Posterior Vertebral Column Resection for VATER/VACTERL Associated Spinal Deformity: A Case Report

Matthew E. Cunningham, MD, PhD · Gina Charles, BS · Oheneba Boachie-Adje, MD

Published online: 9 December 2006
© Hospital for Special Surgery 2006

Abstract The VATER/VACTERL association is a syndrome notable for congenital vertebral malformations, anal atresia, cardiovascular anomalies, tracheoesophageal fistula, esophageal atresia, and renal or limb malformations. Vertebral malformations may include the entire spectrum of congenital spinal deformities, including kyphosis, as was seen in this case. A 14-year-old girl presented to our institution with severe rigid sagittal deformity in the thoracolumbar spine that had recurred following three prior spinal fusion surgeries: the first posterior only, the second anterior and posterior, and the third a posterior only proximal extension. These surgeries were performed to control progressive kyphosis from a complex failure of segmentation that resulted in a 66° kyphosis from T11 to L3 by the time she was 9 years old. Our evaluation revealed solid arthrodesis from the most recent procedures with resultant sagittal imbalance, and surgical options to restore balance included anterior and posterior revision spinal fusion with osteotomies, multiple posterior extension osteotomies with circumferential spine fusion, and posterior vertebral column resection with circumferential spine fusion. She was advised that multiple posterior extension osteotomies would likely be insufficient to restore sagittal balance in the setting of solid arthrodesis from anterior and posterior surgery, and that the posterior-only vertebral column resection would provide results equivalent to revision anterior and posterior surgery, without the morbidity of the anterior approach. She successfully underwent posterior vertebrectomy and circumferential spinal fusion with instrumentation and is doing well 2 years postoperatively. Severe rigid sagittal deformity can be effectively managed with a posterior-only surgical approach, vertebrectomy, and circumferential spinal fusion with instrumentation.

Key words VATER · VACTERL · kyphosis · kyphectomy · spinal deformity · recurrent

Introduction

The VATER/VACTERL association is a syndrome that has characteristic congenital anomalies involving vertebral malformations, anal atresia, cardiovascular anomalies, tracheoesophageal fistula, esophageal atresia, renal malformations, and dysplasias of the limbs [1–3]. Additional orthopedic associations also include congenital spinal deformity, defects of the thumb, congenital hip dislocation, deficiencies of multiple lower extremity bones (proximal femoral focal deficiency with absence of tibia and fibula), absence of the tibia, coxa valga, vertical talus, and rib anomalies [1, 4]. The degree of involvement of any of the above elements of the VATER/VACTERL association is case-dependent [2, 3], and—as exemplified for vertebral/spine involvement—can range from *unaffected* [5] to *intermediate* (tethered cord [6, 7] or spinal deformity [1]), to *severe* vertebral malformations/sacral agenesis [1, 8, 9]. Surgical reconstruction for each of the elements of the VATER/VACTERL association that meet surgical criteria is typically undertaken at the earliest age appropriate time for the specific procedure [2, 3].

The largest series of patients with VATER/VACTERL association in the orthopedic literature is from Lawhon et al. [1], who reported on 28 patients treated at 2 institutions. They reported approximately equal gender distribution in the group, typical primary orthopedic referrals for evaluation of spine or upper extremity issues, and no consensus etiology for the association that was obvious from birth history, family history, or maternal infection/drug exposure during gestation. Patients were noted to have growth retardation and poor weight gain early (up to 3 years of age), but recovered to normal values later in life [1, 3]. Ten percent of the children from the Lawhon series died within the first 2 years of life. Spinal findings at birth included hemivertebrae, butterfly vertebrae, wedge vertebrae, and unilateral bars, all associated with varying degrees of congenital scoliosis that was detected by 4–6 years of age.

M. E. Cunningham, MD, PhD · G. Charles, BS ·
O. Boachie-Adje, MD (✉)
Department of Orthopaedic Surgery, Scoliosis Service,
Hospital for Special Surgery,
535 East 70th Street, New York, NY 10021, USA
e-mail: Boachie@HSS.edu

Sixteen of the patients (57%) had scoliotic curves that were being monitored for progression, 4 of these patients were undergoing brace management, 5 had undergone surgeries including posterior fusions, and 4 additional patients were scheduled for surgery. Preoperative curve magnitudes ranged from 45° to 68°, and an average of 12° of correction was reported in follow-up evaluation. None of the patients in this series were reported to have sagittal plane imbalances.

Kyphosis and kyphoscoliosis is seen in several congenital syndromes, including Jarcho–Levin [10], Coffin–Lowry [11], and Costello syndrome [12], but is perhaps best described for myelomeningocele [13–19]. Other etiologies for kyphosis include iatrogenic (postsurgical or postirradiation) [20–23], skeletal dysplasias [24], and congenital kyphosis not associated with a known syndrome [25]. Patients with myelomeningocele have a natural history of progression in their kyphotic deformity and fail nonoperative attempts at management [15, 16]. This has led to the standard of care being kyphectomy (vertebrectomy at the level immediately proximal to and involving the proximal kyphus) and instrumented fusion, which yields predictable and lasting results [13–15, 17, 18]. In the patient population with congenital kyphoscoliosis, who are young and have relatively flexible deformity, less dramatic measures such as hemiepiphysiodesis have had mixed success in controlling sagittal deformity [26, 27], but allowed the protection and preservation of residual neurological function. Similar poor outcomes of hemiepiphysiodesis have been found in patients with the skeletal dysplasia chondrodysplasia punctata [24]. Postsurgical and postirradiation kyphosis has been approached in a similar manner, with flexible curves being treated with posterior instrumented fusions and rigid deformities receiving anterior and posterior fusions or osteotomies and posterior fusion, all of which have had good results [20–23].

In this report, we describe the case of a 14-year-old girl with VATER/VACTERL syndrome, who originally had a complex failure of segmentation, and presented to our institution with recurrent kyphotic deformity at the thoracolumbar junction after 3 prior deformity surgeries, the first posterior only, the second anterior and posterior, and the third a posterior only proximal extension. Described is a brief summary of her care prior to presentation, the impression and surgical intervention performed at our institution, brief review of her follow-up course, and a discussion of the literature.

Case description

A 14-year-old girl with VATER/VACTERL syndrome presented with recurrent thoracolumbar kyphosis that was progressive, painful, and which was severely impacting on her self-image. Her medical history was significant for being the product of an uneventful pregnancy, and being born at term via a normal spontaneous vaginal delivery. Upon birth, several components of VATER/VACTERL syndrome were recognized when the patient was noted to have congenital anomalies including supralevator imper-

forate anus, distal tracheoesophageal fistula, and esophageal atresia. Within the first week of life the patient had undergone Stamm gastrostomy, modified sigmoid loop colostomy, and thoracotomy for repair of the esophageal atresia and tracheoesophageal fistula. At 2 months of age, the patient underwent an aortopexy, via anterior approach, secondary to supracarinal tracheal collapse from aortic compression. It was during this admission that she was noted to have a single functioning kidney, and that this kidney was hydronephrotic secondary to a partial obstruction at the uretero-vesicular junction; she had a percutaneous urostomy placed to decompress the kidney. She has subsequently undergone several other nonorthopedic surgical interventions, including colostomy reversal, placement of permanent urostomy, and cloacal reconstruction.

She had been followed for thoracolumbar kyphosis at an outside institution since the age of 8 years, when documentation revealed a Cobb measurement of 47°. Evaluation at that time also revealed tethered cord, which was released at L5–S1 by a neurosurgery specialist in consultation with the case. In the following year, the kyphosis deformity progressed to 66°, and the patient subsequently underwent posterior spinal fusion. A successful arthodesis was achieved; however, the kyphosis continued, and the patient returned for combined anterior spine fusion with discectomies (T10–L5) and posterior spinal fusion (T4–L5) the following year. Within 2 months of the second deformity surgery, the patient was again noted to have kyphosis progression, and a third intervention extended the posterior instrumented fusion from T3 to L5 when the patient was 10 years old. In the interval from this last surgery until presentation, the spinal fusion healed, and the patient has not had problems with wound breakdown, fevers, or infection associated with the hardware.

At presentation to our institution, she reported that the kyphosis deformity had again been progressing, and that it was dramatically affecting her self-image. Although she did report mild pain at the kyphus at the end of long and active days and easy fatigability in general, this was well controlled with rest and nonsteroidal anti-inflammatory drugs (NSAIDs). Her poor body image, and constant taunting and teasing by schoolmates had led her to enter into a program of homeschooling. She was an intelligent ninth grader, fully and independently mobile with a five- to six-block walking tolerance. Medically, other issues included hypertension well controlled with enalapril and lasix, chronic renal insufficiency (residual function of remaining left kidney was 30% of normal), chronic urinary tract infections controlled with antibiotic prophylaxis, and drug sensitivity to gentamycin.

Physical examination was notable for a large gibbus at the thoracolumbar junction that had trace tenderness to palpation. Well-healed posterior midline and right thoracotomy scars were evident, as well as a healthy-appearing urostomy on the left flank. Spinal range of motion was severely restricted secondary to the prior fusions. The left shoulder was elevated 1.5 cm, the pelvis was level, C7 plumb line was 1 cm left of the gluteal fold, and sagittal

alignment with knees straight was notable for marked kyphosis (Fig. 1c). Power and sensation in bilateral upper and lower extremities was intact, gait was normal with heel and toe walking demonstrated, tendon reflexes were brisk and symmetric, no pathological reflexes were elicited, and Babinski testing revealed down-going toes bilaterally. X-rays revealed T10–L4 right scoliosis of 21° with instrumentation from T3 to L5, C7 sagittal plumb line 17.7 cm anterior to the posterior border of S1, T8–L4 kyphosis of 87° with gibbus deformity at L1–L2 (Fig. 1a).

After preoperative assessment by multiple consultation services, including anesthesiology, nephrology, neurology, neurosurgery, cardiology, and pulmonology, she was cleared for revision orthopedic spinal surgery. As final preparation and evaluation, further imaging studies were obtained to better define the anatomy in the previously instrumented area. CT myelogram demonstrated that the conus medullaris was located at L2–L3, that there was no definite cord compression throughout the visualized spine, and that the cord closely hugged the posterior aspects of the kyphotic apical vertebrae. Magnetic resonance imaging (MRI) with MR angiography (MRA) was obtained but, because of the metal artifact present, could not be used to predict the viability of segmental vessels in the intended operative region.

Surgical procedure

Utilizing the scar from the previous surgery, a posterior midline approach of the spine was used to expose point T4 to L5. The fusion mass was carefully inspected, but no evidence of pseudarthrosis was observed. Prior hardware was identified and exposed, revealing a left-sided 3/16-in. single rod with hooks proximally and pedicle screws at L3 and L4 distally. Additional pedicle screws were placed at L5 on the left side, and at L4 and L5 on the right side, in addition to hooks proximally on the right side that were connected to a 1/4-in. rod and tensioned/compressed in appropriate fashion. The posterior elements of T12, L1, and L2 were removed. Laminectomies were then performed one level proximally and distally to allow ample space for the dural sac and neural elements (Fig. 2a). Corresponding rib heads were removed and extrapleural dissection was performed via a costotransversectomy approach to expose the lateral margins of the three apical vertebral bodies. In the process, nerve roots and segmental vessels at these levels were ligated and divided. With proper protecting retractors in place, a Midas Rex high-speed burr was used to perform the L1 and L2 verte-brectomies (Fig. 2b). The final portion to be removed was the thinned posterior vertebral wall, which was carried out with a curved Penfield dissector. The prior instrumentation rod was then sectioned at the level of the kyphectomy, and the new 1/4-in. proximal and distal rods were used to manipulate the spine into a relatively extended position. A titanium mesh (Harms) cage was then packed with host bone from the verte-brectomy, and was positioned between T12 and L3 to support the anterior column of the spine

Fig. 1. (a) Preoperative full-length lateral x-ray showing prior single rod posterior instrumentation from T3–L5, kyphosis from T8–L4 measuring 87° by Cobb method, and gibbus deformity at L1–L2. (b) Postoperative full-length lateral X-ray showing improved sagittal balance and kyphosis from T8–L4 measuring 46 degrees by Cobb method. (c) Preoperative clinical photograph demonstrating thoracolumbar kyphosis with high lumbar gibbus deformity, and poor sagittal alignment. (d) Postoperative clinical photograph showing improved sagittal contour and balance

(Fig. 2c). The proximal and distal segments of the new rods were then compressed together using side-by-side rod

Fig. 2. Schematic diagrams illustrating the surgical technique of posterior vertebral column resection. (a) Old instrumentation was used for temporary fixation of the spine while additional pedicle screws were added, posterior elements were removed at the apex of the deformity, and laminectomies were performed. Note the increased space available for the spinal cord and dural sac (stippled structure in the diagram). (b) After rib head removal, high-speed burr was used to

remove the vertebral bodies. (c) The old rod was then removed, new rods were placed proximally and distally, Harms cage was placed anteriorly, and cantilever maneuver was used to reduce the spinal segments. (d) Proximal and distal instrumentation was then connected and tightened, and bone graft was placed around the Harms cage and within the intended fusion bed

connectors to maneuver the spine into the desired amount of correction (judged as 50–60% intraop) and secured (Fig. 2d). A Stagnara wake up test was performed, and the patient demonstrated voluntary movement of both arms and legs. The wound was then copiously irrigated, the local bone graft was placed, and the wound was closed in layers over drains. Intraoperative x-rays confirmed appropriate position of the implants.

Her in-hospital postoperative course was uneventful, and she was discharged to home on postoperative day 7. Her only complaint in subsequent postoperative follow-up was a subjective loss of sensibility over the anterior aspect of her thighs. Standing x-rays performed at 5 weeks postoperatively demonstrated a kyphosis Cobb measurement of 46°, with appropriate position of implants (Fig. 1b). Standing sagittal balance at this visit (Fig. 1d) was markedly improved from preoperative sagittal balance (Fig. 1c). Physical therapy for truncanal strengthening was initiated, with plan for continued brace wear for 6 months postoperatively. At her latest follow-up (2 years), her physical exam revealed well-healed incisions, physiological coronal and sagittal balance, and no localized tenderness to palpation over the spine. She had a normal reciprocal gait, and she had no focal findings on neurological exam. Her x-rays demonstrated that the patient had no scoliosis and had a residual kyphosis of 50°, and that the hardware remained in

appropriate position. She was very satisfied with the surgery, had returned to school, and was engaging in a moderate level of activity.

Discussion

We have described the clinical course of an adolescent girl with VATER/VACTERL syndrome and recurrent sagittal plane spine deformity successfully treated with posterior vertebral column resection (kyphectomy) and circumferential spinal fusion with instrumentation. Recurrent spinal deformity in the pediatric population is uncommon when not associated with laminectomies [20–22], and is a surgical problem when associated with pain, pseudarthrosis, instrumentation failure/pullout, or progressive deformity/spinal imbalance [28].

The described surgical technique used here is most similar to the classical kyphectomy used for surgery to correct the kyphotic deformity associated with myelomeningocele. In the classical technique of kyphectomy for myelomeningocele, the spinal column is transected, the spinal cord is sectioned and tied off, the kyphosis is excised (through removal of consecutive vertebral bodies in the deformity), and then posterior instrumentation is placed to stabilize the posterior fusion bed and spinal

column until arthrodesis is achieved. This approach was not applicable to our patient, in that preoperatively she was neurologically intact and therefore transection of her spinal cord to gain deformity correction and stabilization was not acceptable. Instead, we describe vertebral column resection with preservation of spinal cord function. To complete the procedure, bilateral nerve roots were sacrificed at the apex, as were the vascular bundles at these levels. Sacrifice of the vasculature puts the otherwise skeletonized spinal cord at risk, in that the only perfusion to the intervening segment is by the anterior and posterior spinal artery systems collaterally supplying the segment from above and below. With this tenuous perfusion appreciated, mitigation of cord ischemia is achieved by optimizing perfusion pressures and through use of normotensive anesthesia. Both of these kyphectomy approaches are typically done under a single anesthesia, and are not staged.

Treatment of pediatric spinal deformity involving kyphosis is often quite challenging, requiring a methodical approach and careful preoperative assessment of the patient and their pathology [29]. Lenke, in a 2004 Instructional Course Lecture, reviewed the problems and pitfalls of primary and revision treatment of pediatric kyphosis, emphasizing the need to apply evidence-based medicine in the setting of primary surgery, and to fully understand why a primary reconstruction has failed prior to initiating any revision surgical intervention. He recommended routine exploration of the prior fusion mass to rule out pseudarthrosis followed by the indicated revision surgery, ranging from simple extensions of the fusion mass proximally or distally to the use of single or multiple osteotomies to allow realignment of the spine for the purpose of achieving spinal balance.

Primary surgical intervention for congenital kyphosis has better outcomes when performed at earlier patient age, and prior to the attainment of large sagittal deformity [30–32]. However, even when patients are identified and treated early, failures of treatment occur as commonly as 2/11 (18%) [31]. Surgical failures may result in pseudoarthroses or adding-on of segments above or below the fusion, as was the case for the two failures described above, and these can be easily treated with revision fusion procedures and grafting [31]. More challenging revision surgeries are presented by the patients that return with deformity surgery failures that have resulted in rigid kyphotic deformities associated with sagittal imbalance syndromes. In this situation, spinal osteotomies are required to shorten the spinal axis and to allow realignment of the vertebral weight-bearing structures.

Two recent studies have described techniques for enacting osteotomies of the pediatric spine to correct kyphotic deformities [33, 34]. Smith et al. [34] reported on their experience using a simultaneous anterior and posterior technique to gain circumferential access to thoracic and lumbar vertebrae for purpose of vertebrectomy, anterior releases, osteotomies, tethered cord releases, and fusions. The study included 16 patients, had kyphosis correction averaging 31°, and had complications in four patients including failure of posterior

fixation, lower extremity dysesthesias, and late progressive pelvic obliquity. Outcomes, via a simplified satisfaction score, showed 13 patients as being satisfied, and 3 considering their outcome fair/poor. They concluded that the approach is safe, versatile, and effective, but that it can be technically challenging. Shimode et al. [33] reported on the experience of three hospitals in Tokyo using a posterior-only-based surgical approach, through which they were able to obtain circumferential access to the spine. Their surgical technique is quite similar to the one we detail in this case report. They describe the use of this exposure technique to perform three-column vertebral osteotomies in seven patients (six in the thoracic and one in the lumbar region), resulting in kyphosis corrections from preoperative values averaging 105.4° to postoperative values averaging 48.9° (52.9% correction) [33]. Three of the patients in their series (all were thoracic level approaches) had previously been operated upon for their deformity, and transient leg paresthesias in two patients were the only complications reported. They conclude that the posterior-only vertebral osteotomy technique is a safe and reliable method for correcting rigid or severe kyphotic deformity.

In summary, this case demonstrates that a posterior-only approach to severe kyphoscoliosis allows for complete anterior vertebrectomy, osteotomies, and deformity correction with an excellent potential for healing. In the setting of this case report, these three techniques were completed through a posterior-only surgical approach in a 14-year-old girl with congenital spinal deformity associated with VATER/VACTERL syndrome. Kyphosis was corrected from 87° to 46°, sagittal balance was restored, and she was very satisfied with her surgical result.

References

1. Lawhon SM, MacEwen GD, Bunnell WP (1986) Orthopaedic aspects of the VATER association. *J Bone Jt Surg, Am* 68(3):424–429
2. Muraji T, Mahour GH (1984) Surgical problems in patients with VATER-associated anomalies. *J Pediatr Surg* 19(5):550–554
3. Weber TR, Smith W, Grosfeld JL (1980) Surgical experience in infants with the VATER association. *J Pediatr Surg* 15(6):849–854
4. Botto LD, Khoury MJ, Mastroiacovo P, Castilla EE, Moore CA, Skjaerven R, Mutchinick OM, Borman B, Cocchi G, Czeizel AE, Goujard J, Irgens LM, Lancaster PA, Martinez-Frias ML, Merlob P, Ruusinen A, Stoll C, Sumiyoshi Y (1997) The spectrum of congenital anomalies of the VATER association: an international study. *Am J Med Genet* 71(1):8–15
5. Patankar JZ, Vidyadhar M, Prabhakaran K, Bo L, Lsk Loh D (2004) Urogenital sinus, rectovaginal fistula, and an anterior stenosed anus—another cloacal variant. *Pediatr Surg Int* 20(7):556–558
6. James HE, Chesnut R, Krous H, Billman G, Jones KL, Jones M (1994) Distal spinal cord pathology in the VATER association. *J Pediatr Surg* 29(11):1501–1503
7. Warf BC, Scott RM, Barnes PD, Hendren WH, 3rd (1993) Tethered spinal cord in patients with anorectal and urogenital malformations. *Pediatr Neurosurg* 19(1):25–30
8. Pang D (1993) Sacral agenesis and caudal spinal cord malformations. *Neurosurgery* 32(5):755–778; discussion 78–79

9. Tongsong T, Wanapirak C, Piyamongkol W, Sudasana J (1999) Prenatal sonographic diagnosis of VATER association. *J Clin Ultrasound* 27(7):378–384
10. del Rio Holgado M, Martinez JM, Gomez O, Casals G, Bargallo N, Fortuny A, Puerto B (2005) Ultrasonographic diagnosis of Jarcho–Levin syndrome at 20 weeks' gestation in a fetus without previous family history. *Fetal Diagn Ther* 20(2):136–140
11. Hanauer A, Young ID (2002) Coffin–Lowry syndrome: clinical and molecular features. *J Med Genet* 39(10):705–713
12. Yassir WK, Grottkau BE, Goldberg MJ (2003) Costello syndrome: orthopaedic manifestations and functional health. *J Pediatr Orthop* 23(1):94–98
13. Lalonde F, Jarvis J (1999) Congenital kyphosis in myelomeningocele. The effect of cordotomy on bladder function. *J Bone Jt Surg Br* 81(2):245–249
14. Lintner SA, Lindseth RE (1994) Kyphotic deformity in patients who have a myelomeningocele. Operative treatment and long-term follow-up. *J Bone Jt Surg Am* 76(9):1301–1307
15. Martin J, Jr, Kumar SJ, Guille JT, Ger D, Gibbs M (1994) Congenital kyphosis in myelomeningocele: results following operative and nonoperative treatment. *J Pediatr Orthop* 14(3):323–328
16. Mintz LJ, Sarwark JF, Dias LS, Schafer MF (1991) The natural history of congenital kyphosis in myelomeningocele. A review of 51 children. *Spine* 16(8 Suppl):S348–S350
17. Niall DM, Dowling FE, Fogarty EE, Moore DP, Goldberg C (2004) Kyphectomy in children with myelomeningocele: a long-term outcome study. *J Pediatr Orthop* 24(1):37–44
18. Nolden MT, Sarwark JF, Vora A, Grayhack JJ (2002) A kyphectomy technique with reduced perioperative morbidity for myelomeningocele kyphosis. *Spine* 27(16):1807–1813
19. Sarwark JF (1999) Kyphosis deformity in myelomeningocele. *Orthop Clin North Am* 30(3):451–455, viii–ix
20. Lonstein JE (1977) Post-laminectomy kyphosis. *Clin Orthop Relat Res* (128):93–100
21. Otsuka NY, Hey L, Hall JE (1998) Postlaminectomy and postirradiation kyphosis in children and adolescents. *Clin Orthop Relat Res* (354):189–194
22. Papagelopoulos PJ, Peterson HA, Ebersold MJ, Emmanuel PR, Choudhury SN, Quast LM (1997) Spinal column deformity and instability after lumbar or thoracolumbar laminectomy for intraspinal tumors in children and young adults. *Spine* 22(4):442–451
23. Farcy JP, Schwab FJ (1997) Management of flatback and related kyphotic decompensation syndromes. *Spine* 22(20):2452–2457
24. Mason DE, Sanders JO, MacKenzie WG, Nakata Y, Winter R (2002) Spinal deformity in chondrodysplasia punctata. *Spine* 27(18):1995–2002
25. Basu PS, Elsebaie H, Noordeen MH (2002) Congenital spinal deformity: a comprehensive assessment at presentation. *Spine* 27(20):2255–2259
26. Cil A, Yazici M, Alanay A, Acaroglu RE, Uzumcugil A, Surat A (2004) The course of sagittal plane abnormality in the patients with congenital scoliosis managed with convex growth arrest. *Spine* 29(5):547–552; discussion 52–53
27. Walhout RJ, Rhijn LWvan, Puijls JE (2002) Hemi-epiphysiodesis for unclassified congenital scoliosis: immediate results and mid-term follow-up. *Eur Spine J* 11(6):543–549
28. Dias RC, Miller F, Dabney K, Lipton GE (1997) Revision spine surgery in children with cerebral palsy. *J Spinal Disord* 10(2):132–144
29. Lenke LG (2004) Kyphosis of the thoracic and thoracolumbar spine in the pediatric patient: prevention and treatment of surgical complications. *Instr Course Lect* 53:501–510
30. McMaster MJ, Singh H (1999) Natural history of congenital kyphosis and kyphoscoliosis. A study of one hundred and twelve patients. *J Bone Jt Surg Am* 81(10):1367–1383
31. McMaster MJ, Singh H (2001) The surgical management of congenital kyphosis and kyphoscoliosis. *Spine* 26(19):2146–2154; discussion 55
32. Montgomery SP, Hall JE (1982) Congenital kyphosis. *Spine* 7(4):360–364
33. Shimode M, Kojima T, Sowa K (2002) Spinal wedge osteotomy by a single posterior approach for correction of severe and rigid kyphosis or kyphoscoliosis. *Spine* 27(20):2260–2267
34. Smith JT, Golligly S, Dunn HK (2005) Simultaneous anterior–posterior approach through a costotransversectomy for the treatment of congenital kyphosis and acquired kyphoscoliotic deformities. *J Bone Jt Surg Am* 87(10):2281–2289