Combined anterior–posterior fusion with laterally placed threaded interbody cages and pedicle screws for Scheuermann kyphosis

Case report and review of the literature

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The authors report their preferred method for correcting Scheuermann disease via a combined anterior–posterior approach; their procedure is associated with a lower morbidity rate than the standard approach. Twenty-month follow-up examination demonstrated excellent maintenance of correction. The results satisfied the requirements to function without restriction in a vigorous military environment.

KEY WORDS • Scheuermann disease • kyphosis • spinal deformity • spinal instrumentation

Scheuermann disease is found in 0.4 to 8% of the general population and is one of the more common causes of spinal deformity in adolescents. Thoracic kyphosis of greater than 45 to 50° in adolescents as well as thoracolumbar kyphosis of any degree is considered abnormal. Abnormal thoracic kyphosis can lead to a compensatory lumbar and cervical lordosis, resulting in an inefficient and painful spine. Nonoperative treatments include physical and brace therapy. Indications for surgical intervention in Scheuermann disease have included progressive deformity greater than 75°, neurological compromise, cardiopulmonary compromise, pain, and cosmesis. Operative treatment can be performed via a posterior-only approach when the deformity is supple or in cases of skeletal immaturity. A combined anterior–posterior approach should be undertaken in cases of fixed deformities or skeletal maturity.

Historically, neurosurgeons have been reluctant to treat this spinal deformity. Recent advances in surgical techniques and implant technology have offered new safer, easier ways to restore a balanced and efficient spine in cases of Scheuermann disease. Based on results illustrated in the proceeding case, the authors encourage the neurosurgical community to become more active in the treatment of this spinal deformity.

CASE REPORT

History. This 21-year-old active-duty military service member was involved in a motor vehicle accident 30 months prior to presentation. At the time he suffered 10 days of moderate thoracic back pain that resolved after bed rest and gradual mobilization. Twenty-four months prior to presentation he experienced progressive worsening of back pain while undergoing advanced military training involving frequent strenuous activity, which included significant axial weight bearing. Thoracic pain was noted to be severe and unrelenting with a stabbing quality. He also noted increasing episodes of urinary frequency, for which he underwent urological evaluation. He was treated with the following conservative measures: limited physical activity, brace therapy, nonsteroidal antiinflammatory drugs, and physical therapy focusing on postural exercises for strength and mobility. These measures provided no relief of his symptoms.

Examination. Physical examination demonstrated a healthy-appearing man with obvious thoracic kyphotic deformity. Attempted hyperextension in the prone position did not reverse the kyphosis. Neurological examination showed full strength and normal symmetrical reflexes without evidence of myelopathy. His sensory status was intact. He had no stigmata of neurofibromatosis or Morquio syndrome. Routine hematological and electrolyte in-

Abbreviation used in this paper: VB = vertebral body.

vestigations demonstrated no abnormalities suggestive of rickets or osteoporosis. Posteroanterior and lateral standing radiographs demonstrated significant thoracic kyphosis and exaggerated lumbar lordosis with minimal levoscoliosis. The apex of the kyphosis was located at T7–8. Measurement of the sagittal angle from T-3 to T-12 showed a kyphotic deformity of 72° ; that from T-12 to L-3 indicated a thoracolumbar curvature of 29° (Figs. 1, 2, and 3).

Operation. In the left lateral decubitus position, the patient underwent a modified retropleural approach to the anterior spine. The modification involved mobilization of two consecutive ribs and a cut at the anterior axillary line of a single rib, both in lieu of the standard rib resection. These ribs were then reflected inferiorly and superiorly for the desired retropleural exposure. Anterior spinal release was accomplished by near-complete discectomy and failing of the anterior longitudinal ligament over the apex of the kyphosis. To obtain partial deformity correction, large-diameter threaded interbody cages (Interfix; Medtronic Sofamor Danek, Memphis, TN) were placed at T6–7, T7–8, and T8–9. The retropleural thoracotomy was closed without a chest tube because the pleural cavity was not entered. The ribs were then reconstructed using nonabsorbable suture. The patient was then positioned prone for the standard posterior approach to the thoracolumbar spine. A titanium multiaxial pedicle screw and posterior rod construct was inserted from T-3 to L-2. The rod was underbent to the desired correction and further compression was applied across the kyphotic segments. The cylindrical threaded cages provided an anterior pivot point to allow further kyphosis correction over the released and instrumented anterior segments. Coronal-plane balance was obtained by sequential compression and distraction over the scoliotic segment. Cancellous freeze-dried bone and Grafton Bone Matrix (American Red Cross) were used as bone graft. The patient was fitted with a thoracolumbosacral-orthosis.

Postoperative Course. The patient's recovery was unre-

Fig. 1. Sagittal T₂-weighted magnetic resonance images demonstrating endplate changes at multiple levels with kyphotic deformity.

Fig. 2. *Left:* Preoperative standing posteroanterior radiograph demonstrating minimal scoliosis. *Right:* Preoperative standing lateral radiograph revealing T3–12 kyphosis of 72° with compensatory lumbar lordosis of 29° .

markable. He was discharged 6 days after admission. Follow-up imaging included computerized tomography scanning and plain radiography. The sagittal angle of thoracic kyphotic curvature improved from 72 to 56° and that of the thoracolumbar lordosis from 29 to 19° (Fig. 3). At 20-month follow-up examination, he remained neurologically intact with near-complete relief of back pain with maintenance of correction. He has returned to full unrestricted duty as a military policeman.

DISCUSSION

Overview of Scheuermann Disease

The purpose of the spine is to orient the body and head in space and to protect the spinal cord. A stable, balanced spine is achieved by keeping the head centered over the pelvis in both the sagittal and coronal planes. From end vertebra to end vertebra, the normal sagittal contour of the thoracic spine has been defined as 20 to 40° .^{2,30} Life can be described as a “kyphosing process,” as demonstrated by the increased kyphosis in the thoracic spine with normal aging.¹¹ Thoracic kyphosis greater than 45 to 50° in adolescence as well as any thoracolumbar kyphosis is considered abnormal. There are numerous causes of kyphosis in addition to the normal aging process. Examples include postural, congenital, Scheuermann, myelomeningocele, and postlaminectomy instability.³⁵ Additionally, metabolic, developmental, paralytic, and neuromuscular disorders as well as tumors, infections, and traumatic injury may contribute to the development of kyphosis.

History and Origin

Scheuermann disease was originally described as a rigid kyphosis associated with wedge-shaped VBs and

Fig. 3. Postoperative standing posteroanterior radiograph demonstrating correction after placement of instrumentation. *Right:* Postoperative standing lateral radiograph revealing that the T3–12 kyphosis improved to 56° and the lumbar lordosis to 19°.

endplate irregularities occurring in late childhood. Scheuermann believed the abnormalities were caused by avascular necrosis of the vertebral ring apophysis, resulting in a growth disturbance of the VBs. He also noted that most of his patients were young agricultural workers involved in heavy labor, perhaps indicating a contribution from ongoing trauma.^{1,34} In 1930, Schmorl proposed another theory in which he suggested that the kyphosis occurred as a result of intervertebral disc herniation through the VB growth plate.^{1,34} He believed that weakened areas along the growth plate predisposed the spine to these herniations. The rostrocaudal disc herniations decreased the disc space height and altered the growth of the VB, leading to progressive kyphosis. These herniations, now referred to as Schmorl nodes, are easily visualized on plain radiographs. Schmorl's theory is currently disputed because these nodes may occur outside the area of kyphosis in patients with Scheuermann disease or they may be demonstrated as incidental findings on radiographs obtained in healthy patients with no evidence of disease. Of interest, Schmorl nodes are usually found in the anterior or vertebral endplate in cases of Scheuermann disease, whereas they are located in the posterior endplate in cases of scoliosis or in the middle endplate in healthy individuals. Other suggested causes of the vertebral wedging in Scheuermann disease have included osteoporosis, physical activity–induced stress, disorganized intracartilaginous ossification, increased height, and increased growth hormone.^{1,3,13,20,21,28} Genetic transmission has also been explored as a cause of Scheuermann disease. The authors

of some studies have suggested an autosomal-dominant mode of inheritance with incomplete penetrance.^{10,14} Although there are many proposed causes of Scheuermann disease, evidence is lacking to support exclusively any single one. Other proposed mechanisms for the development of Scheuermann disease have been challenged over time. For example, Bick had established that the ring apophysis does not contribute to VB height.¹ Gilsanz, et al.,¹² and Scoles, et al.,²⁷ found no evidence of osteoporosis when using single-photon absorptiometry. In concordance with Scheuermann's original thinking, however, abnormal physical activity likely contributes to disease development, and this notion has been supported by various studies in which some effectiveness resulting from brace therapy was demonstrated.^{7,22,26} Regardless of the exact origin, it is clear that mechanical forces resulting in abnormal increased compressive anterior forces and decreased tensile posterior forces create an environment suited to development of a progressive deformity.

Incidence and Clinical Findings

The incidence of Scheuermann disease has been estimated to be 0.4 to 8%.^{15,24} The sex prevalence is difficult to determine because the definition of the disease process varies. It is thought that the disease typically affects males and females equally; however, the reported ratios have varied widely.^{7,23} Although the deformity in Scheuermann disease begins during the preadolescent period, most patients do not present until puberty. Initial appearance is one of a prominence of the thoracic or thoracolumbar spine, which is accentuated with forward bending. Attempted hyperextension in the prone position is severely limited because of the rigidity of the spinal segments. This is in contrast to the typical flexibility on hyperextension seen in postural round back. Unfortunately, because the kyphotic deformity is often attributed to poor posture by parents or other individuals, a delay in diagnosis results. The angular thoracic kyphosis is often accompanied by compensatory lumbar lordosis and increased cervical lordosis. Pain occurs in the area of the deformity and can be aggravated by physical activity or postural changes. Disease progression into adulthood often leads to low-back pain due to facet and disc degeneration.^{1,34} Tightness in the hamstrings is associated with an increased pelvic tilt but the neurological examination usually yields normal results. Occasionally, neurological deficits, such as spastic paraparesis, are encountered. This is often related to compression secondary to the kyphotic deformity or thoracic disc herniation.^{5,18,31,34,36} Another manifestation of Scheuermann disease includes pulmonary dysfunction, with restrictive lung disease occurring in the presence of kyphosis greater than 100°.²³

Diagnostic Imaging

The imaging-related minimum standard in cases of Scheuermann disease includes a full-length posteroanterior and a lateral radiograph obtained with the patient in the erect position. The criteria for radiographic diagnosis of Scheuermann disease have been modified over time. In 1964, Sorenson described a criterion of three consecutive wedged vertebrae of at least 5° each.^{1,34} Drummond subsequently modified this requirement to include the need

for only two or more wedged vertebrae to satisfy a diagnosis.¹ Bradford then reduced the requirement to one or more vertebrae wedged 5° or more with the idea that this can lead to an earlier diagnosis. The number of wedged vertebrae typically increases as the disease and deformity progress.¹ Mild scoliosis can also be associated with Scheuermann disease (as seen in the case reported here).⁹ The increased lumbar lordosis often leads to stress placed on the pars interarticularis and subsequent development of spondylolysis.²³ When the disease progresses into adulthood, progressive disc space narrowing, facet joint degeneration, and formation of anterior vertebral osteophytes occur.

Nonoperative Management

The decision of how to treat Scheuermann disease is based on the severity of the deformity, patient age, and associated symptoms. Treatment can range from medical management to surgical intervention. The degree of the kyphotic curve and skeletal maturity dictate the initial management. Brace therapy is often recommended in skeletally immature patients with kyphosis. Sachs, et al.,²⁶ has proposed brace treatment when the curvature is 45°. The Milwaukee brace has been the most popular type of brace used when the apex of the kyphosis is present at T-8 or above. A molded thoracolumbar orthosis is most commonly recommended if the apex is below T-9. Although compliance is an issue in any case involving brace therapy, various authors have reported success with long-term bracing of flexible curves less than 75°. ^{7,22,26} In general, a 50% correction should be expected with brace treatment, but a gradual loss of correction will occur when the use of the brace is discontinued. There has been a report of 15° loss of correction at 18 months after brace therapy. Sachs, et al.,²⁶ also demonstrated a poor success rate for brace treatment in patients in whom kyphosis was greater than 75°. Although one author has reported some success in managing skeletally mature patients with brace treatment,⁷ bracing is generally not indicated in the skeletally mature patient because it does not alter the natural history of curvature progression.

Other nonoperative treatments have been directed at postural exercises. Although postural exercises have been shown to be useful for the alleviation of pain and correction of deformity in cases of postural kyphosis, these exercises have never been demonstrated to halt or improve they kyphotic deformity in Scheuermann disease.³³ Rather, they are directed at decreasing lumbar lordosis and maintaining flexibility and often include hamstring stretching and pelvic tilt drills.

Operative Management

Controversial and noncontroversial indications for surgical intervention in Scheuermann disease have included progressive deformity greater than 75°, neurological compromise, cardiopulmonary compromise, pain, and cosmesis.³³ The relatively noncontroversial indications for surgery include the presence of a neurological deficit, which tends to occur in adults,⁶ and resultant cardiopulmonary compromise, which typically occurs in cases involving kyphosis greater than 100°. ²³ Two controversial indications for surgery include pain and cosmesis. Surgery

can be performed via a posterior-only approach or a combined anterior–posterior approach. An anterior-only approach has been described but is not universally accepted. In his report on an anterior-only approach, Kostuik¹⁹ reported only a mean correction of 15° after anterior interbody fusion and placement of Harrington distraction instrumentation. Good results have been described by authors who have undertaken surgery via the posterior-only approach.^{8,17} Ideal candidates for the posterior-only approach include patients with kyphosis less than 65° and in whom radiography demonstrates flexibility on hyperextension that corrects the kyphosis to less than 50°. ¹ Other authors have found that the posterior-only approach was adequate in skeletally immature patients but unsatisfactory in skeletally mature patients.²⁹ Sturm, et al.,³² reported good results (mean correction 43°) with the posterior-only approach and emphasized the importance of preventing junctional kyphosis by including the proximal vertebra and the first lordotic segment in the fusion. The combined anterior–posterior approach is generally recommended in cases of skeletally mature patients or in those with rigid curves that do not correct to less than 50° on hyperextension. ^{16,33} The anterior approach involves a resection of the anterior longitudinal ligament and disc with subsequent placement of interbody support at the involved levels. The latter can be performed through an open thoracotomy or a thoracoscopic approach, depending on the surgeon's preference. Interbody support can be provided with autologous graft, titanium cages, allograft, or bioabsorbable cages. After an anterior release and fusion, the chest is closed before proceeding with the placement of the posterior instrumentation. Although a combined approach increases operative time and thoracotomy-related morbidity, it does decrease failure and pseudarthrosis rates associated with the hardware. ^{4,25} Of note, staged surgery with interval traction has not been shown to improve the overall deformity correction.¹⁶ Neuromonitoring should be performed throughout spinal deformity correction surgery to provide timely warning of spinal cord compromise that may occur during necessary corrective maneuvers.

CONCLUSIONS

Scheuermann disease is a progressive kyphotic spinal deformity that affects a small percentage of the population without sex preference. Although the cause remains debated, typically there is a delay in diagnosis because patients are mistaken for those merely with poor posture. If conservative therapy involving a brace fails, surgery via a posterior-only (in cases of skeletal immaturity or flexible curve) or a combined anterior–posterior (in cases of skeletal maturity or rigid curve) can correct the deformity and provide the patient with balanced, stable spine.

This case report illustrates our preferred method for obtaining correction with decreased morbidity compared with the standard anterior–posterior approach. Historically, neurosurgeons have been reluctant to treat this spinal deformity. Recent advancements in surgical techniques and technology have offered new safer, easier ways to restore a balanced and efficient spine in cases involving Scheuermann kyphosis. We encourage the neurosurgical community to become more active in the treatment of this spinal deformity.

References

1. Ali RM, Green DW, Patel TC: Scheuermann's kyphosis. **Curr Opin Pediatr** 11:70-75, 1999
2. Bernhardt M, Bridwell KH: Segmental analysis of the sagittal plane alignment of the normal thoracic and lumbar spines and thoracolumbar junction. **Spine** 14:717-721, 1989
3. Bradford DS: Juvenile kyphosis. **Clin Orthop** 128:45-55, 1977
4. Bradford DS, Ahmed KB, Moe JH, et al: The surgical management of patients with Scheuermann's disease: a review of twenty-four cases managed by combined anterior and posterior spine fusion. **J Bone Joint Surg Am** 62:705-712, 1980
5. Bradford DS, Brown DM, Moe JH, et al: Scheuermann's kyphosis: a form of osteoporosis? **Clin Orthop** 118:10-15, 1976
6. Bradford DS, Garica A: Neurological complications in Scheuermann's disease. A case report and review of the literature. **J Bone Joint Surg Am** 51:567-572, 1969
7. Bradford DS, Moe JH, Montalvo FJ, et al: Scheuermann's kyphosis and roundback deformity. Results of Milwaukee brace treatment. **J Bone Joint Surg Am** 56:740-758, 1974
8. Bradford DS, Moe JH, Montalvo FJ, et al: Scheuermann's kyphosis. Results of surgical treatment by posterior spine arthrodesis in twenty-two patients. **J Bone Joint Surg Am** 57:439-448, 1975
9. Deacon P, Berkin CR, Dickson RA: Combined idiopathic kyphosis and scoliosis. An analysis of the lateral spinal curvatures associated with Scheuermann's disease. **J Bone Joint Surg Br** 67:189-192, 1985
10. Findlay A, Conner AN, Connor JM: Dominant inheritance of Scheuermann's juvenile kyphosis. **J Med Genet** 26:400-403, 1989
11. Fon GT, Pitt MJ, Thies AC Jr: Thoracic kyphosis: range in normal subjects. **AJR** 134:979-983, 1980
12. Gilsanz V, Gibbens DT, Carlson M, et al: Vertebral bone density in Scheuermann disease. **J Bone Joint Surg Am** 71:894-897, 1989
13. Greene TL, Hensinger RN, Hunter LY: Back pain and vertebral changes simulating Scheuermann's disease. **J Pediatr Orthop** 5:1-7, 1985
14. Halal F, Gledhill RB, Fraser C: Dominant inheritance of Scheuermann's juvenile kyphosis. **Am J Dis Child** 132:1105-1107, 1978
15. Heithoff KB: Juvenile discogenic disease. **Spine** 19:335-340, 1994
16. Herndon WA, Emans JB, Micheli LJ, et al: Combined anterior and posterior fusion for Scheuermann's kyphosis. **Spine** 6:125-130, 1981
17. Hosman AJ, Langeloo DD, de Kleuver M, et al: Analysis of the sagittal plane after surgical management for Scheuermann's disease: a view on overcorrection and the use of an anterior release. **Spine** 27:167-175, 2002
18. Klein DM, Weiss RL, Allen JE: Scheuermann's dorsal kyphosis and spinal cord compression: case report. **Neurosurgery** 18:628-631, 1986
19. Kostuik JP: Anterior Kostuik-Harrington distraction systems. **Orthopedics** 11:1379-1391, 1988
20. Lopez RA, Burke SW, Levine DB, et al: Osteoporosis in Scheuermann's disease. **Spine** 13:1099-1103, 1988
21. Lowe TG: Scheuermann disease. **J Bone Joint Surg Am** 72:940-945, 1990
22. Montgomery SP, Erwin WE: Scheuermann's kyphosis—long-term results of Milwaukee braces treatment. **Spine** 6:5-8, 1981
23. Murray PM, Weinstein SL, Spratt KF: The natural history and long-term follow-up of Scheuermann kyphosis. **J Bone Joint Surg Am** 75:236-248, 1993
24. Nissinen M: Spinal posture during pubertal growth. **Acta Paediatr** 84:308-312, 1995
25. Papagelopoulos PJ, Klassen RA, Peterson HA, et al: Surgical treatment of Scheuermann's disease with segmental compression instrumentation. **Clin Orthop** 386:139-149, 2001
26. Sachs B, Bradford D, Winter R, et al: Scheuermann kyphosis. Follow-up of Milwaukee-brace treatment. **J Bone Joint Surg Am** 69:50-57, 1987
27. Scoles PV, Latimer BM, Digiovanni BF, et al: Vertebral alterations in Scheuermann's kyphosis. **Spine** 16:509-515, 1991
28. Skogland LB, Steen H, Trygstad O: Spinal deformities in tall girls. **Acta Orthop Scand** 56:155-157, 1985
29. Speck GR, Chopin DC: The surgical treatment of Scheuermann's kyphosis. **J Bone Joint Surg Br** 68:189-193, 1986
30. Stagnara P, De Mauroy JC, Dran G, et al: Reciprocal angulation of vertebral bodies in a sagittal plane: approach to references for the evaluation of kyphosis and lordosis. **Spine** 7:335-342, 1982
31. Stambough JL, VanLoveren HR, Cheeks ML: Spinal cord compression in Scheuermann's kyphosis: case report. **Neurosurgery** 30:127-130, 1992
32. Sturm PF, Dobson JC, Armstrong GW: The surgical management of Scheuermann's disease. **Spine** 18:685-691, 1993
33. Tribus CB: Scheuermann's kyphosis in adolescents and adults: diagnosis and management. **J Am Acad Orthop Surg** 6:36-43, 1998
34. Wenger DR, Frick SL: Scheuermann kyphosis. **Spine** 24:2630-2639, 1999
35. Winter RB, Hall JE: Kyphosis in childhood and adolescence. **Spine** 3:285-308, 1978
36. Yablon JS, Kasdon DL, Levine H: Thoracic cord compression in Scheuermann's disease. **Spine** 13:896-898, 1988

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