Four-Rod Constructs for Complex Spinopelvic Reconstruction

Andrew H. Milby, MD
Jonathan B. Slaughter, MD
Harvey E. Smith, MD
Vincent M. Arlet, MD

Department of Orthopaedic Surgery, University of Pennsylvania, Philadelphia, PA

Introduction

Segmental instrumentation has allowed for increasingly-complex spinal deformity correction, as well as reconstruction and stabilization following tumor resection or trauma. While pedicle screw and rod constructs have improved upon the early limitations of segmental wiring or hook techniques, spinopelvic fixation remains biomechanically-demanding and has been associated with high rates of pseudoarthrosis and instrumentation failure.[1-5]

A variety of methods have been described to optimize screw pull-out strength in high-demand cases;[6-9] however, these techniques do not address the risk of subsequent rod fracture. The use of additional rods has been described to increase spinopelvic construct stability and afford the achievement of bony fusion following extensive reconstructive procedures.[10-12]

Indications

Due to the increased cost and potential for complications associated with additional instrumentation, the use of four-rod constructs should be considered only in cases that present a high risk of pseudoarthrosis. Procedures resulting in extensive destabilization of the lumbosacral junction, or long thoracolumbar constructs resulting in a long lever arm, may benefit from additional rod placement. In general, fusion constructs extending cranially past L2 may be at risk for pseudoarthrosis with extension to the sacrum, as seen in deformity correction with pedicle subtraction osteotomies or posterior vertebral column resections. Four-rod constructs may also be beneficial in cases of total sacrectomy for tumor, permitting early mobilization despite a lack of initial bony structural support. These reconstructive goals are similar for cases of traumatic spondylopelvic dissociation or comminuted sacral fractures requiring iliolumbar instrumentation. In addition, four-rod constructs may be especially useful in cases of spinal cord injury to facilitate aggressive rehabilitation and potentially decrease the risk of neuropathic spondyloarthropathy (Charcot spinal arthropathy).

Operative Technique

Preoperative imaging is essential to confirm that the patient's anatomy is amenable to implantation of the planned spinopelvic instrumentation. The patient is positioned prone on a radiolucent table to facilitate the use of intraoperative fluoroscopy with attention paid to the maintenance of appropriate lumbar lordosis. A posterior midline exposure is performed. Depending on the surgeon's preference, instrumentation may or may not be placed prior to decompression or exposure of the spinal canal.

To facilitate dual-rod placement on both sides, the surgeon must be cognizant of the need to place pedicle screws using two different trajectories at corresponding alternating levels: 1) the "convergent" trajectory as described by Magerl,[13] and 2) the "straight-ahead" trajectory as described by Roy-Camille.[14] The heads of the convergent screws are thus connected by the lateral rod, and the straight-ahead screws connected by the medial rod. While the optimal biomechanical configuration of the alternating screws has not been defined, the senior author prefers to use convergent screws at the most cranial level due to their superior pull-out strength and lower risk of impingement on the preserved cranial adjacent facet joint.[15]

In order to serve as a base for the medial and lateral rods, two divergent iliac screws must be inserted on either side of the pelvis. The distal screws are placed using a Galveston-like technique from a starting point at the posterior-superior iliac spine directed toward the anterior-inferior iliac spine.[16] A second set of screws are placed from a more proximal starting point on a divergent trajectory into the iliac wing; the exact trajectories of these screws are dependent the rod trajectory from the corresponding lumbar screws and individual anatomic variations. The starting points of all pelvic screws should be recessed and the screws fully seated to minimize screw head prominence. If at all possible, iliac crest bone graft harvesting is avoided so as not to diminish distal fixation of the pelvic screws. However, the risk-benefit of biologic augmentation with autologous bone grafting

Corresponding author:
Vincent M. Arlet, MD
Director, Penn Orthopaedic Spine Center
Professor of Orthopaedic Surgery
University of Pennsylvania
3400 Spruce Street, 2 Silverstein Pavilion
Philadelphia, PA 19104
vincent.arlet@uphs.upenn.edu

versus diminished screw purchase must be considered on a case-by-case basis. When necessary, cancellous bone may still be harvested while preserving the tables of the ilium to maximize screw purchase.

Utilization of the four-rod technique with monoaxial side-loading screws as originally described presented significant technical challenges. The use of polyaxial screws has made four-rod constructs easier to achieve, as it is possible to

Figure 1. Case Example: preoperative (A,C) and immediate postoperative (B,D) standing radiographs of a 56 year-old female who underwent posterior instrumented fusion from T10 to the pelvis with transforaminal lumbar interbody fusion at L4-5 and L5-S1 for correction of thoracolumbar degenerative kyphoscoliosis. At five months postoperatively, the patient complained of recurrent pain and deformity, and fracture of the bilateral 6.3mm titanium rods was noted (E,F,G). The patient subsequently underwent revision instrumentation from T10 to the pelvis with use of a four-rod construct (H,I).

tilt the screw head crown medially for the medial rod and laterally for the lateral rod. This allows for increased latitude in the placement and connection of the rods. In addition, the lateral screws may be left slightly proud in order to facilitate connection to the lateral iliac screws.

While cross-links have been demonstrated to increase the torsional stiffness of four-rod constructs in cadaveric mechanical testing,[10] the optimal configuration of cross-links is uncertain and highly-dependent on anatomic considerations. It is the senior author's practice to place the proximal cross-links in compression and the distal cross-links in distraction; this configuration offers the theoretical advantages of grasping the lumbar vertebrae with the cranial pedicle screws and driving the caudal pelvic screws into the ilium. Preparation of the posterolateral fusion bed and bone grafting are performed in the standard fashion following placement of the instrumentation.

Discussion

Use of the four-rod technique for spinopelvic reconstruction ideally results in sufficient stability to permit immediate postoperative weight-bearing and activity as tolerated. This postoperative protocol has been employed successfully even in cases of total sacrectomy for tumor.[11]

Jacobs *et al* were among the first to report clinical outcomes with the use of four-rod constructs as part of a series of 23 patients with neuropathic spondyloarthropathy following fusion for traumatic spinal cord injury (SCI).[17] The spinopelvic four-rod technique was used in 9 of these patients treated after 2000 with SCI levels in the lumbar spine; 4 of these were revisions of failed prior instrumentation, and 5 were used at the index procedure. While spondyloarthropathy cranial to the fusion mass prompted inclusion in the cohort, no cases of instrumentation or spinopelvic fixation failure were observed in patients with four-rod constructs.

As demographic trends result in increasing numbers of adults undergoing spinal deformity correction, the four-rod technique is emerging as a powerful means of achieving spinopelvic fixation (Figure 1).[12] However, despite promising biomechanical data and clinical experience, it must be acknowledged that comparative evidence or cost-effectiveness data regarding four-rod constructs is limited at this time. Future studies will help elucidate the ideal indications for and refine the technique of four-rod constructs in spinopelvic reconstruction.

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