Iliac screw placement in neuromuscular scoliosis using anatomical landmarks and uniplanar anteroposterior fluoroscopic imaging with postoperative CT confirmation

Clinical article

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Object. Neuromuscular scoliosis is a challenging pathology to treat. Surgical correction can involve long fusion constructs extending to the pelvis. The deformity inherent in these patients makes it difficult to obtain adequate lateral intraoperative radiographs for traditional image-guided placement of iliac screws.

Methods. A clinical and radiographic assessment of 14 patients with neuromuscular spinal deformity was conducted. From 2007 to 2013, 12 of these patients (mean age 14.25 years, range 10–20 years) underwent long spinal instrumentation (mean 15 levels, range 10–18 levels) and fusion to the pelvis, and 2 underwent placement of a growing rod construct with iliac screw placement at a single institution. The average length of follow-up was 33.7 months (range 6–64 months). Iliac screws were placed after identifying the posterior superior iliac spine and using only anteroposterior fluoroscopy (view of the inlet of the pelvis), rather than the technique of direct palpation of the sciatic notch. The accuracy of iliac screw placement was assessed with routine postoperative CT.

Results. A total of 12 patients had 24 screws placed as part of a long-segment fusion to the pelvis, and 2 patients had two iliac screws placed as part of a growing rod construct for neuromuscular scoliosis. There were no iliac screw misplacements, and no complications directly related to the technique of iliac screw placement. For cases of definitive fusion (n = 12), the average coronal Cobb angle of patients with neuromuscular spinal deformity measured 62° before surgery and 44.3° immediately after surgery. The average preoperative thoracic kyphosis and lumbar sagittal lordosis measured 37.3° and 60.7°, respectively. Immediately after surgery, the thoracic and lumbar angles measured 30° and 41.1°, respectively. At last follow-up, the average coronal Cobb angle was maintained at 45.1°, and the thoracic and lumbar sagittal angles were maintained at 32.8° and 45.3°, respectively.

Conclusions. A less invasive technique for iliac screw placement can be performed safely with a low likelihood of screw misplacement. This technique offers the biomechanical advantages of iliac fixation without the soft tissue exposure typically needed for safe screw insertion. The technique relies on identification of the posterior superior iliac spine and high quality anteroposterior fluoroscopic imaging for a view of the pelvic inlet.

Key Words • neuromuscular scoliosis • iliac instrumentation • fusion • posterior superior iliac spine • recombinant human bone morphogenetic protein-2

Neuromuscular scoliosis is a challenging condition to treat, as the curves tend to be very long, severe, and rigid.2 Surgical intervention is further complicated by congenital bone anomalies, muscle weakness, dysplastic anesthetic skin, and a predisposition to wound healing problems and skin breakdown.2 Many patients with neuromuscular scoliosis require long fusions to the sacrum and pelvis, spanning the spinopelvic junction to adequately treat their spinal deformity. Pseudarthrosis rates have historically been reported as high,4 thus a variety of spine instrumentation systems, surgical techniques, and strategies to enhance fusion rates have rapidly developed over the past 2 decades.1,5,13

Originally described by Allen and Ferguson,1 lumbarpelvic fixation has since become an important adjunct for long-segment spine stabilization.5,10,11,18 Multiple techniques for the safe placement of lumbarpelvic instrumen-
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tation have been developed.12 These techniques require extensive surgical exposure as screw cannulation trajectory is determined by visualization of the outer table of the ilium and manual palpation of the sciatic notch. The patient population with neuromuscular scoliosis is fragile and poorly tolerant of the added morbidity incurred by extensive muscular dissection.17 Additionally, the severe deformity or pelvic obliquity inherent in this patient population significantly limits the utility of fluoroscopy for sagittal guidance due to an inability to obtain adequate intraoperative lateral images leading to relatively high false-negative rates (approximately 13%).3 Although other authors have reported techniques aimed at limiting exposure of the ilium in adults, the operative techniques focus on either bone anatomical landmarks or require additional image guidance consisting of multiple views, and do not confirm screw placement with CT, considered by many authors to be the gold standard.15,16

We have therefore sought to validate a less invasive technique for iliac screw placement, consisting of exposure of the posterior superior iliac spine and pelvic inlet anteroposterior fluoroscopy only for coronal guidance alone. The primary goal of this study was to demonstrate the feasibility and safety of placing iliac screws with this technique. Accuracy as determined with postoperative CT, as well as intraoperative or postoperative complications directly related to iliac screw placement, were recorded. We also measured our patients’ outcomes with regard to maintenance of spinal alignment, although this was not the primary goal of this paper, and longer follow-up may be necessary to draw definitive conclusions.

Methods

Patient Population

This study was a retrospective review of a cohort of 14 consecutive patients with lumbar or thoracolumbar neuromuscular deformities treated with long, instrumented, segmental spinal fusions to the ilium between 2007 and 2013 at Texas Children’s Hospital (Neuro-Spine Program) in Houston, Texas. Institutional review board approval was obtained to conduct the study. Inclusion criteria consisted of age younger than 21 years at surgery, with a minimum of 6 months follow-up. Two children underwent placement of iliac screws as part of a growing rod construct rather than a definitive fusion, and thus are reported as a subgroup and not included in the statistical analysis.

The preoperative diagnosis was pediatric neuromuscular spinal deformity in all patients, which included 12 patients with scoliosis and 2 with kyphosis. Preoperative MR images and CT scans were obtained in all patients. Radiographic follow-up included evaluation of 36-inch, upright, full-spine radiographs obtained preoperatively, immediately postoperatively, and at the most recent follow-up, as well as postoperative CT scans.

Surgical Decision Making

The indications for spinal fusion were a combination of factors for each patient, including clinical presentation, radiographic studies, progression of deformity, intractable back pain, sitting imbalance, skin breakdown over gibbus deformity, and restrictive lung disease. In patients undergoing a definitive fusion, arthrodesis to the pelvis was performed using bilateral iliac screws and a combination of allograft, local autograft, and recombinant human bone morphogenetic protein-2 (rhBMP-2). Very young patients with progressive deformity were treated with a growing rod construct to slow curve progression.

Operative Procedure

For the operation the patient is positioned prone on a Wilson frame. Surgery consists of a standard posterior midline approach, following the course of the spinous processes in patients with severe deformity. In all cases, care is taken to incorporate previous back scars into the present incision. Meticulous facet joint excision and implementation of a segmental spinal instrumentation system are performed with multiple correction techniques using pedicle screws, hooks, sublaminar polyester bands, and rods. If S-1 screws are used, they are placed in a bicortical fashion through the sacral promontory ventrally.

Fluoroscopic imaging is used to obtain an inlet view of the pelvis via a caudal projection (Fig. 1). Fluoroscopy is oriented orthogonal to the plane of the pelvic inlet with the beam directed approximately 40° cephalad to caudal. The sciatic notch is identified bilaterally on fluoroscopy to assist with trajectory (Fig. 2A). After exposing the posterior superior iliac spine and the top of the outer table of the iliac crest to help guide mediolateral screw trajectory, the iliac screw entry site is placed within the most distal 1 cm of the posterior superior iliac spine. A rongeur is used to remove cortical bone so that the screw head may be countersunk to minimize hardware prominence. A pedicle finder is then advanced and guided both by the contour of the outer table of the iliac crest and the anteroposterior image of the pelvis, keeping the tip of the instrument within the width of the sciatic notch (Fig. 2B). This is followed by a tap (Fig. 2C) and iliac screw placement (Fig. 2D and E). Screw length and diameter are dependent on the measured length of a ball-tipped probe in the bone canal and intraoperative assessment of the width of the iliac crest, respectively.

For patients undergoing definitive fusion, either pedicle screws or laminar hooks are used at the rostral end of the construct for all patients. Pedicle screws or sublaminar polyester bands are placed bilaterally at all intervening spinal levels. After posterior instrumentation is placed, all exposed bone surfaces are thoroughly decorticated with a high-speed, air-powered drill. In addition to local autograft harvested from spinous processes and/or facet joints, allograft and rhBMP-2 (12- or 24-mg dose) is routinely used and evenly distributed in the operative bed for the posterior surgery. For the 2 patients with primary fixed sagittal imbalance, a kyphectomy was performed.

For patients undergoing placement of growing rod construct, short-segment fusion with segmental instrumentation and rhBMP-2 was performed at the apex of the curve. This was followed by long nonsegmental spinal instrumentation ipsilateral to the concavity of the curve. Sublaminar polyester bands were placed rostrally; a uni-
lateral iliac screw was placed caudally (ipsilateral to the concavity of the curve). These anchor points were connected with a single rod.

Characteristics of Pseudarthrosis

The criteria used to detect pseudarthroses were: 1) loss of fixation, such as implant breakage, dislodgement of rods or hooks, or halo around a pedicle screw (a halo around an iliac screw is an expected finding from preservation and motion of the sacroiliac joint); 2) significant progression of deformity with or without pain; 3) subsequent disc space collapse observed from the first postoperative visit to the most recent visit where pseudarthrosis was determined; and 4) lucency across the fusion mass on CT imaging.

The effect of patient age at surgery, patient sex, and comorbidities at surgery were evaluated. Coronal Cobb angle, thoracic kyphosis from T-5 to T-12, and lumbar lordosis from L-1 to L-5 were measured radiographically using upright, 36-inch scoliosis radiographs preoperatively, immediately postoperatively, and at last follow-up.

Statistical Analysis

Clinical, operative, and radiographic parameters were collected. Frequency distributions and summary statistics were calculated for these data. We also report the outcome data from the 2 patients who underwent placement of growing rod constructs, but we did not include these data in the statistical analysis.

Results

Patient Demographics

We reviewed the outcomes of 14 patients with lumbar or thoracolumbar neuromuscular deformities treated with long, instrumented, segmental spine fusions to the ilium between 2007 and 2013 at our institution (Tables 1 and 2). Since the primary goal of this study was to demonstrate
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the ability to safely place iliac screws using the method described, 2 patients who had iliac screws placed as part of a growing rod construct were included, as well as 12 patients with definitive fusions to the pelvis. This yielded a series of 14 patients (10 males and 4 females). The average age of our patients undergoing fusion at the time of surgery was 14.25 years (range 10–20 years). The 2 patients undergoing growing rod placement were 2 and 3 years old, respectively. In our cohort, 6 patients had myelomeningoceles; 6 had cerebral palsy; 1 had spinal lipoma, tethered cord, and congenital scoliosis from an L-1 hemivertebra; and 1 had an unspecified neurodegenerative disorder. Two of the children with myelomeningoceles had kyphosis only; the remainder of the patients in our cohort had scoliosis.

Clinical and Operative Data

All patients were assessed preoperatively with MRI, CT, and upright 36-inch scoliosis radiographs. The average coronal Cobb angle of patients undergoing definitive fusion measured 62° before surgery (Table 1). The average preoperative thoracic kyphosis and lumbar sagittal lordosis measured 37.3° and 60.7°, respectively. An average of 15 vertebrae (range 10–18) were fused. Arthrodesis to the pelvis was performed using bilateral iliac screw fixation and posterolateral fusion with allograft/local autograft and rhBMP-2. All patients received either a 12- or 24-mg dose of rhBMP-2. Mean estimated blood loss was 979 ml (95% CI 506–1452 ml) and mean operative time was 448 minutes (95% CI 407–539 minutes). Two patients with severe kyphosis associated with myelomeningocele underwent L1–2 and T12–L2 kyphectomy, respectively.

The 2 patients undergoing placement of iliac screws as part of a growing rod construct had an average coronal Cobb angle of 96° before surgery (Table 2). The average preoperative thoracic kyphosis and lumbar sagittal lordosis measured 11° and 19.5°, respectively. The constructs extended from T-4 to the ileum in 1 patient and T-6 to the ileum in the other. Arthrodesis to the pelvis was performed using unilateral iliac screw fixation with short-segment posterolateral fusion using allograft and rhBMP-2 only at the apex of the curve. Mean blood loss was 150 ml, and mean operative time was 254 minutes.

Postoperative Data

Postoperative CT showed satisfactory iliac screw placement for all patients. All patients remained at their neurological baseline postoperatively. In the immediate postoperative period, the average coronal Cobb angle for patients undergoing a definitive fusion was 44.3°, and the thoracic and lumbar angles were 30° and 41.1°, respectively. The mean coronal Cobb angle for patients with a growing rod construct was 68.5°, and the thoracic and lumbar sagittal angles were 20° and 19.5°, respectively. Patients were followed up for a minimum of 6 months with an average of 33.7 months (range 6–64 months).
<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Associated Comorbidities</th>
<th>Primary Spinal Deformity</th>
<th>Preop Cobb Angle (°)</th>
<th>Spinal Construct</th>
<th>BMP Dosage (ml)/Concentration (mg)</th>
<th>Bone Graft</th>
<th>EBL (ml)</th>
<th>Op Time (mins)</th>
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*EBL = estimated blood loss; L = lumbar; T = thoracic.
†In 2 patients a unilateral iliac screw was placed as part of a growing rod complex.
TABLE 2: Postoperative and outcome data in 14 pediatric patients with neuromuscular spinal deformity and iliac screw placement*

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<th>Case No.</th>
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<th>Coronal</th>
<th>Sagittal (T/L)</th>
<th>Length × Width of Iliac Screws (mm)</th>
<th>Follow-Up (mos)</th>
<th>% Correction</th>
<th>Complications</th>
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<td>Cobb Angle at Last Follow-Up (°)</td>
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* L = lumbar; T = thoracic.
† In 2 patients a unilateral iliac screw was placed as part of a growing rod complex.
Most patients undergoing definitive fusion (11 of 12 patients) did not have significant progression of his or her deformity after surgery. At last follow-up, the average coronal Cobb angle was maintained at 45.1°, and the thoracic and lumbar sagittal angles were maintained at 32.8° and 45.3°, respectively, at the most recent follow-up. The mean deformity correction was 36.1% (range 2%–67%) at last follow-up. Of the patients with growing rod constructs, the average coronal Cobb angle at last follow-up was 72.5°, and the thoracic and lumbar sagittal angles were 27.5° and 25.5°, respectively.

**Complications**

One patient in our group (Case 5) developed pseudarthrosis as evidenced by iliac screw fracture. This patient was a 10-year-old boy with myelomeningocele and kyphosis who underwent kyphectomy and fusion with instrumentation from T-9 to the ileum. The iliac screws used in this case were adapted from polyaxial 5.5 × 50 mm pedicle screws instead of larger dedicated iliac screws because the small anatomical size of the iliac crest would not accommodate the larger dedicated iliac screws. This is the only case in our series in which we used polyaxial screws for iliac fixation in a definitive fusion. This patient’s postoperative course was further complicated by erosion of skin over the instrumentation with resultant deep wound infection that necessitated reoperation. Because the patient had solid bone fusion on CT, the instrumentation was removed. At last follow-up, the patient was noted to have a fracture of fusion mass at L2–3 with progression of kyphotic deformity. He is currently undergoing treatment with a rigid orthosis and close observation.

A second patient (Case 12) suffered loss of engagement of the rod from the left iliac screw within 6 weeks after surgery. This failure likely resulted from using a 5.5-mm diameter rod, instead of a 6.5-mm diameter rod, directly within the head of the iliac screw. Furthermore, we did not use a 6.5-mm diameter lateral connector from the rod to the iliac screw, as we did on the contralateral side, which may have obviated this complication. At 6 months after surgery, there was a slight loss of correction of the pelvic obliquity but no loss of correction of the coronal or sagittal alignment of the spine. Moreover, there was an expected halo around the contralateral right iliac screw. However, a CT scan obtained 3 months after surgery showed bridging bone spanning the instrumented spinal segments.

A third patient (Case 14) developed wound breakdown with formation of a sinus tract in communication with the spinal instrumentation, and deep wound infection necessitating removal of hardware after 18 months. The patient is currently undergoing treatment in a detorsional brace and is being followed closely until a definitive fusion can be performed near the age of skeletal maturity.

Other complications included proximal junction kyphosis (n = 1), pleural effusion (n = 1), urinary tract infection (n = 2), postoperative ileus (n = 2), and transient urinary retention (n = 1). No complications directly related to the technique of iliac screw placement were identified, such as screw misplacement and cortical violations.

**Discussion**

Management of neuromuscular scoliosis is characterized by the need to fuse a longer segment of the spine at a younger age due to the rapid progression of neuromuscular curves. Many of these patients have significant pelvic obliquity and impaired sitting balance, thus commonly requiring fusions to the sacrum and pelvis.\(^2\) Neuromuscular scoliosis surgery has a higher rate of complications than idiopathic scoliosis surgery. Complications can include pseudarthrosis, deformity progression, hardware failure, wound breakdown, neurological deterioration, respiratory decompensation, and death.\(^8\)

The evolution of our technique for iliac screw placement, from direct palpation to an image-guided approach, was motivated by a desire to avoid extensive soft tissue dissection, decrease operative time, and decrease blood loss. The exclusive use of minimally invasive approaches for the placement of iliac screws engenders significant difficulties in connecting the iliac instrumentation to complex 3D constructs beneath the fascia.\(^7\)

Established methods for image-guided placement of iliac screws include the use of multiplanar fluoroscopic imaging advocated by König et al. as a reliable guide for the placement of iliac screws and the use of a single obturator outlet view described by Schildhauer et al. as safe and efficacious.\(^14\) We have found the functionality of these methods limited due to the difficulty in attaining a reliable lateral fluoroscopic image because of the severe deformity and pelvic obliquity noted in our patients (Fig. 2F). We could, however, easily obtain an anteroposterior fluoroscopic image of the pelvis, or a view of the inlet of the pelvis. This method of fluoroscopic imaging, combined with a less invasive and less extensive exposure of the posterior superior iliac spine and top of the outer table of the iliac crest, provides rostrocaudal and mediolateral trajectory information, respectively. This combination provides complete spatial orientation for placement of an iliac screw.

There were no instances of hardware misplacement in our clinical series, consisting of 26 screws confirmed by CT. No cases required conversion to a more invasive procedure such as total exposure of the outer table to palpate the sciatic notch. This technique of iliac screw placement was congruent with a durable spinal construct resulting in fusion in most cases, and in intermediate-term (minimum 6-month follow-up) maintenance of reduction of the spinal deformity. More follow-up may be needed to determine long-term maintenance of spinal alignment.

**Conclusions**

In this small pilot study of pediatric patients with neuromuscular scoliosis, iliac screws were placed safely and accurately utilizing the identification of the posterior superior iliac spine as a starting point, the contour of the outer table of the iliac crest to provide mediolateral trajectory, and an anteroposterior intraoperative radiograph of the pelvic inlet to guide rostrocaudal trajectory. This less invasive approach obviates the drawbacks of the open direct palpation method and complete minimally invasive approach for iliac screw placement by minimizing soft tissue disruption.
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while facilitating the connection of iliac instrumentation to the rest of the spinal construct. This technique will require validation in a larger clinical study with longer follow-up prior to advocating its universal use.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Jea. Acquisition of data: Jea. Analysis and interpretation of data: Jea. Drafting the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Jea.

References


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