Contemporary Spine Surgery

VOLUME 6 ■ NUMBER 2 ■ FEBRUARY 2005

Anterior Surgery in the Management of Scoliosis

Part I: Introduction and Anterior Release

Steven Mardjetko, MD

LEARNING OBJECTIVES: After reading this article, the participant should be able to:

1. Describe the history and evolution of anterior surgery for scoliosis.
2. Explain the biomechanical principles and limitations of anterior scoliosis instrumentation systems.
3. Describe the role of anterior release in the management of scoliosis.

Anterior spine surgery for the management of scoliosis has evolved during the past 40 years. Anterior release can greatly enhance curve correction with either anterior or posterior fusion techniques. Anterior fusion offers certain advantages over traditional posterior approaches, including shorter spinal fusion segments, preservation of distal lumbar motion segments, lower risk of coronal plane decompensation, and more rapid fusion consolidation. Implants and techniques have changed as surgeons gain greater awareness of spinal balance, with greater attention given to normalization of the sagittal plane. Currently, single or dual solid-rod constructs are in favor. Structural interbody grafting material is preferred in regions where segmental lumbar lordosis should be maintained. The open anterior approach remains the standard, but a few spine centers in the United States have adapted minimally invasive and thoracoscopic techniques to achieve anterior spinal fusion with or without instrumentation. Disadvantages of the anterior approach include the effects on the chest wall and mild but permanent alterations in pulmonary function testing. With the recent proliferation and remarkable corrections achieved from the posterior approach with pedicle screw constructs, the utility of the anterior approach for scoliosis correction warrants reassessment.

HISTORY

The application of anterior implants to achieve correction of scoliosis deformity has a long history dating back at least four decades. One of the first systems used was the Dwyer cable and screw system.[1] This system was made of titanium, did not have very good biomechanical properties, and failures were common in stand-alone constructs. The Dwyer system was followed by Zielke's threaded spinal rod and screw system. Zielke et al. introduced the concept of ventral derotation spondylodesis.[2] Initial publications discussed the importance of varying the screw position in the vertebral bodies from posterior at the apex to mid-body at the end vertebra to enhance derotation. The Zielke system had a complicated spinal derotation device that seemed to achieve the stated goal when used properly. Both of these systems allowed segmental fixation with one screw in each vertebral body.

Dunn developed an anterior spinal implant system that had two screws anchored to each vertebral body through a bulky side plate, which captured two parallel rods. Kostuik developed an anterior spinal rod system with two rods. This system was based on Harrington's system and used a smooth ratcheted ¼-inch Harrington rod for distraction and a threaded 4-mm rod for compression. Neither of these systems had true segmental capabilities, so they had little utility in scoliosis correction. Harms and Beiderman developed the MOSS system (DePuy) that could be applied to either the anterior or posterior spine. This system initially featured a 3.4-mm threaded rod; ultimately, a smooth rod and monoaxial screws were used for anterior scoliosis corrections. Many surgeons adapted posterior implant systems for anterior spinal use as well. These include the TSRH and CD systems (Medtronic).[3] The solid rods that these systems offered, along with the ability to achieve segmental fixation, proved desirable. Spinal correction was achieved with a rod derotation maneuver and coronal plane correction was

Dr. Mardjetko is Assistant Professor, Department of Orthopedic Surgery, Rush-Presbyterian-St. Lukes Medical Center and Illinois Bone & Joint Institute, 9000 Waukegan Road, Suite 200, Morton Grove, IL 60053; E-mail: stevenmardjetko@msn.com.

Dr. Mardjetko has disclosed that he receives grant/research support from Medtronic/Sofamor Danek.

This continuing education activity is intended for orthopedic and neurologic surgeons and other physicians with an interest in spine surgery.

achieved by segmental compression. The solid-rod constructs also offered some protection against the kyphogenic effect of anterior compression constructs. Based on the Kaneda device's superior biomechanical profile, Kaneda developed a segmental dual-rod system designed for scoliosis correction.[4] Other manufacturers have followed suit. Anterior implant systems currently offer single- and dual-rod capability and a range of rod sizes: 4 mm; 5 mm; 5.5 mm; and 6.25 mm. Most systems have single and dual-screw staples and offer rod–rod cross connectors. Recently, implant systems that allow implant placement and scoliosis correction via thoracoscopic approaches have been developed.

BIOMECHANICS

The biomechanics of scoliosis correction from the anterior approach have been thoroughly described. Discectomy remains the major destabilizing procedure that enhances intersegmental motion and thus achieves scoliosis correction.[5,6] Discectomy must be as complete as necessary to achieve intersegmental motion. This usually involves a subtotal discectomy leaving only a small peripheral rim of annulus on the concave side. Most surgeons remove the posterior annulus to the posterior longitudinal ligament. Intersegmental motion is then evaluated with intradiscal spreaders. The early work of Zielke et al. showed coronal plane corrections in the range of 10 to 15 degrees per level.[2] This was substantially greater than corrections achieved with Harrington instruments via a posterior approach and allowed curve convexity to be shortened, with enhanced ability to achieve segmental derotation, against which the disc serves as the primary restraint.

Scoliosis correction is the result of many biomechanically mediated steps. These include:

- Anterior and lateral column shortening by removal of the discs;
- Cantilever forces applied as the rod is introduced into the laterally positioned bone anchors;
- Achieving the obligate 90-degree alignment between a monoaxial screw and the rod;
- Rod derotation from a scoliotic position into the correct sagittal position; and
- Application of compression forces in an intersegmental fashion from apex to end vertebra.

The biomechanics of lateral vertebral body screws have been studied extensively.[7,8] Unicortical versus bicortical purchase has been analyzed. There appears to be a significant biomechanical advantage of bicortical purchase with the current screw designs.[9] This advantage is somewhat diminished when two screws are used in each vertebral body. The position of the screw in the vertebral body has important biomechanical implications. Screws positioned in an oblique orientation or placed in dense juxta-endplate bone demonstrate better biomechanical characteristics than screws positioned in the traditional mid-body position.[10]

The effect of screw diameter and staples on implant–bone interface stability also has been studied. A wide variety of staples has been developed with the goal of enhancing vertebral body screw purchase. It seems that staples that are not anchored to the vertebral body provide no significant biomechanical benefit. Staples that have spikes that enter the lateral vertebral body wall appear to offer some protection against cephalad or caudad ploughing of the

LIPPINCOTT WILLIAMS & WILKINS

Contemporary Spine Surgery (ISSN 1527-4268) is published monthly by Lippincott Williams & Wilkins, Inc., 16522 Hunters Green Parkway, Hagerstown, MD 21740-2116. Phone (800) 787-8981. Or call **customer service (410) 528-8572. 24-Hour Fax (410) 528-4105 or E-mail adyson@lww.com.** Visit our website at LWW.com.

Priority postage paid at Hagerstown, MD, and at additional mailing offices. POSTMASTER: Send address changes to *Contemporary Spine Surgery*, Subscription Dept., Lippincott Williams & Wilkins, P.O. Box 1600, 16522 Hunters Green Parkway, Hagerstown, MD 21740-2116.

Publisher: Daniel E. Schwartz • Customer Service Manager: Audrey Dyson

Subscription rates: Personal: $229 US, $253 Foreign; Institutional: $279 US, $303 Foreign; In-Training: $109 US and Foreign. Single copy: $21.

screw within the vertebral body. Pullout along the screw's long axis is not affected by the presence of a staple.

Rod diameter is an important variable in determining the risk of rod failure. Threaded rods have a high risk of failure due to their small minor diameter and flexibility. Larger rods have better fatigue characteristics but may be too stiff to apply to certain spinal deformities without significant rod contouring.

The addition of a second screw into each vertebral body along with a second rod has been shown to increase construct stability significantly. The addition of a second rod with a single vertebral body screw seems to have intermediate biomechanical characteristics between the single-rod screw and dual-rod dual-screw constructs.[11] The use of two screws allows a triangulation effect, which increases fixation strength by 79%.

There are many potential modes of failure for anterior spinal constructs. Failure of the bone–screw interface can occur by a direct pullout along the screw's long axis. This is a function of bone quality and the major and minor diameters of the screw.[8] This occurs most commonly at the construct end during the application of corrective cantilever force. This mode of failure is noted very early during the postoperative period and is frequently recognized on the first standing spinal x-ray. Loss of bone–screw interface integrity occurs at the construct ends. There is usually an angular change of the screw within the vertebra, suggesting ploughing of the screw within the bone. Usually this mode of failure occurs at the construct ends and is noted early, i.e., by 6 weeks postsurgery.

Rod failures can occur when a pseudarthrosis arises.[12] Rod failure with pseudarthrosis occurs later in the postoperative period, usually after the 6-month mark and most often at the apex of the deformity.

The removal of the intervertebral discs creates a space that becomes larger as one proceeds distally into the thoracolumbar spine. The early threaded rod designs depended on compression to achieve coronal plane correction and were kyphogenic by design. This kyphogenic effect was increased in the lumbar spine. Additionally, these rods were too flexible to avoid bending in axial loading during the healing process, resulting in a progression of this kyphosis until fusion was solid. Significant loss of intersegmental, sagittal lordosis was an undesirable byproduct of these procedures, including the older Dwyer and Zielke techniques.

In an effort to prevent these undesirable sagittal plane changes, structural interbody fusion strategies were advanced. These included structural allograft or autograft and titanium mesh cages.

The use of solid rods reduced the kyphogenic changes at the time of surgery. These rods negated the need for compression as the sole mode of curve correction and resisted disc space collapse during the healing process.

In an effort to manage the biomechanical deficiency of a single coronally placed screw in a vertebral body, surgeons developed anterior spinal implants for the thoracic and lumbar spine that allowed the placement of two screws in each vertebral body. Initially, these were plate and screw systems, but ultimately, Kaneda developed a threaded dual-rod system with a laterally positioned vertebral body staple. The initial application of this device was for traumatic spinal injuries.[13] When combined with a structural interbody iliac graft and a transverse rod connector, this device was able to restore biomechanics back to normal in a corpectomy model. This system was ultimately modified to include two smooth 1/4-inch rods and open screws with an Isola (DePuy) locking mechanism. This allowed fixation of multisegmental pathologies, such as thoracolumbar scoliosis. The smooth-rod Kaneda system was downsized to 3/16 inch and modified to fit on the lateral side of the smaller, adolescent spine.

Biomechanical evaluation of multisegmental dual-rod constructs suggests that these constructs achieve rigidity of the fixed spinal segments beyond that achieved with a single screw–rod construct. They can maintain sagittal alignment better than single screw–rod constructs and do so without the need for structural interbody grafting techniques. Taking advantage of this added rigidity and sagittal plane control, Gaines et al. have used the dual-rod constructs without interbody material, in a "bone on bone" interbody fusion technique. In this technique, a complete radical discectomy with removal of the posterior longitudinal ligament is performed at each level. The fusion segments include only those in the Cobb measured curve. The sagittal alignment is maintained by rod contouring in the sagittal plane. This technique remains under evaluation, but it demonstrates the utility of the dual-rod–dual-screw constructs in achieving and maintaining correction in the sagittal and coronal planes.

ANTERIOR SPINAL RELEASE FOR SCOLIOSIS SURGERY

The indications for scoliosis surgery include one or more of the following: (1) stopping the progression of a progressive deformity, usually in a growing child; (2) correcting spinal deformity that has the potential to cause the patient problems into the future; and (3) correcting a deformity that has resulted in significant postural or cosmetic deviations.

The vast majority of scoliosis corrections are managed from the posterior approach. Traditionally, the posterior approach with application of posterior instrumentation and posterior fusion was used to achieve partial correction and long-term stability of a scoliosis deformity. In severe rigid spinal deformities involving the thoracic and lumbar spine, however, a posterior approach alone was not adequate to achieve the desired corrections in the sagittal, coronal, and axial planes. This is because the anterior structures are important in maintaining the spine in the deformed position. In the thoracic spine, the discs and rib heads contribute significantly to spinal stability. In the lumbar spine, the discs are the primary restraint to rotational correction. Scoliosis surgeons soon realized that curve corrections could be enhanced when the anterior spinal structures were released. Expanding on Hodgson's experience with anterior spinal approaches, spinal surgeons in Europe and the United States began experimenting with anterior spinal release procedures for the management of severe and rigid scoliosis deformities as well as other pathologic entities.

Since the mid 1970s, anterior release procedures have become commonplace in the management of severe scoliosis deformities. In some instances, these procedures are mandatory to achieve acceptable spinal realignment. Removal of discs, rib heads, and vertebral bodies, if necessary, effectively allows the anterior spinal column shortening and apical derotation required for correction of severe and rigid spinal deformities. Curves considered appropriate for anterior release frequently are greater than 75 degrees and demonstrate minimal flexibility on bending x-rays. The discs that remain rigid on bending x-rays should be considered for anterior release.

Anterior release is usually performed as the primary procedure when the indication is improved curve correction. The procedure involves a thoracotomy on the convex side of the curve. Rib excision is typically one level above the most proximal disc targeted for excision by the surgeon. From a single thoracotomy, typically four to five discs can be removed. If a greater number of disc excisions are required, a second thoracotomy can be performed distally. If the curve extends into the lumbar spine, the thoracotomy can be converted to a thoracoabdominal approach. Theoretically, this allows exposure of the lateral aspect of the entire thoracic and lumbar spine from T3–S1.

For rigid thoracic and lumbar deformities, the surgeon often will perform an anterior release procedure and evaluate the degree of spinal mobilization. If rigidity persists after a complete anterior release, other structures may be maintaining the deformed spinal position. These can include the chest wall and sternum, asymmetric muscle/ligament contractures of the thoracic and lumbar spine, pelvis, and facet joint pathology. In these cases, intervening halo-gravity traction can provide gradual and safe correction of these ultra-severe spinal deformities. Gradual correction of the spinal curve, improvement in the coronal and sagittal plane alignment, and correction of pelvic obliquity can be achieved.

During the anterior release procedure with supplemental traction, a cranial halo ring is applied. During the early postoperative period, usually starting at 24 hours postoperatively, traction weight is applied to the halo ring. It is critical that the cervical spine be evaluated preoperatively to ensure that there is no hidden pathology in this region. Traction weight usually can begin at 5 pounds and increase in 2- to 3-pound increments until 35% to 40% of the patient's body weight is applied. In most cases, several days are required to achieve the desired traction weight. The patient's bed is rigged with an orthopedic overhead trapeze. Traction position should be varied according to the patient's desired positions. This will typically include a 90-degree upright position and a 30-degree reclined position for sleeping. Wheelchairs and specially prepared walking devices allow for traction during upright positioning. Small breaks from traction are allowed for bathroom privileges and physical therapy. In general, the patient remains hospitalized during the entire course of traction. This is necessary so that careful evaluation of the patient's neurologic condition, especially the cranial nerves, can be documented.

The period of traction duration varies. Some deformities respond rather rapidly, (e.g., in 10 to 14 days), whereas others may require traction periods of up to 6 weeks. The response to traction can be tracked with weekly x-rays obtained while the patient is in traction. The indicators for proceeding to second-stage posterior surgery are a plateau in deformity correction despite effective traction application or any traction-related complications. The posterior spinal instrumentation then can be performed with intraoperative traction applied.

Substantial improvements in curve corrections, pelvic obliquity, and other coronal and sagittal plane measurements are possible using the halo-gravity traction technique combined with anterior release and posterior fusion procedures for ultra-severe spinal deformity.

The role of apical corpectomy/vertebrectomy as a release mechanism in the management of scoliosis correction is still under evaluation. Clearly, these procedures should only be used for the most severe and rigid deformities. The removal of the apical vertebral body (or bodies) achieves spinal column shortening and allows major corrections in the coronal and sagittal plane. The posterior elements of the same vertebra may be removed at the same level, if the deformity requires it, completing the vertebrectomy procedure. Up to 90 degrees of correction can be achieved with a single-level corpectomy/vertebrectomy. This demanding surgical technique submits the patient to increased blood loss and increased risk of neurologic injury. The surgeon must keep these factors in mind when considering adding this procedure as a component of anterior release. Halo-gravity traction may be used after anterior corpectomy procedures in preparation for second-stage posterior surgery.

In general, most of the deformities that are severe enough to warrant a corpectomy/vertebrectomy technique would not be amenable to anterior spinal instrumentation. Exceptions include patients with a congenital spinal deformity, such as a hemivertebra, that must be excised. In these cases, the hemivertebra and the adjacent discs are excised, and correction is achieved by spinal column shortening. Usually, the posterior portion of the hemivertebra needs to be removed as well. This achieves complete correction and results in the fewest spinal segment fused.

Thoracoscopic anterior scoliosis procedures have gained a great deal of notoriety during the past 10 years. The spinal applications were a logical extension of thoracic surgical experience with this technology.[14] In general, one-lung ventilation is required in patients undergoing this procedure in the lateral decubitus position. Typically, three to four portals are required for a standard anterior release procedure.[15] Anterior release procedures involve the excision of disc material and rib heads similar to what can be done through an open thoracotomy.[16] The parietal pleura is opened, and the segmental vessels are sacrificed. The exposure is circumferential from convex to concave rib head. Harmonic scalpels are used to dissect the spine and incise the annulus. The annulus then can be removed with a variety of standard spinal instruments modified for the thoracoscopy technique. These include osteotomes, elevators, curettes, and rongeurs. As in the open anterior discectomy procedure, the disc can be removed back to the posterior longitudinal ligament and from posterior corner to posterior corner.[17] If necessary, the convex rib head may be excised as well. Thoracoscopic anterior releases can be as thorough as open anterior releases, depending on the experience and tenacity of the surgeon. In a biomechanical comparison, thoracoscopic anterior release and open anterior release achieved the same degree of spinal mobility.[18] Fusion results currently are equal with open and thoracoscopic techniques.

Thoracoscopic anterior spinal instrumentation has been developed for application to the lateral aspect of the spine.[19] By use of a thoracoscopic exposure, the intervening discs are removed, and spinal implants are applied to the lateral aspect of the spine. The currently available systems use a single screw per vertebra.[20] C-arm fluoroscopy is used to aid implant insertion. Innovative techniques of rod reduction and screw compression have been developed that allow correction of thoracic curves into ranges comparable with open techniques. In initial series, pseudarthrosis was the major problem. This seems to have improved with greater attention to endplate preparation and bone-grafting techniques. Interestingly, there have not been demonstrated significant benefits to thoracoscopic technique over open thoracotomy technique when the following parameters are analyzed: operative time (greater for thoracoscopy); blood loss; and chest tube drainage. Days of hospitalization are lessened by thoracoscopic techniques as are postoperative pain ratings. Pulmonary function tests are initially better with thoracoscopic technique than open thoracotomy 6 weeks postoperatively, but there is no difference at 1 year.

Thoracoscopic anterior release is also possible in the prone position. This apparently decreases the need for one-lung ventilation and does not require repositioning the patient to perform the anterior release and posterior fusion during same operative session.

CONCLUSION

Anterior surgery for the treatment of scoliosis has evolved greatly. Anterior surgery remains an important adjunctive technique that surgeons can use to treat scoliotic deformities of the spine. The anterior release can enhance anterior correction and fusion. It also can be used as a component of a two-part anterior release, posterior instrumentation and fusion procedure to correct and maintain some of the most severe spinal deformities. One must think of anterior surgery as part of the global approach to surgical management of scoliosis.

REFERENCES

1. Hall JE. Dwyer instrumentation in anterior fusion of the spine. *J Bone Joint Surg Am* 60:1188–1190, 1981
2. Zielke K, Stunkat R, Duquesne J, et al. Ventral derotation spondylosis. *Orthop Praxis* 11:56, 1975
3. Turi M, Johnson CE, Richard BS. Anterior correction of idiopathic scoliosis using TSRH instrumentation. *Spine* 18:417–422, 1993
4. Kaneda K, Shono Y, Satoh S, et al. New anterior instrumentation for the management of thoracolumbar and lumbar scoliosis: application of the Kaneda two-rod system. *Spine* 21:1250–1262, 1996
5. Haher T, Felmly W, O'Brien M, et al. The effect of the three columns of the spine on the instantaneous axis of rotation in flexion. *Spine* 17(6 Suppl):S149–S154, 1992
6. Haher T, Felmly WT, Baruch H, et al. The contribution of the three columns of the spine to rotational stability: a biomechanical model. *Spine* 14:663–669, 1989
7. Breeze SW, Doherty BJ, Noble PS, et al. A biomechanical study of anterior thoracolumbar screw fixation. *Spine* 23: 1829–1831, 1998
8. Horton WC, Blackstock SF, Norman JT, et al. Strength of fixation of anterior vertebral body screws. *Spine* 21: 439–444, 1996
9. Lieberman IH, Khazim R, Woodside T. Anterior vertebral body screw pullout testing. *Spine* 23: 908–910, 1998
10. Lowe T, O'Brien M, Smith D, et al. Central and juxta-endplate vertebral body screw placement: a biomechanical analysis in a human cadaveric model. *Spine* 27: 369–373, 2002
11. Ogon M, Haid C, Krismer M, et al. Comparison between single-screw and triangulated, double-screw fixation in anterior spine surgery. *Spine* 21: 2728–2734, 1996
12. Snyder BD, Zaltz I, Hall JE, et al. Predicting the integrity of vertebral bone screw fixation in anterior spinal instrumentation. *Spine* 20: 1568–1574, 1995
13. Oda I, Cunningham BW, Lee GA, et al. Biomechanical properties of anterior thoracolumbar multisegmental fixation: an analysis of construct stiffness and screw-rod strain. *Spine* 25: 2303–2311, 2000.
14. Newton PO, Cardelia JM, Farnsworth CL, et al. A biomechanical comparison of open and thoracoscopic anterior spinal release in a goat model. *Spine* 23: 530, 1998
15. Newton PO, Shea KG, Granlund KF. Defining the pediatric spinal thoracoscopy learning curve: sixty-five consecutive cases. *Spine* 25: 1028–1035, 2000
16. Newton PO, Wenger DR, Mubarak SJ, et al. Anterior release and fusion in pediatric spinal deformity: a comparison of early outcome and cost of thoracoscopic and open thoracotomy approaches. *Spine* 22: 1398–1406, 1997
17. Picetti GD, Blackman RG, O'Neal K, et al. Anterior endoscopic correction and fusion of scoliosis. *Orthopedics* 21: 1285–1287, 1998
18. Picetti GD III, Blackman RG, O'Neal K. Preliminary results of endoscopic procedures of the anterior thoracic spine. *J Bone Joint Surg Br* 79(Suppl 3): 289, 1997
19. Connolly PJ, Ordway NR, Sacks T, et al. Video-assisted thoracic discectomy and anterior release: a biomechanical analysis of an endoscopic technique. *Orthopedics* 22:923, 1999
20. Cunningham BW, Kotani Y, McNulty PS, et al. Video-assisted thoracic surgery versus open thoracotomy for anterior thoracic spinal fusion: a comparative radiographic, biomechanical, and histologic analysis in a sheep model. *Spine* 23:1333–1340, 1998

CME Quiz

To earn CME credit, you must read the CME article and complete the quiz and evaluation assessment survey on the enclosed form, answering at least 70% of the quiz questions correctly. Select the best answer and place a check mark or an X mark in the corresponding space on the enclosed answer form. Do not fill in the answer box completely. Please indicate any name and address changes directly on the answer form. If your name and address do not appear on the answer form, please print that information in the blank space at the top left of the page. Make a photocopy of the completed answer form for your own files and mail the original answer form to Lippincott Williams & Wilkins, Continuing Education Department, P.O. Box 1543, Hagerstown, MD 21741-9914 by **January 31, 2006.** For more information, call (800) 787-8981.

Wolters Kluwer Health is accredited by the Accreditation Council for Continuing Medical Education to provide continuing medical education for physicians.

Wolters Kluwer Health designates this educational activity for a maximum of 1.5 category 1 credits toward the AMA Physician's Recognition Award. Each physician should claim only those credits that he/she actually spent in the activity.

1. Which of the following advantages does anterior fusion offer over posterior surgery for scoliosis?
A. Shorter spinal fusion
B. Preservation of distal lumbar motion segments
C. Lower risk of coronal plane decompensation
D. All of the above

2. Mechanisms of anterior scoliosis correction include all of the following *except*
A. anterior and lateral column shortening by removal of the discs
B. cantilever forces applied as the rod is introduced into the laterally positioned bone anchors
C. achieving 90-degree alignment between a monoaxial screw and the rod
D. rod derotation from a scoliotic position into the correct sagittal position
E. application of distraction forces in an intersegmental fashion from apex to end vertebra

3. The role of discectomy for anterior scoliosis surgery is
A. overrated
B. important only for spine fusion
C. open for surgical techniques
D. the main mechanism for spinal correction if performed thoroughly and subtotally

4. Enhanced vertebral body screw pullout strength is achieved by
A. oblique orientation
B. mid-body positioning
C. placement in juxta-endplate bone
D. A and C

5. Anterior release via thoracotomy is performed
A. on the concave side
B. in the middle of the discs to be excised
C. to preserve rib heads over the disc spaces
D. none of the above

6. Anterior discectomy and release can
A. provide 10 to 15 degrees of correction per level
B. allow for rod derotation to provide correction
C. result in kyphosis
D. all of the above

7. Anterior release is probably best used in patients with
A. spinal deformity greater than 75 degrees
B. spinal deformity greater than 45 degrees and flexible
C. rigid spinal deformity on bending x-rays
D. A and C

8. The use of spiked vertebral body staples provides
A. resistance to screws ploughing through the vertebral body
B. targets for the surgeon to better enhance rod attachment to the screws
C. improved biomechanical strength in screw pullout
D. all of the above

9. Indications for scoliosis surgery include
A. stopping the progression of a progressive deformity, usually in a growing child
B. correction of spinal deformity that has the potential to cause the patient problems into the future
C. correction of a deformity that has resulted in significant postural or cosmetic deviations
D. all of the above

10. Halo-gravity traction is used
A. for severe curves that are rigid even after anterior release
B. to increase height prior to posterior fusion
C. to enhance fusion rates
D. all of the above