



Incidence and Risk Factors for Neurological Deterioration in Posterior Corrective Surgeries for Severe Angular Kyphotic Deformities: A 10-Year Institutional Retrospective Study

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Abstract

Study Design: Retrospective case-control study.

Objective: Neurological deficit is one of the dreaded complications of kyphotic deformity correction procedures. There is inconsistency in the reports of neurological outcomes following such procedures and only a few studies have analyzed the risk factors for neurological deficits. We aimed to analyze the factors associated with neurological deterioration in severe kyphotic deformity correction surgeries.

Methods: We performed a retrospective study of 121 consecutive surgically treated severe kyphotic deformity cases (49 males, 56 females) at a single institute (May 1st 2008 to May 31st 2018) and analyzed the risk factors for neurological deterioration. The demographic, surgical and clinical details of the patients were obtained by reviewing the medical records.

Results: 105 included patients were divided into 2 groups: Group A (without neurological deficit) with 92 patients (42 males, 50 females) and Group B (with neurological deficit) with 13 patients (7 males, 6 females) (12.4%). Statistically significant difference between the 2 groups was observed in the preoperative sagittal Cobb's angle ($p < 0.0001$), operative time ($p = 0.003$) and the presence of myelopathic signs on neurological examination ($p = 0.048$) and location of the apex of deformity ($p = 0.010$) but not in other factors.

Conclusions: Preoperative Sagittal Cobb's angle, presence of signs of myelopathy, operative time and location of apex in the distal thoracic region were significantly higher in patients with neurological deterioration as compared to those without neurological deterioration during kyphotic deformity correction surgery. Distal thoracic curve was found to have 4 times more risk of neurological deterioration compared to others.

Keywords

kyphotic correction, risk factors, neurological deterioration, severe kyphosis, myelopathy

Introduction

Kyphotic deformity correction presents a surgical challenge, particularly when the deformity is severe.¹ Kyphotic deformity of the spine can have congenital, degenerative, post-traumatic, post-infective, inflammatory, post-operative causes among others. Spinal cord compression and resulting neurologic deficit, pain, cardiopulmonary dysfunction, costo-pelvic impingement and cosmetic concerns are the usual reasons for which the deformity correction is advised.

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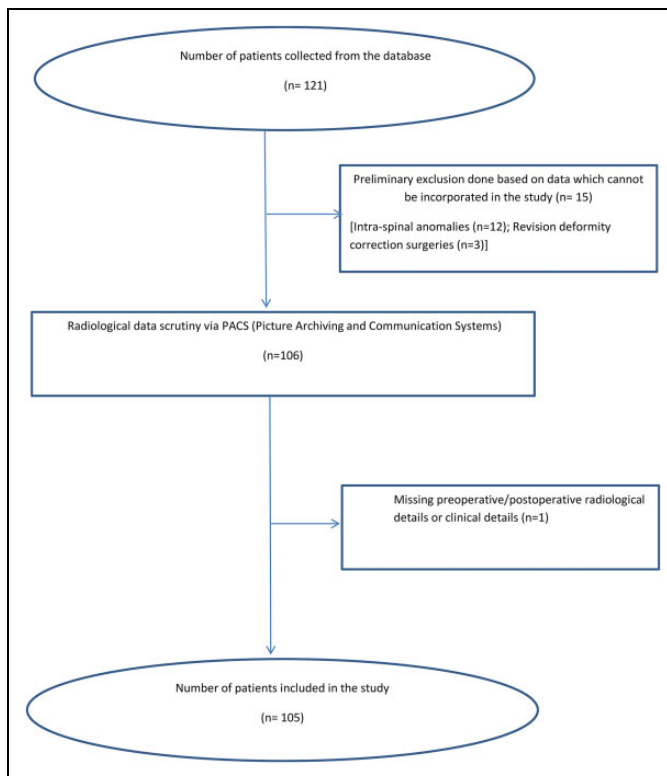


Figure 1. Flow chart depicting the selection criteria for including patients for the study.

Neurological deficit is one of the dreaded complications of kyphotic deformity correction procedures and its incidence is highly varied in the literature.²⁻¹⁵ Also, only a few studies have analyzed the risk factors for neurological deficits after severe kyphotic deformity correction by etiologies stratified by age, sex, sagittal Cobb's, etiology of deformity, presence of signs of myelopathy, location of apex of the curve, type of osteotomy, amount of correction, operative time and blood loss.^{8,12,15} There is inconsistency in the reports of neurological outcomes following kyphotic deformity correction surgeries. Hence, we aimed to analyze the factors associated with neurological deterioration in severe kyphotic deformity correction surgeries.

We performed a retrospective study of all severe kyphotic deformity cases (taken as Cobb's angle >60 degrees from superior end plate of upper end vertebra to inferior end plate of lower end vertebra) which were surgically treated at our institute and analyzed the risk factors for neurological deterioration.

Methods

The medical records of 121 consecutive patients who underwent kyphotic deformity correction at a single tertiary care institute between 1st May 2008 and 31st May 2018 were retrospectively reviewed. After excluding patients who underwent revision deformity correction surgeries, those with presence of intraspinal anomalies and those who had missing clinical/radiological data, 105 patients (49 males, 56 females) were included in the analysis (Figure 1). 35 patients had congenital

causes, 27 patients had infectious causes (Potts spine), 6 patients had osteoporotic causes and 10 patients had post traumatic causes for the kyphotic deformity. Rest of the patients (n = 27) had causes such as Scheuermann's (n = 4), Neurofibromatosis (n = 4), Neuromuscular [Post-Polio (n = 2), Cerebral palsy (n = 2)], Inflammatory causes (Ankylosing spondylitis, n = 5) and post laminectomy kyphosis (n = 7). The demographic, surgical and clinical details of the patients were obtained by reviewing the medical records. We conducted this study in compliance with the principles of the Declaration of Helsinki. The place of study accepts retrospective studies without Institutional Review Board approval.

All the surgeries were performed by a spine team headed by senior orthopedic spine surgeon. The decision on the type of osteotomy to be performed was based on the vertebral level, extent of involvement of the vertebrae and type of deformity. All the patients except those with complete spinal cord injury [American Spinal Injury Association Impairment Scale (AIS)-A] underwent surgery under multi-modal neuromonitoring guidance. All the patients underwent pedicle screw instrumentation and Mesh/ Polyether ether ketone (PEEK) cages were used for anterior reconstruction if necessary. Intraoperative methylprednisolone (1 gram, bolus dose) was given in cases where a neurological deficit was suspected based on the drop in neuromonitoring signals and continued according to the National Acute Spinal Cord Injury (NASCIS)-3 protocol postoperatively if postoperative assessment revealed neurological deterioration. Patients with loss of motor power of 2 or more grades were considered to have severe neurological deficit and patients with loss of motor power of 1 grade were considered to have mild neurological deficit. The neurological deficits were classified as either transient or permanent and mild or severe (at least 1 year follow-up). Patients were considered to have signs of myelopathy if 1 or more of exaggerated reflexes (Knee, ankle, medial hamstring) or clonus, Babinski sign, positive Romberg test/toe to heel test were present. Antero-posterior and lateral standing plain radiographs were analyzed retrospectively from the imaging data base. Details such as the apex of the curve, pre and postoperative sagittal Cobb's angle, site of osteotomy are noted. The review and analysis of clinical and radiological data was performed by 2 fellowship trained senior spine surgeons independently of the senior operating surgeon. The representative patient details have been provided in Figure 2 and Figure 3.

Statistical Analysis

Statistical analysis was performed using IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp. Results on continuous measurements are presented as mean and Standard deviation (Min-Max). Results on categorical measurements are presented as numbers (n) and percentages. The significance is assessed at 5% level of significance. Chi square/Fisher exact test has been utilized to find the significance of study parameters on a categorical scale between 2 or more groups. Independent samples t-test (2* 1 tailed)/Mann Whitney test has been utilized to find the significance of

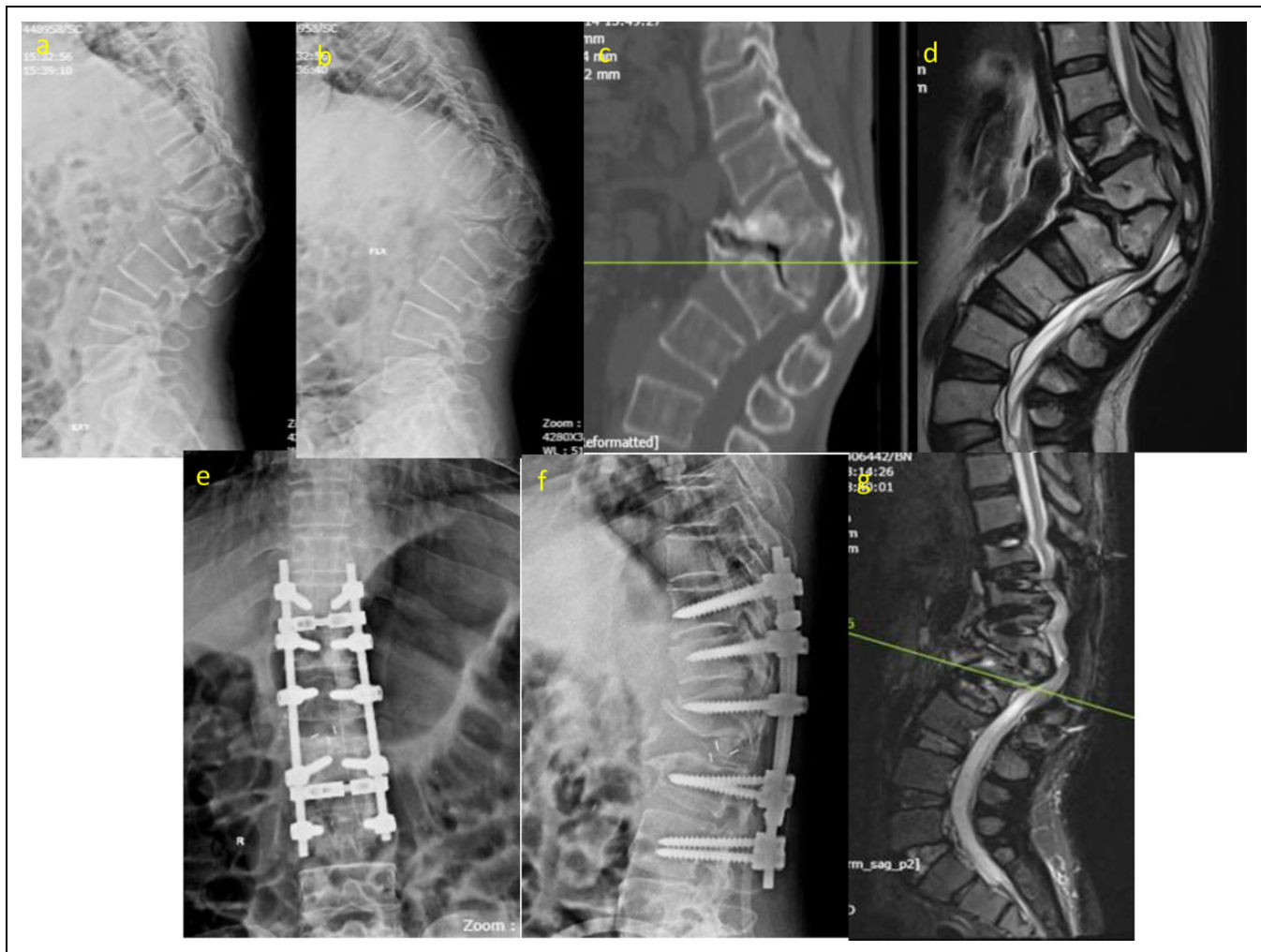


Figure 2. A 56-year-old patient presented with a kyphotic deformity with apex at L1 vertebra. The neurological examination was intact. Extension (a) and flexion (b) lateral X-rays of the thoracolumbar spine show a stiff curve. The Cobbs angle was 105 degrees. CT scan (c) and T2-weighted MRI (d) of the patient show a severe kyphotic deformity with apex at L1 vertebra. The patient underwent a Vertebral Column Resection of L1 vertebra with pedicle screw instrumentation from T10 to L3 vertebrae. The postoperative neurological examination was intact, Postoperative Cobbs angle was 35 degrees and there were no procedural complications.

parameters on a continuous scale between 2 groups as per the distribution of data. Univariate logistic regression is used to find association between the outcome and risk factors and results were presented in OR with 95% confidence interval (CI).

Results

The 105 patients were divided into 2 groups: Group A (without neurological deficit) with 92 patients (42 males, 50 females) and Group B (with neurological deficit) with 13 patients (7 males, 6 females) (12.4%). The mean age of patients was 31.15 years in Group A and 26.54 years in Group B. Statistical analysis showed no significant difference in the 2 groups in terms of age/gender.

Type of Neurological Deficit

The details of patients with neurological deficit are provided in Table 1. Out of 13 patients with neurological deficit (12.3%), 5

patients had mild neurological deficit (4.7%) and 8 patients had severe neurological deficit (7.6%). Four out of 5 patients with mild neurological deficit have recovered completely. Seven patients had complete neurological deficit (6.7%) at the final follow up.

Pediatric Versus Adult Deformity

In group A, 44 patients had age <18 years and 48 patients had age >18 years. In Group B, 3 patients had age <18 years and 10 patients had age >18 years. Fisher exact test showed no statistically significant difference in the 2 groups with respect to pediatric or adult deformity.

AIS Grading

The distribution of patients according to the preoperative AIS grade is given in Table 2. Chi square test showed no significant



Figure 3. A 35-year-old female presented to us with a kyphotic deformity in the mid-thoracic region and deteriorating neurological deficit. She was AIS-C at the time of presentation. T2-weighted (a), T1 weighted (b) sagittal images and T2 weighted parasagittal (c) images show a congenital deformity with apex at T5-T6 level. The preoperative sagittal Cobb's angle was 75 degrees. The patient underwent a Vertebral Column Resection of T5, T6 vertebrae and posterior pedicle screw instrumentation from T3 to T8 vertebra (d, e). The postoperative sagittal Cobb's angle was 45 degrees. Postoperative MRI images (f, g) show adequate decompression of the cord and well-placed instrumentation. The postoperative neurological examination was intact.

difference between the 2 groups with regard to the AIS grading [Exact significance (2 sided) = 0.973].

Signs of Myelopathy

Out of 13 patients with neurological deficits, 12 patients had signs of myelopathy. On the other hand, 61 out of 92 patients in group A had signs of myelopathy. Chi square test showed a significant difference between the 2 groups [Exact significance (1 sided) = 0.048].

Etiology of Deformity

The distribution of patients in the 2 groups based on the etiology of deformity is provided in Table 3. Chi square test showed no significant difference between the 2 groups with

regard to the etiology of the deformity [Exact significance (2 sided) = 0.842].

Apex of the Curve

The distribution of apex of the curve in both the groups is provided in Table 4. Chi square test showed a significant difference between the 2 groups with regard to the apex of the kyphotic deformity [Exact significance (2 sided) = 0.010]. The patients with apex of the deformity at distal thoracic level had the maximum incidence of neurological deficit.

Type of Osteotomy

The details of the type of osteotomy performed in both the groups are given in Table 5. Chi square test showed no

Table 1. A Table Showing the Details of 13 Patients who Underwent a Kyphotic Deformity Correction and Had Neurological Deterioration.

S No.	age	sex	Preop neurology (AIS grading)	Etiology	Sagittal Cobb's	Type of curve(Apex)	Intra-op osteotomy type	Post-op neurology(AIS grading)	Intra-op blood loss	Complications	Post-op Cobb's	Neurology at final followup	Operative time	Myelopathy
1	11	F	Intact	Potts spine	54	Lumbosacral (L4-L5)	VCR (L4,L5)	AIS-D (right foot drop)	1000ml	Neurological deficit (Right foot drop)	11	Normal	4.5 hours	No
2	24	F	AIS-D	Congenital	150	Distal thoracic (T9-T10)	VCR (T9,T10)-2 stage surgery	AIS-B	1500ml,both stages	Neurological deficit	100	AIS-A	10 hours(combined)	Yes
3	15	M	AIS-C with B/B involvement	Congenital	140	Distal thoracic(T6-T7)	VCR(T5, T6, T7)-2 stage surgery	AIS-A (after second surgery)	1600 ml, both stages	Neurological deficit	90	AIS-A	9 hours(combined)	Yes
4	21	M	Intact	Congenital	110	Distal thoracic(T7-T8)	VCR (T7-T9)- 3 stage surgery	AIS-A (after 1st surgery)	2000 ml	Neurological deficit	72	AIS-A	total 14 hours	Yes
5	58	M	AIS-C with B/B involvement	Post-traumatic	85	Distal thoracic(T9-T10)	VCR(T9, T10)	AIS-A	800ml	Neurological deficit , Wound infection	48	AIS-A	6 hours	Yes
6	35	F	AIS-C with B/B involvement	Congenital	75	Distal thoracic(T5-T6)	VCR(T5, T6)	AIS-A	1100ml	Neurological deficit, Pneumonitis	42	AIS-A	6.5 hours	Yes
7	31	F	Intact	Potts spine	95	Distal thoracic(T6-T7)	VCR (T6,T7)	AIS-D with left lower limb weakness	1000ml	Neurological deficit, Pleural tear, Haemothorax	42	Normal	6.5 hours	Yes
8	15	M	Intact	Post-traumatic	85	Cervico thoracic (C7-T1)	Corpectomy C7	AIS-B	800ml	Neurological deficit, Dural tear, Meningitis	15	AIS-C	11 hours	Yes
9	42	M	Intact	Ankylosing spondylitis	80	Thoracolumbar(L2-T9)	PSO (L2)	AIS-D	1100ml	Neurological deficit, Deep wound infection	45	Normal	8 hours	Yes
10	23	F	AIS-D with B/B involvement	Congenital	155	Distal thoracic(T8-T9)	VCR (T8,T9)	AIS-A	1200ml	Neurological deficit , DVT , Deep wound infection with Sepsis,	108	AIS-A	10.5 hours	Yes
11	28	M	Intact	Ankylosing spondylitis	110(Thoracic kyphosis) 48(Lumbar kyphosis)	Thoracolumbar(L2-T9)	PSO (L2,L4)	AIS-D (Right foot drop)	1300ml	Neurological deficit	65(thoracic kyphosis) 25 (lumbar lordosis)	Normal	9 hours	Yes
12	22	F	Intact	Neurofibromatosis	165	Distal thoracic(T8-T9)	VCR (T8)	AIS-A (after 24 hours of surgery)	800ml	Neurological deficit, Haemo-pneumothorax B/L	122	AIS-A	7 hours	Yes
13	20	M	Intact	Potts spine	65	Thoracolumbar (T12-L1)	VCR (T10-T12)	AIS-D	750ml	Neurological deficit, Dural tear	32	AIS-D	9 hours	Yes

Table 2. A Table Showing the Distribution of Preoperative AIS (American Spinal Injury Association (ASIA)- Impairment Scale) Grades Among Patients in the 2 Groups.

Preoperative AIS grade	Group A(n)	Group B(n)	Total
E	50	8	58
D	12	1	13
C	20	3	23
B	8	1	9
A	2	0	2
	92	13	105

Table 3. A Table Showing the Distribution of Patients Based on the Etiology of Deformity Among the 2 Groups.

Etiology of deformity	No of patients in Group A	No of patients in Group B	Total
Congenital	30	5	35
Potts Spine	24	3	27
Osteoporotic	6	0	6
Post-traumatic	8	2	10
Others	24	3	27

Table 4. A Table Showing the Distribution of Patients Based on the Apex of the Kyphotic Deformity Among the 2 Groups.

Apex of curve	Group A	Group B	Total
Cervico-thoracic(C7-T2)	8	1	9
Proximal thoracic(T2-T3 disc to T5)	8	0	8
Distal thoracic(T5-T6 disc to T10)	28	8	36
Thoraco-lumbar(T10-T11 disc to L2)	38	3	41
Lumbar(L2-L3 disc to L4)	10	0	10
Lumbosacral(L4-L5 disc to S1)	0	1	1

Table 5. A Table Showing the Distribution of Patients Based on the Type of Osteotomy Performed in the 2 Groups.

Type of osteotomy	Group A(n)	Group B(n)
Vertebral column resection	66	11
Pedicle subtraction osteotomy	4	2
Bone disc bone osteotomy	2	0
Smith Peterson osteotomy	20	0

significant difference between the 2 groups with regard to the type of osteotomy performed [Exact significance (2 sided) = 0.104].

Sagittal Cobb's

The mean Sagittal Cobb's angle was 65.24 degrees in Group A and 109 degrees in Group B. Independent Samples t-test showed a statistically significant difference between the 2 groups ($p < 0.0001$).

Operative Time and Blood Loss

The mean intraoperative blood loss was 1087 ml in Group A and 1112.5 ml in Group B. The mean intraoperative time was 6.51 hours in Group A and 8.54 hours in Group B. Statistical analysis showed a significant difference between the 2 groups in operative time ($p = 0.003$) but no difference in the intraoperative blood loss ($p = 0.889$).

Postoperative Cobb's and Amount of Correction

The mean postoperative Sagittal Cobb's angle was 24.3 degrees in group A and 59 degrees in group B. The postoperative sagittal Cobb's angle showed a statistically significant difference between the 2 groups ($p = 0.001$). The amount of correction did not show a statistically significant difference ($p = 0.064$) between the 2 groups.

Univariate Logistic Regression Analysis

Table 6 shows the univariate logistic regression analysis which was used to find association between various categorical variables and risk of neurological deterioration during kyphotic deformity correction surgery. Type of curve was found to be a significant risk factor for complications with OR of 3.66 (95%CI: 1.10-12.17) whereas age, gender, AIS grading, etiology of deformity and signs of myelopathy were not found to be significant risk factors. There is 4 times more risk of neurological deterioration in distal thoracic curve as compared to others. Also data shows that males are more prone to risk of neurological deficit though a significant association was not observed.

Discussion

Among all the analyzed risk factors, we found that sagittal Cobb's angle, signs of myelopathy and location of apex showed a statistically significant difference between the 2 groups. Type of curve was found to have a significant risk of neurological deterioration during kyphotic deformity correction procedures. On reviewing the literature, there are a few studies on correction of sagittal plane deformities using a Pedicle subtraction Osteotomy (PSO) or Vertebral Column Resection (VCR). Buchowski et al² has tried to introspect into the cause of a neurologic deficit that occurs in pursuit of correcting the deformity. In a review of 108 consecutive patients by Buchowski et al² with global sagittal imbalance treated with a lumbar pedicle subtraction osteotomy over a 10-year period, the incidence of intraoperative and postoperative deficits was 11.1% (12 of 108 patients). The incidence of a permanent deficit was 2.8% (3 of 108 patients). Fortunately, despite these complications, an overall improvement in Oswestry Disability Index (ODI) and Scoliosis Research Society outcomes Questionnaire (SRS-22) scores was noted after surgery even in the group of patients with a neurologic deficit. The authors believed that the

Table 6. A Table Showing Univariate Regression Analysis Used to Find Association Between Various Risk Factors and Neurological Deterioration in Kyphotic Deformity Correction Surgeries.

Characteristics*	Patients without neurodeficit n	Patients with neurodeficit n	Odds Ratio	95% Confidence interval
Age				
≤ 18 yrs	44	3	Ref	
> 18 yrs	48	10	3.06	0.79-11.83
Gender				
Male	42	7	1.39	0.43-4.45
Female	50	6		
AIS**				
E	50	8	Ref	-
D	12	1	0.52	0.06-4.57
C	20	3	0.94	0.23-3.89
B	8	1	0.78	0.09-7.11
Etiology				
Congenital	30	5	Ref	-
Potts spine	24	3	0.75	0.16-3.46
Osteoporotic/others	30	3	0.60	0.13-2.74
Post traumatic	8	2	1.50	0.24-9.22
Type of Curve				
Distal thoracic	28	5	3.66	1.10-12.17
Other	64	8	Ref	-
Signs of myelopathy				
+	61	12	6.098	0.758-49.074
-	31	1		

*Only categorical variables have been included for calculating the Odds ratio.

*Type of osteotomy was not included as none of the patients who underwent an SPO suffered neurological deterioration.

** AIS-A grade was not included in the analysis as it does not have a risk of neurological deterioration.

deficits were caused by a combination of subluxation, residual dorsal impingement, and dural buckling.²

In an earlier report from the same institution, focusing on complications and outcomes of pedicle subtraction osteotomies for fixed sagittal imbalance, Bridwell et al³ found that, in a series of 33 consecutive patients, 5 experienced a transient neurologic deficit for an overall incidence of a neurologic deficit of 15.2%.³ No patients had a permanent deficit in this series; and despite the complications, the authors found a significant improvement in overall ODI and pain scores.

In a recent retrospective review of 35 patients who underwent a thoracic or lumbar pedicle subtraction osteotomy for fixed sagittal imbalance, Yang et al⁴ found an incidence of intraoperative or postoperative neurologic deficits to be 3.6% (1 of 28 patients who underwent a lumbar pedicle subtraction osteotomy). The single deficit noted in the series was thought to be due to nerve root compression. In a similar retrospective review of 83 consecutive patients with fixed sagittal imbalance treated with a spinal osteotomy, Ahn et al⁵ found a 12.0% incidence of neurologic deficits. In a retrospective review of 59 patients treated with a pedicle subtraction osteotomy, Murray et al⁶ found that, of the 31 patients who were neurologically intact before surgery, all remained intact after surgery. In an analysis of 45 patients with ankylosing spondylitis, Kim et al⁷ found an incidence of neurologic deficits of 11.1%; more specifically, 4 patients were noted to have transient postoperative

radiculopathy and 1 patient was noted to have spinal cord compression from a bone fragment at T12.

Suk et al,⁸ who described the posterior VCR, reported an incidence of 6% transient nerve root injuries and 3% permanent complete spinal cord injury. They reported that the spinal cord injury patients had a significant preoperative cord compromise. Lenke et al⁹ in their multi center study of 147 pediatric VCR patients reported intraoperative neurologic events of 27%. However, no patients suffered permanent neurological deficits whereas transient neurologic deficit was seen in 3% of cases. Kim et al¹⁰ reported a 13.8% and 3.3% incidence of transient and permanent neurologic deficits, respectively, with PVCR. Papadopoulos et al,¹¹ in their study on 50 patients, reported 4% incidence of isolated nerve root injuries and 2% incidence of permanent complete spinal cord injury. Xie et al¹² reported that preexisting neurologic dysfunction was the greatest risk factor for postoperative neurologic deficit in deformity correction surgeries. Other risk factors reported were potential intraspinal and brainstem anomalies, scoliosis associated with hyperkyphosis, and level of VCR. Kim et al¹³ reported preoperative neurologic deficit and resection of 2 or more vertebrae as the risk factors for neurological deterioration. A narrative review by Iyer et al¹⁴ on the complications and outcomes following VCR in 2016 reported that the rate of neurological complications was 13.3% with most cases being transient and 2% rate of permanent neurological deficits.

Auerbach et al¹⁵ showed that preoperative sagittal imbalance, age and the presence of 3 or more comorbidities were risk factors for complications following VCR. However, all these studies included all types of deformities including scoliosis. The kyphotic deformity correction carries a greater risk of neurological deterioration. Mechanical stresses due to the kyphotic deformity, intraoperative manipulation, dural kinking or buckling, dural stretching are possible reasons for neurological deterioration in kyphotic deformity correction surgeries.

Xie et al¹² reported that the level of vertebral column resected was correlated with neurological deficit in posterior VCR. However, they categorized the levels into thoracic, thoracolumbar and lumbar region. We believed that a distinction of the proximal thoracic and distal thoracic levels is essential. Based on our results, we assume that the less space available for the cord, the water shed regions in the lower thoracic spine, ligation of segmental vessels in the lower thoracic spine for exposure and fusion may compromise spinal cord perfusion and thereby causing neurological deficit. We recommend a more careful approach in cases of kyphotic deformities with apex in the lower thoracic spine, particularly when dealing with segmental vessels or handling of the cord.

Suk et al⁸ and Xie et al¹² reported that preoperative cord compromise is a risk factor for postoperative neurological deficit. Suk et al⁸ used Frankel grading for assess neurological dysfunction whereas Xie et al¹² used physical examination to document neurological dysfunction but did not mention any examination criteria. We observed that patients with myelopathy often present with signs and symptoms of myelopathy and a relatively preserved motor strength on AIS/Frankel grading. We therefore analyzed the risk factors using both AIS grade as well as the presence of signs of myelopathy. Of note, presence of signs of myelopathy was observed to be a more reliable predictor of risk of neurological deterioration than the AIS grade in our study. Except for 1 patient who had a transient and mild neurological deterioration, all of the patients in group B had signs of myelopathy.

None of the patients who underwent a Smith-Peterson osteotomy (SPO) (n = 20) had neurological deterioration. However, since majority of the patients (n = 77) underwent VCR and the numbers of patients who underwent PSOs (n = 6) and disc bone osteotomies (n = 2) are less to compare the results, the type of osteotomy did not show a significant difference between the groups.

The preoperative Sagittal Cobbs angle and not the amount of correction was found to be associated with neurological deterioration. A possible reason could be a reduction in the amount of correction following a drop in neuromonitoring signals. The significant difference in the operative time between the 2 groups could also be due to the time spent on the neuromonitoring in case of signal changes. However, this factor was not analyzed in our study.

Limitations

The study was retrospective in nature. Factors such as intraoperative monitoring and intraoperative hypotension, surgical

factors such as number of segmental vessels ligation etc. which can affect the outcomes have not been analysed in our study. Confounding factors such as signal changes in the neuromonitoring may have influenced variables such as operative time and amount of correction differently in each group. Also, the study involved radiological measurements. Hence, errors such as issues with image resolution, position of the patient and calculation of the angles are possible. Since the study is conducted at a single institute by a common team of spine surgeons, surgeon bias would have been minimal.

Conclusions

Preoperative Sagittal Cobbs angle, presence of signs of myelopathy, operative time and location of apex in the distal thoracic region were significantly higher in patients with neurological deterioration as compared to those without neurological deterioration during kyphotic deformity correction surgery. Distal thoracic curve was found to have 4 times more risk of neurological deterioration as compared to others. Age, gender, AIS grading, etiology of the deformity and amount of blood loss were not associated with a risk of neurological deterioration.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.


Declaration of Conflicting Interests

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