Spinal Procedure Atlas for Cerebral Palsy Deformities

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Freeman Miller and Kirk W. Dabney

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Abstract

Scoliosis is a common deformity in nonambulatory children with cerebral palsy, and most of the children require surgical correction. The surgical correction of scoliosis in children with cerebral palsy has to involve considerations that are not common for children with idiopathic scoliosis. It is especially important to consider the amount of the spine to fuse since it is very common for deformities to occur at the ends of the fusion area if it is not extensive enough. Therefore, almost all children with nonambulatory cerebral palsy (GMFCS IV and V) who have scoliosis should have a fusion from T1–T2 to the pelvis. This corrects the deformity and also assures that the deformity will remain corrected long term with maximum benefit to the patient. The technique of using cantilever correction has been used extensively to make sure that the pelvis will align with the spine. This has been the best documented and most accurate way to get a pelvic alignment corrected. The description of this procedure requires that the rod systems be fixed in the pelvis first and then sequentially the correction is made so that the spine is

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brought to normal alignment with the pelvis. This technique is not well recognized by spine surgeons who do not have familiarity with treating children with cerebral palsy. The goal of this chapter is to describe the technique for using cantilever deformity correction to align the trunk and pelvis.

Keywords

Cerebral palsy · Posterior spinal fusion · Anterior spinal release · Unit rod · Modular unit rod · Sublaminar wires · Pedicle screws · Cantilever correction

Introduction

Scoliosis is a common deformity in nonambulatory children with cerebral palsy. Since there is no conservative treatment for spinal deformities in children with cerebral palsy who have a progressive spinal deformity, most of the children require surgical correction. The surgical correction of scoliosis in children with cerebral palsy has to involve considerations that are not common for children with idiopathic scoliosis. It is especially important to consider the amount of the spine to fuse since it is very common for deformities to occur at the ends of the fusion area if it is not extensive enough. Therefore, almost all children with (GMFCS IV and V) nonambulatory cerebral palsy who have scoliosis should have a fusion from T1–T2 to the pelvis. This corrects the deformity and also assures that the deformity will remain corrected long term with maximum benefit to the patient (Dias et al. 1996; Smucker and Miller 2001; Tsirikos et al. 2004, 2008). It is also very common to have pelvic malalignments; therefore, the attention should be placed on making sure the pelvis has correct alignment with the spine. This frequently requires correction of pelvic obliquity and anterior pelvic tilt as well as pelvic malrotation. The technique of using cantilever correction has been used extensively to make sure that the pelvis will align with the spine. This has been the best documented and most accurate way to get a pelvic obliquity alignment corrected. The description of this procedure requires that the rod systems be fixed in the pelvis first and then sequentially the correction is made so that the spine is brought to normal alignment with the pelvis. This technique is not well recognized by spine surgeons who do not have familiarity with treating children with cerebral palsy. The goal of this chapter is to describe the technique for using cantilever deformity correction for alignment of the trunk and pelvis.

Posterior Spinal Fusion with Single Unit Rod or Modular Unit Rod Using Cantilever Correction

Indication

The primary instrumentation for fusion of cerebral palsy scoliosis is posterior spinal fusion using a unit rod or the modular system that allows cantilever correction of the pelvic obliquity. The primary benefit of the modular system is easier insertion in the pelvis especially when there is significant lumbar lordosis or severe pelvic obliquity. It is also easier to combine this system with pedicle screws. The indications for fusion in the growing child are a curve approaching 90° when sitting or a curve that is becoming stiff such that side bending to the midline is difficult (▶ Chap. 118, "Surgical Treatment of Scoliosis Due to Cerebral Palsy"). The same instrumentation is indicated for kyphosis in the adolescent when the kyphosis is becoming stiff or is a significant impairment to sitting. Surgical correction of lordosis is indicated when sitting is difficult or if there is pain with sitting from the severe lordosis (▶ Chap. 119, "Surgical Management of Kyphosis and Hyperlordosis in Children with Cerebral Palsy").

Procedure

1. Preparation of the child should start with insertion of two large-bore peripheral intravenous lines if possible. The child then is intubated with careful attention to having the endotracheal tube well secured (▶ Chap. 82, "Anesthetic Management of Spine Fusion").

2. An arterial line is inserted, usually in the radial artery by percutaneous insertion. If it is impossible to obtain a percutaneous peripheral arterial line, cutdown of the radial artery is indicated with insertion of a line. If this is not possible, a cutdown onto the posterior tibial artery at the posterior aspect of the proximal medial malleolus is recommended.
3. A large-bore central line is inserted, typically using a tunneled central line, which will be used postoperatively as a feeding line. Usually, this line is inserted via the subclavian approach with the catheter exiting on the lateral inframammary line or at the medial midline.
4. A Foley catheter is inserted to monitor urinary output, and a nasogastric tube is inserted to continuously keep the stomach decompressed to decrease venous bleeding.
5. The patient is turned prone on the spine frame, making sure that the abdomen is fully dependent to decrease bleeding from increased abdominal venous pressure, and the hips are flexed sufficiently to maximally reduce lumbar lordosis (Fig. 1).
6. Spinal cord monitoring using Somatosensory Evoked Potentials (SSEPs) and Motor Evoked Potentials (MEPs) is recommended for all children with functional lower extremities who are able to stand or ambulate. Most children with this level of function can be monitored. Children with severe cognitive limitation and no lower extremity function often cannot be monitored, and there is little benefit to monitoring this population.
7. After prepping and draping, a posterior incision is made from T1 to the middle of the sacrum. The longitudinal direction of the line is chosen to be halfway between a straight line from T1 to the sacrum and a line that follows the curve of the spinous process (Fig. 2).
8. A small superficial dermal incision is made, and then the subcutaneous tissue is infiltrated with a large volume, up to 500 ml, of a normal saline solution diluted 1–500,000 with epinephrine. An alternative is to use electrocautery to cut through the subcutaneous tissue and dermis.
9. Utilizing lateral pressure from a clamp and a knife, the interspinous ligaments and spinous process apophysis are transected. By staying exactly in the midline where there are few crossing blood vessels, little bleeding is encountered (Fig. 2A).
10. Subperiosteal dissection is performed over each lamina with packing of a sponge at each level (Fig. 2B).

Fig. 1 The patient is turned prone on the spine frame, making sure that the abdomen is fully dependent to decrease bleeding from increased abdominal venous pressure, and the hips are flexed sufficiently to maximally reduce lumbar lordosis

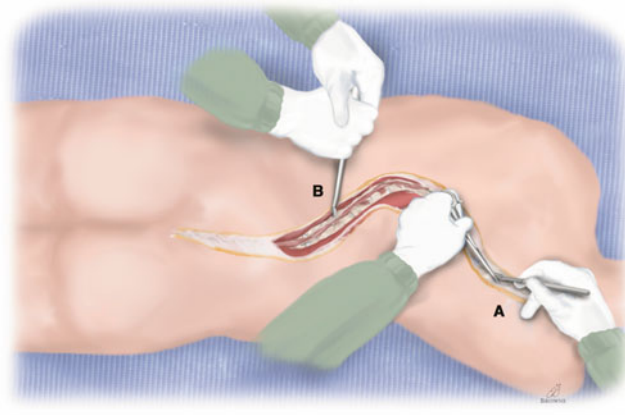

Fig. 2 Utilizing lateral pressure from a clamp and a knife, the interspinous ligaments and spinous process apophysis are transected. By staying exactly in the midline where there are few crossing blood vessels, little bleeding is encountered (Fig. 2A). Subperiosteal dissection is performed over each lamina with packing of a sponge at each level (Fig. 2B)

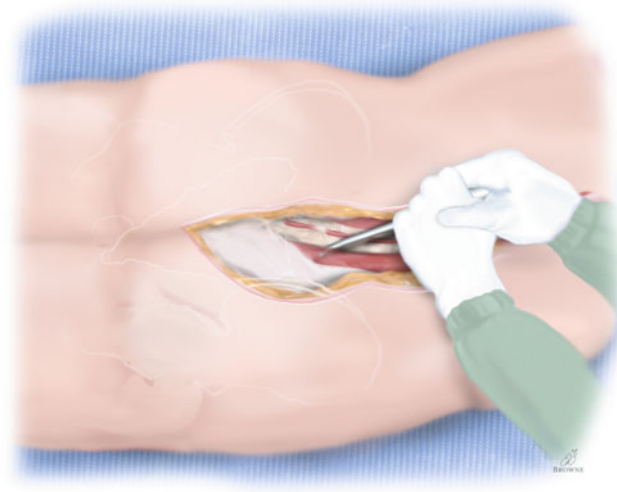

Fig. 3 Identify the crest of the posterosuperior iliac spine, and then make a longitudinal incision down the midline of the crest to the inferior aspect of the posterosuperior iliac spine

11. After all the laminae are subperiosteally exposed and packed from T1 to L5, attention is directed to the sacrum, where the sacrum is stripped with exposure of the paraspinal muscles until the posterosuperior iliac crest can be palpated. This stripping and elevation need to occur from L5 to the distal end of the sacrum.
12. While doing periosteal elevation over the sacrum and L5, care should be taken to avoid opening the sacroiliac joints or violating the posterior sacroiliac ligaments, as these will have significant bleeding.
13. Identify the crest of the posterosuperior iliac spine, and then make a longitudinal incision down the midline of the crest to the inferior aspect of the posterosuperior iliac spine (Fig. 3).
14. **Pelvic Instrumentation Option 1** – Subperiosteally strip the lateral aspect of the ilium anterior and inferior.
15. Use a packing sponge; dissect inferior toward the sciatic notch and the posterosuperior iliac spine.
16. Clean the inferior two-thirds of the posterosuperior iliac spine so its medial and lateral border and caudal edge are visible clearly.
17. Insert the drill guide hook into the sciatic notch, and align the drill insertion point at the inferior aspect of the posterosuperior iliac spine. Do not get too close to the inferior

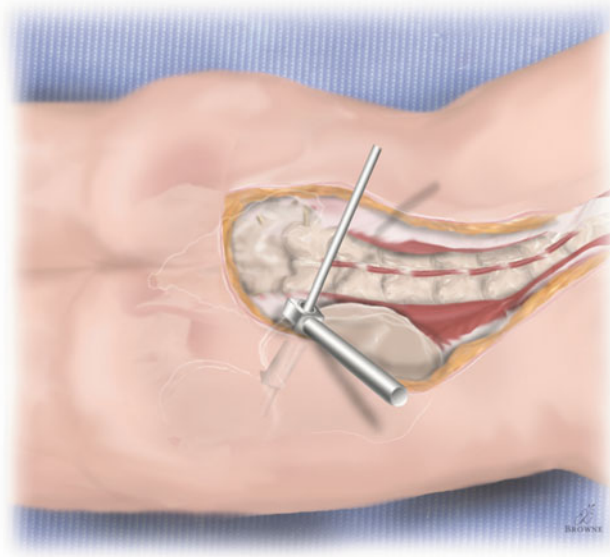

Fig. 4 Insert the drill guide hook into the sciatic notch, and align the drill insertion point at the inferior aspect of the posterosuperior iliac spine. Do not get too close to the inferior border. Before drilling, make sure that the drill guide is held into the apex of the sciatic notch with its lateral border being flat against the ilium. Also, before drilling, mark the drill bit so that it will protrude 1–2 cm past the distal end of the drill guide. Drill the hole into the pelvis to, or just past, the mark on the drill bit. Always be careful to stabilize the drill guide in the proper position

border. Before drilling, make sure that the drill guide is held into the apex of the sciatic notch with its lateral border being flat against the ilium. Also, before drilling, mark the drill bit so that it will protrude 1–2 cm past the distal end of the drill guide (Fig. 4).

18. Drill the hole into the pelvis to, or just past, the mark on the drill bit. Always be careful to stabilize the drill guide in the proper position (Fig. 4).
19. Using a wire or a thin probe, document that the drillhole is entirely within the bone.
20. Pack Gelfoam into the drillholes to prevent bone bleeding.
21. Pack the lateral side of the iliac crest with a sponge to prevent bleeding. These sponges have to be inserted completely over the edge of the iliac crest or they will become entangled in the rod or wires. These sponges will be removed just before wound closure.
22. **Pelvic Instrumentation Option 2** – After exposure of the posterior superior iliac crest, the intramedullary canal of the ilium can be defined using a pedicle probe and fluoroscopy requiring oblique positioning (Fig. 5). Make sure the tip of the probe is just above the sciatic notch and in the middle (Fig. 6) of the teardrop image of the ilium viewed on axis (Fig. 7).

Fig. 5 After exposure of the posterior superior iliac crest, the intramedullary canal of the ilium can be defined using a pedicle probe and fluoroscopy requiring oblique positioning

23. After the probe is confirmed to have developed the correct track, a pedicle screw is chosen so the length goes at least 1–2 cm past the apex of the sciatic notch. The screw

Fig. 6 Make sure the tip of the probe is just above the sciatic notch and in the middle

Fig. 7 Make sure the tip of the probe is just above the sciatic notch and in the middle of the teardrop image of the ilium viewed on axis

Fig. 8 After the probe is confirmed to have developed the correct track, a pedicle screw is chosen so the length goes at least 1–2 cm past the apex of the sciatic notch. The screw position is then confirmed with fluoroscopy

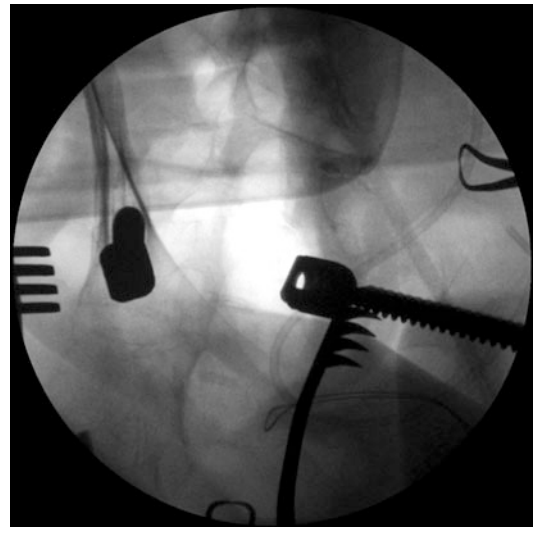

Fig. 9 After the probe is confirmed to have developed the correct track. The screw position is also confirmed with fluoroscopy with axial view to confirm that the screw is centered in the ilium

position is then confirmed with fluoroscopy (Figs. 8 and 9).

24. Repeat the same procedure on the iliac crest on the opposite side.
25. Remove the sponge packs from the prior exposure of the spine, and clean each vertebra so that all the soft tissue is removed from the tips of the transverse process over all the laminae and the spinous processes. Make a good clean exposure of the facet joints.

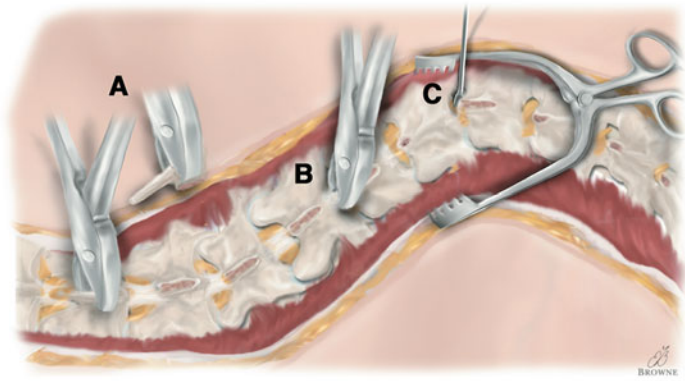

Fig. 10 Remove the spinous processes by using a bone biter. In the thoracic spine, cut vertically approximately 1 cm distal to the superio aspect of the lamina

Fig. 11 It is important never to violate the superior border of the posterior elements, as this is where the strength for wire fixation occurs. In the lumbar spine, the spinous processes should be transected transversely at their base. In the lumbar area, the spinous process is cut horizontally; then at the thoracolumbar junction, they are cut at 45°, and in the thoracic area, the process is cut off vertically

26. Remove the spinous processes by using a bone biter. In the thoracic spine, cut vertically approximately 1 cm distal to the superior aspect of the lamina (Fig. 10). By proper removal of the spinous processes, the spinal interspace is opened. It is important never to violate the superior border of the posterior elements, as this is where the strength for wire fixation occurs. In the lumbar spine, the spinous processes should be transected transversely at their base (Fig. 11). In the lumbar area, the spinous process is cut horizontally; then at the thoracolumbar junction, they are cut at 45°, and in the thoracic area, the process is cut off vertically (Fig. 11).
27. Use a rongeur with a serrated end to remove the ligamentum flavum (Fig. 10A). If more bone removal is indicated, remove the bone from the inferior aspect of the spinous process base and lamina only. Never remove bone from the superior aspect of the lamina because this is the aspect of the lamina that provides strength for the wire (Fig. 10B).
28. Complete the spinal interspace opening with a curette, making sure that the ligamentum flavum is cut a sufficient distance on either side so wire can be passed (Fig. 10C). If epidural bleeding occurs during this time, the interspace should be packed gently with Gelfoam and a neural sponge. There may be substantial bleeding from these epidural veins; however, it is almost impossible to cauterize them without an extremely large exposure that destroys the lamina. The

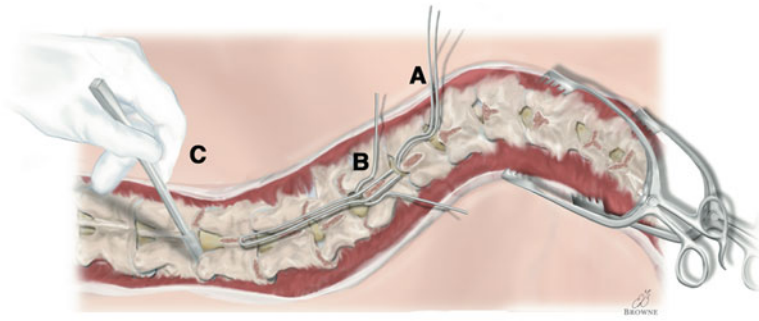

Fig. 12 Wires are inserted starting at the distal end at L5. Usually, two double wires are inserted at L5 and T1 and only a single double wire at each other level (Fig. 12A). The wires are bent over the laminae so that the double end of the wire is bent into the midline pointing caudally, and each beaded lateral single wire is brought out laterally and cross-cranially over the laminae. This double crossing of the wires provides extra protection to prevent the inadvertent protrusion of the wires into the neural canal (Fig. 12B)

bleeding can be controlled with gentle pressure, and occasionally wire passing has to be done in the face of some of the epidural bleeding.

29. Wires are inserted starting at the distal end at L5. Usually, two double wires are inserted at L5 and T1 and only a single double wire at each other level (Fig. 12A). The wires are bent over the laminae so that the double end of the wire is bent into the midline pointing caudally, and each beaded lateral single wire is brought out laterally and cross-cranially over the laminae. This double crossing of the wires provides extra protection to prevent the inadvertent protrusion of the wires into the neural canal (Fig. 12B). When passing wires, it is important to roll the wires under the lamina, being especially careful not to roll the wire with the tip caught under the lamina, as this will cause high pressure on the spinal cord (Fig. 13). Also always pull up on the wire, to prevent any wire loop from developing in the spinal canal which will likely cause spinal cord injury (Fig. 14).
30. Utilizing gouges or rongeurs, all facet joints are removed from T1 to the sacrum (Fig. 7). The transverse processes and far lateral borders of the laminae are decorticated. Bone graft then is packed into this decorticated bone. Bleeding that cannot be controlled with electrocautery will occur during this period as the bone is opened, and it should be controlled by packing the wound with bone graft soaked with thrombin and Gelfoam. Pressure from additional sponge packing also will help control the bleeding. If severe bleeding is encountered, this portion of the procedure can be done after insertion

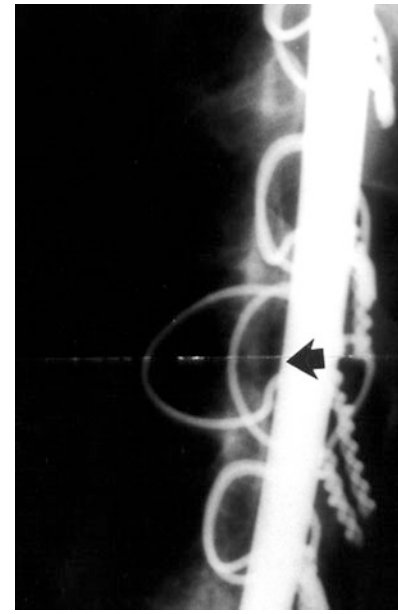

Fig. 13 It is important to roll the wires under the lamina, being especially careful not to roll the wire with the tip caught under the lamina, as this will cause high pressure on the spinal cord

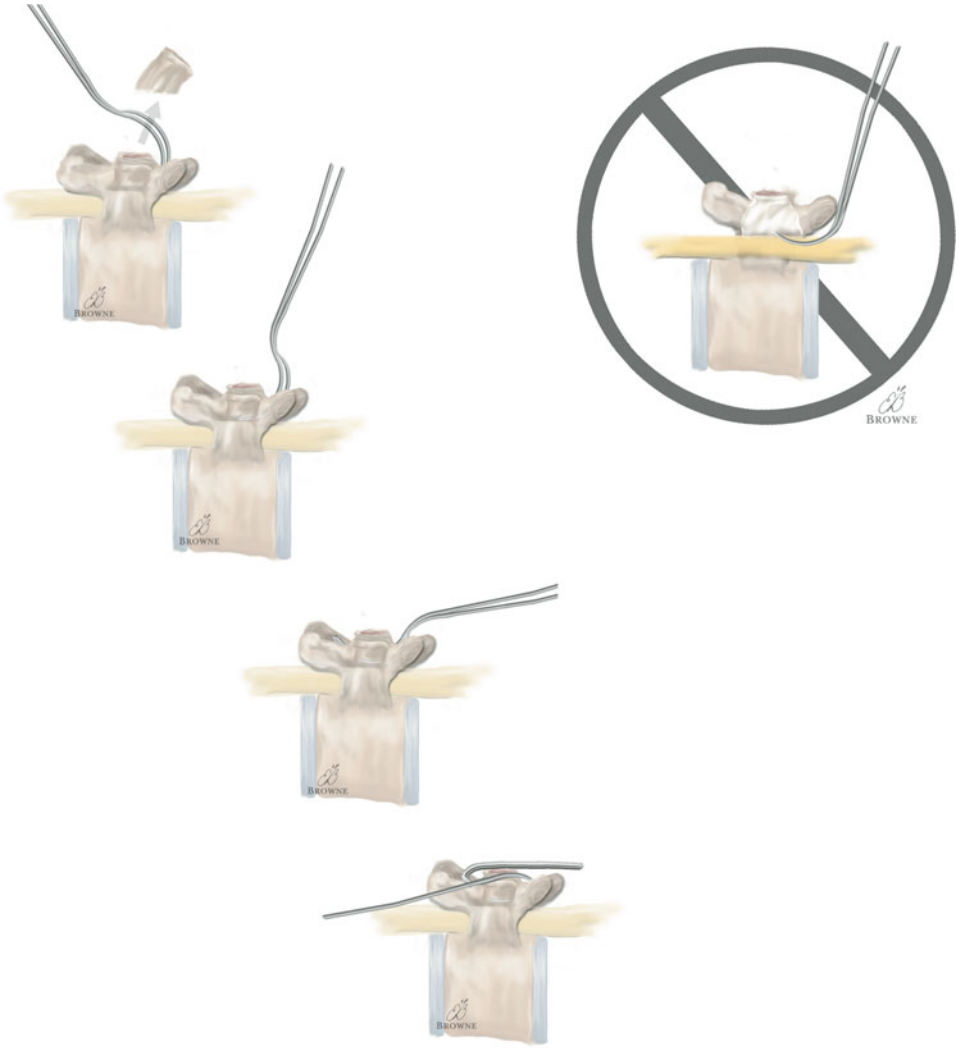

Fig. 14 Also always pull up on the wire, to prevent any wire loop from developing in the spinal canal which will likely cause spinal cord injury

of the rod, but it is more difficult, and decortication and facetectomy performed after rod insertion will be much less adequate. Some prefer to decorticate and remove facets after rod insertion to decrease the blood loss; however this severely limits the ability to decorticate and do a facetectomy.

31. When using the single unit rod, choose the correct rod length by estimating the rod and laying it upside down with the legs pointing posteriorly. The most caudal end of the rod is now aligned with the holes drilled in the pelvis. If significant pelvic obliquity is present, choose a midway point between the right and left holes. The cranial end of the rod then is aligned to lie at the level of T1. If there is severe lumbar lordosis or severe scoliosis, one size longer rod may be chosen. If severe kyphosis is present, one size shorter rod should be chosen (Fig. 15).
32. When the modular rods are used (Fig. 16), insert the fixed lateral connectors to the inserted pelvic screws, and then insert the individual rods into the lateral connector.

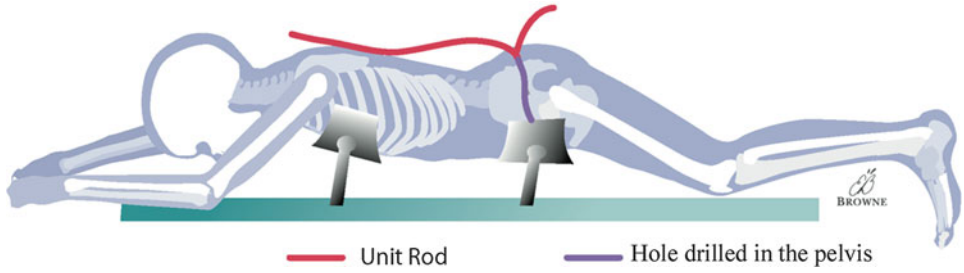

Fig. 15 When using the single unit rod, choose the correct rod length by estimating the rod and laying it upside down with the legs pointing posteriorly. The most caudal end of the rod is now aligned with the holes drilled in the pelvis. If significant pelvic obliquity is present, choose a midway point between the right and left holes. The cranial end of the rod then is aligned to lie at the level of T1. If there is severe lumbar lordosis or severe scoliosis, one size longer rod may be chosen. If severe kyphosis is present, one size shorter rod should be chosen

Fig. 16 When the modular rods are used, insert the fixed lateral connectors to the inserted pelvic screws, and then insert the individual rods into the lateral connector

The sagittal bend in the two rods should be aligned, so their contours match (Fig. 17) and the rods are perfectly perpendicular to the horizontal axis of the pelvis. The sagittal contour should align with the sacrum. The two rods should then have a cross connector placed at the thoracic spine or proximal end of the rod (Fig. 18). The length of the modular rod is much easier to address, because the rod can be left a little long and then cut off as one progresses with deformity correction. The lumbar cross connector should always be added after partial correction to stabilize the system and always before the thoracic connector is loosened or moved. If the rod is too long, the thoracic connector can be moved distal and the rod cut off in situ.

33. When the single unit rod is used, the caudal end of the rod legs then are crossed over for insertion. The holes drilled in the pelvis should be palpated with a probe and their orientation carefully memorized. The hole that is most vertical has the rod leg inserted first, with that leg of the unit rod having to be anterior to the leg of the unit rod to be inserted last. By memorizing the direction, the leg of the unit rod is inserted for approximately half its length. Attention then is directed to the opposite hole, where it is again probed and its direction carefully memorized, and then the leg is directed in the proper direction. Each of the legs is impacted sequentially until they are driven down completely below the level of the bone of the superior iliac spine. In small children, or those with severe osteoporosis, it is extremely important to very carefully monitor the direction in which the legs of the rod are being impacted, which

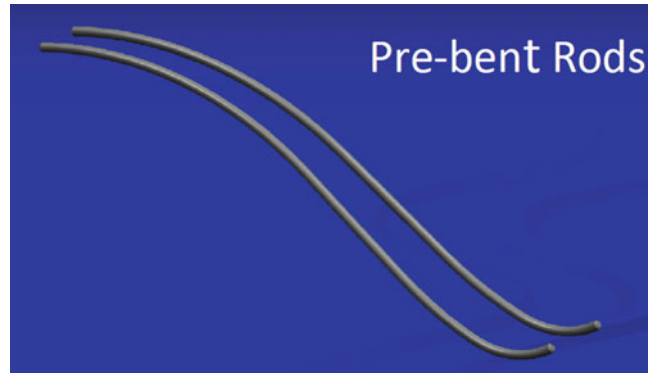

Fig. 17 The sagittal bend in the two rods should be aligned, so their contours match and the rods are perfectly perpendicular to the horizontal axis of the pelvis

Fig. 18 The two rods should then have a cross connector placed at the thoracic spine or proximal end of the rod

Fig. 19 After the rod is inserted, a fluoroscopy image should be obtained to document the correct position in the medullary canal of the ilium

often requires holding onto the rod with a device and helping direct the rod into the correct direction staying on the drilled hole. With weak bones, the rod may cut its own hole if impaction is not performed carefully. The distal end of the rod then is impacted fully into the pelvis until it is below the level of the posterosuperior iliac spine and should be lying in the gutter between the iliac spine and the lateral sacrum. After the rod is inserted, a fluoroscopy image should be obtained to document the correct position in the medullary canal of the ilium (Fig. 19). If the rod leg is not in the correct position (Fig. 20), it must be repositioned. This usually means cutting the rod and removing the leg that is malpositioned and reinserting it and reattaching it to the remaining rod with rod connectors.

34. The rod is pushed to L5 using a rod pusher, and the wires are twisted and tightened (Fig. 21). **It is extremely important to not try to push the rod down to the spine to see if the spine can be corrected and the rod is**

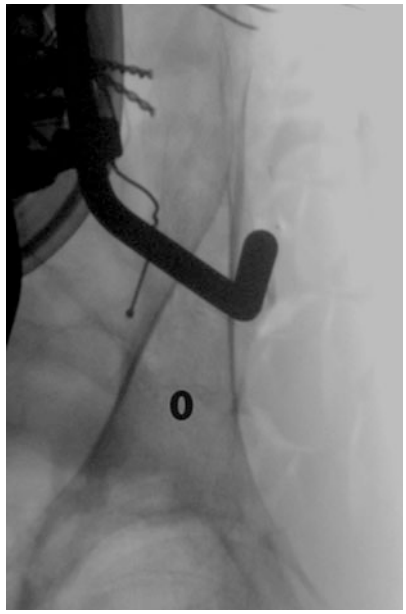

Fig. 20 If the rod leg is not in the correct position, it must be repositioned

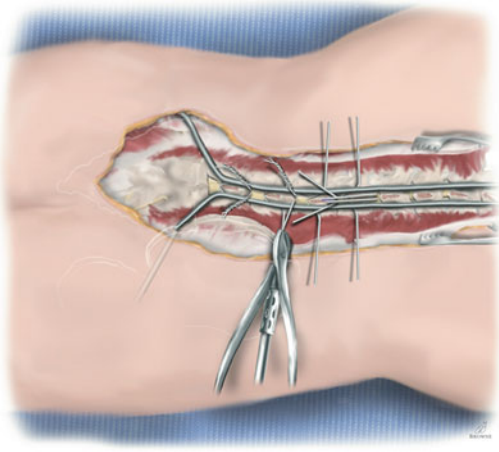

Fig. 21 The rod is pushed to L5 using a rod pusher, and the wires are twisted and tightened. It is extremely important to **NOT** try to push the rod down to the spine to see if the spine can be corrected and the rod is the right length at this time

the right length at this time. This maneuver may cause the pelvis to fracture and the rod to lose its distal fixation.

35. The rod is pushed using a rod pusher to each sequential vertebral level, and the wire is tightened to the rod sequentially (Fig. 22). **Do not use the wires to pull the rod to the bone**.
36. The cut wires that protrude laterally (Fig. 23A) are now bent to the midline (Fig. 23B), and additional bone graft is added with bank bone until the rod is covered almost completely (Fig. 23C). The dry bank bone may be mixed with liquid undiluted Gentamycin using 10 mg per KG of body weight. This has been shown to reduce infection risk (Borkhuu et al. 2008). An alternative is to add vancomycin powder to the wound. By digital palpation of the rod, make sure there are no laterally protruding wires. A single wire may easily be missed if there is substantial bleeding before wound closure.
37. Closure of the spinal fascia requires suturing so that the closure is watertight and no leaking or bleeding can occur from the deep hematoma. This leaking leads to a high likelihood of developing a subcutaneous hematoma, which causes wound leakage, and then developing an infection from the outside in.
38. The subcutaneous tissue is closed to obliterate all dead space. No wound drains are needed.
39. The skin is subsequently closed, and an occlusive dressing should be carefully applied to prevent wound contamination with stool as many of the children are incontinent of stool (Fig. 24).
40. After dressing is applied, the child is turned into the supine position, and there is careful palpation of the abdomen, especially in the super pubic region and just to the medial side of the ilium. The anterior tip of the rod can be palpated if it has inadvertently cut a new track and is in the lower abdomen and has not stayed in the drilled holes.
41. An anteroposterior pelvic radiograph is obtained, and if there is any question about the position of the rod, additional 30–40° right and left oblique radiographs of the pelvis are obtained to document that the rod is within the pelvis.
42. A chest radiograph is obtained to document that there is no pneumothorax and also

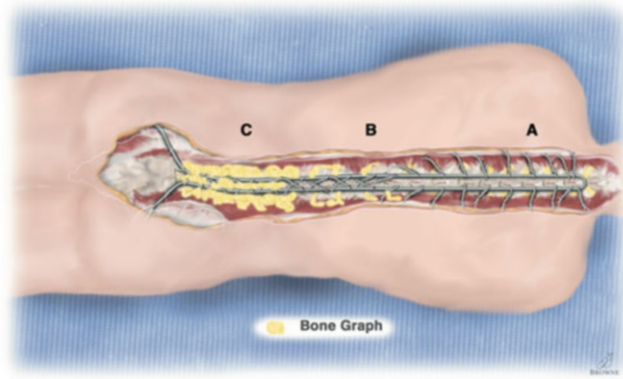

Fig. 22 The rod is pushed using a rod pusher to each sequential vertebral level, and the wire is tightened to the rod sequentially. Do not use the wires to pull the rod to the bone

to document the position of the rod postoperatively.

43. If the radiographs demonstrate adequate position, the child then is transferred to the intensive care unit. It is very important to continue with diligent, continuous monitoring throughout the whole postoperative period, especially the period of transfer to the intensive care unit. When the child is sitting well, full-length postoperative radiographs are obtained. Figure 25 is the single unit rod and, Fig. 26 is the modular unit rod.

Postoperative Care

The child is kept in the intensive care unit and mobilized as tolerated. Oral feeding is initiated as soon as the bowels are functioning, but there should not be prolonged period of fasting. If the child does not tolerate intestinal feeds by the fifth postoperative day, central venous hyperalimentation should be started. No postoperative orthotic immobilization is required, and no special handling is necessary. Wheelchairs must be adjusted before the child uses them postoperatively because the significant change in body shape will cause high skin pressure areas with a risk of skin breakdown, which can then lead to deep infection.

Special Consideration for Correction of Kyphosis and Lordosis

Some children with CP develop almost pure thoracic kyphosis or only severe lordosis. The indications for correction of these deformities are not well defined. If the deformity causes pain or difficulty sitting that impacts quality of life, surgical correction is indicated. The same instrumentation with cantilever correction can also be used for these deformities with some modifications.

1. Kyphosis – When kyphosis is isolated to the thoracic or thoracolumbar spine and there is no pelvic obliquity or lumbar scoliosis deformity, the instrumentation level does not need to extend into the pelvis. In this case, the cantilever correction should proceed from proximal to distal with the distal fixation ending in lumbar pedicle screws usually to L4 or L5 (Fig. 27), with the lumbar fixation using extended tab pedicle screws (Fig. 28).
2. Lordosis – Primary lordosis is the most difficult deformity to correct, and it is a clear contraindication for the use of the single unit rod as it is not possible to insert the rod because of the pelvic tilt (Fig. 29). This deformity also makes passing wires very difficult. A common cause of severe lordosis is following dorsal rhizotomy in which there is also poor or no posterior

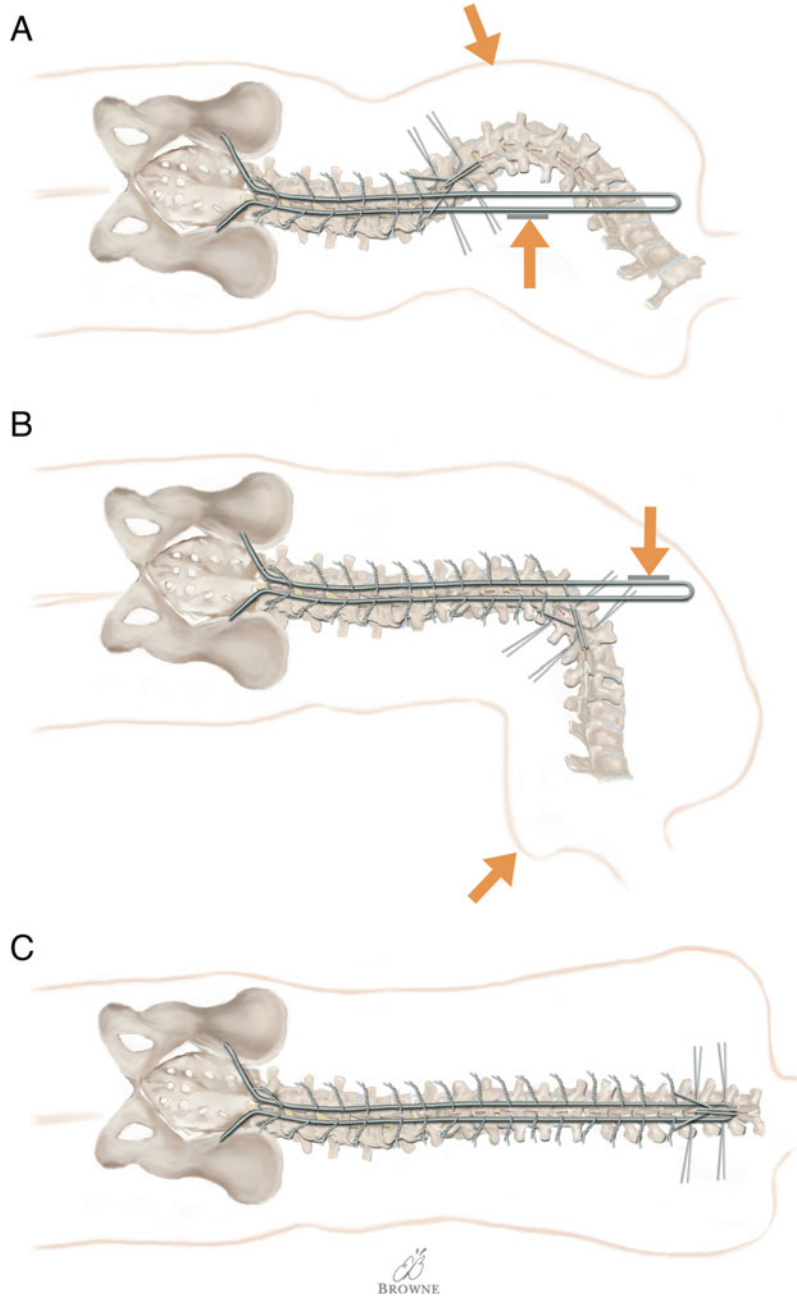

Fig. 23 The cut wires that protrude laterally (Fig. 23A) are now bent to the midline (Fig. 23B), and additional bone graft is added with bank bone until the rod is covered almost completely (Fig. 23C)

lamina for fixation. For these multiple reasons, pedicle screws are almost always the better option in the face of severe lordosis. Strong well-seated screws are required because pull-out during correction is a common problem (Fig. 30). Very generous anterior release with wedge resections of the disks is also indicated for severe deformity especially following dorsal rhizotomy as a large posterior correction will cause significant nerve root traction and prolonged sciatic or neuropathic leg pain. The correction of the lordosis will make a major

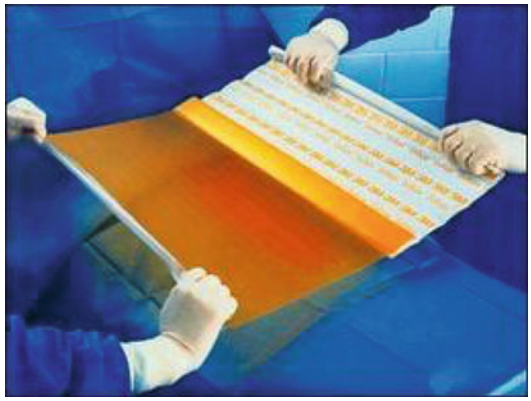

Fig. 24 The skin is subsequently closed, and an occlusive dressing should be carefully applied to prevent wound contamination with stool as many of the children are incon tinent of stool

change in the appearance of the child's sitting posture (Fig. 31). This usually requires lumbar pedicle screws (Fig. 31c).

Anterior Spinal Release

Indication

Anterior spinal release is indicated for spinal curves that are excessively large, usually greater than 100°, and for release of severe lumbar lordosis or kyphosis. Very stiff curves of more than 50°, as defined by children who cannot side bend to bring the spinous processes to the midline, also require anterior release. With the use of the unit rod, anterior release is not required because of a concern about crankshaft deformity with growth. No anterior instrumentation is used, as this procedure always is done in combination with a posterior spinal fusion using a singular or modular unit rod. Both the anterior and posterior procedures may be done on the same day if the child is very healthy and the surgeon feels comfortable with this much surgery in 1 day. Our experience suggests that it is safer in very compromised children to separate the procedures by 1 week. Typically the anterior procedure is done first, and then 1 week later, the posterior procedure is performed. However, if there is an experienced team of surgeons doing both anterior and posterior procedures on the same day, it is also a reasonable option.

Fig. 25 The postoperative radiograph of a the Single Unit rod

Fig. 26 The postoperative radiograph of the Modular Unit rod

Procedure

1. The exposure is determined by the length of the release to be performed. A thoracic

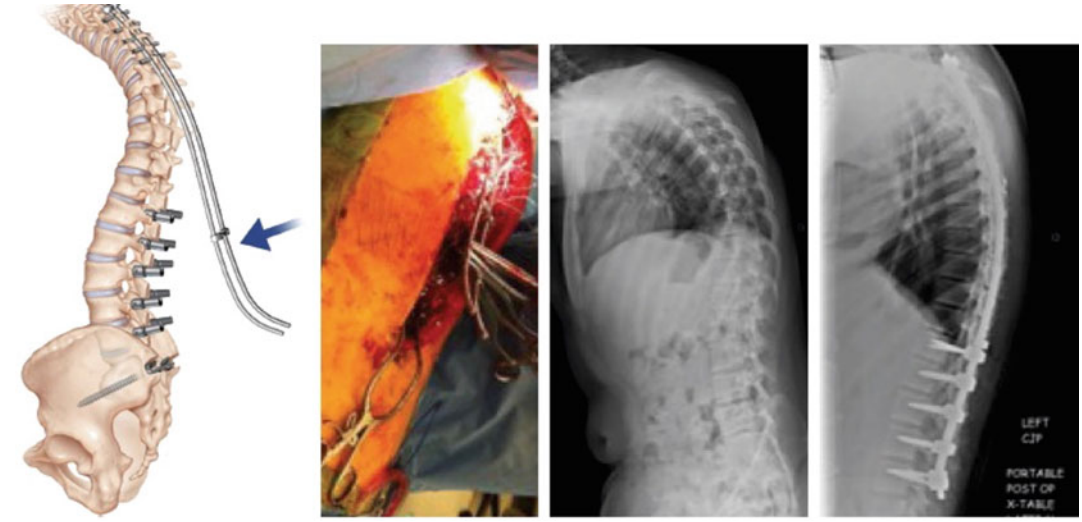

Fig. 27 When the deformity is primary thoracic kyphosis, the cantilever correction should proceed from proximal to distal with the distal fixation ending in lumbar pedicle screws usually to L4 or L5

Fig. 28 The lumbar fixation is provided using extended tab pedicle screws

exposure is adequate for a release that will extend from the T10–T11 disk space up to the T3–T4 disks. A lumbar exposure is adequate for release from L1–T12 disks to the L4–L5 disks. Thoracolumbar exposures are required for releases crossing the T11–T12 disks. The side of the exposure is always toward the apex of the scoliosis, or if there is no scoliosis, left-side exposure is easier to avoid the vena cava.

2. If thoracic exposure is sufficient, then the exposure should be made through the ribs, which are two ribs cranial to the apex of the curve.
3. Thoracolumbar exposure is made through the 10th rib bed (Fig. 32).
4. A lumbar exposure typically is made through the bed of the 12th rib.
5. After the level is chosen, an incision is made along the rib and carried anteriorly to the border of the rectus abdominis muscle and then longitudinally along the rectus abdominis muscle to the level.
6. The ribs are exposed and subperiosteally dissected free (Fig. 33). The anterior osteocartilaginous junction is separated, and the rib is subperiosteally dissected leaving it attached posteriorly and then stripped as far posteriorly as possible and transected. The thoracic cavity is entered by opening the periosteum and pleura in the middle of the rib bed and extending it anteriorly. The incision is extended posteriorly to the area of the resection of the rib.

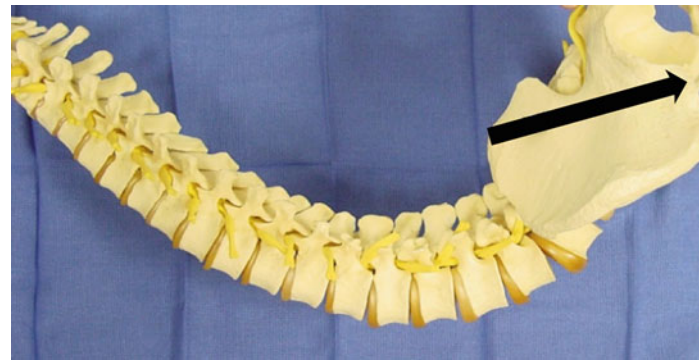

Fig. 29 Primary lordosis is the most difficult deformity to correct, and it is a clear contraindication for the use of the single unit rod as it is not possible to insert the rod because of the pelvic tilt

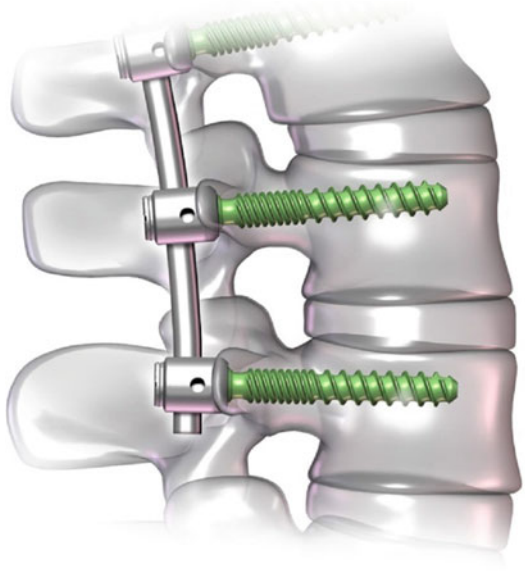

Fig. 30 For these multiple reasons, pedicle screws are almost always the better option in the face of severe lordosis. Strong well-seated screws are required because pullout during correction is a common problem

7. If this is a thoracolumbar exposure, the chondral cartilage then is sharply transected longitudinally to where it ends, and it is gently opened using a blunt instrument for dissection at its caudal end. This, then, will enter the abdominal cavity, and the peritoneum should be dissected off the undersurface of the abdominal muscles. At the distal end of the 10th rib, the anterior insertion of the diaphragm is encountered beneath the split cartilage.
8. The anterior dissection then is carried down through the abdominal muscles in line with the incision to the lateral border of the abdominis rectus and can be carried along parallel to the rectus as far caudally as is needed.
9. The peritoneum then is dissected by blunt dissection off of the lateral and posterior abdominal cavity to enter the retroperitoneal space.
10. The retroperitoneal space is entered posterior to the kidneys and spleen on the left and posterior to the liver on the right side. At this time the anterior aspect of the spine can be palpated.
11. The retroperitoneal fat then is incised over the vertebrae, and using a blunt dissection, all the anterior longitudinal ligaments of the vertebrae are cleanly exposed. Segmental vessels are identified, hemoclips are applied, and the vessels are transected.
12. In the thoracic cavity, the pleura is incised over the spine, and the retropleural space is opened with gentle dissection over the anterior longitudinal ligament. Segmental vessels are identified, hemoclips are applied, and the vessels are transected (Fig. 34).
13. If a thoracolumbar exposure is required, the anterior origin of the diaphragm is identified under the split anterior cartilage of the 10th rib and incised at the border between the lateral third and medial two-thirds. Marker sutures are placed on each side of the diaphragmatic incision every 2 cm and cut in such a way that they can be identified as

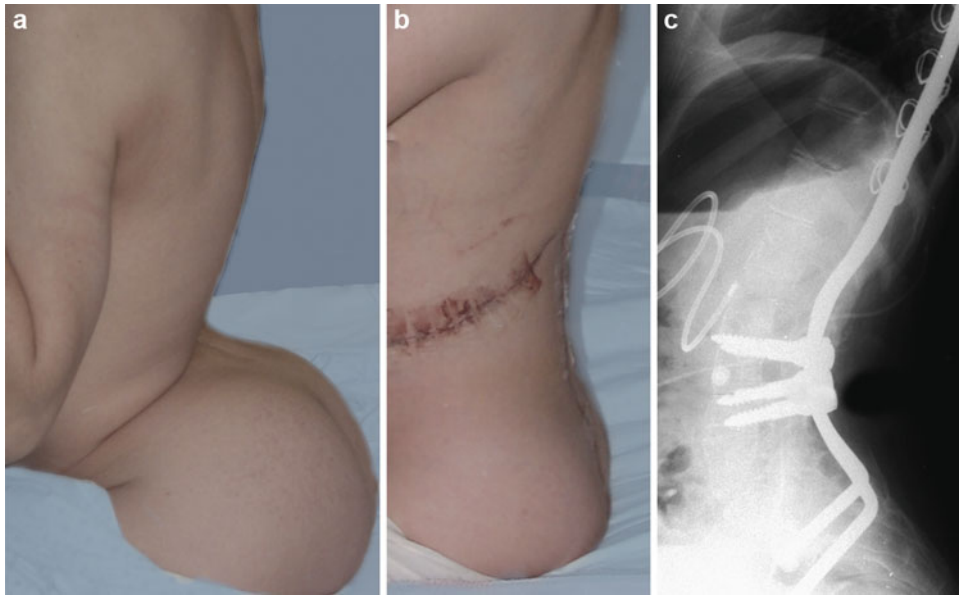

Fig. 31 The correction of the lordosis will make a major change in the appearance of the child's sitting posture (Fig. 31a-b). This usually requires lumbar pedicle screws (Fig. 31c)

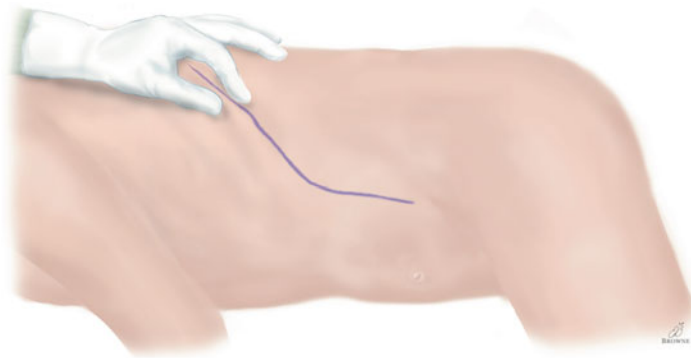

Fig. 32 Thoracolumbar exposure is made through the 10th rib bed

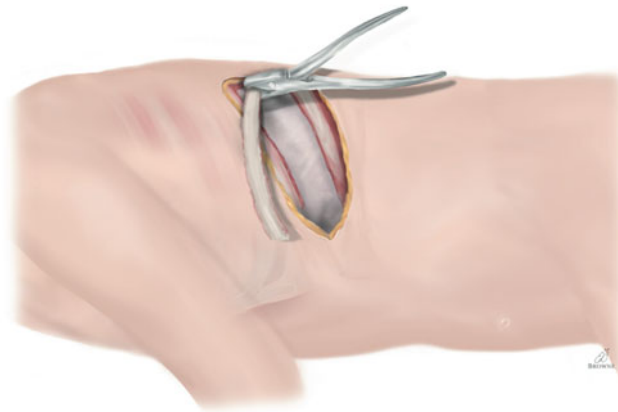

Fig. 33 The ribs are exposed and subperiosteally dissected free

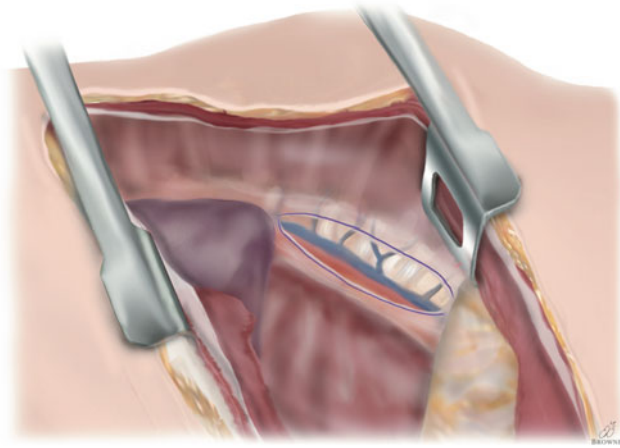

Fig. 34 In the thoracic cavity, the pleura is incised over the spine, and the retropleural space is opened with gentle dissection over the anterior longitudinal ligament. Segmental vessels are identified, hemoclips are applied, and the vessels are transected

markers for repair. Usually a pair of sutures is cut short and the next pair is cut long. The diaphragm is cut through its whole circumference, aiming to the middle of the spine so that the separation between the medial and lateral cruz of the diaphragm will be opened (Fig. 35).

14. The spine now can be exposed with the anterior longitudinal ligament for the intended length. Utilizing Cobb elevators, the iliopsoas muscle can be elevated off the insertion on the bone, although care should be taken not to do subperiosteal dissection, which increases the bleeding.
15. Segmental vessels are ligated or clipped at each level.
16. The disk spaces are identified as the large, thicker areas on the spine and are incised anteriorly using a sharp knife (Fig. 36).
17. All the disk material is eliminated with removal of a large wedge of all the end plate and some of the bone on the convex side of the scoliosis (Fig. 37B). Alternatively, if this is a severe lordosis, the anterior-based wedge is resected to allow the spine to close anteriorly. The posterior longitudinal ligament is left intact. For kyphotic deformities, there occasionally is a very thin disk in the front, sometimes even with a bony fusion, so bone burrs or rongeurs are necessary to make an osteotomy of the bone. In the thoracic spine, removal of the rib heads at two or more levels at the apex of the curve helps to provide flexibility.
18. The disk spaces are packed with Gelfoam material for hemostasis, and very thin pieces of the bone are applied at the borders. No attempt is made to pack the disk spaces with bone graft (Fig. 37C).
19. The wound is closed starting by using a running suture to close the posterior pleura over the spine. A suture is utilized, and the posterior aspect of the diaphragm is closed with

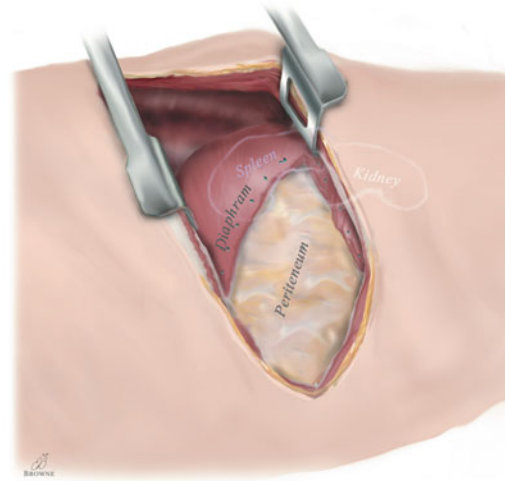

Fig. 35 The diaphragm is cut through its whole circumference, aiming to the middle of the spine so that the separation between the medial and lateral cruz of the diaphragm will be opened

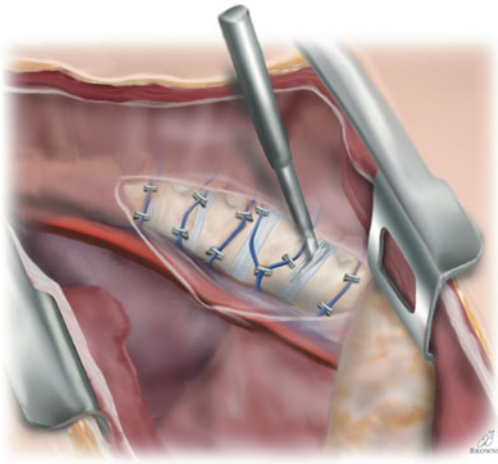

Fig. 36 The disk spaces are identified as the large, thicker areas on the spine and are incised anteriorly using a sharp knife

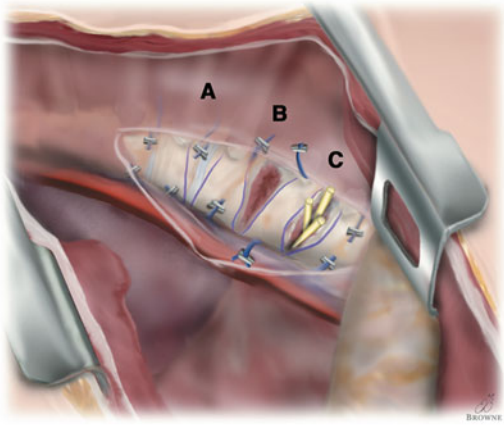

Fig. 37 All the disk material is eliminated with removal of a large wedge of all the end plate (Fig 37A) and some of the bone on the convex side of the scoliosis (Fig. 37B). The disk spaces are packed with Gelfoam material for hemostasis, and very thin pieces of the bone are applied at the borders. No attempt is made to pack the disk spaces with bone graft (Fig. 37C)

a running suture to close the incision in the diaphragm to its anterior aspect.

20. Sutures are placed around the superior and inferior ribs and used to approximate the thoracotomy wound. Muscle, subcutaneous, and skin closure follows. A chest tube is inserted into the thoracotomy wound before closure. Then, the patient is turned into the supine position for the posterior fusion.

Postoperative Care

The chest tube is left in place for 2 or 3 days until the chest tube drainage is less than 50 ml per 8 h. There is no special attention except as one manages the posterior fusion, which is the major aspect of this procedure.

Cross-References

- ▶ Anesthetic Management of Spine Fusion
- ▶ Surgical Management of Kyphosis and Hyperlordosis in Children with Cerebral Palsy
- ▶ Surgical Treatment of Scoliosis Due to Cerebral Palsy

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