Navigated placement of iliac bolts: description of a new technique

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Abstract

BACKGROUND CONTEXT: Image navigation has improved the safety and ability to perform complex spinal procedures where visibility is not optimal or anatomic deformity is present. Numerous published studies are available demonstrating its effectiveness in improved pedicle screw placement in complex multiplanar deformities. Studies have also demonstrated image navigation technology versatility; however, stabilization of the lumbopelvic junction with navigated iliac bolt fixation has not been reported.

PURPOSE: To describe an innovative versatile application of image navigation technology in spine surgery. We examine the safety, accuracy, and effectiveness of navigated iliac bolt placement while minimizing challenges associated with current techniques.

STUDY DESIGN: Case series.

PATIENT SAMPLE: Five patients requiring lumbopelvic fixation for multiple indications, including lumbosacral pseudoarthrosis, complex sacral fracture patterns, compromised revision sacral fixation, and as an adjunct to degenerative deformity with multilevel fusion, underwent navigated iliac bolt placement.

OUTCOME MEASURES: Accurate placement was verified using intraoperative computed tomography (CT) imaging using O-ARM (Medtronic, Inc.) after placement.

METHODS: Five patients requiring lumbopelvic fixation have undergone navigated iliac bolt placement using Medtronic Stealth Station Treon in conjunction with the O-ARM (Medtronic, Inc.). A right percutaneous posterior superior iliac spine (PSIS) reference frame was placed at the superior lateral margin of the PSIS, and bilateral iliac bolts were placed via navigation using both the anatomic and traditional surgical techniques. Both techniques were performed without direct notch palpation and minimal soft-tissue exposure. Postplacement intraoperative CT imaging was obtained to confirm position and trajectory of the bolts using O-ARM (Medtronic, Inc.).

RESULTS: Ten iliac bolts were successfully placed in five patients. Intraoperative CT demonstrated ideal iliac screw bone placement projecting within 2 cm over sciatic notch, between pelvic tables. With image navigation, both anatomic and traditional iliac bolt placement techniques were performed with less surgical exposure, no radiation exposure, and complete accuracy using image navigation techniques with a percutaneous reference frame. The percutaneous reference frame placed in the superior lateral PSIS did not cause any interference with our navigated trajectory or bolt.

CONCLUSIONS: Image-navigated iliac fixation allows for safe and accurate placement of bilateral iliac bolts without PSIS percutaneous reference frame interference. Image guidance eliminates fluoroscopic radiation exposure and extensive soft-tissue dissection and facilitates both traditional and anatomic iliac bolt placement techniques. © 2011 Elsevier Inc. All rights reserved.

Keywords: Image guidance; Navigation; Lumbopelvic fixation; Computer-Assisted surgery

Introduction

Galveston iliac fixation was originally described by Allen and Ferguson [1,2] as a technique for stabilizing the lumbosacral joint in Luque rod instrumentation for neuromuscular scoliosis. This technique is still useful in neuromuscular scoliosis and remains a commonly used technique in stabilization of the lumbopelvic junction for complex...
reconstructive spinal deformities and as an advantageous adjunct to lumbosacral constructs [3,4]. McCord et al. [5] has also demonstrated the biomechanical advantage of iliac bolt fixation with a far superior anterior moment arm, providing a more robust construct and thus a higher fusion rate across the lumbosacral junction. Iliac bolts have been shown to increase the stiffness of lumbosacral constructs. This technique has been modified to include direct rod-iliac bolt attachment; anatomic technique or as originally described with the use of offset connectors [6].

Surgical complications and/or disadvantages to lumbopelvic fixation have been reported, and many of these are related to the wide surgical exposure necessary to safely place the iliac bolts. Wide dissection along the lateral aspect of the ilium has been described to allow digital palpation of the sciatic notch to avoid breach and neurovascular injury. Bilateral sciatic notch exposure may lead to longer surgical time, increased blood loss, and the risk of soft-tissue complications associated with extensive gluteal stripping and compromised postoperative extensor function. Alternatively, fluoroscopically-assisted bolt placement has inclusive challenges related to radiation exposure, a two-dimensional pelvic view, poor radiographic quality, and surgical field congestion. Other disadvantages to lumbopelvic fixation may include difficulty in connecting the iliac bolt tulip to adjacent sacral screws and rod construct, painful or prominent hardware requiring removal, and the inability to place screws in patients with deficient cortical posterior superior iliac spine (PSIS) anchorage from previous autograft harvest [6,7].

Image navigation has improved the safety and ability to perform complex procedures where visibility is not optimal or anatomic deformity is present. Numerous published studies are available demonstrating its efficiency and effectiveness in improved implant placement involving complex multiplanar spinal deformities [7–11]. A meta-analysis of pedicle screw placement accuracy has demonstrated a 95% median accuracy with three-dimensional navigation [12]. With its versatile spectrum of use and safety, we have recently employed intraoperative image navigation using the O-Arm (Medtronic, Inc., Littleton, MA, USA) linked with Stealth Station Treon to allow placement of iliac bolts using both anatomic and traditional placement techniques without extensive soft-tissue dissection.

**Methods**

We present a case series demonstrating three-dimensional image navigation during lumbopelvic fixation. Patients included lumbosacral nonunions, a sacral U-type fracture, compromised revision sacral fixation, and as an adjunct to degenerative deformity with multilevel fusion.

**Surgical technique**

After patient positioning, the right PSIS is palpated and sterile percutaneous placement of the dynamic reference frame at the superior lateral margin of the PSIS is performed. The reference frame is tilted caudally and laterally facilitating an unobstructed working field and will remain fixed for the remainder of the case (Fig. 1). Subsequent imaging data to include pelvis and lumbar spine were acquired at our institution using the Medtronic Stealth Station Treon in conjunction with the O-ARM (Medtronic, Inc.). After data acquisition, care must be taken to avoid moving the fixed reference frame, which will inadvertently affect the accuracy of navigation and may require a repeat computed tomography spin. During image data acquisition (13 seconds/spin), all personnel step out of the surgical suite, avoiding any radiation exposure. On completion and removal of O-ARM, surgical re-prep, drape and exposure was performed and navigated pedicle screw instrumentation completed. Patient body habitus determined whether traditional or anatomic iliac bolt placement was preferred, preferring anatomic technique for thinner patients. The PSIS was exposed through a second fascial incision over the PSIS. Focal subperiosteal exposure was completed, and the lateral ilium was not exposed nor was direct palpation of sciatic notch performed minimizing any potential soft-tissue complication or disadvantages to such. For the traditional approach, a bone notch was removed using a rongeur allowing for a lower profile of the bolt tulip. Alternatively, with the anatomic technique, the dissection was carried out as described without the bone notch and a more medial subperiosteal exposure was performed, taking care not to violate the sacroiliac joint. Bone graft was not harvested from the ilium; laminectomy autograft with bone morphogenetic-2 protein and demineralized bone matrix was used versus bone morphogenetic-2 protein/demineralized bone matrix alone in those without decompression.

The navigated pedicle probe was used to confirm starting point and create trajectory for iliac bolt fixation (Fig. 2). In the anatomic surgical technique, the starting point was created with a small awl and is more medial without violating the sacroiliac joint facilitating a direct rod-to-screw tulip assembly. Subsequent real-time multiplanar navigation allows for ideal bone trajectory drilling with straight pedicle probe. Iliac bolt–navigated insertion is then completed without digital palpation of the sciatic notch nor lateral ilium exposure. Posterior superior iliac spine exposure and pelvic palpation was performed standing on the contralateral side of table for both anatomic and traditional technique facilitating trajectory angle and bolt placement. Virtual trajectory screw length was measured off the computer workstation three-dimensional image. The bolt tulip was later secured directly to the rod construct or attached by means of an offset connector. Intraoperative postinstrumentation computed tomography was obtained with the O-ARM to confirm appropriate placement (Fig. 3).

**Results**

No violations of the sciatic notch nor misplacement of iliac bolts were noted as a result of image navigation use.
Ten bolts were successfully placed in five patients without the need to palpate the sciatic notch or perform extensive soft-tissue dissection. No cortical breaches of the pelvic table were attained. Intraoperative postplacement computed tomography confirmed placement to within 2 cm of the sciatic notch without violations of the notch. Both the traditional and anatomic iliac bolt placement techniques were successfully performed without reference frame interference. A variety of bolt dimensions can be used with image navigation pending pelvic table width and anatomic patient variations. We used a width range of 7.5 to 8.5 mm and a length of 85 to 100 mm.

Discussion

Image navigation technology has led to many innovative versatile uses in spine surgery. It has improved the safety and ability to perform complex procedures where visibility is not optimal or anatomic deformity is present. Numerous published studies are available demonstrating its effectiveness in improved pedicle screw placement in complex multilobar spinal deformities [9–11,13]. Aside from pedicle screw insertion, many versatile applications are now being described for image navigation, which incorporate the advantages of image navigation demonstrating safety and accuracy with less radiation exposure and operative time savings [14–16].

Fusion across the lumbosacral junction has often resulted in nonunion secondary to the unfavorable biomechanical forces across this junction [3–5]. Iliac bolt fixation has provided supplemental biomechanical stability, rigidity, and hence higher fusion rates; however, disadvantages to iliac bolt placement exist including the need for further soft-tissue dissection, prominence of hardware, and difficulty in linking to the lumbosacral construct [5,17]. Traditional iliac bolt fixation technique has required extensive soft-tissue dissection with a second fascial incision over the lateral iliac crest and subperiosteal gluteal stripping off the lateral crest and ilium to provide digital palpation of the sciatic notch. Careful iliac crest medial dissection is also required to avoid disruption of the distal insertion of the erector spinae muscles, which may compromise their viability. Such extensive soft-tissue dissection has led to adverse events including soft-tissue devascularization and increased rate of infections. Other techniques for pelvic fixation have been described to mitigate such disadvantages including an anatomic iliac screw fixation technique, a minimally invasive percutaneous method using fluoroscopy, S2 screw fixation, or sacral alar–iliac fixation [6,18–20]. Nottmeier et al. [7] have also recently demonstrated safe placement of sacral alar screws for supplemental lumbosacral biomechanical stability or as an alternative to S1-compromised fixation with the use of image navigation. The multitude of bolt placement options avoids the disadvantages of traditional iliac bolt fixation while attempting to provide supplemental lumbosacral fixation.

Through the use of image navigation, either anatomic iliac bolt fixation or traditional iliac bolt fixation techniques is facilitated, allowing safe placement while minimizing soft-tissue dissection, fluoroscopy exposure, and associated disadvantages. To our knowledge, this is the first article describing the use of navigation for iliac bolt placement.
Limitations to our study do include a representation of a case series with one navigation system, which may not be representative of a large multicenter experience with other image navigation technology systems. In addition, the lack of a control group or other comparative bolt placement technique cohort, such as fluoroscopy based, was not used. Despite the deficient comparative control, what was favorable was the avoidance of radiation.

Fig. 2. Image navigation views demonstrating drill trajectory and projected length through ilium.

Fig. 3. Postplacement intraoperative three-dimensional reconstruction computed tomography confirming iliac bolt placement.
exposure, which has been shown to be less statistically significantly when compared with the use of conventional fluoroscopy [14,15]. Another limitation was the lack of measured operative time savings associated with less soft-tissue dissection and direct digital notch palpation in the traditional placement technique. Further investigation would be necessary to measure these variables and increase the power of our analysis. These preliminary findings are very encouraging to the success of such a technique promoting feasibility, ease of bolt placement, and navigation versatility all without further compromising the soft-tissue or instrumentation placement.

Conclusions

Image navigation has allowed expeditious, accurate, and safe placement of the iliac bolts to within 2 cm of the sciatic notch without percutaneous reference frame interference. With this technique, radiation exposure and operative times have decreased with less required soft-tissue dissection and avoidance of direct sciatic notch palpation. In long term, this may result in fewer vascular, neurologic, and/or soft-tissue complications/infection while promoting biomechanical advantages for fusion across the lumbosacral junction.

References