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Clinical Study

Unilateral versus bilateral lower extremity motor deficit following complex adult spinal deformity surgery: is there a difference in recovery up to 2-year follow-up?

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Abstract

BACKGROUND CONTEXT: Scoli-RISK-1 is a multicenter prospective cohort designed to study neurologic outcomes following complex adult spinal deformity (ASD). The effect of unilateral versus bilateral postoperative motor deficits on the likelihood of long-term recovery has not been previously studied in this population.

PURPOSE: To evaluate whether bilateral postoperative neurologic deficits have a worse recovery than unilateral deficits.

STUDY DESIGN: Secondary analysis of a prospective, multicenter, international cohort study.

METHODS: In a cohort of 272 patients, neurologic decline was defined as deterioration of the American Spinal Injury Association Lower Extremity Motor Scores (LEMS) following surgery. Patients with lower extremity neurologic decline were grouped into unilateral and bilateral cohorts. Differences in demographics, surgical variables, and patient outcome measures between the two cohorts were analyzed.

RESULTS: A total of 265 patients had LEMS completed at discharge. Unilateral decline was seen in 32 patients (12%), while 29 (11%) had bilateral symptoms. At 2 years, there was no significant difference in either median LEMS (unilateral 50.0, interquartile range [IQR] 47.5−50.0; bilateral 50.0, IQR 48.0−50.0, p=.939) or change in LEMS from baseline (unilateral 0.0, IQR −1.0 to 0.0; bilateral 0.0, IQR −1.0 to 0.0, p=.920). In both groups, approximately two-thirds of patients saw recovery to at least their preoperative baseline by 2 years postoperatively (unilateral n=15, 63%; bilateral n=14, 67%). The mean Scoliosis Research Society-22R (SRS-22R) score at 2 years was 3.7±0.6 versus 3.2±0.6 (p=.009) for unilateral and bilateral groups, respectively.

CONCLUSIONS: The prognosis for neurologic recovery of new motor deficits following complex adult spinal deformity is similar with both unilateral and bilateral weaknesses. Despite similar rates of neurologic recovery, patient reported outcomes for those with bilateral motor decline measured by SRS-22R are worse at 2 years after surgery.

Keywords: Complication; Neurologic deficit; Scoliosis; Spinal deformity; Spine; Surgery

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Introduction

Severe spinal deformity often results in dramatic declines in quality of life requiring complex reconstructive surgery. Unfortunately, these surgeries are technically demanding and carry high risk for major complications. Overall complication rates associated with deformity correction surgery are reported in the range of 8.4%-64% [1−10]. Neurologic decline associated with deformity correction surgery is one of the most concerning surgical complications due to its impact on patient outcome, direct relation to surgical technique, and variable recovery rates. Neurologic impairment is reported to occur in 3.7%-23.0% of severe deformity surgeries, that is, curves greater than 70°, sagittal vertical axis (SVA) greater than 10 cm, or surgery involving a three-column osteotomy (3-CO) [9,11−16]. The majority of this data comes from retrospective cohorts that did not use a validated neurologic outcome instrument and thus may be underreporting the true complication rate. Scoli-RISK-1 was a prospective, international, multicenter cohort study designed to report the neurologic complications associated with surgical correction of complex adult spinal deformity (ASD) using pre- and postoperative ASIA Lower Extremity Motor Scores (LEMS) [17]. It thus represents the best available data to evaluate the long-term outcomes of patients with different types of motor deficits following surgery.

The muscle groups affected by a neurologic deficit certainly affect functional outcomes and rehabilitation potential. In the spinal trauma population, the anatomic location of a neurologic injury has been shown to affect motor function recovery [18]. Bilateral motor deficits occur at distinct anatomic sites, are more challenging to rehabilitate, and result in different functional limitations when compared with unilateral injuries. To date, we know of no study that directly compares neurologic recovery rates and long-term outcomes of patients with bilateral or unilateral neurologic injuries following spinal deformity surgery. This information would give clinicians important prognostic information for patients with bilateral neurologic decline.

Materials and methods

The study is a secondary analysis of the data collected from Scoli-RISK-1 [17]. Scoli-RISK-1 is an international, multicenter, prospective, observational cohort of surgical patients undergoing correction of complex ASD. Complex ASD was defined as coronal or sagittal Cobb angle $\geq 80^{\circ}$, corrective osteotomies for congenital spinal deformity, revision spinal deformity with corrective osteotomies, 3-CO between C7−L5, myelopathy due to spinal deformity, or deformity reconstruction with decompression of the spinal cord due to ossification of the ligamentum flavum or ossification of the posterior longitudinal ligament.

The study was conducted in 15 spinal deformity centers worldwide. The respective ethics committees or Institutional Review Boards granted study approval at all participating sites, and all patients signed informed consent prior to enrollment. Forty-three surgeons enrolled 272 consecutive patients over a 14-month period. Within 6 weeks before surgery, at hospital discharge, and at 6 weeks, 6months, and 2 years after surgery, an American Spinal Injury Association (ASIA) neurologic examination was recorded. An ASIA neurologic examination was performed by an ASIA-certified examiner, and each site had multiple certified examiners performing this function. The primary outcome measure was ASIA LEMS at each time-point [19,20]. Secondary end-points including radiographic measurements on standing coronal and sagittal x-rays, patient reported outcomes, and adverse events were recorded at each time-point. Further details on the methods of the original study have been previously published [17].

For the purpose of analysis, patients were divided into two groups: (A) unilateral group, defined as patients with decline in LEMS by at least one point with no new weakness on the contralateral extremity and (B) bilateral group, defined as patients with a decline in LEMS in both legs following surgery. Differences in demographics, surgical variables, and patient outcome measures between the unilateral group and the bilateral group were analyzed using the Fisher exact test or chi-square test for categorical variables and Wilcoxon rank sum test or *t* test for continuous variables. Changes in LEMS from baseline were classified as "maintenance," "improvement," and "decline." A p-value of less than 0.05 was considered statistically significant. The statistical analysis was performed using the SAS version 9.2 software (SAS Institute, Inc., Cary, NC, USA). The study utilized the Web-based online data capture system (eCRF) OpenClinica.

Results

Of the 272 consecutive patients enrolled from September 2011 to October 2012, 7 patients did not have LEMS completed at discharge and 1 patient also lacked preoperative LEMS, resulting in 265 patients included in the group analyses. Thirteen patients (4.8%) missed their 6-week assessment; 19 patients (7.0%) missed their 6-month assessment and 62 patients (22.9%) did not attend the 24-month visit.

At discharge from the hospital, 61 patients (23.0%) displayed decline in LEMS, while 170 (64.2%) remained the same and 34 (12.8%) improved. Unilateral decline was seen in 32 patients (12%), while the other 29 (11%) had bilateral symptoms. In the 61 patients with motor decline, three patients (4.9%) missed their 6-week assessment; two patients (3.3%) missed their 6-month assessment and 16 patients (26.2%) did not attend the 24-month visit.

The unilateral cohort did include more women 26 (81.3%) than the bilateral cohort 14 (48%) (p=.007). The study population mean age was 56.9±15.3 years compared with 63.1±10.5 years in the unilateral group and 60.7±10.1 in the bilateral group. The patients with unilateral decline did not differ from the bilateral group in terms of smoking status, diabetes, body mass index, preoperative

weakness, or previous spine surgery (Table 1). In both groups, the majority of LEMS decline was 5 points or less (unilateral n=25, 78%; bilateral n=19, 66%).

The patients with unilateral motor decline were more likely to have undergone a combined anterior-posterior approach, 11 patients (34.4%) versus 2 patients (6.9%) with bilateral deficits (p=.009). The median number of levels involved in surgery was also higher in the unilateral group compared with the bilateral group, that is, 13.0 (IQR 11.0–17.5) and 10.0 (IQR 9.0–13.0) (p=.005), respectively. There was no statistically significant difference in other operative variables including the rate of staging, blood loss, operative time, rate of 3-CO, or total number of osteotomies between the two groups. Unilateral versus bilateral motor decline did not significantly affect the length of stay in the hospital or disposition upon discharge (Table 2).

At 2 years, no statistically significant difference in either median LEMS (unilateral 50.0 [IQR 47.5–50.0]; bilateral 50.0 [IQR 48.0–50.0], p=.939) or change in LEMS (unilateral −0.0 [IQR: −1.0 to 0.0]; bilateral 0.0 [IQR: −1.0 to 0.0], p=.920) could be found (Table 3). In both groups, approximately two-thirds of patients with initial worsening in motor examination saw recovery to at least their preoperative baseline by 2 years postoperatively (unilateral n=15, 63%; bilateral n=14, 67%) (Table 4).

Patients who initially had new bilateral motor deficits after surgery had worse Scoliosis Research Society-22R (SRS-22R) at 2 years, 3.7±0.6 versus 3.2±0.6 for unilateral and bilateral groups, respectively (p=.009). Analysis of the SRS-22 subscales found the bilateral cohort to have statistically significant lower responses only in the self-image domain. At 2 years, numeric rating scale (NRS) back pain scores were also worse in the bilateral group, with a median score of 1.0 (IQR 0.0–3.0) vs. 3.0 (IQR 1.0–5.0) (p=.048) for unilateral and bilateral groups, respectively (Table 5).

Discussion

The present study found that new neurologic deficits are seen in nearly a quarter of patients following complex deformity surgery. The new weakness affects either one or both legs at a similar rate. At 2-year follow-up, approximately two-thirds recover to at least their preoperative baseline level of lower extremity strength. The prognosis for neurologic recovery of new motor deficits following complex ASD is similar with both unilateral and bilateral weaknesses. Despite similar neurologic function, patients who initially had bilateral deficits have worse patient reported outcome at 2 years after surgery.

Our review of the literature found no previous study comparing functional recovery of iatrogenic neurologic decline, based on the muscle groups affected, following spinal deformity surgery. Previous studies on this topic were unable to answer this question for a variety of reasons. Many were too small, either in the total number of surgeries included in the initial analysis [9,12,14,15,21,22] or in the number of high-risk deformity surgeries [13,23], resulting in inadequate instances of neurologic decline to evaluate functional recovery of different types of neurologic injuries.

Table 1
Demographics and comorbidities according to LEMS decline at discharge: unilateral versus bilateral decline

	Type of LEMS decline at discharge (compared to preoperative values)			
Variable	Unilateral, N=32	Bilateral, N=29	Total, N=61	p Value
Age, n	32	29	61	.367*
Mean (SD)	63.1 (10.5)	60.7 (10.1)	62.0 (10.3)	
Gender, n (%)	32	29	61	.007†
Female	26 (81.3)	14 (48.3)	40 (65.6)	
Male	6 (18.8)	15 (51.7)	21 (34.4)	
Smoker, n (%)	32	29	61	.182‡
No	31 (96.9)	25 (86.2)	56 (91.8)	
Yes	1 (3.1)	4 (13.8)	5 (8.2)	
BMI, n	31	28	59	.106*
Mean (SD)	26.9 (5.8)	29.7 (7.1)	28.2 (6.6)	
Preoperative LEMS Category, n (%)	32	29	61	.963†
LEMS =50	23 (71.9)	21 (72.4)	44 (72.1)	
LEMS <50	9 (28.1)	8 (27.6)	17 (27.9)	
Previous spine surgeries, n (%)	32	29	61	.754†
No	10 (31.3)	8 (27.6)	18 (29.5)	
Yes	22 (68.8)	21 (72.4)	43 (70.5)	
Diabetes, n (%)	32	29	61	.241‡
No	30 (93.8)	24 (82.8)	54 (88.5)	
Yes	2 (6.3)	5 (17.2)	7 (11.5)	

BMI, body mass index; LEMS, Lower Extremity Motor Scores; SD, standard deviation.
* *t* test.
† Chi-square test.
‡ Fisher exact test.

Table 2
Surgical and hospitalization details according to the pattern of LEMS decline at discharge unilateral versus bilateral

Variable	Type of LEMS decline at discharge (compared to preoperative value)			p Value
	Unilateral, N=32	Bilateral, N=29	Total, N=61	
Surgery type, n (%)				.649*
Single-stage procedure	25 (78.1)	24 (82.8)	49 (80.3)	
Multistage procedure	7 (21.9)	5 (17.2)	12 (19.7)	
Approach, n (%)				.009*
Anterior	0 (0.0)	0 (0.0)	0 (0.0)	
Posterior	21 (65.6)	27 (93.1)	48 (78.7)	
Both	11 (34.4)	2 (6.9)	13 (21.3)	
Total estimated blood loss (ccs)				.230†
Median (Q1;Q3)	2,325 (1,900;4,196)	2800 (2,300;4,000)	2500 (2,000;4,000)	
Total operative time (min)				.559†
Median (Q1;Q3)	482.5 (360.0;568.5)	435.0 (360.0;515.0)	448.0 (360.0;534.0)	
Levels involved in surgery				.005†
Median (Q1;Q3)	13.0 (11.0;17.5)	10.0 (9.0;13.0)	12.0 (10.0;16.0)	
Three-column osteotomy, n (%)				.260‡
No	6 (18.8)	2 (6.9)	8 (13.1)	
Yes	26 (81.3)	27 (93.1)	53 (86.9)	
Number of osteotomies				.368†
Median (Q1;Q3)	1.0 (1.0;3.5)	1.0 (1.0;2.0)	1.0 (1.0;3.0)	
Days elapsed between surgery and discharge§				.339†
Median (Q1;Q3)	9.0 (7.0;20.0)	13.0 (9.0;22.0)	12.0 (8.0;21.0)	
Destination after discharge, n (%)				1.000‡
Home	14 (43.8)	12 (41.4)	26 (42.6)	
Rehab	17 (53.1)	16 (55.2)	33 (54.1)	
Nursing home	1 (3.1)	1 (3.4)	2 (3.3)	

LEMS, Lower Extremity Motor Scores.
* Chi-square test.
† Wilcoxon rank sum test.
‡ Fisher exact test.
§ In case of staged procedure with several hospital admissions, sum over the different hospital stays was calculated. For operative time, blood loss, and number of osteotomy in case of staged procedures, sum over stages has been calculated.

Table 3
LEMS at follow-up following unilateral versus bilateral decline

	Type of LEMS decline at discharge (compared to preoperative value)			p Value
	Unilateral	Bilateral	Total	
Preoperative LEMS, n	32	29	61	.812*
Mean (SD)	48.6 (4.1)	47.6 (5.7)	48.1 (4.9)	
Median (Q1;Q3)	50.0 (49.0;50.0)	50.0 (48.0;50.0)	50.0 (49.0;50.0)	
LEMS at last discharge, n	32	29	61	.052*
Mean (SD)	44.8 (5.9)	42.0 (8.0)	43.5 (7.1)	
Median (Q1;Q3)	46.5 (44.0;48.0)	46.0 (41.0;47.0)	46.0 (43.0;48.0)	
LEMS at 6 weeks, n	30	28	58	.372*
Mean (SD)	46.4 (4.8)	44.7 (6.6)	45.6 (5.8)	
Median (Q1;Q3)	48.0 (45.0;50.0)	46.5 (42.5;50.0)	48.0 (44.0;50.0)	
LEMS at 6 months, n	31	28	59	.182*
Mean (SD)	48.6 (3.5)	46.7 (5.1)	47.7 (4.4)	
Median (Q1;Q3)	50.0 (49.0;50.0)	50.0 (45.0;50.0)	50.0 (46.0;50.0)	
LEMS at 24 months, n	24	21	45	.939*
Mean (SD)	48.3 (2.9)	47.7 (4.7)	48.0 (3.8)	
Median (Q1;Q3)	50.0 (47.5;50.0)	50.0 (48.0;50.0)	50.0 (48.0;50.0)	
Change in total LEMS at 24 months versus preoperative, n	24	21	45	.920*
Mean (SD)	−0.9 (3.0)	−1.0 (3.2)	−1.0 (3.0)	
Median (Q1;Q3)	0.0 (−1.0;0.0)	0.0 (−1.0;0.0)	0.0 (−1.0;0.0)	

LEMS, Lower Extremity Motor Scores; SD, standard deviation.
* Wilcoxon rank sum test.

Table 4
LEMS change compared to preoperative following unilateral versus bilateral decline

	Type of LEMS decline at discharge (compared to preoperative value)		
	Unilateral	Bilateral	Total
Change in total LEMS at last discharge versus preoperative, n (%)	32	29	61
Maintenance	0 (0.0)	0 (0.0)	0 (0.0)
Improvement	0 (0.0)	0 (0.0)	0 (0.0)
Decline	32 (100.0)	29 (100.0)	61 (100.0)
Change in total LEMS at 6 weeks versus preoperative, n (%)	30	28	58
Maintenance	10 (33.3)	8 (28.6)	18 (31.0)
Improvement	4 (13.3)	2 (7.1)	6 (10.3)
Decline	16 (53.3)	18 (64.3)	34 (58.6)
Change in total LEMS at 6 months versus preoperative, n (%)	31	28	59
Maintenance	17 (54.8)	12 (42.9)	29 (49.2)
Improvement	5 (16.1)	6 (21.4)	11 (18.6)
Decline	9 (29.0)	10 (35.7)	19 (32.2)
Change in total LEMS at 2 years versus preoperative, n (%)	24	21	45
Maintenance	13 (54.2)	12 (57.1)	25 (55.6)
Improvement	2 (8.3)	2 (9.5)	4 (8.9)
Decline	9 (37.5)	7 (33.3)	16 (35.6)

LEMS, Lower Extremity Motor Scores.

Furthermore, many studies did not report laterality or severity of the neurologic deficit with a validated outcome instrument [15,16,23]. Also, retrospective studies used to evaluate neurologic outcomes have a high risk of introducing unintended biases due to the fact that approximately half of objective neurologic injuries are missed by retrospective chart review [24].

One previous large study evaluated iatrogenic neurologic deficit recovery rates stratified by anatomic location, though they did not specifically evaluate laterality. Hamilton et al. reported on recovery rates following 108,419 spine surgeries included in the Scoliosis Research Society morbidity and mortality database [23]. They did not report on laterality or severity of neurologic decline but did stratify the new neurologic deficits into nerve root, cauda equina, and spinal cord groups. They found similar rates of complete recovery among the three sites, 47.1%, 45.2%, and 45.7%, respectively. A severe deformity subgroup similar to the patient population of this study was not analyzed. Despite the large sample size, the study is limited by retrospective design, no validated neurologic or patient reported outcome instrument, and voluntary data entry by the surgeon without quality control or validation.

The incidence of new unilateral and bilateral weaknesses following complex deformity was found to be comparable at 12% and 11%, respectively. We found no statistically significant difference in preoperative demographic information beyond female sex being more common in the unilateral

Table 5
Two-year outcomes according to LEMS decline at discharge unilateral versus bilateral

	Type of LEMS decline at discharge (compared to preoperative value)			
	Unilateral	Bilateral	Total	p Value
SRS-22R total score, n	23	22	45	.009*
Mean (SD)	3.7 (0.6)	3.2 (0.6)	3.5 (0.7)	
Oswestry disability index, n	22	22	44	.232*
Mean (SD)	26.9 (18.0)	34.0 (21.0)	30.5 (19.6)	
NRS back pain, n	23	22	45	.048†
Median (Q1;Q3)	1.0 (0.0;3.0)	3.0 (1.0;5.0)	2.0 (1.0;4.0)	
NRS leg pain, n	23	22	45	.212†
Median (Q1;Q3)	2.0 (0.0;4.0)	2.5 (1.0;5.0)	2.0 (0.0;4.0)	
SF-36 Physical Component Summary Score, n	23	21	44	.146*
Mean (SD)	38.5 (11.6)	33.5 (10.4)	36.1 (11.2)	
SF-36 Mental Component Summary Score, n	23	21	44	.589†
Median (Q1;Q3)	53.0 (41.5;59.0)	47.3 (43.9;55.6)	49.7 (42.4;58.8)	

LEMS, Lower Extremity Motor Scores; SD, standard deviation.
* *t* test.
† Wilcoxon rank sum test.

group. For the most part, surgical variables were similar in the unilateral and bilateral groups, with the exception of number of levels instrumented and approach. Interestingly, patients with a unilateral deficit were nearly five times as likely to have undergone an anterior approach in addition to their posterior fusion. This may be explained, at least in part, by the high incidence of unilateral lower extremity weakness following lateral fusions. In the minimally invasive lateral transpsoas literature, iatrogenic hip flexion weakness is seen 13.6%-30.8% of patients, while other motor deficits are reported in 0%-23.9% of patients [25].

The worse patient-reported outcomes in patients with bilateral deficits support the intuitive conclusion that patients perceive bilateral injuries as worse than unilateral deficits. Interestingly, this difference persists until 2 years after surgery despite similar overall LEMS and rates of complete neurologic recovery in the two groups. Analysis of the function, pain, mental health, and satisfaction SRS-22 subscales found to have statistically significant difference, while self-image was worse for the cohort with bilateral deficits. In the traumatic spinal cord injury population, severity of neurologic injury, functional status, and anatomic level of injury have been previously correlated with worse health-related quality of life metrics [26,27]. This represents the first reported association between iatrogenic bilateral motor decline, either transient or permanent, and worse long-term patient reported outcome compared with unilateral weakness.

The current study is unique in its ability to compare risk factors for and outcomes of new unilateral and bilateral weaknesses following a complex deformity surgery. Prospective collection of all data, including detailed neurologic examinations (complete ASIA examinations) at multiple time-points, provides comprehensive, high-quality data that is particularly suited for a secondary analysis. The relatively large number and equal distribution of unilateral and bilateral weaknesses in this study improve the ability to compare these two groups. The multi-institutional international design also increases generalizability of the results.

The current study does have limitations despite its prospective multicenter design. First, it is a secondary analysis and was not specifically designed to compare the factors associated with recovery rates and long-term outcomes of new bilateral and unilateral neurologic deficits. Thus, it may be underpowered and at risk for type II errors that miss important associations. Second, inclusion criteria and treatment modality were relatively heterogeneous given the multiple etiologies of severe deformity and the multicenter design, respectively. Third, despite ASIA certification of all examiners in the study and the reported low inter- and intra-observer variability of the ASIA motor examination [28,29], some variability may have been introduced by the sheer volume of different examiners at the 15 sites. Fourth, 26.2% of patients were lost to follow-up or did not complete the ASIA motor examination at the 2-year time-point. Finally, this study only included severe deformity patients so the results may not be generalizable to the spine deformity let alone the spinal surgery population as a whole.

Conclusion

The prognosis for neurologic recovery of new motor deficits following complex ASD is similar with both unilateral and bilateral weaknesses. The high likelihood of complete recovery of motor decline after complex deformity whether they are unilateral (63%) or bilateral (67%) provides important prognostic information. Despite similar rates of neurologic recovery, patient-reported outcomes for those with bilateral motor decline measured by SRS-22R and NRS for back pain are worse at 2 years after surgery. This discordance in long-term outcome of bilateral versus unilateral weakness in terms of objective neurologic examination (LEMS) and patient perception (SRS-22R and NRS back pain) is interesting and merits further investigation.

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