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### Authors

Kelly, Michael P  
Lenke, Lawrence G  
Shaffrey, Christopher I  
[et al.](#)

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## Evaluation of Complications and Neurological Deficits with Three Column Spine Reconstructions for Complex Spinal Deformity: A Retrospective Scolio-Risk 1 Study

Michael P. Kelly, M.D.<sup>1</sup>, Lawrence G. Lenke, M.D.<sup>1</sup>, Christopher I. Shaffrey, M.D.<sup>2</sup>, Christopher P. Ames, M.D.<sup>3</sup>, Leah Y. Carreon, M.D., M. Sc<sup>4</sup>, Virginie Lafage, Ph.D.<sup>5</sup>, Justin S. Smith, M.D. Ph.D.<sup>2</sup>, and Adam L. Shimer, M.D.<sup>6</sup>

<sup>1</sup>Washington University School of Medicine, Department of Orthopaedic Surgery, Saint Louis, MO, USA

<sup>2</sup>University of Virginia School of Medicine, Department of Neurological Surgery, Charlottesville, VA, USA

<sup>3</sup>University of California, San Francisco, Department of Neurological Surgery, San Francisco, CA, USA

<sup>4</sup>Norton Leatherman Spine Center, Louisville, KY, USA

<sup>5</sup>NYU Medical Center, Department of Orthopaedic Surgery, New York, NY, USA

<sup>6</sup>University of Virginia School of Medicine, Department of Orthopedic Surgery, Charlottesville, VA, USA

### Abstract

**Object**—To evaluate the risk factors for complications, including new neurological deficits, in the largest cohort of adult spinal deformity patients to date.

**Methods**—Scoli-RISK-1 inclusion criteria were used to identify eligible patients from five centers, treated from June 1, 2009 to June 1, 2011. Records were reviewed for patient demographics, surgical data, and reports of perioperative complications. Neurological deficits were recorded as pre-existing or as new neurological deficits. Patients undergoing a three column osteotomies (3CO) were compared to those not (PSF). Between group comparisons were performed using independent samples t-tests and Chi-square analyses.

**Results**—Two hundred and seven patients were identified, with 75 PSF and 132. 3CO patients were older (58.9 vs 49.4,  $p<0.0001$ ), had higher BMI (29.0 vs 25.8,  $p=0.034$ ), had smaller preoperative coronal Cobb measurements (33.8 vs 56.3,  $p<0.001$ ), had more preoperative sagittal malalignment (116.6 vs 54.5mm,  $p<0.001$ ), and had similar sagittal Cobb measurements (45.8 vs 57.7,  $p=0.113$ ). Operative times were similar (393 vs 423 min,  $p=0.112$ ), though 3CO sustained higher EBL (2120 vs 1700mL,  $p=0.013$ ). Rates of new neurologic deficits were similar (PSF:6.7%

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Corresponding Author: Michael P. Kelly, MD, Department of Orthopaedic Surgery, IOH 5<sup>th</sup> Floor, Box 8233, 660 South Euclid Avenue, Saint Louis, MO 63110, Phone 314-747-2511, Fax 314-747-2000, kelymi@wudosis.wustl.edu.

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vs 3CO:9.8%,  $p=0.435$ ) and rates of any perioperative medical complication were similar (PSF: 45.3% vs 3CO:34.8%,  $p=0.136$ ). VCR patients were more likely to sustain medical complications than PSO (73.7% vs 46.9%,  $p=0.031$ ), though new neurologic deficits were similar (15.8% vs 8.8%,  $p=0.348$ ). Regression analysis did not reveal significant predictors of neurologic injury nor complication from collected data.

**Conclusions**—Despite higher EBL, rates of all complications (49.3%) and new neurologic deficits (8.7%) did not vary for complex reconstruction patients, whether a 3-CO is performed or not. VCR patients sustained more medical complications without an increase in new neurologic deficits. Prospective study of patient factors, provider factors, and refined surgical data are needed to define and optimize risk factors for complication and neurologic deficits.

### Keywords

Three column osteotomy; pedicle subtraction; vertebral column resection; adult deformity; complications; Adult Spinal Deformity; Osteotomy

## Introduction

Adult spinal deformity is associated with relatively high rates of perioperative complications, with a concordant increased risk in a new, neurologic deficit.<sup>6,7,10–12,15</sup> The combination of an aging population and increasing number of spine fusion procedures results in an increasing number of patients with adult deformities, as well as an increasingly complex revision burden.<sup>13,14</sup> With the rising revision burden, the diagnosis of fixed sagittal malalignment is increasingly common.<sup>20</sup> Numerous centers have reported their individual experiences, though few multi-center analyses of these complex adult, spinal deformity patients exist.

Sagittal alignment is a primary driver of outcomes in adult spinal deformity surgery.<sup>4,16</sup> While not the only factor, spinopelvic anatomy is one of the determinants of overall sagittal alignment.<sup>22</sup> Multiple different techniques have been proposed to restore lumbar lordosis in cases of fixed sagittal malalignment, including posterior column osteotomies, pedicle subtraction osteotomies (a three column osteotomy (3CO)), and combined anterior/posterior procedures.<sup>2,3,5,8,9,21,24</sup> A number of reports have shown higher rates of complications with the more invasive osteotomies (e.g. 3CO).<sup>6,7,10</sup> As techniques and experience evolve, however, the risks of complications, including neurologic deficit, may be declining.

The Scolio-RISK-1 trial is a prospective observational cohort of patients undergoing surgery for major adult spinal deformities. A retrospective cohort study was performed using Scolio-RISK-1 inclusion criteria. In this study we sought to investigate the rates of complications occurring in major reconstructions performed at five centers participating in Scolio-RISK-1. Specifically, we sought to examine whether 3CO is a risk factor for complication. As techniques have evolved, surgical complications may be minimized due to shorter operative times and better management of potential perioperative risk factors, including blood loss.

## Methods

### Patient Selection

Five centers participating in the Scolio-Risk-1 prospective cohort study were selected to identify patients treated from June 1, 2009 to June 1, 2011. The inclusion criteria are identical to those used to enroll patients in Scolio-Risk-1 and are found in Table 1. All patients were aged 18 to 80 years old at the time of surgery and had major spinal deformities. Patients were excluded if they had a history of recent substance dependency, psychosocial disturbance, active malignancy, active bacterial infection (systemic or local), recent (3 months) trauma, prior paraplegia, or were pregnant or nursing.

### Data Collection

Standardized data collection sheets were distributed to all participating centers. Preoperative data collected included age, gender, body mass index (BMI), primary diagnosis with Cobb and alignment measurements (C7 coronal and sagittal), and any history of prior spine surgeries. Operative data collected included number of levels treated, whether osteotomies were performed and if yes, which type, estimated blood loss, total operative time. Data regarding planned staged procedures were collected. Neurologic complications and medical complications were gathered from reviews of medical records. Any mention of a postoperative motor or sensory deficit, that was not recorded or consistent with a preoperative record, was recorded as a new neurological deficit. Patients were divided into two groups, those undergoing a three column osteotomy (pedicle subtraction (PSO) or vertebral column resection (VCR), 3CO) and those undergoing other reconstruction procedures (PSF).

### Statistical Analysis

Continuous data were compared between using the independent samples t-test. Rates of neurological deficit and medical complications were compared between groups using the Chi-Square test. Rates of these two complications were also examined for the PSO and VCR groups. Multivariate regression analysis with block entry was used to evaluate the relationship between known and reasonable predictors of a new perioperative neurologic deficit and for any perioperative complication. Statistical significance was defined as  $p < 0.05$ . SPSS v20 (SPSS Inc, Chicago, IL) was used for all analyses.

## Results

Two hundred and seven patients were identified and included in the analysis. Seventy-five (53 Females, 22 Males) underwent a reconstruction without 3CO. One hundred and thirty-two patients (83 Females, 46 Males) underwent 3CO as part of the management of their deformity (PSO=113, VCR=19). Those patients undergoing 3CO were older and had a higher BMI. 3CO patients had smaller maximum preoperative coronal Cobb measurements but similar preoperative maximal sagittal Cobb measurements. 3CO Patients had greater sagittal malalignment, by the C7 plumb line. Patients undergoing 3CO were more likely to have a preoperative motor deficit and were more likely to be undergoing a revision surgery

The distribution of American Society of Anesthesiologist (ASA) scores were similar between groups. (Table 2)

Total operative times were similar between groups, though estimated blood loss (EBL) was higher in the 3CO group. (Table 3) PSF patients had more coronal Cobb improvement, while 3CO had greater sagittal alignment correction. Rates of new postoperative neurologic deficits were similar (PSF: 5/75(6.7%), 3CO:13/132(9.8%),  $p=0.435$ ). Rates of acute, perioperative complications were similar also (PSF: 35/75(45.3%), 3CO: 67/132(50.7%),  $p=0.571$ ). Major complications, as classified by Glassman et al, were similar between groups (PSF: 6/75 (8%), 3CO 19/132 (14%),  $p=0.12$ ).<sup>17</sup> Most patients suffering a perioperative complication sustained one only. 3CO patients undergoing a VCR were more likely to sustain a perioperative complication, compared with PSO patients (VCR: 14/19(73.7%), PSO: 53/113(46.9%),  $p=0.031$ ). Rates of new neurologic deficits were similar between the PSO and VCR groups, however (PSO: 10/113(8.8%), VCR: 3/19(15.8%),  $p=0.348$ ).

Multivariate regression analyses did not reveal associations between the performance of a three column osteotomy and a new postoperative deficit or medical complication when controlling for age, BMI, gender, EBL and revision status.

## Discussion

As the population ages, an increasing number of adult spinal deformity surgeries will likely be performed. These surgeries often require multilevel, instrumented arthrodesis and are at a higher risk for perioperative complications.<sup>13,14</sup> With an improved awareness of the importance of sagittal alignment and lumbopelvic balance, more osteotomies, both posterior column and three column, are likely to be performed. Prior research has shown that patients undergoing three column osteotomies may be at an increased risk for perioperative complications, including new neurologic deficits.<sup>6,7</sup> Whether the performance of the osteotomy or the nature of the deformity and other patient characteristics is the primary risk factor has not been appropriately examined. In this multicenter, observational cohort, we sought to investigate the relationship between perioperative complications, specifically neurological deficits, and three column osteotomies in adult spinal deformity surgery.

We identified 207 patients, already treated for their spinal deformity, meeting the inclusion criteria for participation in the Scolio-Risk-1 trial. 132 Patients underwent some three column osteotomy as part of their reconstruction, with 113 patients managed with a PSO and 19 managed with a VCR. As expected, patients undergoing 3CO were more likely to have a severe preoperative sagittal plane malalignment. They also obtained greater sagittal plane realignment from the osteotomy. Also as expected, surgeries with a 3CO had higher blood loss and longer operative times, than patients treated with posterior reconstructions without any osteotomy or with posterior column osteotomies (e.g. Smith-Petersen, Ponte) only. Despite higher blood loss, longer operative times, and the known increased technical difficulty associated with 3CO, the rates of perioperative complication and neurologic deficits were similar between the PSF and 3CO groups. Multivariate analysis did not

indicate that any particular preoperative variable was associated with the development of a new neurologic deficit nor perioperative complication.

Prior work has indicated that a three column osteotomy (PSO, VCR) may be risk factors for perioperative complications.<sup>6,7,10-12</sup> Increasing amounts of intraoperative blood loss and postoperative allogeneic blood transfusions have also been shown to increase the risk of a complication. The increased technical challenges associated with 3CO have been described as well, with the potential for concomitant increase in complications with the technical complexities.<sup>1,6,7,18</sup>

Auerbach reviewed the results of three column procedures at a single institution in an effort to differentiate the risk profiles of PSO and VCR.<sup>1</sup> They reported an overall major complication rate of 35.2% (PSO: 38%, VCR: 22%) underscoring the high risk profile of these procedures. A preoperative sagittal malalignment of 40mm or more, age greater than 60 years old, and 3 or more medical were associated with a postoperative major complication. Despite the serious nature of these complications, most patients were improved with a minimum of two years followup and no differences were observed between the improvements obtained with and without perioperative complications. Patients with permanent deficits were less satisfied with their procedure, though they did improve with surgery. Hassanzadeh et al reported the results of PSO/VCR in patients older than 60 years of age and noted a similarly high complication rate, 57% (18% Major, 39% Minor).<sup>18</sup> Again, despite these risks, significant improvements outcomes scores were obtained and the authors note that strict selection criteria should be used to determine eligible patients.

Revision surgeries, in particular, have been shown to have higher rates of complication in one series, while others have suggested that primary and revision surgeries have similar rates of early and late complications.<sup>10,19</sup> Buchowski et al noted an 11.1% rate of new neurologic deficits in a series of 108 PSO.<sup>7</sup> The majority of these deficits were transient, noting a permanent deficit rate of 2.8%. These deficits were the result of inadequate decompression, subluxation, or buckling of the dura, suggesting that procedure factors and not patient factors play a role in the development of neurological deficits. Intraoperative neurological monitoring did not detect these deficits, limiting the ability of the surgeons to respond appropriately at the time of the initial surgery. Boachie-Adjei et al described their experience with PSO and reported a high complication rate, 58%.<sup>5</sup> The majority of these complications did not have any effect on long term patient outcomes and only 12.5% sustained neurologic deficits. Two of the three neurologic deficits were treated with a revision procedure, again suggesting that procedural factors and not patient factors, remain the risk factor for developing a new neurologic deficit.

In this study, the largest cohort of 3CO studied, we have found a rate of perioperative complications comparable to those previously presented in the literature, with an overall rate of 49%.<sup>1,5,6,18,24</sup> Similarly, the rate of new neurologic deficits was similar to published rates, with an overall rate of 8.7%.<sup>5,7</sup> The rates of complication and neurologic deficit were not statistically different between patients undergoing the more complex three column osteotomies versus those treated with posterior column only procedures. We did not find

that age, blood loss, nor the performance of a three column osteotomy predicted the occurrence of a complication, neurologic or otherwise, with multivariate regression analysis.

The findings of these data analyses were surprising to us. The lack of significant findings with multivariate analysis may be due to the retrospective nature of the study. Our rates of perioperative complication and neurologic deficit are likely lower than the true rates, due to the retrospective design. Retrospective studies are suspect to recall bias and are limited by what is available in the charts as they are reviewed.<sup>23</sup> This was a multi-center effort and reporting likely varies between institutions. It may be that we have not collected the appropriate confounding variables and that other variables, such as surgeon experience, significantly correlate with complications and neurologic deficits. That Buchowski et al found surgical technique to be at fault in the majority of their PSO related neurological deficits supports this theory.<sup>7</sup>

## Conclusion

In conclusion, we have examined the rates of perioperative complication and neurologic deficits in a cohort of patients with severe, adult spinal deformities, meeting criteria for enrollment in the Scolio-Risk-1 trial. We found an overall perioperative complication rate of 49%, with a new neurologic deficit rate of 8.7%. These numbers agree well with prior published data. Interestingly, we did not observe an increase in complications or neurologic deficits in patients undergoing three column osteotomies, such as PSO or VCR. It may be that the complex deformity is the primary driver of the perioperative risks, rather than the procedure performed. Analysis of the data obtained from the prospective Scolio-Risk-1 trial will shed further light on this subject, to allow surgeons and patients to prepare adequately for the reconstructions and recoveries.

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**Table 1****Scoli-RISK-1 Inclusion Criteria**

<b>Scoli-RISK-1 Inclusion Criteria</b>
<ul style="list-style-type: none"><li>• Age 18 to 80 years old</li><li>• Primary Scoliosis, Kyphosis, or Kyphoscoliosis with major Cobb angle greater than or equal to 80 degrees in the coronal or sagittal plane</li><li>• Congenital spinal deformity undergoing reconstruction with an osteotomy (posterior column or 3CO)</li><li>• Revision spinal deformity undergoing reconstruction with an osteotomy (posterior column or 3CO)</li><li>• Any patient undergoing a 3CO</li><li>• Any patient with preoperative myelopathy due to their spinal deformity</li><li>• Any patient with ossification of the ligamentum flavum or posterior longitudinal ligament and undergoing a reconstruction with decompression.</li></ul>

**Table 2**

## Preoperative Demographic Data

Variable	Three Column Osteotomy		p-value
	No (N=75)	Yes (N=132; 113 PSO, 19 VCR)	
Age	49.4 (17.0)	58.9 (14.0)	<0.001
Gender			0.274
Female	53 (70.7%)	83 (62.9%)	
Male	22 (29.3%)	46 (34.8%)	
Body Mass Index	25.8 (9.5)	29.0 (10.6)	0.029
Preoperative Maximum Coronal Deformity	56.4 (34.4)	33.8 (30.7)	<0.001
Preoperative Maximum Sagittal Deformity	57.7 (38.4)	45.8 (46.0)	0.113
Preoperative Sagittal C7 Plumb Alignment	5.4 (7.6) cm	11.7 (7.3) cm	<0.001
Preoperative Neurological Deficit			0.005
No	58 (77.3%)	76 (58%)	
Yes	17 (22.7%)	55 (42%)	
Revision Procedure			<0.001
No	30 (43.5%)	17 (13.6%)	
Yes	39 (56.5%)	108 (86.4%)	
ASA Score			0.096
1	6 (8.6%)	7 (5.9%)	
2	45 (64.3%)	57 (47.9%)	
3	15 (21.4%)	49 (41.2%)	
4	3 (4.3%)	5 (4.2%)	

**Table 3**

## Perioperative Data

Variable	Three Column Osteotomy		p-value
	No (N=75)	Yes (N=132; 113 PSO, 19 VCR)	
<b>Operative Time</b>	422.9 (140.9)min	392.9 (119.4) min	0.130
<b>Estimated Blood Loss</b>	1700 (SE 182.1)cc	2120 (135.3) cc	0.066
<b>Total Levels Fused</b>	11.5 (4.6)	9.9 (4.1)	<b>0.014</b>
<b>Postoperative Maximum Coronal Deformity</b>	31.8 (27.2)	20.4 (19.3)	<b>&lt;0.001</b>
<b>Postoperative Maximum Sagittal Deformity</b>	43.6 (30.3)	32.2 (36.0)	0.054
<b>PostOperative Sagittal C7 Plumb Alignment</b>	2.4 (4.6) cm	3.8 (5.1) cm	0.065
<b>Any Medical Complication</b>			0.571
No	40 (53.3%)	65 (49.2%)	
Yes	35 (46.7%)	67 (50.8%)	
<b>Post Operative Neurological Deficit</b>			0.389
No	70 (93.3%)	119 (90.2%)	
<b>Root Level Deficit</b>	2 (2.7%)	7 (5.3%)	
<b>Cauda Equina Syndrome</b>	0 (0%)	3 (2.3%)	
<b>Spinal Cord Deficit</b>	3 (4.0%)	3 (2.3%)	
<b>Any Medical Complication</b>			0.571
No	40 (53.3%)	65 (49.2%)	
Yes	35 (46.7%)	67 (50.8%)	