



Early clinical outcomes and medical complications following long segment fusion for adult spinal deformity with and without three column osteotomy

Simon G. Ammanuel^{*}, Paul S. Page, Garret P. Greenaway, Darius Ansari, James A. Stadler

Department of Neurological Surgery, University of Wisconsin Hospital and Clinics, Madison, WI, 53792, United States

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ABSTRACT

Background: Surgical treatment of adult spinal deformity (ASD) commonly involves long-segment fusion with or without three column osteotomies (3CO) to provide satisfactory correction of sagittal and coronal balance. While some clinical studies have implicated 3CO as a driver of high surgical complication rates, these prior investigations are limited by small sample size. Herein, we compare early outcomes and adverse events in patients undergoing long segment posterior spinal fusion for ASD with and without 3CO.

Methods: A multicenter administrative database was queried for patients undergoing elective posterior spinal fusion for ASD. Patients were stratified based upon long segment fusion with and without 3CO. Preoperative patient demographics, procedural characteristics, hospitalization events, and postoperative complication rates were evaluated. Student's *t*-test and Fisher's exact test were utilized where appropriate to compare differences between the two groups for continuous and categorical variables.

Results: 340 cases met the inclusion criteria, of which 156 involved 3CO. Patients who required 3CO had a lower rate of preoperative diabetes (22.3 % vs 10.3 %, $p = 0.003$), higher rates of non-home discharge (26.2 % vs 57.1 %, $p < 0.001$), longer operation time (245.62 ± 9.45 vs. 434.40 ± 11.65 , $p < 0.001$), and longer length of stay (4.17 ± 0.66 vs. 7.76 ± 0.83 , $p < 0.001$). In terms of complications, 3CO patients had higher rates of deep surgical site infection (0 % vs 3.2 %, $p = 0.02$), reintubation (0 % vs 4.5 %, $p = 0.004$), inability to wean off ventilator (0 % vs 2.6 %, $p = 0.04$), and perioperative blood transfusion (20.1 % vs 76.3 %, $p < 0.001$).

Conclusions: In this retrospective analysis, posterior 3CO was frequently undertaken but associated with higher risk for postoperative adverse events following spinal deformity correction.

1. Introduction

The correction of sagittal and coronal imbalance, in the setting of adult spinal deformity, has demonstrated significant impact on health-related quality of life outcome scores and patient satisfaction in numerous studies to date. Osteotomy is a surgical technique commonly employed in spinal deformity surgery to achieve adequate correction. Of these, three column osteotomies (3CO), including vertebral column resection (VCR) and pedicle subtraction osteotomies (PSO), have been shown to have the highest complication rates and resultantly are reserved for cases of rigid deformity.^{2,3,14,15} Despite their ability to provide large amount of correction to the rigid spine, these procedures are associated with high complication rates in regards to medical and

surgical complications in the early and late post-operative period.^{5,6,10,16}

The complication rate associated with three column osteotomies has been previously described in the literature in only small retrospective series.^{2,4,13} While a more comprehensive review was conducted by the international spine study group (ISSG), the series suffers from the limitation of potentially underestimating the complication rate of these procedures as their results reflect only those at the tertiary care facilities rather than the national population.¹⁷ To this end, we utilize the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database to accurately quantify the medical complications associated with 3CO in the setting of long segment fusion for adult spinal deformity.

Abbreviations: ACS-NSQIP, American College of Surgeons National Surgical Quality Improvement Program; ASA, American Society of Anesthesiologists; ASD, Adult spinal deformity; CCI, Charlson Comorbidity Index; CPT, Current Procedural Terminology; 3CO, Three column osteotomies; ICD, International Classification of Diseases; ISSG, International spine study group; PSO, Pedicle subtraction osteotomies; VCR, Vertebral column resection.

^{*} Corresponding author. Department of Neurological Surgery University of Wisconsin Hospitals and Clinics, 600 Highland Ave Madison, Wisconsin, United States.

E-mail address: sammanuel@uwhealth.org (S.G. Ammanuel).

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2. Methods

Data were abstracted from the ACS-NSQIP database from years 2015–2020. The ACS-NSQIP contains patient-level data regarding medical comorbidities, procedural characteristics, and 30-day adverse events from >500 hospitals in the United States. As the ACS-NSQIP data are deidentified and publicly available, this study is not considered human subject research by the institutional review board at our institution, and thus patient consent was not required nor sought.

The database was queried for all patients undergoing elective posterior spinal fusion identified by Current Procedural Terminology (CPT) codes 22842, 22843, and 22844. The use of three column osteotomy was identified with CPT codes 22206 and 22207. Patients were only included if the primary International Classification of Diseases (ICD) 9 and 10 codes for the indexed encounter were identified as adult spine deformity. Patients under the age of 18 were excluded from the analysis.

Following this, patients’ baseline demographic characteristics and risk factors were identified and compared, including Charlson Comorbidity Index (CCI), American Society of Anesthesiologist class (ASA), wound classification, and additional medical comorbidities as provided by the NSQIP database. Primary clinical end points collected were operative duration, length of inpatient hospital stay, adverse events, and 30-day readmission rates following the indexed procedure. Adverse events were defined according to the American College of Surgeons guidelines as unplanned readmission, reoperation within 30 days, surgical site infections, organ space infection, unplanned intubation, wound complications, renal insufficiency, acute renal failure, pneumonia, pulmonary embolism, deep vein thrombosis, urinary tract infections, stroke, myocardial infarction, cardiac arrest, blood transfusion, septic shock, and sepsis.

Student’s *t*-test and Fisher’s exact test were used to compared differences between two groups for continuous and categorical variables. All statistics were conducted in SPSS Version 28 (IBM Corporation).

3. Results

In total 340 patients were identified as undergoing long segment fusions with or without 3CO for adult spinal deformity. Of this cohort, 184 patients did not undergo 3CO while 156 patients did require 3CO. There were no statistically significant differences between the two cohorts with regards to medical comorbidities and baseline demographics, except for a lower rate of diabetes among those not undergoing osteotomy (22.4 % vs 10.3 %, *p* = 0.001, Table 1).

Compared to those not undergoing 3CO, patients undergoing 3CO were significantly less likely to be discharged home (42.9 % vs. 73.8 %, *p* < 0.001), had longer mean operative duration (434.40 ± 11.65 vs. 245.62 ± 9.45, *p* < 0.001), and had longer inpatient length of stay (7.76 ± 0.83 vs. 4.17 ± 0.66, *p* < 0.001). There was no statistically significant difference in 30-day readmission rates between the two study cohorts (6.0 % vs 6.4 %, *p* = 1.00).

With regards to medical complications, patients undergoing 3CO experienced significantly higher rates of deep surgical site infection (3.2 % vs. 0 %, *p* = 0.02), reintubation (4.5 % vs. 0 %, *p* = 0.004), inability to wean off ventilator (2.6 % vs. 0 %, *p* = 0.04), and perioperative blood transfusion (76.3 % vs. 20.1 %, *p* < 0.001). There were no significant differences between the two cohorts in any additional reported complications including 30-day reoperation rate, unplanned readmission, stroke, myocardial infarction, deep venous thrombosis, or sepsis (*p* > 0.05, Table 2). In terms of overall complication rates, 80.1 % of patients who required 3CO experienced at least one complication, compared to 26.5 % of patients not undergoing 3CO (*p* < 0.001).

4. Discussion

In cases of rigid adult spinal deformity, the use of three column osteotomies allow for significant deformity correction, however are

Table 1
Baseline patient characteristics.

Variables	No Osteotomy (n = 184)	Three Column Osteotomy (n = 156)	p-value
Demographics			
Geriatric Age (≥ 65)	77 (41.8 %)	72 (46.2 %)	0.44
BMI	31.3 ± 0.51	30.1 ± 0.51	0.13
Male sex	81 (55.1 %)	66 (42.3 %)	0.83
Race			
White	139 (75.5 %)	111 (71.2 %)	0.13
Black	18 (9.8 %)	17 (10.9 %)	
Asian	8 (4.3 %)	2 (1.3 %)	
Native American	0 (0.0 %)	2 (1.3 %)	
Unknown	19 (10.3 %)	24 (15.4 %)	
Comorbidities			
Diabetes	41 (22.3 %)	16 (10.3 %)	0.003
Current Smoker	39 (21.2 %)	25 (16.0 %)	0.27
Dyspnea	12 (6.5 %)	12 (7.7 %)	0.68
Independent status	175 (95.1 %)	147 (94.8 %)	1.00
COPD	12 (6.5 %)	12 (7.7 %)	0.68
Ascites	1 (0.5 %)	0 (0.0 %)	1.00
CHF	5 (2.7 %)	0 (0.0 %)	0.07
Hypertension	113 (61.4 %)	86 (55.1 %)	0.27
Renal Failure	0 (0.0 %)	0 (0.0 %)	–
Dialysis	2 (1.1 %)	0 (0.0 %)	0.50
Cancer	5 (2.7 %)	1 (0.6 %)	0.22
Chronic Steroid Use	9 (4.9 %)	14 (9.0 %)	0.19
Weight loss	2 (1.1 %)	0 (0.0 %)	0.50
Sepsis/Septic Shock	0 (0.0 %)	0 (0.0 %)	–
ASA >2	108 (58.7 %)	107 (68.6 %)	0.07
Clean Wound Class	181 (98.4 %)	152 (97.4 %)	0.71
Outcomes Measures			
Home discharge	135 (73.8 %)	67 (42.9 %)	<0.001
Operation time	245.62 ± 9.45	434.40 ± 11.65	<0.001
Total length of stay	4.17 ± 0.66	7.76 ± 0.83	<0.001
30 Day Readmission	11 (6.0 %)	10 (6.4 %)	1.00

Table 2
Rate of complications.

Variables	No Osteotomy (n = 184)	Osteotomy (n = 156)	p-value
Unplanned readmission	11 (6.0 %)	10 (6.4 %)	1.00
Reoperation	11 (6.0 %)	18 (11.5 %)	0.08
Superficial surgical infection	4 (2.2 %)	2 (1.3 %)	0.69
Deep surgical infection	0 (0.0 %)	5 (3.2 %)	0.02
Organ space infection	1 (0.5 %)	1 (0.6 %)	1.00
Wound Dehiscence	3 (1.6 %)	3 (1.9 %)	1.00
Pneumonia	3 (1.6 %)	6 (3.8 %)	0.31
Reintubation	0 (0.0 %)	7 (4.5 %)	0.004
Pulmonary embolism	1 (0.5 %)	6 (3.8 %)	0.051
Unable to wean off ventilator	0 (0.0 %)	4 (2.6 %)	0.04
Renal insufficiency	1 (0.5 %)	2 (1.3 %)	0.60
Acute renal failure	0 (0.0 %)	1 (0.6 %)	0.46
Urinary tract infection	6 (3.3 %)	8 (5.1 %)	0.42
Stroke	0 (0.0 %)	1 (0.6 %)	0.46
Cardiac arrest	0 (0.0 %)	2 (1.3 %)	0.21
Myocardial infraction	0 (0.0 %)	3 (1.9 %)	0.10
Perioperative blood transfusion	37 (20.1 %)	119 (76.3 %)	<0.001
Deep Venous Thrombosis	3 (1.6 %)	3 (1.9 %)	1.00
Sepsis	4 (2.2 %)	4 (2.6 %)	1.00
Septic Shock	0 (0.0 %)	2 (1.3 %)	0.21

associated with high medical and surgical complication rates.^{4-6,13} While previous studies have evaluated complication rates associated with 3CO, these studies are either small or only include specialized sites that perform these procedures on a routine basis.^{7-9,11} To inform accurate risk stratification, therefore, evaluation of a large multicenter database is necessary. To this end, we utilized a nationally representative sample to obtain a generalizable complication rate associated with 3CO in the setting of long segment fusion for adult spinal deformity and demonstrated that patients receiving 3CO had significantly higher rates of surgical site infection, respiratory complications, and blood transfusion compared to those who did not.

In our study 3CO was associated with a significantly higher rate of medical complications compared to those undergoing long segment fusions without 3CO. Specifically, in our series 80.1 % of patients with 3CO demonstrated at least one medical complication compared to only 26.6 % of those without 3CO. These results are comparable to other previously cited rates. In a recent series conducted by the ISSG in 2017 78 % of patients experienced at least one complication in a two year follow up time with 59.9 % of them being major complications.¹⁷ Given the limitations of the NSQIP database, these complications are not stratified by major and minor complications. While these complications appear high it is important to note that many of the cited complications may not impact patients' clinical outcomes. For example, the need for transfusion was the most common complication occurring in 76.3 % of patients with 3CO, however this would be unlikely to have long term clinical consequence.

In our series the use of 3CO was also associated with a statistically significantly longer length of stay of 7.76 days compared with 4.17 days. While the use of 3CO results an increased length of operative time and blood loss, associations with increased hospital length of stay have not been well established. In a recent retrospective review by Lovecchio et al in 2021 of 82 patients undergoing fusion of at least five levels, the use of a 3CO was not significantly associated with an increased length of stay. In their series a 3CO was performed in 11.4 % of patients with a length of stay of less than 6 days compared with 23.4 % of patients who had a length of stay greater than 6 days, $p = 0.4402$.¹² This finding is likely to be underpowered however as only 16 patients required 3CO in their series. Additionally, our study demonstrated a lower rate of home discharge (42.9 % vs 73.8 %, $p < 0.0001$). This finding has also been corroborated as 3CO has been shown previously to be an independent risk factor for nonroutine discharge.¹

In addition to medical complications, surgical complications of 3CO have been well documented. In a study by Smith et al in 2017, A retrospective review of 106 patients undergoing 3CO patients were found to have a high rate of rod fracture (31.7 %), dural tear (20.7 %), radiculopathy (9.8 %), and proximal junctional kyphosis (9.8 %).¹⁷ Of these patients, 33 % required reoperation. Rod fracture has frequently been reported to be the most common surgical complication following 3CO. In another study completed by the ISSG in 2014, rod fracture was seen in 22 % of patients undergoing PSO compared to only 9 % in those with long segment fusion and no PSO.¹⁸ Further research into multi-rod constructs and evaluating the severity of rod contouring have been conducted to help reduce the incidence of this complication.¹⁹

Despite the use of the NSQIP database our series has significant limitations. Firstly, while the NSQIP database contains useful information regarding 30-day adverse events, not all events that could be considered surgical complications are collected, such as neurologic decline and hardware complications. While factors such as reintubation, blood transfusion, and readmission are important measurements by the Center for Medicaid Services and other regulatory agencies, they do not focus on specific outcomes that are relevant to the index procedure, such as neurological deficits as mentioned above. Additionally, as the CPT code for vertebral column resection and pedicle subtraction osteotomies are the same, differences in postoperative outcomes between these two procedures are impossible to conclude. Finally, differences in sagittal balance at follow up and health related quality of life scores are not

included in this database making clinical outcome conclusions impossible.

5. Conclusions

The use of 3CO in the setting of long segment fusion for adult spinal deformity is associated with a significantly higher medical complication rate, length of stay, and decreased likelihood of home discharge. While these procedures may be necessary to achieve adequate correction, providers should understand the risk and benefit of their use to appropriately counsel patients in the perioperative setting.

CRedit authorship contribution statement

Simon G. Ammanuel: Formal analysis, Conceptualization, Writing – original draft, Data curation, Writing – review & editing. **Paul S. Page:** Conceptualization, Writing – review & editing, Formal analysis, Writing – original draft. **Garret P. Greenaway:** Writing – review & editing, Writing – original draft. **Darius Ansari:** Writing – original draft, Writing – review & editing. **James A. Stadler:** Writing – review & editing, Writing – original draft, Conceptualization.

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.

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References

- Amin RM, Raad M, Jain A, et al. Risk factors for nonroutine discharge in adult spinal deformity surgery. *Spine J.* 2019;19:357–363.
- Auerbach JD, Lenke LG, Bridwell KH, et al. Major complications and comparison between 3-column osteotomy techniques in 105 consecutive spinal deformity procedures. *Spine.* 2012;37:1198–1210.
- Booth KC, Bridwell KH, Lenke LG, Baldus CR, Blanke KM. Complications and predictive factors for the successful treatment of flatback deformity (fixed sagittal imbalance). *Spine.* 1999;24:1712–1720.
- Bridwell KH. Decision making regarding Smith-Petersen vs. pedicle subtraction osteotomy vs. vertebral column resection for spinal deformity. *Spine.* 2006;31: S171–S178.
- Bridwell KH, Baldus C, Berven S, et al. Changes in radiographic and clinical outcomes with primary treatment adult spinal deformity surgeries from two years to three- to five-years follow-up. *Spine.* 2010;35:1849–1854.
- Bridwell KH, Glassman S, Horton W, et al. Does treatment (nonoperative and operative) improve the two-year quality of life in patients with adult symptomatic lumbar scoliosis: a prospective multicenter evidence-based medicine study. *Spine.* 2009;34:2171–2178.
- Cho K-J, Kim K-T, Kim W-J, et al. Pedicle subtraction osteotomy in elderly patients with degenerative sagittal imbalance. *Spine.* 2013;38:E1561–E1566.
- Cogniet A, Aunoble S, Rigal J, Demezon H, Sadikri R, Le Huec JC. Clinical and radiological outcomes of lumbar posterior subtraction osteotomies are correlated to pelvic incidence and FBI index : prospective series of 63 cases. *Eur Spine J Off Publ Eur Spine Soc Eur Spinal Deform Soc Eur Sect Cerv Spine Res Soc.* 2016;25:2657–2667.
- Dickson DD, Lenke LG, Bridwell KH, Koester LA. Risk factors for and assessment of symptomatic pseudarthrosis after lumbar pedicle subtraction osteotomy in adult spinal deformity. *Spine.* 2014;39:1190–1195.
- Glassman SD, Bridwell K, Dimar JR, Horton W, Berven S, Schwab F. The impact of positive sagittal balance in adult spinal deformity. *Spine.* 2005;30:2024–2029.
- Gupta MC, Ferrero E, Mundis G, et al. Pedicle subtraction osteotomy in the revision versus primary adult spinal deformity patient: is there a difference in correction and complications? *Spine.* 2015;40:E1169–E1175.
- Lovecchio F, Steinhaus M, Elysee JC, et al. Factors associated with short length of stay after long fusions for adult spinal deformity: initial steps toward developing an enhanced recovery pathway. *Glob Spine J.* 2021;11:866–873.
- Norton RP, Bianco K, Lafage V, Schwab FJ, International Spine Study Group Foundation. Complications and intercenter variability of three-column resection osteotomies for spinal deformity surgery: a retrospective review of 423 patients. *Evid-Based Spine-Care J.* 2013;4:157–159.
- Qiao J, Xiao L, Sun X, et al. Three column osteotomy for adult spine deformity: comparison of outcomes and complications between kyphosis and kyphoscoliosis. *Br J Neurosurg.* 2018;32:32–36.

15. Qiao J, Xiao L, Sun X, et al. Vertebral subluxation during three-column osteotomy in surgical correction of adult spine deformity: incidence, risk factors, and complications. *Eur Spine J Off Publ Eur Spine Soc Eur Spinal Deform Soc Eur Sect Cerv Spine Res Soc*. 2018;27:630–635.
16. Smith JS, Shaffrey CI, Berven S, et al. Improvement of back pain with operative and nonoperative treatment in adults with scoliosis. *Neurosurgery*. 2009;65:86–93. ; discussion 93–94.
17. Smith JS, Shaffrey CI, Klineberg E, et al. Complication rates associated with 3-column osteotomy in 82 adult spinal deformity patients: retrospective review of a prospectively collected multicenter consecutive series with 2-year follow-up. *J Neurosurg Spine*. 2017;27:444–457.
18. Smith JS, Shaffrey E, Klineberg E, et al. Prospective multicenter assessment of risk factors for rod fracture following surgery for adult spinal deformity. *J Neurosurg Spine*. 2014;21:994–1003.
19. Tang JA, Leasure JM, Smith JS, Buckley JM, Kondrashov D, Ames CP. Effect of severity of rod contour on posterior rod failure in the setting of lumbar pedicle subtraction osteotomy (PSO): a biomechanical study. *Neurosurgery*. 2013;72:276–282. ; discussion 283.