Review Article

Strategies for Surgical Management of Large, Stiff Spinal Deformities in Children

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Abstract

Management of large, severe, stiff spinal deformities in children can be challenging. Adjunctive treatments used in conjunction with spinal osteotomy, instrumentation, and fusion can improve the ultimate degree of deformity correction. These adjunctive treatments include preoperative halo-gravity traction, intraoperative halo-femoral traction, temporary internal spinal distraction, and anterior spinal release. Each of these techniques has unique indications and individual risks. When the appropriate protocols are followed, these techniques can be safe and efficacious.

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Management of large, severe stiff spinal deformities can be difficult, with a high risk of complications. Several strategies may improve the surgeon's ability to correct deformities and may decrease the risk of complications. These techniques include preoperative halo-gravity traction (HGT), intraoperative halo-femoral traction (HFT), temporary internal distraction (TID), and two-stage spinal procedures that involve an initial anterior spinal release followed by posterior spinal fusion. Each technique should improve flexibility, allow a more gradual reduction of the deformity to safely maintain the integrity of the spinal cord, and improve the final correction. These techniques can be used alone or in combination, depending on the needs of the patient.

Halo-gravity Traction

HGT involves the application of a cranial halo device to which gradual traction can be applied. The device acts as a countermeasure to gravity and allows gradual stretching of stiff spinal deformities. Gradual increases in traction weight are applied while the patient is awake; thus, the patient can be continually monitored for signs of neurologic compromise.

Patients with large, severe, stiff, or unusual spine curves may benefit from HGT. Successful HGT requires motion segments and is thus unlikely to work in the setting of a previous fusion. In our experience, HGT is most effective in achieving correction of upper thoracic curves, particularly kyphotic curves, and is less successful in correcting lumbar curves. HGT has been used before placement of growing rod instrumentation to achieve some preliminary correction of the spine, thereby decreasing the amount of deformity correction required. HGT also has been used before definitive fusion in the setting of adolescent idiopathic scoliosis with severe curvature. Commonly reported indications for HGT include curves >70° to 80°, those associated with marked hyperkyphosis, and those with <20%

correction on bending or manual traction radiographs.[1,2] Contraindications for HGT include patient age <18 months (increased risk of pin penetration in the infantile skull); curves with short, sharp, rigid, or congenital kyphosis; and cervical spine instability (increased risk of neurologic compromise).[1]

Numerous protocols for placing HGT and increasing the amount of traction have been described (Table 1). Sink et al[3] treated 19 children with scoliosis of varying etiologies using HGT, with 5 to 10 lb (2.3 to 4.5 kg) of traction applied initially and increasing the weight as tolerated until 25% to 50% of body weight was reached. Frequent neurologic examinations were performed. Traction was continuous and transferrable between a wheelchair, walker, and the bed and was maintained for 6 to 21 weeks until definitive posterior fusion was achieved. In a retrospective review, Rinella et al[4] used a protocol with a starting weight of 3 to 5 lb (2.3 kg) that was increased by 2 to 3 lb (0.9 to 1.4 kg) daily until reaching 33% to 50% of body weight. Traction was maintained for a minimum of 12 hours daily and was reduced by 50% to 75% at night to avoid proximal migration during sleep. Neurologic checks were done every 8 hours, and thorough cranial nerve checks were done daily. Park et al[8] reported on 20 pediatric patients with spinal deformity treated using HGT with up to 46% of body weight applied for a minimum of 3 weeks. The authors noted coronal and sagittal curve corrections of 66% and 63%, respectively, after traction. Watanabe et al[9] reported on 21 patients with scoliosis who had curves ≥100° that were treated with HGT for an average of 67 days (range, 10 to 78 days). A 51% correction of the major Cobb angle was achieved. Garabekyan et al[5] used a protocol similar to that used by Watanabe et al,[9] except nighttime traction was reduced by only 5 to 10 lb (2.3 to 4.5 kg), and the bed was placed into reverse Trendelenburg position to prevent proximal migration during sleep. In a study of 29 patients with severe spinal deformities treated with HGT, a starting weight of 20% body weight was used, with increases of 10% body weight performed weekly until reaching 50% body weight.[2] If any intolerance of the weight increase delayed this pattern, the increase was made up during the fourth week so that 50% body weight was still achieved. Traction was removed during meals and hygiene but full weight was maintained while the patient was asleep.

Reported outcomes for each of these protocols have shown some improvement in the Cobb angle before definitive surgical fusion. Sink et al[3] reported an average Cobb angle of 83° pretraction and 55° posttraction for an overall improvement of 35%. Rinella et al[4] reported similar improvements in Cobb angles (approximately 43%) after HGT. Garabekyan et al[5] noted a similar range of improvements in coronal Cobb angles and found statistically notable improvements in sagittal balance and forced vital capacity, and increases in trunk height. Nemani et al[2] noted similar improvements in Cobb angles and found that these improvements seemed to plateau after an average of 63 days in traction. The authors used the Scoliosis Research Society-22 patient questionnaire and noted improved scores in the self-image and mental health domains posttraction compared with pretraction, but these improvements did not reach statistical significance.[2] Sponseller et al[17] compared two groups of patients with large, stiff curves (ie, Cobb angles >90°, flexibility <25%) who were treated with or without HGT. The authors collected data on 30 patients treated with HGT and a control group of 23 patients. The HGT group had more complications than did the control group, but the difference was not significant. They also found no statistical difference in surgical time, blood loss, and ultimate postoperative correction of deformity as measured by final Cobb angles at 2-year follow-up. The HGT group did have a lower incidence of required vertebral column resection, which approached significance ($P = 0.015$).

It should be noted that a full comparison of these protocols and their outcomes is difficult, even within individual studies, because of the heterogeneity of the patients. Diagnoses include neuromuscular and idiopathic scoliosis. Patients may or may not have had previous anterior or posterior spinal procedures before traction was applied. However, this heterogeneity likely implies that HGT can be generalized to many patients with large, stiff scoliotic curves, regardless of the underlying etiology.

Although HGT is generally thought to be safe and well-tolerated, patients must be monitored for traction-related complications. Reported complications include neck pain, pin-site infection, pin loosening, nerve palsies, damage to preexisting implants, skull penetration, epidural abscess, brachial plexus palsy, superior mesenteric artery syndrome, and osteonecrosis of the odontoid.[1,16] Most of these complications are rare, with only individual case reports describing their occurrence.

Nerve palsies can be the result of direct trauma from pin placement or the amount of traction applied. Medial frontal bone pin placement risks injury to the supraorbital or supratrochlear nerves. The most common neurologic injury associated

Table 1

Summary of Protocols and Outcomes for Preoperative and Intraoperative Traction Used to Treat Large, Stiff Spinal Deformities

Study	Traction	Number of Pins	Weight: Initial, per day, maximum % body weight	Duration	ASR	Postoperative Correction
D'Astous and Sanders[1]	Preoperative HGT	6 to 8	3–5 lb (1.4–2.3 kg), 1–2 lb (0.5–0.9 kg), 30%–50%	Not specified	Not specified	Not specified
Nemani et al[2]	Preoperative HGT	6 to 8	20% of body weight, 10% per wk, 50%	8–25 wk	Not specified	56%
Sink et al[3]	Preoperative HGT	Variable	5–10 lb (2.3–4.5 kg), "as tolerated," 25%–50%	6–28 wk	Some	39%
Rinella et al[4]	Preoperative HGT	6 to 8	3–5 lb (1.4–2.3 kg), 2–3 lb (0.9–1.4 kg), 33%–50%	2–12 wk	Some	46%
Garabekyan et al[5]	Preoperative HGT	6 to 8	3–5 lb (1.4–2.3 kg), 2 lb (0.9 kg), 50%	3–8 wk	Some	43%
Ginsburg and Bassett[6]	Preoperative HGT	6	6 lb (2.7 kg), 6 lb (2.7 kg), 39%	2 wk	All	53%
Blakeney and D'Amato[7]	Preoperative HGT	Not specified	5 lb (2.3 kg), 1 lb (0.5 kg), 45%	6 wk	No	Not specified
Park et al[8]	Preoperative HGT	4 to 8	3–5 lb (1.4–2.3 kg), 2–3 lb (0.9–1.4 kg), 30%–46%	3–10 wk	Some	46%
Watanabe et al[9]	Preoperative HGT	6 to 8	3–5 lb (1.4–2.3 kg), 2–3 lb (0.9–1.4 kg), 33%–50%	2–12 wk (2–8 wk after ASR)	Some	51%
Takeshita et al[10]	Intraoperative HFT	4	15 lb (6.8 kg) halo, 15–40 lb (6.8–18 kg) femur (intraoperative only)	N/A	Some	59%
Huang and Lenke[11]	Intraoperative HFT	4	15 lb (6.8 kg) halo, 25 lb (11 kg) femur (intraoperative only)	N/A	All	Not specified
Hamzaoglu et al[12]	Intraoperative HFT	4	6 kg (13 lb) halo, 3 kg (6.6 lb) femur (intraoperative only)	N/A	No	51%
Barsoum et al[13]	Intraoperative tongs	2	5 lb (2.3 kg, intraoperative only)	N/A	No	Not specified
Mehlman et al[14]	Preoperative HFT	Variable	5 lb (2.3 kg), not specified, 20%–113%	5–13 d	All	70%
Keeler et al[15]	Intraoperative HFT	6 to 8	15 lb (6.8 kg) halo, 15–35 lb (6.8–16 kg) femur (intraoperative only)	N/A	No	66%
Qian et al[16]	Preoperative HGT	Variable	4 lb (1.8 kg), 2–3 lb (0.9–1.4 kg), 33%–50%	2–12 wk	No	56%
Sponseller et al[17]	Preoperative HGT or HFT	6 to 8	5–15 lb (2.3–6.8 kg), 2–3 lb (0.9–1.4 kg), 33%–50%	2–12 wk	Some	62%

ASR = anterior spinal release, HFT = halo-femoral traction, HGT = halo-gravity traction, N/A = not applicable

with traction is cranial nerve VI palsy, which is manifested by loss of lateral gaze and diplopia.[18] Other common cranial nerve palsies resulting from traction include nerves IX, X, and XII, which are thought to be the most vulnerable to traction because of their oblique course within the cranium, placing them at risk for compression where they exit the foramen.[19] Ginsburg and Bassett[6] reported on a patient who underwent a pretraction anterior release. On day 5 of traction (39% of body weight) the patient presented with a bilateral hypoglossal nerve injury. The palsy completely resolved with reduced traction. Neurologic deficits are treated by reducing the traction weight until symptoms resolve. Weight can then be gradually increased with close monitoring for a return of symptoms. No permanent neurologic deficits as a result of HGT have been reported.

The location of preexisting subcutaneous implants must be noted

Figure 1

Clinical photograph demonstrating a set-up table for halo placement, including chlorhexidine gluconate and isopropyl alcohol swabs, local anesthetic, halo pins with iodine for the tips, 4 × 4 gauze, and paper tape.

Figure 2

Clinical photograph demonstrating a patient wearing a halo with pins in place. Note that two pins are placed on each side anteriorly and two are placed on each side posteriorly to create an eight-pin construct.

when planning pin placement for HGT. Blakeney and D'Amato[7] reported on a patient with neuromuscular scoliosis and a ventriculoperitoneal shunt placement who underwent a posterior release followed by HGT, which was gradually increased to 45% of body weight. After 6 weeks of traction, a surveillance radiograph demonstrated fracture of the ventriculoperitoneal shunt, which required surgical repair. During the repair procedure, it was noted that the fracture was likely a result of traction.

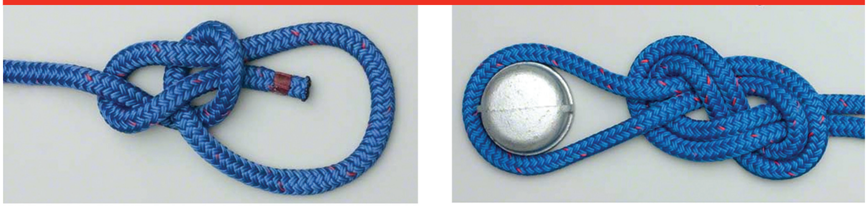
The most common complications associated with HGT are pin-site infection and pin loosening.[2-5,8,9] Typically, pin-site infection is successfully treated with oral antibiotics. Loose pins can either be retightened or exchanged, depending on surgeon preference. Pin exchange does not require complete revision of the halo but may require sedation or general anesthesia.

At our institution, the preferred method for HGT includes placing the halo under anesthesia (Figure 1). The pins are placed as described by D'Astous and Sanders.[1] Anterior pins are placed 1 cm above the lateral portion of the eyebrow. Medial placement risks injury to the supraorbital and supratrochlear nerves, and lateral placement may impinge on the muscles of mastication. Posterior pins are placed 1 cm above and just posterior to the pinna. Focal hair removal is not required but may facilitate pin placement. Skin incisions are not necessary. An experienced orthopaedic technician should be present for assistance. Typically, two pins are placed on either side in the frontal bone, and one or two pins are placed posteriorly on either side, for a total of six to eight pins (Figure 2).

There should be 1 to 2 cm of space between the halo and the head. The halo is attached to a rope, which can be run over a pulley and attached to weights or an adjustable tension device, such as a simple spring scale. The orthopaedic surgeon either directly supervises or carries out knot tying at the ends of the rope to ensure their security. Tying the rope around a carabiner allows easy manipulation of the hook without having to adjust or retie knots. Because substantial amounts of weight may be used for prolonged periods, the strength of the knots is critical to avoid slipping. Our protocol encourages the use of bowline or figure-of-8 follow-through knots to ensure adequate strength for prolonged traction (Figure 3). The use of a magnetic safety mechanism that runs inline with the traction has been described and can be released in the event of a sudden increase in traction force, such as in a transportation accident.[20]

The patient is allowed to become accustomed to the halo before traction is placed. Traction is initiated with 5 lb (2.3 kg) of weight beginning on the day following halo placement, with increases of 2 lb (0.9 kg) daily. The goal is to achieve a traction of 50% body weight and to maintain traction for approximately 2 weeks. We recommend maintaining a log of when and how much weight is added, the patient's tolerance of the

Figure 3



A **B**

Photographs of the bowline (**A**) and figure-of-8 follow through (**B**) knots, which are known to be the strongest looped knots. (Copyright Alan Grogono. http://www.animatedknots.com.)

Figure 4

Clinical photograph of a patient in halo-gravity traction, which has been set up in a wheelchair for mobility.

additional weight, and neurologic examination findings. Neurologic checks, including checks of the cranial nerves, are also repeated every 8 hours by trained nursing staff.

Traction is maintained as much as possible, although nurses are permitted to remove traction as needed for toileting, movement, or patient intolerance. Customized wheelchairs and walkers are used to maintain traction during daily activities (Figures 4 and 5). When the patient is supine, the head of the bed is elevated to 45° to prevent the patient from being pulled proximally (Figure 6). Traction is intended to be used at night but may be removed for comfort, if needed. No well-defined protocol for radiographic surveillance exists, but at a minimum, we recommend obtaining PA and lateral radiographs of the spine in traction after the maximum weight has been added and before the planned definitive spinal fusion. Traction can be continued during the definitive surgical procedure. In our experience, only approximately 15 lb (6.8 kg) is necessary to maintain the correction intraoperatively.

Preoperative Halo-femoral Traction

HFT is another option for preoperative traction. Similar to HGT, HFT is done before definitive posterior instrumentation and fusion, and a preceding anterior spinal release may or may not have been done before traction. Qiu et al[21] reported on their HFT technique, which included anterior spinal release. Two days after the anterior spinal release, HFT was initiated with a weight of 2 lb (0.9 kg), increasing 2 to 3 lb (0.9 to 1.4 kg) per day until 33% to 50% of body weight was reached. Traction was maintained for a minimum of 12 hours per day and decreased by 50% during sleep. For patients with idiopathic scoliosis, the major curve was corrected an average of 39% at the end of traction, whereas pretraction side bending radiographs showed an average correction of only 24%. Similarly, for patients with congenital scoliosis, preoperative bending radiographs showed an average correction of 22%, and post-HFT radiographs showed an average correction of 35%. Although HGT is transferrable to devices, such as wheelchairs and walkers, HFT is not transferrable and requires continuous bed rest while traction is in place. The patient's limited mobility during traction may increase the potential for complications (eg, pressure ulcers, pulmonary issues). This limitation also results in more frequent removal of traction during the day, thus limiting the duration of traction before the definitive posterior fusion. For these reasons, preoperative HGT has been more popular than preoperative HFT.

The same complications associated with HGT are associated with HFT. In addition, brachial plexus palsy has been associated with HFT. Qiu et al[21] reported on four patients in whom brachial plexus palsy developed during preoperative HFT after an anterior spinal release. All four patients had complete return of function within 2 months.

Intraoperative Halo-femoral Traction

Large spinal deformities, especially those caused by underlying neuromuscular disorders or severe lumbar scoliosis, can present the additional challenge of pelvic obliquity. Pelvic obliquity leads to inappropriate sitting posture and recalcitrant pressure sores. Improvement of pelvic obliquity is key to an optimal outcome but achieving improvement can be challenging. Intraoperative HFT can be a useful adjunct for improved correction of pelvic obliquity (Figure 7).

In a study of 40 patients with neuromuscular scoliosis who underwent posterior final fusion with extension of fixation to the pelvis, 20 patients had intraoperative HFT,[10] which was set up after the induction of anesthesia. Each halo was held with four pins tightened with 6 to 8 lb (2.7 to 3.6 kg) of torque. A heavy Kirschner wire was placed through the distal femur on the side with the elevated hemipelvis. After prone positioning in the standard fashion, 15 lb (6.8 kg) of traction was applied to the halo. Femoral traction was then gradually increased to an average of 25 lb (11.3 kg) until the pelvis became level. Outcomes of this study include a 78% correction of pelvic obliquity in the HFT group compared with a 52% correction in the control group (P = 0.001). Similarly, Huang and Lenke[11] presented a case of severe pelvic obliquity treated with intraoperative HFT in which good correction of the deformity was achieved.

Hamzaoglu et al[12] reported on 15 patients with thoracic scoliosis >100° treated with intraoperative HFT and posterior-only instrumentation. This review differs from earlier reviews in that HFT was not specifically used for correction of pelvic obliquity. The protocol involved obtaining a preoperative traction radiograph while the patient was under anesthesia. If the curve corrected to ≤60°, the authors proceeded with posterior-only instrumentation and fusion. The average improvement of the major thoracic curve was 51%. If the curve did not adequately correct, they proceeded with wide facet resection and posterior release.

The aforementioned studies of intraoperative HFT report no traction-related complications. Because the traction is short-term, complications associated with preoperative traction, such as pin-site infection or loosening, should be less common. Barsoum et al[13] reported on an adult patient treated with 5 lb (2.3 kg) of traction applied via Gardner-Wells tongs who experienced a postoperative cranial nerve VI palsy. At 6-month follow-up, this neurologic deficit had completely resolved.

Figure 5

Clinical photograph of a patient in halo-gravity traction that has been set up in a walker for mobility.

Figure 6

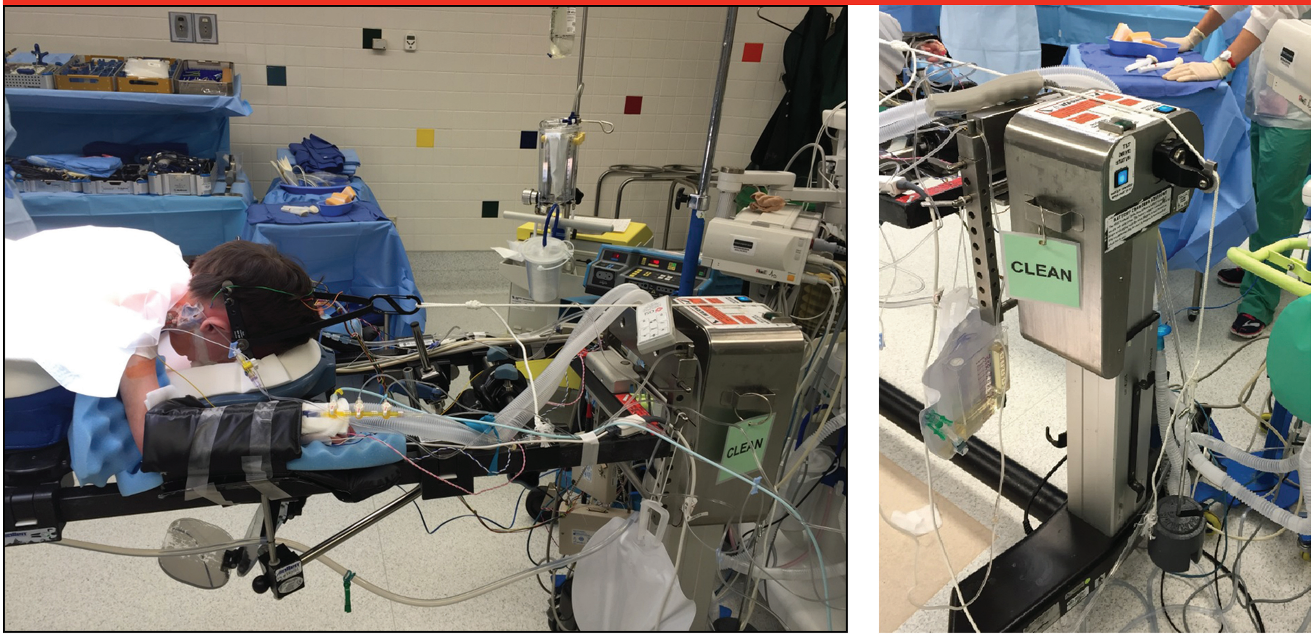
Clinical photograph of a patient lying in bed in halo-gravity traction. The head of the bed has been elevated to 45° to prevent proximal migration.

Temporary Internal Distraction of the Spine

TID involves placing fixation points at the top and bottom of stiff curves and using spinal instrumentation to distract the spine, similar to the techniques used for growing rod constructs. Because of the prolonged hospital stay and potential complications associated with HGT and HFT, these options may not be acceptable for all patients. TID may be an option when external traction is contraindicated. TID can also be used as part of a single-stage procedure as an adjunct to other corrective measures.

In a study of 10 patients with large, stiff curves in whom HGT was contraindicated, 6 patients had an initial anterior release, and 4 did not.[22] Temporary posterior distraction instrumentation was used in all patients who then returned to the operating room at an average of 2.4 weeks for definitive fusion. Six patients had more than one distraction procedure during the treatment. Buchowski et al[22] reported that the average curve correction was 53% (range, 39% to 79%), which was better than their pretraction bending radiograph correction. This also compared favorably with the reported outcomes of HGT and HFT. No neurologic or infectious complications

Figure 7



A **B**

A and **B,** Clinical photographs demonstrating an intraoperative halo traction construct.

were noted. In a study of 11 patients with severe and rigid scoliosis treated with TID, Hu et al[23] reported a 53% improvement in the major Cobb angle, and the forced expiratory volume in 1 second improved from 61.4% to 71.3%. The authors also noted no neurologic or infectious complications.

Our technique for TID is similar to the technique described by Buchowski et al.[22] Standard prone positioning is used, as for any posterior spinal procedure. Neuromonitoring is always used and is an especially important measure during the distraction procedure. A midline skin incision is made and subperiosteal dissection is done to expose the desired anchor points. Infralaminar or subpedicle hooks are placed for cephalad fixation. It is important not to place these hooks at the desired levels for final fusion because some plowing through the bone can occur. The ribs may also be used for cephalad anchor points. Caudal anchor points are commonly downgoing laminar hooks, lumbar pedicle screws at two adjacent levels, or fixation to the pelvis. These anchor points frequently loosen during the distraction; thus, they should not be used as final anchor points during fusion. If iliac screws are used, they should be placed so that new screws can be positioned just distal to them during the definitive procedure. Several rod constructs can be used. The simplest construct is composed of one rod for the cephalad anchors and one for the caudal anchors (Figure 8). These rods can be connected via a side-to-side connector. Once the rods are in place and distraction is applied, wide posterior releases are done at each rigid level of deformity. Sequential increases in distraction are then done to take advantage of the viscoelastic properties of the spine and to obtain maximal distraction. The wound is closed per surgeon preference, and patients are mobilized postoperatively without bracing or casting. Typically, at least 1 week of TID is allowed before definitive fusion is performed. A longer period of distraction can be done but is not likely to impart better correction. At the time of definitive fusion, the temporary implant is removed, and final instrumentation is placed.

TID can also be used in a single-stage fashion. The distraction construct is placed as early as possible during the procedure to obtain distraction while other parts of the procedure are completed. The construct can then be sequentially lengthened until final instrumentation is placed. The TID construct is then removed before closure, eliminating the need for a second procedure.

Hu et al[23] described a different technique for TID using minimally invasive incisions only at the levels required for the anchor points. The authors did not perform subperiosteal dissection. They placed two pedicle screws at the cephalad and caudal levels of the major Cobb angle and placed a rod in each set of screws, connected by a side-to-side crosslink. They recommended the use of an orthosis after surgery and allowed up to 15 weeks of distraction before performing definitive fusion.

Anterior Spinal Release

Traditionally, an anterior spinal release with or without anterior fusion was combined with posterior surgery to achieve maximum correction of large, stiff deformities. The separate procedures could be done the same day or in a staged fashion. As mentioned earlier, many patients who had preoperative or intraoperative traction also had an initial anterior spinal release. In these situations, anterior release is meant to improve the flexibility of the spine, increase the efficacy of the traction, improve the final correction achieved, and create greater surface area for healing bone to fuse.

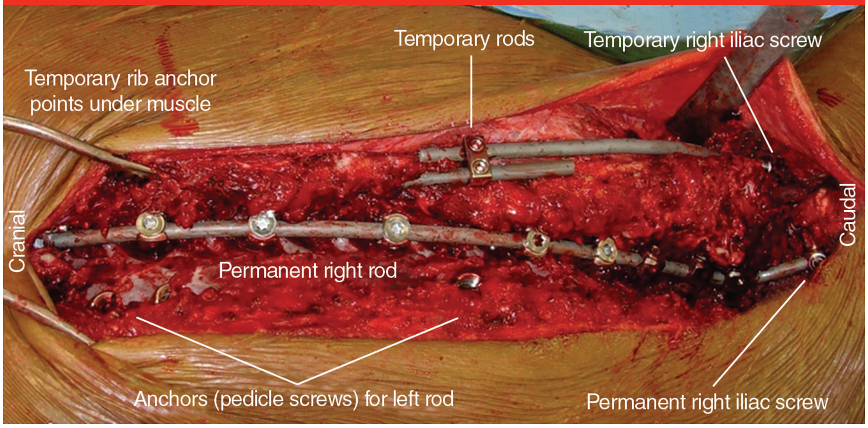
In a review of 24 patients treated with an anterior spinal release (with or without a concomitant posterior release) and application of 5 lb (2.3 kg) of HFT before definitive posterior fusion, Mehlman et al[14] reported that the final traction radiographs demonstrated an average 59% correction. This was a statistically significant improvement compared with the best preoperative bending radiographs. Final postoperative correction was an average of 70%.

Several studies have questioned the efficacy of adding an anterior spinal release to deformity correction protocols. Keeler et al[15] compared two groups of patients with nonambulatory neuromuscular scoliosis. One group underwent anterior and posterior surgery, and the other underwent posterior-only surgery for correction of the deformities. Both groups had intraoperative HFT. The group treated with posterior-only surgery had significantly shorter surgical time, less blood loss, a decreased need for postoperative intubations, and few postoperative pulmonary complications than did the group treated with anterior and posterior surgery. The authors found no difference between the two groups with regard to final Cobb angles, percentage of corrections, or sagittal balance. Zhang et al[24] reported on 29 patients with idiopathic scoliotic curves >100°; 12 patients had an anterior spinal release followed by 2 weeks of HFT and posterior fusion, and 17 had posterior-only surgery with intraoperative HFT and a wide posterior release. The authors found no significant difference in final curve correction between the two groups. In their report on patients who underwent TID to correct severe scoliosis, Buchowski et al[22] noted that there was no difference in curve correction between those patients who had an initial anterior spinal release and those who did not.

Anterior spinal release can be performed as an open or a video-assisted procedure. Typically, the apex and adjacent vertebra of the major curve are exposed from the convex side. Anterior structures, including the anterior longitudinal ligament, intervertebral disks, and vertebral end plates, are excised. Mehlman et al[14] recommended achieving an approximately 250° arc of release extending from the near-side rib head to the far-side posterolateral body. Autogenous or allograft bone graft can then be placed within the disk spaces to obtain fusion.

Complications related to anterior spinal release typically are related to the increased surgical time and blood loss associated with the procedure. Keeler et al[15] found that pneumonia, prolonged postoperative intubation, coagulopathy, and hypotension requiring vasopressors were more commonly associated with anterior spinal releases than with posterior-only fusion. The authors also reported that one case of superior mesenteric artery syndrome occurred in the anterior release group.

Figure 8



Intraoperative view of a temporary internal distraction construct. The two temporary distraction rods were connected side-to-side on the patient's left side. The permanent rod was then placed on the patient's right side. (Reproduced with permission from Buchowski JM, Skaggs DL, Sponseller PD: Temporary internal distraction as an aid to correction of severe scoliosis: Surgical technique. *J Bone Joint Surg Am* 2007;89 [suppl 2 pt 2]:297-309.)

Summary

Large, stiff spinal deformities in children present many treatment challenges. Preoperative HGT is a safe and efficacious method for improving deformity correction that has largely replaced HFT because it is associated with less morbidity and allows patient mobilization in a wheelchair or walker without removal of traction. Protocols for HGT and HFT should include proper cranial halo placement, appropriate knot tying, setups for traction wheelchairs and walkers to allow mobility, incremental increases in traction weight, frequent neurologic examinations, and radiographic imaging to assess goals before the definitive procedure. Intraoperative HFT can help reduce pelvic obliquity and help obtain correction of spinal curvatures. TID is an option when external traction is not feasible. Although this method does not allow for an incremental increase in traction force without a return to the operating room, it does not require a prolonged hospital stay and may prevent some of the complications related to the use of external traction devices. Surgical release of anterior spinal structures may increase the flexibility of the spine before initiating traction, but several studies have questioned the efficacy of anterior spinal release for management of large, stiff spinal deformities. When the appropriate protocols are followed, each of these techniques can be a useful tool to safely improve patient outcomes.

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