Partially Overlapping Limited Anterior and Posterior Instrumentation for Adult Thoracolumbar and Lumbar Scoliosis: A Description of Novel Spinal Instrumentation, “The Hybrid Technique”

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Abstract Progressive and/or painful adult spinal deformity in the thoracolumbar and lumbar spine is sometimes treated surgically by long posterior fusions from the thoracic spine down to the pelvis, especially where there is a major thoracic curve component. Recent advances in anterior spinal instrumentation and spinal surgery technique have demonstrated the improved corrective ability offered by anterior stabilization systems, and the added benefit of limiting the number of vertebral fusion levels required for control of the deformity. The “hybrid technique” is a novel use of anterior instrumentation that applies limited anterior instrumentation down to the low lumbar spine (rods and screws), and partially overlapping short-segment posterior instrumentation to the sacrum (pedicle screws and rods). These constructs avoid posterior thoracic instrumentation and fusions, and avoid extension of posterior instrumentation to the pelvis. In the first 10 patients treated using this technique, thoracolumbar and lumbar major curve correction has averaged 71 and 82% in the immediate postoperative period ($n = 7$), respectively, and 59 and 68% at 2-year follow-up, respectively. The technique is an appealing and attractive alternative for treatment of thoracolumbar and lumbar scoliosis in the adult population, and avoids the requirement for applying spinal fixation to the thoracic spine and the pelvis.

Key words thoracolumbar · lumbar · spinal deformity · surgical technique

Background

The standard of care for surgical management of adult double major thoracic and thoracolumbar spinal deformity involves posteriorly instrumented fusions with extensions to the pelvis [1–4]. Extension to the pelvis has been shown to prevent loss of fixation, sacral fracture, instrumentation failure, and loss of lumbar lordosis [5, 6]. These posteriorly instrumented fusions are either done alone, or after anterior releases for mobilization of stiff or severe deformity. Long posteriorly instrumented fusions have well-described complications such as junctional degeneration and pain associated with pelvic implants at rates ranging from 16–60% [1, 2, 4]. Junctional degeneration is thought to be secondary to either increased loads created by the long fusion, surgical trauma created during the index procedure, physiological predisposition, or a combination of these [7]. Complications associated with pelvic instrumentation are frequent enough that it should be avoided if possible.

Anteriorly instrumented spinal fusions for adolescent idiopathic thoracolumbar scoliosis management have recently been shown to provide corrective success similar to the gold standard of posteriorly instrumented fusions [8]. Prior anterior spine fusion instrumentation systems have been shown to be kyphogenic, particularly in areas of preexisting hypokyphosis, due to insufficient stiffness of the rods used and lack of routine use of anterior column structural support; however, modern anterior instrumentation used with anterior and middle column support prevents this problem. Anteriorly instrumented fusions have also been shown to achieve spinal deformity correction using shorter constructs and typically spare 1–3 motion segments when compared to standard posteriorly instrumented fusions. The overall complication rates associated with anteriorly instrumented fusions were similar to posteriorly instrumented fusions. A limiting factor of anteriorly instrumented fusions is the inability to extend

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anterior instrumentation to the sacrum, due to anatomical constraints.

In this report, we describe a novel surgical technique for treatment of adult thoracolumbar and lumbar scoliosis. Ideal placement of instrumentation for bony fixation, spinal reduction procedure, placement of anterior structural supports, and techniques for salvage options will be discussed. Illustrative case examples will be presented as well as a brief summary of operative results in the first 10 consecutive patients treated using these techniques.

Materials and methods

During the period between November 1996 and November 1999, ten adult patients being evaluated for thoracolumbar or lumbar spinal deformity from degenerative etiology or untreated adolescent idiopathic scoliosis were noted to have flexible major curves and x-rays with good bone stock, making them candidates for the “hybrid” instrumentation technique. Full risks and benefits of the technique were explained, as well as risks and benefits of the standard anterior/posterior fusion surgery with posterior instrumentation to the sacrum, the patients chose to undergo the hybrid instrumentation design. Preoperative full-length AP and lateral scoliosis films were obtained, as were identical radiographs immediately postoperatively, and at multiple postoperative visits and at annual office visits. There were nine females and one male in the group, who had an average age of 60.6 years at the time of surgery. Patients with minimum follow-up of 2 years ($n=7$) had an average follow-up duration of 5.2 years, with a range from 3.2 to 8.5 years. Two patients were immediately lost to follow-up, and one additional patient was lost prior to 2-year follow-up. Eight of the nine patients that had radiographs available for review had peroperative bending films to assess the flexibility of the deformity. Coronal and sagittal curve magnitudes were quantified using the Cobb method and were measured preoperatively and throughout the follow-up period. Coronal (T1 to center sacral line) and sagittal (T1 to posterior aspect of S1) balances were also measured preoperatively and throughout the follow-up period.

Description of technique

For anterior implant placement, exposure of the spine is obtained using a thoracoabdominal approach. A subperiosteal dissection is then completed in the region of planned instrumentation, and involved segmental vessels are identified, ligated, and sectioned. Thorough intervertebral disk excisions are performed, leaving only the posterior annulus and/or posterior longitudinal ligament.

Preoperative planning is necessary to have available the implants to be used, as well as guide the bony preparation required for their placement. Decision for use of single versus dual rod instrumentation is made on a case by case basis, and is influenced by the size of the vertebral body to receive the screws, the magnitude of the deformity present, and the body habitus of the patient. As will be described

below, slightly different vertebral body screw placements are used for 1-rod versus 2-rod constructs, and use of screw anchors (“staples”) also may have an impact on the ideal placement of screws. Closed screws are preferred in the proximal and distal most vertebrae of the reconstruction, and open screws are used in the screws central to these. Another issue to consider, at the distal extent of the anterior instrumentation, is that posterior pedicle screw implants have the potential to impinge upon the anterior vertebral body screws. Use of a slightly inferiorly placed single vertebral body screw in the distal vertebra, or vertebrae, is recommended to limit the possibility for difficulty in placement of pedicle screws in the second portion of the procedure. The anterior vertebral body screws are typically stopped at L3–L4 distally, and in our experience L4 has been the most frequent distal level.

Anterior vertebral body screws are placed with a starting point just posterior to the farthest lateral point of the vertebral body. The probe for creating the screw path is then directed parallel to the vertebral endplates and through the center of the vertebral body, with optimal exit just anterior to the most lateral point of the down-lateral aspect of the vertebral body. The screw path is then measured for depth, tapped, and the screw is placed. Screw placement is confirmed for depth by the surgeon manually palpating the tip of the screw on the down-lateral side to ensure bicortical purchase while simultaneously minimizing extrusion of the screw tip. When the decision is made to use dual-rod instrumentation, screw placement is generally performed as above, except that the anterior screw is started just anterior to the posterior screw in a convergent manner. Dual screws placed in this fashion will cross within the vertebral body and impart improved pullout strength to the construct.

Screw anchors, also referred to as screw “staples”, can help to prevent or limit screw motion at the screw-bone interface, as well as to guide two-screw placement in two-rod constructs. Their use requires minor modification of the screw placement technique described above. For one-rod constructs, the staple is placed in the midvertebral body as far posteriorly on the lateral wall of the vertebra as possible. The path of the screw is constrained by the staple base plate, but can be guided as desired by the surgeon. The screw is then placed in the standard fashion, and screw depth is confirmed by palpation. For two-rod constructs, the staple is again placed with attention to the location of the ideal starting places and screw path holes for the two screws, and is seated (Fig. 1A). Keep in mind that the first screw path will be able to be guided by the surgeon, but that the second will be largely constrained by the first screw and staple-base construct. For this reason, we recommend that the posterior screw be placed first in that there is less tolerance for nonideal screw placement and room for maneuvering for this screw.

Anterior rods are then measured, cut, and contoured to deliver physiological lumbar lordosis, and a relatively neutral contour through the thoracolumbar junction. The rod is placed within the distal closed screw and laid into the open heads of the intervening screws utilizing the

Fig. 1. Intraoperative photographs of the anterior instrumentation technique. Perspective shows operative field through a left thoracolumbar approach as viewed by the surgeon, with top being the anterior of the patient and right being the head of the patient. Subpanel (A) shows the placement (upper) and seating (middle) of vertebral staples, and probing (lower) for vertebral body screws. Subpanel (B) shows prerotation/reduction position of the rod (upper), postrotation/reduction position of the rod and placement of interbody cages (middle) and axial compression (lower) to prevent kyphosis and agument deformity correction. Subpanel (C) shows intraoperative deformity correction achieved. Subpanel (D) shows the placement of the second (stabilizing) rod

lumbar bend placed in the rod and the rod is manipulated to place the proximal end of the rod through the top closed screw. Screw caps are then placed on the open screws, and preparation is made for the reduction maneuver (Fig. 1B). If intraoperative monitoring is being used, then prerotation readings are assessed, and anesthesia is alerted that reduction is being performed. Using two rod-holding clamps, the rod is slowly and sequentially rotated to place the lumbar lordosis in correct alignment, and the apical screw is provisionally tightened (Fig. 1B).

If anterior structural grafts are planned to prevent or to treat kyphosis, they should be placed at this time (Fig. 1B). Options include rib autograft, femoral ring autograft, and titanium mesh cages packed with autograft, allograft or a mixture of these. Prior to placement of the structural grafts, the endplates should be decorticated and prepared for fusion, and hemostasis obtained using surgicell and thrombin. Grafts should be of adequate size to support the anterior and middle columns and minimize kyphosis generation, but should not be so large as to require distraction within the intervertebral disk space and predispose to neurological injuries. At a first approximation, the

grafts will be cylindrical in shape and will have the tightest fit in the concave side of the coronal deformity and in the posterior aspect of the disk space in curves with large rotational components. Placement of suitably sized structural grafts can help in obtaining correction, in that they will drive the endplates of the vertebrae into a rectangular configuration as the reduction procedure is performed with the other portions of the implant construct.

Segmental compression and tightening of set screws is then completed from the apex, alternately proximally and distally, until all of the screws are secured (Fig. 1B, C). If a two-rod construct is being utilized, the second rod is measured at this time, cut, contoured, and placed using standard techniques (Fig. 1D). All implants are tightened, wounds are irrigated, and additional graft material is placed within the disk spaces. The pleura or peritoneum is closed over the implants (with optional use of Vicryl mesh to augment implant coverage) and the wounds are closed in layers.

In the event of proximal anterior vertebral body screw fixation failure, several options are available to the surgeon. The first option is to extend the anterior instrumentation proximally to incorporate one to two additional

segments to obtain desired bony fixation. A second option is to perform a “proximal hybrid” instrumentation overlap, similar to the distal hybrid instrumentation, where posterior instrumentation is placed one to two levels proximal to the anterior instrumentation level and extending distally to overlap one to two levels into the anterior instrumentation construct. A posterolateral fusion is then performed in this proximal hybrid region. A third option is to convert the procedure to a long posteriorly instrumented fusion from one to two levels above the anterior instrumentation and down to the sacrum.

The posterior portion of the hybrid instrumentation procedure is then performed. Posterior approach to the spine is completed in the lower lumbar region using a midline plane and extending proximally to overlap the anterior instrumentation by one to two levels, and distally to the sacrum. Subperiosteal dissection is used to minimize bleeding and is extended laterally to the tips of the transverse processes proximally, and to the sacral ala distally. Pedicle screws are placed using standard techniques in the lumbar vertebrae L3–L5 and down to S1. Rods are measured, cut, and contoured, and screw/rod connectors and rod cross-connectors are placed. The wounds are copiously irrigated, fusion beds grafted, and wounds closed in layers over drains.

Patients are maintained on patient-controlled anesthesia in the immediate postoperative period, and mobilization is initiated on the first postoperative day. Clear liquid diet is initiated when bowel function returns, and is advanced as tolerated. Drains are removed only after patient is ambulatory and after output has tapered to minimal levels. Standing AP and lateral full-length spine films are obtained prior to discharge, and a multidisciplinary team evaluates the patients prior to their transfer to rehabilitation facilities or discharge to home.

Results

Of the first 10 patients receiving the hybrid instrumentation reconstruction, half were operated upon in a staged technique, and half under a single anesthesia. Seven of the first ten patients had a minimum of 2-year follow-up for x-ray review. Major curves were in the thoracolumbar region in five patients, averaging 47° , and were in the lumbar region in two patients, averaging 51° . Compensatory curves in the thoracic region averaged 28° for all of the patients, and in the lumbosacral region averaged 25° for all of the patients. Thoracic kyphosis averaged 35° , lumbar lordosis averaged 40° and balances averaged 1.4 cm to the left in the coronal plane and 0.4 cm anterior in the sagittal plane. At the time of discharge, corrections averaged 71 and 82% in the thoracolumbar and lumbar regions, respectively, and 36 and 82% in the compensatory curves of the thoracic and lumbosacral regions, respectively. Thoracic kyphosis averaged 42° , lumbar lordosis averaged 47° , and balances averaged 1.8 cm to the left in the coronal plane and 2.1 cm anterior in the sagittal plane. Minimum 2-year follow-up radiographs showed corrections of 59 and 68% in

the thoracolumbar and lumbar regions, respectively. Compensatory curves had corrections of 40 and 71% in the thoracic and lumbosacral regions, respectively. Thoracic kyphosis averaged 37° and lumbar lordosis averaged 36° . Coronal balance averaged 0.6 cm to the left and sagittal

Fig. 2. Single-rod hybrid instrumentation case summary. An otherwise healthy 50-year-old woman with previously untreated adolescent idiopathic scoliosis presented with complaints of low back pain and deformity. She underwent single-rod hybrid instrumentation spine surgery with left iliac crest bone graft for supplementation of the posterior fusion. Four years postoperatively, she had upright posture, physiological coronal and sagittal balance, and occasional back and leg symptoms controlled by NSAIDs. Subpanel (A) shows preoperative x-ray with 37° thoracic, 59° lumbar, and 40° lumbosacral fractional curves. Subpanel (B) shows postoperative x-ray with single-rod hybrid construct of 1/4 inch stainless steel, anterior spine fusion from T10–L5 and posterior spine fusion from T10–S1. Postoperative curves measured 23, 20, and 11° in the thoracic, lumbar, and lumbosacral fractional curves, respectively. Subpanel (C) shows preoperative clinical photograph illustrating coronal imbalance 2.5 cm to the left and obvious scoliosis deformity. Subpanel (D) shows postoperative clinical photograph illustrating physiological coronal balance and improvement of deformity

balance averaged 3.7 cm anterior. One dural tear was noted intraoperatively, directly repaired, and managed with bed-rest for 48 hours prior to routine mobilization and uneventful discharge. Two patients had required follow-up surgeries, one for proximal junctional breakdown performed 6 years postoperatively, and the second performed at an outside

institution 1 year postoperatively from the index procedure for loss of proximal fixation and junctional kyphosis. There were no patients with loss of distal fixation. Representative cases for a single rod (Fig. 2) and dual rod (Fig. 3) illustrate the corrective power and clinical success of the hybrid instrumentation technique.

Fig. 3. Dual-rod hybrid instrumentation case summary. A 56-year-old woman with mitral valve prolapse and lumbar stenosis previously treated by L5–S1 laminectomy presented with complaints of low back pain and deformity which had caused her to leave her job. She underwent dual-rod hybrid instrumentation spine surgery with right iliac crest bone graft for supplementation of the posterior fusion. Three years postoperatively, her pain was gone and she was back to work. She had upright posture, physiological coronal and sagittal balance, occasional leg symptoms, and was very satisfied with her surgery. Subpanel (A) shows preoperative x-ray with 29° thoracic, 53° lumbar, and 28° lumbosacral fractional curves. Subpanel (B) shows postoperative x-ray with titanium dual-rod hybrid construct, anterior spine fusion from T11–S1, and posterior spine fusion from L4–S1. Postoperative curves measured 14, 13, and 12° in the thoracic, lumbar, and lumbosacral fractional curves, respectively. Subpanel (C) shows preoperative clinical photograph illustrating coronal imbalance 4.5 cm to the left and obvious scoliosis deformity. Subpanel (D) shows postoperative clinical photograph illustrating physiological coronal balance and improvement of deformity

Discussion

Surgical management of thoracolumbar and lumbar adult scoliosis is typically managed with anterior surgery for mobilization of the spine followed by posterior spine fusion with long posteriorly instrumented constructs anchored to the pelvis, or by posterior-only methods [1–4]. Here, we describe an alternative to these techniques, where anterior spinal fusion with anterior instrumentation is combined with overlapping limited posterior spinal fusion with instrumentation. This novel instrumentation design may spare proximal spinal fusion levels, does not require instrumentation or fusion to the pelvis, and as assessed in our initial clinical cohort provides correction similar to that achieved with long posteriorly instrumented fusions.

Eck et al. reported on a series of 58 consecutive adult scoliosis patients treated by posterior only ($n=21$) or combined procedures from the thoracic spine to L4, L5, or the sacrum with a minimum of 2-year follow-up [1]. They report corrections obtained with the surgeries and describe complication rates and the lack of long-term predictability for fusions not extended to the sacrum. The lumbar and thoracolumbar deformity corrections averaged 27% (from 51 to 37°), disk degeneration distal to the fusion (for those stopping at L4 or L5) averaged 14% (six of 44), and complication rates between the groups were similar (total was 18 of 58 or 31%). Ali et al. reported on a consecutive series of 28 patients submitting to primary corrective surgery for adult scoliosis [9]. Preoperative deformity magnitude averaged 65°, and 29% of the patients (eight of 28) received posterior only surgical intervention, and all patients were fused short of the sacrum. Postoperative correction averaged 61%, and the reported complication rate was 18% (five in 28 patients). These deformity corrections are similar to the 58–67% obtained with the hybrid technique, and complication rates are also similar to the three of 10 that we have found in our initial cohort.

We have found that implementation of the hybrid technique can be safely done under staged or single operative interventions, and has corrective power and complication rates that are comparable to the current standard

anterior and posterior or posterior-only techniques. Further study is warranted to gain increased numbers of patients for follow-up to power large case series for comparison with outcomes from current techniques, as well as to determine the long-term follow-up of patients treated with hybrid instrumentation. It is anticipated that the shorter thoracic fusions and lack of required extension of instrumentation to the pelvis will make the hybrid technique superior to other current techniques.

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