org/) package "MatchIt."26

Variable Definitions
Several comorbidities were grouped into the following categories: pulmonary, renal, cardiac, and peripheral vascular disease and neuromuscular injury. Pulmonary comorbidity included a history of severe chronic obstructive pulmonary disease or ventilator dependence during the 48 hours preceding surgery. Renal comorbidity included dialysis or acute renal failure. Cardiac comorbidity included a history of congestive heart failure within 30 days before admission or hypertension requiring medication. Obesity was defined as a body mass index ≥ 30, per World Health Organization guidelines. Patients were characterized as smokers by the ACS-NSQIP if they had smoked cigarettes in the year prior to admission for surgery. Using the list of CPT codes described in the work by Martin et al.,27 patients were categorized according to the type of surgical procedure performed.

This study’s definition of morbidity included all ACS-NSQIP-defined complications, including the need for an intra- or postoperative blood transfusion. The scope of this study extended further to mortality, return to operating room, unplanned reoperation, unplanned readmission, extended operative time (>4 hours), and extended length of hospital stay (>5 days).

Statistical Analysis
Descriptive and comparative statistics of demographics, comorbidities, operative details, and postoperative complications were analyzed for all patients. In the univariate analysis, categorical variables were assessed using Pearson chi-square or Fisher exact test where appropriate. Continuous variables were examined using one-way analysis of variance test. Preoperative variables with a \( p < 0.2 \) in the univariate analysis were carried forward into the multivariate analysis, as has been demonstrated in previous studies.28 This specific selection criterion was used to consider as many potential risk factors as possible without compromising the validity of regression models. Stepwise multivariate logistic regression analysis was used to determine the independent risk factors for each postoperative complication based on this criterion. A \( p \) value < 0.05 was considered significant; 95% confidence intervals (CIs) are reported for each odds ratio (OR) and can be interpreted as being 95% certain the true odds ratio falls between this range. SAS software (Version 9.3, SAS Institute, Inc., Cary, North Carolina, United States) was used for all statistical analyses.

Results
In the unmatched cohorts, patients with pelvic fixation were more likely to be female \( (p = 0.0002) \) and be between the ages of 61 and 70 years \( (p < 0.0001) \). They were less likely to be of Black or African American race \( (p = 0.0103) \), to have American Society of Anesthesiologists (ASA) score ≥ 3 \( (p < 0.0001) \), and to smoke \( (p < 0.0001) \). They had higher total RVUs \( (p < 0.0001) \); \( \textit{Table 2} \). Additionally, the pelvic fixation cohort was more likely to have cardiac comorbidity \( (p = 0.0287); \textit{Table 3} \).

After propensity matching, there were no significant differences in patient demographics or preoperative comorbidities between the two cohorts (\( \textit{Tables 2} \) and 3), except for race \( (p < 0.0001) \).

Univariate Analysis
Pelvic fixation was associated with greater overall morbidity \( (p < 0.0001) \), higher rate of intra- and postoperative transfusion \( (p < 0.0001) \), higher likelihood for operative time > 4 hours \( (p < 0.0001) \), and extended length of stay > 5 days \( (p < 0.0001) \). Importantly, the pelvic fixation cohort had no additional risk for wound complications \( (p = 0.3191) \). All other complications studied showed no statistical difference as well (\( \textit{Table 4} \)).

Multivariate Analysis
The multivariate analysis showed that pelvic fixation was a significant predictor of overall morbidity \( (OR = 2.3, 95\% CI: 1.7 \text{ to } 3.1, p = 0.0002) \), intra- or postoperative blood transfusion \( (OR = 2.3, 95\% CI: 1.7 \text{ to } 3.1, p < 0.0001) \), extended operative time \( (OR = 4.7, 95\% CI: 3.1 \text{ to } 7.0, p < 0.0001) \), and length of stay > 5 days \( (OR = 2.1, 95\% CI 1.5 \text{ to } 2.8, p < 0.0001) \) in patients undergoing fusion for spinal deformity (\( \textit{Table 5} \)).

Discussion
This investigation presents a comparative analysis on 830 patients undergoing spinal fusion for ASD, divided into propensity-matched cohorts based on the additional procedure of pelvic fixation. Few studies have directly evaluated the differences in short-term complication rates between...
patients with ASD who underwent spinal fusion with and without pelvic fixation, and to our knowledge, none have been performed using a large national database such as the ACS-NSQIP. The present study revealed that intraoperative or postoperative transfusion, operative time, and length of stay were significantly greater in the pelvic fixation cohort (►Table 5). However, no other complications were found to be statistically different between the two cohorts (►Table 4).

A major finding of this analysis was that pelvic fixation itself did not increase the incidence of wound complications (superficial and deep surgical site infections, organ space infection, and wound dehiscence, $p = 0.3191$; ►Table 4). In the unmatched cohort comparison, patients with pelvic fixation were older (63.4 versus 58.4 years, $p < 0.0001$). Previously, age has been shown to be a significant risk factor for wound complications in several studies focused on spinal fusion (►Table 2).$^{29-31}$ Patients having pelvic fixation were also more likely to have ASA class of $\geq 3$ (66.1 versus 54.8%, $p < 0.0001$; ►Table 2). Higher ASA score has also been correlated with an increased risk of wound complications in spinal fusion surgeries.$^{32}$ When adjusted for risk factors, there was no longer any statistical difference in the wound complications between the two cohorts, indicating that patient-related factors may have played a more significant role than pelvic fixation.

Based on the multivariate analysis, pelvic fixation was an independent risk factor (OR = 2.3, $p < 0.0001$) for intra- or postoperative transfusion (►Table 5). These findings were consistent with previous studies.$^{10,11}$ Overall, 73.5% of patients having pelvic fixation required blood transfusion compared with 54.9% of patients not having pelvic fixation who required transfusion, which was statistically significant.

### Table 2 Demographics and clinical characteristics

|                           | No pelvic fixation | Pelvic fixation, matched (n = 415) | $p$ Value |
|---------------------------|-------------------|-----------------------------------|-----------|
|                           | Unadjusted (n = 3,233) | Matched (n = 415) | Unadjusted | Matched |
| Sex                       |                   |                                   |           |
| Female                    | 1,809             | 55.89                             | 1,272      | 65.5     | 0.0002 | 0.5140 |
| Male                      | 1,424             | 44.11                             | 1,143      | 34.5     |         |        |
| Age (y)                   |                   |                                   |           |
| <50                       | 787               | 24.3                              | 48        | 11.5     | <0.0001 | 0.3521 |
| 51–60                     | 881               | 27.3                              | 75        | 18.0     |         |        |
| 61–70                     | 980               | 30.3                              | 170       | 40.9     |         |        |
| 71–80                     | 495               | 15.3                              | 106       | 25.5     |         |        |
| >80                       | 90                | 2.8                               | 17        | 4.1      |         |        |
| Race                      |                   |                                   |           |
| Caucasian                 | 2,620             | 81.0                              | 340       | 81.7     | 0.0103 | <0.0001 |
| Black                     | 276               | 8.5                               | 19        | 4.6      |         |        |
| Hispanic                  | 116               | 3.6                               | 16        | 3.9      |         |        |
| Other                     | 221               | 6.8                               | 41        | 9.9      |         |        |
| Obesity                   | 1,311             | 40.6                              | 180       | 43.3     | 0.2708 | 0.6737 |
| ASA score $\geq 3$        | 1,772             | 54.8                              | 275       | 66.1     | <0.0001 | 0.5541 |
| Smoke                     | 730               | 22.6                              | 55        | 13.2     | <0.0001 | 0.8390 |
| Dyspnea                   | 206               | 6.4                               | 29        | 7.0      | 0.6303 | >0.9999 |
| Dependent functional status| 161              | 5.0                               | 27        | 6.5      | 0.1855 | 0.2249 |
| Total relative value units| 72.02 (28.63)     | 100.7 (32.99)                    | 100.7 (27.91) | <0.0001 | 0.9942 |
| Bone graft                | 2,292             | 70.9                              | 318       | 76.6     | 0.0148 | 0.6790 |
| Osteotomy                 | 415               | 12.8                              | 246       | 59.3     | <0.0001 | 0.3255 |
| Intervertebral device insertion | 1,224            | 37.9                              | 144       | 34.7     | 0.2105 | 0.3014 |
| Anterior approach         | 1,768             | 54.7                              | 12        | 2.9      | <0.0001 | 0.6290 |

Abbreviation: ASA, American Society of Anesthesiologists.
Ramo et al. concluded that the addition of pelvic fixation to spinal fusion surgery caused additional complications simply because pelvic fixation was a proxy for increased operative time. However, on multivariate analysis, pelvic fixation was found to be a risk factor independent of operative time for intra- or postoperative transfusion.

The literature has shown increased blood transfusion to be associated with increased postsurgical morbidity and mortality. These studies have been unable to conclude if the high complication rate was a product of preoperative anemia or the transfusion itself. Dunne et al. concluded that preoperative anemia was the risk factor and that blood transfusion was simply correlated to peri- or postoperative anemia. However, Schwarzkopf et al. hypothesized that blood transfusions have modulatory effects on the immune system of recipients leading to greater infection rates. Furthermore, a recent meta-analysis between programs with liberal versus restrictive blood transfusion programs in Europe showed that a restrictive transfusion protocol led to decreased hospital...

### Table 3 Preoperative comorbidities

|                          | No pelvic fixation | Pelvic fixation, matched | p Value |
|--------------------------|-------------------|--------------------------|---------|
|                          | Unadjusted (n = 3,233) | Matched (n = 415) | Matched |
| Pulmonary comorbidity    | 174 5.4            | 20 4.8                   | 30 7.2  | 0.1232 0.1446 |
| Cardiac comorbidity      | 1,720 53.2         | 253 61.0                 | 245 58.9 | 0.0248 0.5708 |
| Renal comorbidity        | 18 0.6             | 4 1.0                    | 3 0.7   | 0.6737 0.7043 |
| Steroid use              | 121 3.7            | 6 1.4                    | 9 2.2   | 0.1035 0.4344 |
| Recent weight loss       | 6 0.2              | 1 0.2                    | 1 0.2   | 0.8083 >0.9999 |
| Bleeding disorder        | 37 1.1             | 3 0.7                    | 4 1.0   | 0.7425 0.7043 |
| Preoperative transfusion | 9 0.3              | 3 0.7                    | 0 0.0   | 0.2819 – |
| Diabetes                 | 472 14.6           | 60 14.5                  | 58 13.9 | 0.7343 0.8424 |

### Table 4 Thirty-day postoperative complications

| Complication                           | No pelvic fixation, matched (n = 415) | Pelvic fixation, matched (n = 415) | p Value (matched) |
|----------------------------------------|--------------------------------------|------------------------------------|-------------------|
| Operative duration > 4 h               | 321 77.3                             | 383 92.1                           | <0.0001           |
| Any complication                       | 246 59.3                             | 318 76.6                           | <0.0001           |
| Death                                  | 5 1.2                                | 5 1.2                              | >0.9999           |
| Wound complication                     | 16 3.9                               | 22 5.3                             | 0.3191            |
| Pulmonary complication                 | 27 6.5                               | 26 6.3                             | 0.8871            |
| Renal complication                     | 14 3.4                               | 9 2.2                              | 0.2904            |
| Central nervous system complication    | 1 0.2                                | 3 0.7                              | 0.3161            |
| Peripheral nerve complication          | 0 0.0                                | 1 0.2                              | 0.317             |
| Venous thromboembolism                | 13 3.1                               | 22 5.3                             | 0.1201            |
| Sepsis                                 | 17 4.1                               | 17 4.1                             | >0.9999           |
| Cardiac complication                   | 4 1.0                                | 3 0.7                              | 0.7043            |
| Intra-/postoperative blood transfusion | 228 54.9                             | 305 73.5                           | <0.0001           |
| Urinary tract infection                | 19 4.6                               | 16 3.9                             | 0.6044            |
| Unplanned readmission                  | 37 8.9                               | 29 7.0                             | 0.0840            |
| Total length of stay > 5 d             | 234 56.4                             | 303 73.0                           | <0.0001           |
| Unplanned reoperation                  | 25 6.0                               | 26 6.3                             | 0.8851            |
mortality and postoperative infections, adding weight to the thought that transfusions may have deleterious effects on patient outcome. A better understanding of pelvic fixation as a risk factor for blood transfusion may lead to the implementation of interventions designed to control excessive bleeding. Additionally, more stringent patient blood management programs, such as those that are in place in Europe, may have value in this regard.

Another major finding was that pelvic fixation was an independent risk factor for extended operative time (>4 hours; OR = 4.7, p < 0.0001; Table 5). This finding is natural, because extending instrumentation to the pelvis was likely performed with long fusion constructs and the fixation itself was an additional procedure. Nonetheless, it is important to be mindful of extensive operative time when risk-stratifying patients with ASD. Operative time is particularly important because it is correlated to higher morbidity, particularly infection, in spinal fusion surgeries. Tang et al hypothesized that direct contact with the sterile field, airborne contamination from traffic, and loss of sterile technique become more likely with extended operative time. Dalstrom et al conducted a study in a simulated operating room environment and found a significant correlation between the length of time that the sterile tray was exposed to the air and the contamination rate of the instruments. Additionally, studies in general and vascular surgery and neurosurgery studies showed that operative time increased the likelihood of venous thromboembolism. In fact, venous thromboembolism had a higher incidence in the pelvic fixation cohort in our analysis (5.3 versus 3.1%) but was not statistically significant (p = 0.1201).

Finally, the greater length of stay with patients undergoing pelvic fixation is a more complex finding that may be attributed to several causes. Greater operative times and higher rates of transfusion are independent predictors for greater length of stay as shown by Basques et al in spinal fusion. Possible reasons for extended hospitalization may include the generally higher overall rates of complication (76.6 versus 59.3%, p < 0.00001), compared with the cohort without pelvic fixation.

There were several limitations to this study. Different techniques for pelvic fixation exist and are associated with different complication rates. Because this study was performed using CPT codes, only the general procedure was accounted for, so it was not possible to determine the effect of specific techniques used. Furthermore, patients were matched by total relative value units to account for case mix, fusion approach, and additional operative features such as pedicle subtraction osteotomy. Notably, matching by additional characteristics was not feasible given the handicap of working with CPT codes. For example, matching was not conducted to ensure nonsignificant differences in the number of patients who had posterior-only approaches versus those who had an adjunct anterior or lateral interbody fusion in conjunction with posterior fusion. Additionally, in multivariate analysis, the interaction effects between variables were not considered or adjusted for.

The ACS-NSQIP database itself poses several additional limitations. First, information was not captured on the severity of the deformity being treated. For example, no radiographic parameters were captured that would indicate the degree of deformity in the sagittal or coronal plane. However, this issue was addressed by isolating only the cohort of patients who underwent fusions that were greater than four levels with anterior approach and greater than six levels with posterior approach. Furthermore, patients with and without pelvic fixation were propensity-matched with anterior versus posterior approach, total RVUs, and use of pedicle subtraction osteotomy to ensure both cohorts were similar with respect to complexity of the deformity surgery. Additionally, the specific long-term outcomes relevant to spinal fusion such as pseudarthrosis and loss of correction are not captured by the ACS-NSQIP database. This lack of data did not allow us to study the efficacy of pelvic fixation in preventing these complications, although several previous studies have already demonstrated that pelvic fixation does indeed lead to decreased pseudarthrosis rates. Instead, the ACS-NSQIP database only allowed us to understand the short-term morbidity risk of pelvic fixation adjunct to fusion. These limitations are inherent to retrospective analysis conducted on data collected without the specific research question in mind.

The ACS-NSQIP database is also not representative of all U.S. hospitals, because academic medical centers are over-represented in the database. Academic medical centers are significantly different from community hospitals in terms of dedication to using the latest research to improve outcomes and the general profile of patients seen. Furthermore, variations or errors in coding of procedures, comorbidities, and complications may naturally be present and cannot be accounted for. Additionally, creating binary values of "yes" or "no" for comorbidities such as diabetes or chronic obstructive pulmonary disease that have a range of presentation and progression does not fully capture the true profile of that particular patient. Finally, the observation period for morbidity, mortality, and other surgical outcomes was limited to 30 days after surgery. Thus, longer-term complications were not captured, leading to potential underestimation of the risk profile for these surgical procedures.

Despite these limitations, this study was one of the largest examining pelvic fixation as part of spinal deformity surgery in adults. Pelvic fixation was found to increase the risk for overall postoperative morbidity, intra- or postoperative blood

Table 5 Adjusted ORs for selected outcomes for pelvic fixation (n = 832)

| Outcome                     | OR   | 95% CI  | p Value  |
|------------------------------|------|---------|----------|
| Any complications            | 2.3  | 1.7–3.1 | 0.0002   |
| Intra-/postoperative         | 2.3  | 1.7–3.1 | <0.0001  |
| transfusion                  |      |         |          |
| Length of stay > 5 d         | 2.1  | 1.5–2.8 | <0.00001 |
| Operative time > 4 h         | 4.7  | 3.1–7.0 | <0.0001  |

Abbreviations: CI, confidence interval; OR, odds ratio.
transfusion, extended operative time, and extended length of hospitalization. However, there was no increase in any other complications examined. Thus, its use should be encouraged for situations in which it may augment the correction of deformity and reduce rates of pseudarthrosis and implant failure. Future studies should consider the impact of pelvic fixation on complications beyond the 30-day period captured by the ACS-NSQIP.

Disclosures
Parth Kothari: none
Sulaiman Somani: none
Nathan J. Lee: none
Javier Z. Guzman: none
Dante M. Leven: none
Branko Skovrlj: none
Jeremy Steinberger: none
Jun Kim: none
Samuel K. Cho: Consultant (Stryker); Research support (Zimmer)

Note
This study was qualified as exempt by the Mount Sinai Hospital Institutional Review Board.

References
1. Youssef JA, Ormordoff DO, Patty CA, et al. Current status of adult spinal deformity. Global Spine J 2013;3(1):51–62
2. Schwab F, Dubey A, Gamez L, et al. Adult scoliosis: prevalence, SF-36, and nutritional parameters in an elderly volunteer population. Spine (Philp Pa 1976) 2005;30(9):1082–1085
3. Sciubba DM, Scheer JK, Yurter A, et al; the International Spine Study Group (ISSG). Patients with spinal deformity over the age of 75: a retrospective analysis of operative versus non-operative management. Eur Spine J 2015; February 5
4. Cowan JA Jr, Dimick JB, Wainess R, Upchurch GR Jr, Chandler WF, LaMarca F. Changes in the utilization of spinal fusion in the United States. Neurosurgery 2006;59(1):15–20, discussion 15–20
5. Bradford DS, Tay BK, Hu SS. Adult scoliosis: surgical indications, operative management, complications, and outcomes. Spine (Philp Pa 1976) 1999;24(24):2617–2629
6. Moshirfar A, Rand RF, Sponseller PD, et al. Pelvic fixation in spine surgery. Historical overview, indications, biomechanical relevance, and current techniques. J Bone Joint Surg Am 2005;87(Suppl 2):89–106
7. Shen FH, Mason JR, Shimer AL, Arlet VM. Pelvic fixation for adult scoliosis. Eur Spine J 2013;22(Suppl 2):S265–S275
8. Kaloostian PE, Gokaslan ZL. Primary lumbar pelvic fixation versus revision pelvic fixation for adult spinal deformity: a case-specific approach. World Neurosurg 2014;82(3–4):e443–e445
9. Ramo BA, Roberts DW, Tiuson D, et al. Surgical site infections after posterior spinal fusion for neuromuscular scoliosis: a thirty-year experience at a single institution. J Bone Joint Surg Am 2014;96(24):2038–2048
10. Sengupta DK, Mehdian SH, McConnell JR, Eisenstein SM, Webb JK. Pelvic or lumbal fixation for the surgical management of scoliosis in Duchenne muscular dystrophy. Spine (Philp Pa 1976) 2002;27(18):2072–2079
11. McCall RE, Hayes B. Long-term outcome in neuromuscular scoliosis fused only to lumbar 5. Spine (Philp Pa 1976) 2005;30(18):2056–2060
12. Kuklo TR, Bridwell KH, Lewis SJ, et al. Minimum 2-year analysis of sacropelvic fixation and L5–S1 fusion using S1 and iliac screws. Spine (Philp Pa 1976) 2001;26(18):1976–1983
13. Peelle MW, Lenke LG, Bridwell KH, Sides B. Comparison of pelvic fixation techniques in neuromuscular spinal deformity correction: Galveston rod versus iliac and lumbosacral screws. Spine (Philp Pa 1976) 2006;31(20):2392–2398, discussion 2399
14. Ilyas H, Place H, Puryear A. A comparison of early clinical and radiographic complications of iliac screw fixation versus s2 alar iliac (S2ai) fixation in the adult and pediatric populations. J Spinal Disord Tech 2015;28(4):E199–E205
15. Bellabarba C, Schildhauer TA, Vaccaro AR, Chapman JR. Complications associated with surgical stabilization of high-grade sacral fracture dislocations with spino-pelvic instability. Spine (Philp Pa 1976) 2006;31(11, Suppl):S80–S88, discussion S104
16. Ould-Slimane M, Miladi L, Rousseau MA, et al. Sacropelvic fixation with iliosacral screws: applications and results in adult spinal deformities. J Spinal Disord Tech 2013;26(4):212–217
17. Cho W, Mason JR, Smith JS, et al. Failure of lumbopelvic fixation after long construct fusions in patients with adult spinal deformity: clinical and radiographic risk factors: clinical article. J Neurosurg Spine 2013;19(4):445–453
18. Fink AS, Campbell DA Jr, Mentzer RM Jr, et al. The National Surgical Quality Improvement Program in non-veterans administration hospitals: initial demonstration of feasibility. Ann Surg 2002;236(3):344–353, discussion 353–354
19. Khuri SF, Henderson WG, Daley J, et al; Principal Investigators of the Patient Safety in Surgery Study. Successful implementation of the Department of Veterans Affairs’ National Surgical Quality Improvement Program in the private sector: the Patient Safety in Surgery study. Ann Surg 2008;248(2):329–336
20. American College of Surgeons. User Guide for the 2012 ACS NSQIP Participant Use Data File. Available at: https://www.facs.org/quality-programs/acs-nsqip/program-specifics/participant-use
21. Duchman KR, Gao Y, Pugely AJ, Martin CT, Callaghan JJ. Differences in short-term complications between unicompartmental and total knee arthroplasty: a propensity score matched analysis. J Bone Joint Surg Am 2014;96(16):1387–1394
22. Boening A, Friedrick C, Hedderich J, Schoettler J, Fraund S, Cremer JT. Early and medium-term results after on-pump and off-pump coronary artery surgery: a propensity score analysis. Ann Thorac Surg 2003;76(6):2000–2006
23. Milton RC, Sperduto RD, Clemons TE, Ferris FL III; Age-Related Eye Disease Study Research Group. Centrum use and progression of age-related cataract in the Age-Related Eye Disease Study: a propensity score approach. AREDS report No. 21. Ophthalmology 2006;113(8):1264–1270
24. Austin PC, Grootendorst P, Anderson GM. A comparison of the ability of different propensity score models to balance measured variables between treated and untreated subjects: a Monte Carlo study. Stat Med 2007;26(4):734
25. Vikram HR, Buenconsejo J, Hashbun R, Quagliarello VJ. Impact of valve surgery on 6-month mortality in adults with complicated, left-sided native valve endocarditis: a propensity analysis. JAMA 2003;290(24):3207–3214
26. Ho D, Imai K, King G, Stuart E. Matchit: nonparametric preprocessing for parametric causal inference. J Stat Softw 2011;42(8):1–28
27. Martin CT, Pugely AJ, Gao Y, Ilgenfritz RM, Weinstein SL. Incidence and risk factors for early wound complications after spinal arthrodesis in children: analysis of 30-day follow-up data from the ACS-NSQIP. Spine (Philp Pa 1976) 2014;39(18):1463–1470
28. Buerba RA, Fu MC, Grauer JN. Anterior and posterior cervical fusion in patients with high body mass index are not associated with greater complications. Spine J 2014;14(8):1643–1653
29 Kim YJ, Bridwell KH, Lenke LG, Rinella AS, Edwards C II. Pseudarthrosis in primary fusions for adult idiopathic scoliosis: incidence, risk factors, and outcome analysis. Spine (Phila Pa 1976) 2005;30(4):468–474
30 Lippman CR, Spence CA, Youssef AS, Cahill DW. Correction of adult scoliosis via a posterior-only approach. Neurosurg Focus 2003;14(1):e5
31 Takahashi S, Delécrin J, Passuti N. Surgical treatment of idiopathic scoliosis in adults: an age-related analysis of outcome. Spine (Phila Pa 1976) 2002;27(16):1742–1748
32 Pateder DB, Gonzales RA, Kebaish KM, Cohen DB, Chang JY, Kostuik JP. Short-term mortality and its association with independent risk factors in adult spinal deformity surgery. Spine (Phila Pa 1976) 2008;33(11):1224–1228
33 Glance LG, Dick AW, Mukamel DB, et al. Association between intraoperative blood transfusion and mortality and morbidity in patients undergoing noncardiac surgery. Anesthesiology 2011;114(2):283–292
34 Dunne JR, Malone D, Tracy JK, Gannon C, Napolitano LM. Perioperative anemia: an independent risk factor for infection, mortality, and resource utilization in surgery. J Surg Res 2002;102(2):237–244
35 Malone DL, Genuit T, Tracy JK, Gannon C, Napolitano LM. Surgical site infections: reanalysis of risk factors. J Surg Res 2002;103(1):89–95
36 Schwarzkopf R, Chung C, Park JJ, Walsh M, Spivak JM, Steiger D. Effects of perioperative blood product use on surgical site infection following thoracic and lumbar spinal surgery. Spine (Phila Pa 1976) 2010;35(3):340–346
37 Rohde JM, Dimcheff DE, Blumberg N, et al. Health care-associated infection after red blood cell transfusion: a systematic review and meta-analysis. JAMA 2014;311(13):1317–1326
38 Carson JL, Carlsson PA, Hebert PC. Transfusion thresholds and other strategies for guiding allogeneic red blood cell transfusion. Cochrane Database Syst Rev 2012;4:CD002042
39 Spahn DR, Goodnough LT. Alternatives to blood transfusion. Lancet 2013;381(9880):1855–1865
40 Tang H, Zhu J, Ji F, Wang S, Xie Y, Fei H. Risk factors for postoperative complication after spinal fusion and instrumentation in degenerative lumbar scoliosis patients. J Orthop Surg 2014;9(1):15
41 Veeravagu A, Patil CG, Lad SP, Boakye M. Risk factors for postoperative spinal wound infections after spinal decompression and fusion surgeries. Spine (Phila Pa 1976) 2009;34(17):1869–1872
42 Dalstrom DJ, Venkatarayappa I, Manternach AL, Palcic MS, Heyse BA, Prayson MJ. Time-dependent contamination of opened sterile operating-room trays. J Bone Joint Surg Am 2008;90(5):1022–1025
43 Daley BJ, Cecil W, Clarke PC, Cofer JB, Guillamondegui OD. How slow is too slow? Correlation of operative time to complications: an analysis from the Tennessee Surgical Quality Collaborative. J Am Coll Surg 2015;220(4):550–558
44 Kimmell KT, Walter KA. Risk factors for venous thromboembolism in patients undergoing craniotomy for neoplastic disease. J Neurooncol 2014;120(3):567–573
45 Montagnana M, Favaloro EJ, Franchini M, Guidi GC, Lippi G. The role of ethnicity, age and gender in venous thromboembolism. J Thromb Thrombolysis 2010;29(4):489–496
46 Zhang ZH, Shen B, Yang J, Zhou ZK, Kang PD, Pei FX. Risk factors for venous thromboembolism of total hip arthroplasty and total knee arthroplasty: a systematic review of evidences in ten years. BMC Musculoskelet Disord 2015;16(1):24
47 Basques BA, Fu MC, Buerra RA, Bohl DD, Colvinvaux NS, Grauer JN. Using the ACS-NSQIP to identify factors affecting hospital length of stay after elective posterior lumbar fusion. Spine (Phila Pa 1976) 2014;39(6):497–502
48 Schilling PL, Hallstrom BR, Birkmeyer JD, Carpenter JE. Prioritizing perioperative quality improvement in orthopaedic surgery. J Bone Joint Surg Am 2010;92(9):1884–1889
49 Schoenfeld AJ, Ochoa LM, Bader JO, Belmont PJ Jr. Risk factors for immediate postoperative complications and mortality following spine surgery: a study of 3475 patients from the National Surgical Quality Improvement Program. J Bone Joint Surg Am 2011;93(17):1577–1582