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Clinical Study

Apex of deformity for three-column osteotomy. Does it matter in the occurrence of complications?

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Abstract

BACKGROUND: Posterior vertebral column resection (PVCR) is a challenging but effective technique for the correction of complex spinal deformity. However, it has a high complication rate and carries a substantial risk for neurologic injury.

PURPOSE: The aim was to test whether the apex of the deformity influences the clinical outcomes and complications in patients undergoing PVCR.

STUDY DESIGN: A historical cohort was recruited from a single center and evaluated preoperatively, postoperatively, and at final follow-up.

PATIENT SAMPLE: Ninety-eight hyperkyphotic patients undergoing PVCR were included. Inclusion criteria consisted of kyphoscoliosis and hyperkyphosis surgically treated with PVCR as a primary or revision procedure.

OUTCOME MEASURES: The outcome measures included a number of neurologic complications.

METHODS: Receiver operator characteristic (ROC) curve analysis and Youden index (J) were used to estimate the optimum cut-off to predict neurologic complications for each potential risk factor. In three ROC analyses, we included separately body mass index (BMI), kyphosis degree, and age as

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independent variables and neurologic complications as the dependent variable. Logistic regression was used to estimate the odds ratios (ORs) and construct 95% confidence intervals (CIs).
RESULTS: Among the 98 patients, the etiologies were: post infectious (50), congenital (31), and others (17). The averages were: age 14±6.5 years, BMI 20±10 kg/m^2, American Society of Anesthesiologists 3±0.7, forced vital capacity 76±23%, fusion levels 10±3, estimated blood loss 1,319±720 mL, surgical time 375±101 minutes, and preoperative localized kyphosis 104±30°. Thirty-three patients had abnormal preoperative neurologic status. Major complications occurred in 46 patients (neurologic in 25). The apex of kyphosis was proximal thoracic T1–T5 (five patients), thoracic (TH) T6–T9 (17 patients), thoracolumbar T10–L2 (55 patients), and lumbar L3–S1 (nine patients). The level of apex and BMI were independent risk factors for neurologic complications: TH apex (OR: 101.30, 95% CI: 1.420–infinite; p=.037); BMI (OR: 1.92, 95% CI: 1.110–infinite; p=.026).
CONCLUSIONS: Posterior vertebral column resection for severe spine deformity is technically demanding and carries a substantial risk. The apex is a variable that influences the occurrence of neurologic complications, and the presence of a TH apex in particular could be a preoperative risk factor for neurologic complications.

Keywords: Kyphosis; Kyphoscoliosis; Vertebral column resection osteotomy; Pediatric deformity; Neurologic complications

Introduction

Vertebral column resection (VCR) was popularized by Bradford in 1987 who described a circumferential vertebral column resection as a combined anterior/posterior procedure for severe rigid spinal deformities and severe imbalance of the trunk [1–3].

Later, Suk et al. in 2002 described the VCR through a posterior-only approach for correction of fixed lumbosacral deformities as a procedure to reduce the morbidity related to the anterior approach, the amount of surgical blood loss, the surgical procedure time. It also allows the translation of spinal column to restore normal spinal alignment [4,5]. In the last decade, the three-column osteotomy has become popular among spine surgeons as a technically demanding but effective procedure for the management of severe rigid spinal deformities [6].

More recently, Lenke et al. [7–9] have described in detail the surgical technique for posterior vertebral column resection (PVCR) and have evaluated the surgical outcomes and the associated complications in a large series.

Posterior-only three-column osteotomy procedures are associated with high complication rates and carry a significant risk for neurologic injury. Minimizing complications and optimizing outcomes should be essential goals of spine deformity surgery.

Several potential risk factors for neurologic complications have been reported; however, the relationship of the level of the apex of the deformity and the risk for neurologic complications has not been reported to our knowledge. During VCR, the site of resection is always at the apex of the deformity. The extent of resection depends on the number of vertebrae involved in the localized deformity, the extent of compression of the spinal cord, and the amount of deformity correction that is needed.

The purpose of this study was to review the clinical outcomes and complications in hyperkyphotic deformity patients undergoing corrective spine surgery with PVCR and to determine whether there is an association between the risk for overall or neurologic complications and the apex of the deformity.

Materials and methods

Institutional review board approval was obtained for this retrospective review of data collected prospectively in consecutive patients with severe kyphoscoliosis and hyperkyphosis surgically treated with PVCR as a primary or revision procedure from 2002 to 2013.

Patients, clinical, and radiographic parameters

Clinical and radiographic data of a total cohort of 98 patients were evaluated. Data collected included morphometric variables such as age, weight, height, and body mass index (BMI). Other variables evaluated were etiology, American Society of Anesthesiologists classification, forced vital capacity, preoperative neurologic status, and intraoperative variables such as operating room time, estimated blood loss (EBL), number of levels fused, and complications.

Radiographic measures were made from 36-inch, standing anteroposterior, and lateral radiographs and were reviewed preoperatively, immediately postoperatively, and at final follow-up to assess the deformity correction and complications related to the procedure. The radiologic parameters evaluated were Cobb angle of major and minor coronal curves, angle of maximum kyphosis, levels involved in localized kyphosis (LK), and location of the apex of the deformity. We categorized the level of the apex as: proximal thoracic (PT) T1–T5; thoracic (TH) T6–T9; thoracolumbar (TL) T10–L2, and lumbar (L) L3–S1.

Surgical technique

Patients were placed in a prone position with bolsters at nipple line, and distal bolsters at the proximal thighs. In all patients, pre- and post-positioning baseline intraoperative neuromonitoring (IONM) was obtained, consisting of both transcranial motor evoked potentials and somatosensory evoked potentials. A standard posterior approach to the spine was performed and meticulous dissection undertaken to expose the lateral wall of the vertebral body (ies).

a. The VCR technique included exposing the apical segment(s), gaining segmental fixation using pedicle screws at every level, and then performing bilateral costotransversectomies removing the medial 2 to 3 cm of the apical ribs, including the rib head and transverse processes. The neurovascular bundle(s) at the apex is ligated and divided in TH VCRs and preserved in lumbar VCRs.
b. A laminectomy of the apical vertebra(ae) is performed. The superior and inferior margins of the laminectomy are undercut to avoid dural impingement during osteotomy closure. As much as 5-cm wide laminectomy has been performed and shortened to 1 cm without a neurologic deficit. It is also important to remove any scar tissue on the dura to prevent mechanical compression of the cord or dura during the shortening process.
c. The posterior bone resection is extended to the base of the pedicles. Before initiating the anterior column portion of the osteotomy itself, a temporary rod is placed on one side (in anticipation of the destabilization produced by the PVCR). A wedge-shaped vertebral resection with superior and inferior borders parallel to the screws just superior and inferior to osteotomy site was performed using an osteotome or a high-speed burr to outline osteotomy. The posterior wall is preserved. This step is repeated for the opposite side after switching the temporary rod. The posterior wall is the last segment removed to complete the circumferential spinal decompression and resection. A posterior vertebral wall cutter and impactor are used to depress the posterior wall anteriorly.
d. It is critical to combine posterior column shortening with anterior column lengthening to avoid buckling of the cord or dura. Once the desired correction is achieved, a cage is placed anteriorly followed by posterior compression to engage the cage to prevent dislodgement. Posterior column shortening of as much as 3 to 4 cm was safely achieved in our series without a neurologic deficit.
e. Throughout the procedure, a temporary rod is always kept on one side until the final rods are placed.
f. There were no instances of IONM loss during the division of the TH nerve roots. Monitoring changes occasionally occurred with cord stretching and hypotension. This almost always resolved with shortening and elevation of mean arterial blood pressure to above 80 mm Hg.
g. Deformity correction is achieved with sequential rod exchanges and in situ contouring of the rod and gradual straightening with each exchange until the desired correction and shortening is achieved [2,10].

EVIDENCE & METHODS

Context

The authors sought to evaluate the influence of the apex of spinal deformity on outcomes and complications rates following posterior vertebral column resection (PVCR). This was a retrospective review of 98 patients treated at a single center.

Contribution

The authors report the level of the apex of spinal deformity and BMI were independent risk factors for neurological complications in their final adjusted analysis. The authors maintain that patients with an apex of deformity within the thoracic spine are at the greatest risk for complications

Implications

This study provides important information that can be used to inform patients regarding complication risk and to manage expectations in the perioperative period. It also represents one of the largest series on this topic and may very well be the best available evidence at this time. Nonetheless, as a retrospective work derived from a single center, this study is subject to both selection and indication bias. In addition, the statistical testing may have been overly robust given the less than 100 patients included in the study sample. As a result, some of the statistically significant findings may be spurious. Further confirmatory testing in other work of a multi-center nature is likely necessary.

—*The Editors*

During the procedure, special care is taken to control epidural bleeding using hemostatic products such as Floseal Hemostatic Matrix (Baxter, Baxter and Floseal are registered trademarks of Baxter International Inc, Fremont, CA, USA), Gelfoam (Gelfoam absorbable gelatin compressed sponge is a registered mark of Pfizer Inc, New York, NY, USA), and cottonoids. Moreover, a series of IONM recordings are taken to ensure cord functioning. The mean arterial blood pressure is usually kept at greater than or equal to 80 mm Hg depending on IONM responses.

Statistical analysis

We performed a descriptive analysis and overall summary statistics of quantitative variables, which were described with means, standard deviations, and qualitative variables with frequencies and percentages.

We used Mann-Whitney tests to compare patients according to the apex of the deformity (TH vs. L) in EBL and operating room time.

Receiver operator characteristic (ROC) curve analysis was used to estimate the optimum cut-off to predict postoperative complications. In three ROC analyses, we included separately BMI, amount of kyphosis, and age as the independent variables and neurologic complications as classification variable. We included intraoperative neurologic complications as neurologic complications. The cut-off in each independent variable was estimated with the Youden index J (J=sensitivity+specificity−1). We calculated sensitivity, specificity, positive, and negative likelihood ratios, and 95% confidence intervals (CIs) for the optimum cut-off in each independent variable.

Logistic regression analysis was used to estimate odds ratios (ORs) and construct 95% CIs. The dependent variable was intraoperative neurologic complications, and the independent variables were determined based on the Youden index of each potential risk factor: age (>11 years); BMI (>20 kg/m^2); amount of kyphosis (>92°); PT apex; TH apex; and TL apex, using lumbar spine (L) apex as a reference category.

Statistical analysis was performed with MedCalc (Mariakerke, Belgium) and LogXact version 4.1 (Cytel Co., MA, USA). Probability values were estimated using asymptotic or Monte Carlo methods, as appropriate. All p values less than .05 were considered statistically significant.

Results

Of the total cohort of 98 patients, diagnoses included post infectious hyperkyphosis in 50, congenital kyphosis and kyphoscoliosis in 31, idiopathic in 4, neuromuscular in 5, syndromic in 2, and others in 6 patients.

Morphometric variables

The average age was 14±6.5 years. The mean preoperative weight was 34 kg (range 14–62 kg), the mean height was 130 cm (range 100–160 cm), and the mean preoperative BMI was 20±10 kg/m^2. The mean preoperative American Society of Anesthesiologists score was 3±0.7 and the mean forced vital capacity 76±23%. Abnormal preoperative neurologic status was present in 33 patients (Table 1).

Radiographic measures

Preoperative LK was 104±30°. Preoperative major Cobb angle was 79° (range 24°–150°), and minor Cobb angle was 51° (range 19°–90°). The number of vertebrae involved in LK averaged 5.2±1.5 vertebrae. The apex of kyphosis was located in the PT region, above T5, in five patients (T2:1; T3:1; T4:1; T5:2); in the TH region, between T6 and T9, in 17 patients (T7:4; T8:7; T9:6); in the TL region, between T10 and L2 in 55 patients (T10:12; T11:8; T12:16; L1:18; L2:1), and in the lumbar region, between L3 and S1, in nine patients (L3:7; L4:1; L5:1; Table 2).

Table 1
Morphometric, radiographic and surgical variables, expressed with means and standard deviations

Variables	
Age (y)	14±6.5
Weight (kg)	32±14
Height (cm)	130±21
BMI (kg/m^2)	20±10
ASA score	3±0.7
Percentage of FVC	76±23
Preoperative localized kyphosis	104±30
Preoperative major Cobb angle	79±38
Preoperative minor Cobb angle	51±29
Fused vertebrae number	10±3
EBL (mL)	1,319±720
Surgical time (min)	375±101

BMI, body mass index; ASA, American Society of Anesthesiologists; FVC, forced vital capacity; EBL, estimated blood loss.

Surgical parameters

Figs. 1–3 show preoperative and postoperative images of surgical results in three patients, as examples.

The mean number of vertebrae fused was 10±3 levels. The mean EBL was 1,319±720 mL, and the average surgical time was 375±101 min. The total number of patients with complications was 46 (47%). Intraoperative neurologic complications occurred in 25 patients (26%). Among them, 10 patients had an abnormal neurologic status preoperatively.

Postoperative neuro deficits occurred in 14 patients (14%). Spinal cord injuries occurred in 11 patients (11%). Among these patients, the apex of kyphosis was T7 in two patients, T8 in two, T10 in three, T12 in two, and L1

Table 2
Apex categorization

Apex categorization	Apex	Total number of patients
PT (proximal thoracic)≤T5	T2:1 T3:1 T4:1 T5:2	5
TH (thoracic) T6–T9	T7:4 T8:7 T9:6	17
TL (thoracolumbar) T10–L2	T10:12 T11:8 T12:16 L1:18 L2:1	55
L (lumbar)≥L3	L3:7 L4:1 L5:1	9

Not available (N/A) in 12 patients.

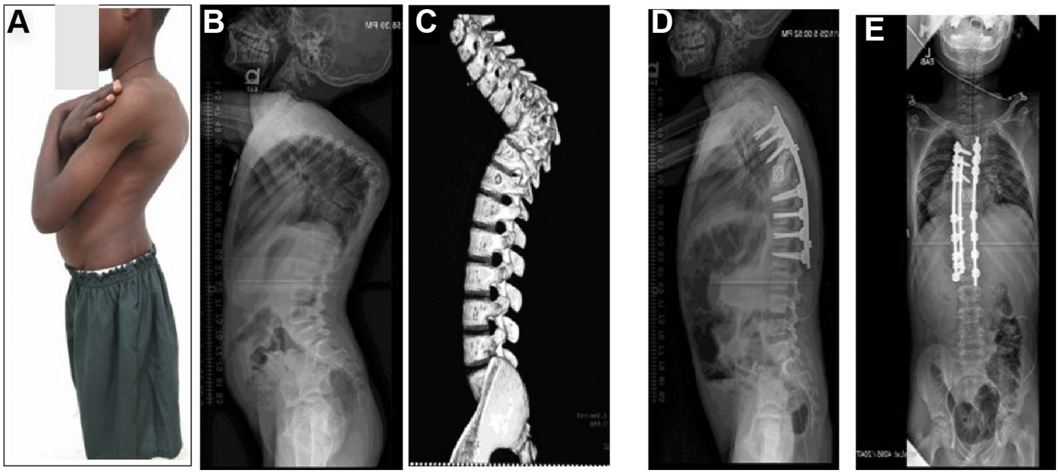

Fig. 1. A 12-year-old male congenital kyphosis patient had posterior spinal fusion T3–L1 and vertebral column resection T7, T8. Complications: transient loss of somatosensory evoked potentials. (A) Preoperative lateral view. (B) Preoperative lateral X-ray: localized kyphosis: T7–T11 101°. (C) Preoperative sagittal computed tomography scan. (D) Postoperative lateral X-ray. (E) Postoperative anteroposterior X-ray.

in one patient. In four patients, the deficit was transient. Seven patients progressed to permanent neuro deficits postoperatively, two patients (apex T8), two patients (apex T7), one patient (apex T10), one patient (apex T12), and one patient (apex L1) who remained paraplegic and died 2 years postoperatively.

Nerve root injuries occurred in three patients (3%), with the apex at T5, T9, and L3, and all three fully recovered at follow-up (Table 3).

Of the 25 patients with intraoperative neurologic complications, 10 patients had preoperatively abnormal neurologic status and of them, four patients had IONM

Fig. 2. A 14-year-old female congenital kyphosis patient had posterior spinal fusion from T8 to L4 and vertebral column resection T11–T12–L1. No complications, somatosensory evoked potentials/motor evoked potentials: normal. Preoperative kyphosis angle: T8–L3 115°. Postoperative kyphosis angle 45°. (Left and Right) Preoperative lateral view and postoperative lateral view.

Fig. 3. A 19-year-old female congenital kyphoscoliosis patient had posterior spinal fusion T3–L3 and vertebral column resection T10, T11. Complications: temporary loss of somatosensory evoked potentials/motor evoked potentials. Preoperative localized kyphosis: T9–L2 160°. Postoperative localized kyphosis 100°. (Left and Right) Preoperative and postoperative views and posterior and lateral views.

changes, and six patients progressed to permanent neuro deficit postoperatively—two (apex T8), two (apex T7), one (apex T12) and one (apex L1).

Nine patients had complications related to the implants, and all required revision surgery. Seven patients had pleural tears during the costotransversectomies, repaired primarily in three patients, with two patients needing chest tube placement and two patients with postoperative atelectasis requiring reintubation. Four patients had deep infections. Among them, three had wound drainage and were treated locally, and one patient required surgical treatment with irrigation and debridement. One patient had a tongue laceration, which healed uneventfully.

Revision surgery was required in 10 patients at the latest follow-up period, one related to surgical site infection and the others related to the implants (nine); three broken rods, two prominent implants, two proximal hook dislodgement, one cage dislodgement, and one proximal junctional failure.

Table 3
Intraoperative neurologic complications and postoperative neuro function

Patients with IONM changes Case#	Abnormal preoperative neuro status (Y/N)	Cord/conus level injury (Y/N)	Postoperative transient cord injury (Y/N)	Postoperative permanent cord injury (Y/N)	Postoperative transient root injury (Y/N)
1	N	N	N	N	Y
2	Y	N	N	Y	N
3	Y	N	N	Y	N
4	N	Y	N	N	N
5	Y	Y	N	N	N
6	N	Y	N	N	N
7	Y	N	N	Y	N
8	Y	N	N	Y	N
9	N	N	N	N	Y
10	Y	Y	N	N	N
11	Y	Y	N	N	N
12	N	Y	N	N	N
13	N	Y	N	N	N
14	N	N	Y	N	N
15	Y	N	N	Y	N
16	N	Y	N	N	N
17	N	Y	N	N	N
18	N	N	Y	N	N
19	Y	N	Y	N	N
20	N	N	N	Y	N
21	N	N	N	N	Y
22	Y	N	N	Y	N
23	N	Y	N	N	N
24	N	N	Y	N	N
25	N	Y	N	N	N
Total	10	11	4	7	3

IONM, intraoperative neuromonitoring.

Table 4
Goodness of fit using the optimal cut-off for age (>11 years), BMI (>20), and kyphosis (>92°)

Optimal cut-off	Sensitivity	95% CI	Specificity	95% CI	+LR	95% CI	−LR	95% CI
Age>11 y	76.00	54.9 to 90.6	49.32	37.4 to 61.3	1.50	1.1 to 2.1	0.49	0.2 to 1.0
BMI>20	59.09	36.4 to 79.3	74.58	61.6 to 85.0	2.23	1.3 to 4.1	0.55	0.3 to 0.9
Kyphosis>92°	85.71	63.7 to 97.0	46.03	33.4 to 59.1	1.59	1.2 to 2.1	0.31	0.1 to 0.9

BMI, body mass index; CI, confidence interval; LR+, Positive likelihood ratio; LR−, Negative likelihood ratio.

No differences were found between patients with TH and L apex in EBL (p=.183) and operating room time (p=.80). Only four patients had deep infections. With so few cases, we could not determine whether there was any association between the development of deep infection and the apex of the deformity.

Results of goodness of fit and logistic regression analysis

Areas under ROC curves and goodness of fit of the cut-off using Youden index

The areas under the ROC curves were: BMI=0.71 (95% CI=0.594–0.801, p=.002), age=0.66 (95% CI=0.56–0.75, p=.013), and amount of kyphosis=0.64 (95% CI=0.54–0.75, p=.019; Table 4).

The optimal cut-offs for predicting complications using the Youden index were: age older than 11 years, BMI greater than 20, and kyphosis greater than 92°. These optimal cut-offs are summarized in Table 4, with corresponding indicators of goodness diagnosed.

Logistic regression analysis

Table 5 shows the logistic regression results. We included in the partial logistic regression models independent variables such as age (>11 years), BMI (>20), kyphosis (>92°), and apex level (PT, TH, TL, and L) using intraoperative neurologic complications as the dependent variable. The results indicate that controlling for BMI (OR: 1.92, 95% CI=1.110–infinite; p=.026), a TH apex is a predictor of intraoperative neurologic complications (OR: 101.30, 95% CI=1.420–infinite; p=.037). Also, we observed that an age over 11 years (OR: 3.05, 95% CI=1.184–infinite; p=.023) and a kyphosis greater than 92° (OR: 5.03, 95% CI=1.519–infinite; p=.008) were also predictors of intraoperative neurologic complications (Table 5).

Table 5
Partial logistic regression model to predict intraoperative neurologic complications

	OR	95% CI	p Value
Model 1			
Age categorized (>11 y)	3.047	1.184 to infinite	**.023**
Model 2			
BMI categorized (>20)	3.46	1.312 to infinite	**.015**
Model 3			
PT apex (reference category: L apex)	53.33	0.228 to 373.148	.28
Model 4			
TH apex (reference category: L apex)	101.30	1.420 to infinite	**.037**
Body mass index	1.92	1.110 to infinite	**.026**
Model 5			
TL apex (reference category: L apex)	2.23	0.360 to infinite	.23
Model 6			
Kyphosis categorized (>92°)	5.03	1.519 to infinite	**.008**

OR, odds ratio; CI, confidence interval; BMI, body mass index; PT, proximal thoracic; TH, thoracic; TL, thoracolumbar.

We tested the potential confounding effect of the "preoperative neurologic status," "EBL," "length of deformity apex," and "time of preoperative neuro deficit". To consider the aforementioned variables as confounders in the relationship between TH apex and neurologic complication, the potential confounding must be associated with the independent variable. The correlation results showed that TH apex was not associated with preoperative neurologic status (rho=0.18; p=.20), EBL (0.46; p=.09), length of deformity apex (rho=0.12; p=.30), or time of preoperative neuro deficit (−0.48; p=.06).

Discussion

The technique for performing a posterior-only VCR was initially described by Suk et al., and it was later, popularized by Lenke et al. and has been widely practiced among experienced spine surgeons, in the last decade. The surgical technique allows a controlled manipulation of both the anterior and posterior columns with adequate spinal column realignment for rigid deformities [10,11].

Complex spinal deformity surgery is technically demanding and carries substantial risks, therefore requiring a highly experienced surgical team. The complication rate in most reported series of PVCR is moderately high (59%) [9].

Surgeons treating patients with severe kyphosis or kyphoscoliosis must be conversant with three-column osteotomy techniques and must have had the requisite training and experience with handful of cases. Anesthetic support with total intravenous anesthetics and invasive monitoring to manage hypotensive episodes is critical. Intraoperative spinal cord monitoring with both transcranial motor evoked potentials and somatosensory evoked potentials are essential and the maintenance of normotensive anesthesia, and a mean arterial blood pressure greater than or equal to 80 mm Hg during the correction maneuver could avert major neurologic complications. Nutritional optimization should be considered. Institution of appropriate dietary supplements improved the nutritional status of the malnourished patients in our series.

A 3D computed tomography is mandatory to fully understand the type of deformity one is dealing with. Intraspinal anomalies must be ruled out with whole spine magnetic resonance imaging. A thorough neurologic evaluation is also necessary to obtain baseline neurologic function.

Neurologic complications can be transient nerve root injuries due to the excessive retraction of nerve roots during resection of the vertebral body or a cord injury from diminished vascular supply to the cord, cord impingement due to subluxation of the spinal column during the osteotomy, or overshortening of the spinal cord during closure of the vertebrectomy gap. Other authors have reported the benefit of temporarily clamping the segmental vessels before definitive ligation to determine the potential neurologic consequence based on the IONM. Under such circumstances, one can try to preserve the segmental vessels or at least only sacrifice them unilaterally. However, this was not the practice for the series reported [12].

The rate of total complications in the present study was 47%, with 26% being intraoperative neurologic complications. In our study, 11 patients had post operative neuro deficits from spinal cord injury: seven resulting in permanent deficits (six of these patients had preoperatively abnormal neurologic status), four patients resulting in transient deficits with complete recovery at follow-up, and one patient with postoperative paraplegia who died 2 years after the operation. Root injury occurred in three patients, will all being transient.

Minimizing the complications and optimizing outcomes are the main goals in complex spine deformity surgery. Although potential risk factors have been reported, there is still an overall lack of information about the independent risk factors for neurologic complications after PVCR. A better understanding of the influence of the level of the apex of the kyphotic deformity on the development of complications was the purpose of our study.

Our results suggested that, when adjusted for the same BMI, performing a PVCR in a kyphotic deformity with the apex at the TH (T6–T9) region has an increased neurologic risk compared with resections at other spinal levels (ie, TL and L). Usually, in acute kyphotic deformity, the spinal cord is stretched and compressed against the anterior angular gibbus. In the middle and upper TH regions, the segmental blood supply to the spinal cord is tenuous, and the diameter of spinal canal is narrowest; hence, the cord is less mobile, which may render it less tolerant to any manipulation. To perform a PVCR in the TH region carries implicit interference in the segmental arteries and therefore in the blood supply to the spinal cord, which may compromise the cord function, especially in the TH region (T6–T9), and additionally, a higher risk of neurologic complication may exist if the neurologic status is abnormal preoperatively.

Currently, underweight, malnourished, and respiratory compromised patients are placed in halo gravity traction for a minimum of 60 days and given enteral nutritional supplements to aid in weight gain and breathing. The long-term traction helps stretch the periapical regions of the deformity gradually and "train the cord" to tolerate stretching. Traction weight of 50% body weight is the target for the first 4 weeks and maintained thereafter.

For kyphoscoliosis, the procedure can be performed in a single stage if completed in less than 8 hours. However if the exposure, placement of implants, and posterior column osteotomies take too long and the patient has lost more than half of their blood volume, the procedure is stopped, a temporary rod placed and the second stage done 3 days to a week later.

Any gap greater than 1 cm left open after the resection is protected with long strips of rib graft. A third or fourth rod is applied to the permanent rods to reinforce the posterior construct or tension band. If a large anterior gap is difficult to bridge with a mesh cage, the gap is left open and secondary graft augmentation is performed in a second stage from an anterior approach.

In the recovery room, mean arterial blood pressure is kept above 80 mm Hg, and hourly neuro checks are done for the first 8 hours, then every 4 hours for the subsequent 8 hours, and every 8 hours thereafter. Hemoglobin is kept above 10 intraoperatively and postoperatively and INR (International Normalized Ratio for Blood Clotting) also kept below 1.2 with plasma infusion as necessary to avoid hematoma formation.

To the best of our knowledge, this is the largest series of young and pediatric kyphoscoliosis and acute kyphotic deformity patients treated with a PVCR from a single institution where resources are also limited. In addition, we are not aware of any other study that has evaluated the relationship of the level of apex of kyphosis and the complications occurring during and after the surgical procedure.

A limitation of our study is that only 25 intraoperative neurologic events occurred, and this allowed us to include only one to two variables in each logistic regression model in a multivariate manner to control, jointly, the confounding effect of those variables classically associated with complications (age, BMI, and amount of kyphosis).

Conclusions

Posterior vertebral column resection for severe spinal deformity is technically demanding and carries a substantial risk. Pure hyperkyphosis is usually an extremely rigid sharp angular deformity due to an infectious or congenital etiology. Establishing surgical risk based on the apex level of kyphosis, can guide surgeons in their preoperative planning and surgical management of severe angular kyphosis deformity to minimize the potential for neurologic complications. The apex is a variable that might influence the occurrence of neurologic complications and that the TH apex

(T6–T9) is a preoperative risk factor for intraoperative and postoperative neurologic complications.

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