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SYMPOSIUM: DISRUPTIONS OF THE PELVIC RING: AN UPDATE

Is Application of an Internal Anterior Pelvic Fixator Anatomically Feasible?

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Abstract

Background Spinal hardware has been adapted for fixation in the setting of anterior pelvic injury. This anterior subcutaneous pelvic fixator consists of pedicle screws placed in the supraacetabular region connected by a contoured connecting rod placed subcutaneously and above the abdominal muscle fascia.

Questions/purposes We examined the placement of the components for anterior subcutaneous pelvic fixator relative to key vascular, urologic, bony, and surface structures.

Methods We measured the CT scans of 13 patients after placement of the pelvic fixator to determine the shortest distances between the fixator components and important anatomic structures: the femoral vascular bundle, the urinary bladder, the cranial margin of the hip, the screw insertion point on the bony pelvis, the relationship between the pedicle screw and the corridor of bone in which it resided, and the position relative to the skin.

Results The average distance from the vascular bundle to the pedicle screw was 4.1 cm and 2.2 cm to the connecting rod. The average distance from the connecting rod to the anterior edge of the bladder was 2.6 cm. The average distance from the screw insertion point to the hip was 2.4 cm; none penetrated the hip. The average screw was in bone for 5.9 cm. The pedicle screws were on average 2.1 cm under the skin. The average distance from the anterior skin to the connecting rod was 2.7 cm.

Conclusions Components of this anterior pelvic fixator are close to important anatomic structures. Careful adherence to the surgical technique should minimize potential risk.

Level of Evidence Level IV, retrospective study. See Guidelines for Authors for a complete description of levels of evidence.

Introduction

Fractures of the pelvic ring frequently involve disruption of the anterior and posterior bony and/or ligamentous structures. Restoration of posterior pelvic stability is typically achieved with the use of either iliosacral screws or plates and screws [13, 17]. Anterior fixation is often used in conjunction with posterior fixation and has traditionally been performed with either plates and screws or anterior external fixation [13, 17]. The most common indications for adjunctive definitive external fixation are situations in which internal fixation with a plate and screws is believed to be disadvantageous such as in the presence of urological injuries, vertically stable lateral compression fractures, multiple comminuted rami fractures, and open pelvic fractures [1, 6, 8, 11]. Anterior external fixation of the pelvis is associated with pin site infection rates ranging

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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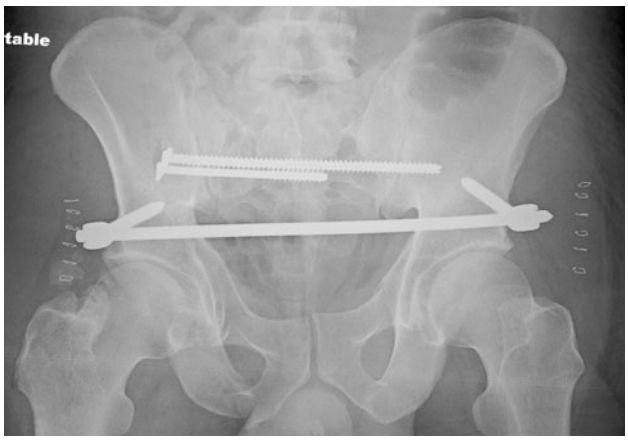

Fig. 1 Immediate postoperative AP of the pelvis with an internal anterior fixator in place for treatment of bilateral pubic rami fractures associated with a pelvic ring injury is shown.

from 2% to 40% with a mean of 18% [9, 19] and can limit access to the abdomen as well as patient mobility [9, 10, 19]. A recently described novel approach to create an anterior subcutaneous pelvic fixator from standard spinal hardware components [3, 7, 20] may avoid some of the complications associated with anterior external fixation. This internal fixator is comprised of two multiaxial pedicle screws such as used in spinal surgery and a contoured, subcutaneous connecting rod (Fig. 1).

Although the technique for placement of the internal anterior fixator has been described, the anatomic relationships of the screws and rod to the vital structures of the pelvis have not been quantified. Two studies have examined the anatomic location of supraacetabular external fixation pins [4, 16] but the internal anterior fixator has an internal rod that connects the supraacetabular region, and the proximity of this bar relative to critical structures is not known.

We therefore quantified the relationship of the components of the internal anterior fixator to the vascular, urologic, and bony structures as well as the skin in and around the fixator.

Materials and Methods

We reviewed our institutional trauma database and identified 18 patients with pelvic ring disruptions treated with an internal anterior fixator. The patient records were then reviewed to identify patients who had received a postoperative CT scan. Three patients did not have a postoperative CT scan, one patient's CT scan was of poor quality such that measurements could not be performed, and one patient was treated for a pelvic malunion/nonunion and the pelvic anatomy was distorted. The remaining 13 patients' CT scans were used to measure the minimum distance between the structure of interest and the components of the internal anterior fixator. Minimum followup was 5 weeks (average, 29 weeks; range, 5–76 weeks), and no patients were lost to followup. We obtained Institutional Review Board approval for this study.

The surgical technique was initially described by Vaidya et al. [20] and later described by Kuttner et al. [7] and Gardner et al. [3] and involves the placement of multiaxial spine pedicle screws into the supraacetabular bone through vertically oriented incisions that are targeted with fluoroscopy. Obturator outlet views are used to localize the bone tunnel for screw placement, and the screw is confirmed to be intraosseous and extraarticular with obturator inlet and iliac oblique views. The screw is advanced until the head is lying just above the fascia of the rectus femoris. The pedicle screws are typically between 6.5 mm and 8.5 mm in diameter and between 60 mm and 80 mm in length, and they are then connected by a contoured rod placed in the subcutaneous tissue anterior to the abdominal fascia. One modification made to this technique by our group is the use of a bullet-nosed vascular tunneler to make a subcutaneous path for the connecting rod. Once the desired reduction is obtained, the rod is connected to the pedicle screw, providing stability to the anterior pelvis.

One of us who was not a treating surgeon (DJM) measured all distances using multiplanar reformatting through our institution's picture archiving and communications system (PACS) software (Clinical Desktop, St Louis, MO, USA) (Fig. 2A–B) to the nearest 0.01 cm. We measured the minimum distances from the pedicle screw and connecting rod components of the internal anterior fixator to the external iliac vascular bundles and the bladder as well as the minimum distance from the pedicle screw head and the connecting bar to the skin. We also measured the location of the screw relative to the hip, the length of the screw that was contained within bone as well as the potential maximum total length of the corridor in which the screw resided. The bone corridor was defined as the length from the starting point of the screw to the point where the screw would exit bone along the axis of the screw. Finally, we measured the maximum length from the screw insertion point on the anterior pelvis to the posterior ilium, which we believed would represent the maximum length of a potential screw.

Postoperative hospital and clinic visits were used to monitor for signs of infection, vascular compromise, and other complications. Patients were seen first at 2 weeks for a wound evaluation and suture removal and subsequently at 6, 12, 24, and 52 weeks. At each visit beginning at 6 weeks postoperatively, a three-view pelvis series (AP, inlet, outlet) was obtained. At all visits, a thorough neurological examination, focusing particularly on the lateral femoral cutaneous and femoral nerves, was performed along with a

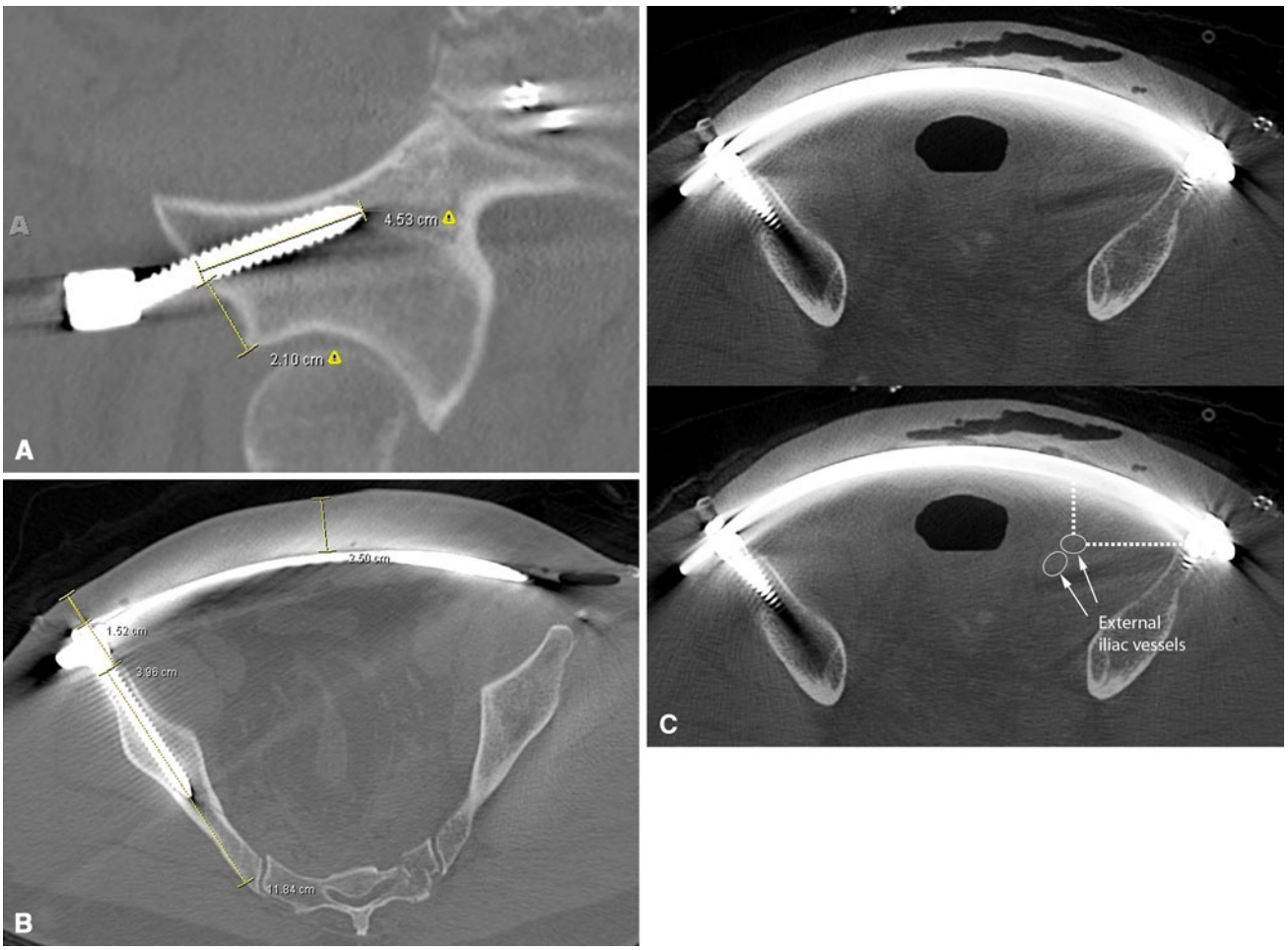

Fig. 2A–C (**A**) A CT slice tangential to the pedicle screw demonstrates the measurements for screw length and distance from the hip. (**B**) The distance from the skin to the tip of the pedicle screw, the tip of the pedicle screw to the bone, the maximal potential length of the screw in the bone, and the distance from the skin to the anterior aspect of the connecting bar are shown. (**C**) The distance from the connecting rod and pedicle screw to the external iliac bundle is demonstrated.

vascular examination of the lower extremities. Additionally, physical examination focused on pelvic stability to manual compression and palpation and local irritation of the implant.

Results

The external iliac vessels were 4.1 cm (range, 1.5–5.5 cm; SD = 1.0 cm) medial to the pedicle screw and 2.2 cm (range, 1.0–5.0 cm; SD = 1.0 cm) posterior to the connecting rod (Table 1). The connecting rod was located an average of 2.6 cm (range, 0.8–4.3 cm; SD = 1.1 cm) anterior to the anterior wall of the urinary bladder.

The screws in this series ranged 6.5 to 8.5 mm in diameter and were between 60 and 80 mm in length. The average distance from the screw insertion point to the hip was 2.4 cm (range, 1.4–3.5 cm; SD = 0.5 cm). Only one of 26 (3.8%) screws was not fully contained in bone. This screw had a lateral to medial trajectory with the screw exiting the inner table of the pelvis. No screws penetrated the hip. The average length of the bone corridor along the trajectory of the screw

Table 1. Mean, standard deviation, maximum, and minimum measured distances

Distance of interest	Mean (cm)	SD (cm)	Longest distance (cm)	Shortest distance (cm)
Bar-vessels	2.2	1.0	5.0	1.0
Screw-vessels	4.1	1.0	5.6	1.5
Bar-bladder	2.6	1.1	4.3	0.8
Screw in bone	5.9	1.5	8.5	2.2
Screw out bone	1.8	1.4	3.2	0.3
Bone corridor	10.7	3.2	15.5	2.2
Screw to hip	2.4	0.5	3.5	1.4
Skin to screw head	2.1	1.0	3.9	0.4
Bone-skin	5.3	1.8	9.4	2.1
Anterior skin-bar	2.7	1.4	4.7	0.7

was 10.7 cm (range, 2.2–15.5 cm; SD = 3.2 cm). The average screw was in bone for 5.9 cm (range, 2.2–8.5 cm; SD = 1.5 cm) and was out of bone for 1.9 cm (range, 0.3–5.3 cm; SD = 1.4 cm). The average length of the corridor in which a maximum length screw would reside was 14.1 cm (range, 13.0–16.1 cm; SD = 0.9 cm).

The screws were, on average, 2.1 cm (range, 0.4–3.9 cm; SD = 1.0 cm) under the skin overlying the anteroinferior iliac spine. The average distance from the anterior skin to the anterior aspect of the connecting rod was 2.7 cm (range, 0.75.8 cm; SD = 1.4 cm). The starting point for the screw on the pelvis was 5.3 cm (range, 2.1–9.4 cm; SD = 1.8 cm) beneath the skin.

Despite the range of screw lengths that were in bone, and their proximities to the hip, we identified no patients with clinically apparent loosening or septic hip arthritis. No patient had evidence of vascular compromise or compression of the vascular bundle. One patient had superficial wound breakdown without infection that was successfully treated with irrigation and débridement at the time of fixator removal. This patient's screw heads were located 2.3 cm and 1.5 cm below the skin. The wound breakdown resolved with fixator removal, irrigation, and débridement approximately 9 months after implantation.

Discussion

Pelvic ring disruptions often involve the anterior and posterior portions of the pelvis. A recent technique describes the use of spinal pedicle screws and a contoured connecting rod to restore and maintain anterior alignment and reduction of anterior pelvic injuries. Our objective was to determine the relationship of the components of the internal anterior fixator to multiple structures that were at risk for injury during placement, including the external iliac vascular bundle, the bladder, the hip capsule, and the skin.

We acknowledge limitations to our study. We had a small number of patients, which may limit our ability to identify rare complications or implications of anatomic variations. This is a relatively new technique with a limited number of patients available for study, limiting our sample size. Second, we measured distances only on CT scans rather on cadavers. We believe the use of postoperative CT scans for obtaining our measurements provided a more realistic representation of how the anatomy relates to the internal anterior fixator in a real-world application. The use of CT scans, however, precluded the measurements of other potential structures of interest, particularly the lateral femoral cutaneous and femoral nerves: they were too small to be accurately seen on CT scans. The location of the femoral nerve was approximately 10 mm lateral to the femoral artery by Haidukewych et al. [4]. By inference, the femoral nerve should lie approximately 3 cm medial to the pedicle screw, rendering it safe. The lateral femoral cutaneous nerve is a structure at risk, both from clinical experience and from anatomic examination [3, 4, 9]. Adherence to the previously described technique for application can minimize the risk of damage. A single surgeon performed all measurements, which may lead to bias; however, this was chosen as a result of the complexity of the multiplanar CT adjustments needed to obtain the measurements. Several studies using CT-based measurements document close agreement with physical measurement [2, 5]. These patients were all treated by experienced trauma surgeons, which may limit the generalization of these results. Finally, this technique involves the surgeon hand-contouring the connecting rod, and variability of this contour can change the proximity to the previously mentioned structures.

We found, on average, the pedicle screws were located 4.1 cm lateral to the vascular bundle, and the connecting bar was located 2.2 cm anterior to the vascular bundle. The range of values indicates the closest patient had the pedicle screw located within 1.5 cm of the vascular bundle and the rod within 1.0 cm. Haidukewych et al. [4] measured the location of Schanz pins used for supraacetabular external fixation frames relative to the femoral neurovascular bundle and found the pins were an average of 4.5 cm from the femoral artery with the closest pin located 4.0 cm from it. Our average value is similar; it is not clear why the discrepancy for the closest value exists. Our technique used CT scans and the shortest distance from the pedicle screw to the vascular bundle was recorded. No patient demonstrated evidence of mechanical compression of the vascular bundle or vascular injury.

The mean distance between the connecting bar and the bladder was 2.6 cm. A critical aspect of the surgical technique is to tunnel the connecting rod in the subcutaneous space, staying anterior to the abdominal wall, protecting the bladder from iatrogenic puncture [14, 18]. This technique also minimizes the risk of damaging the external iliac vascular bundle. Another critical technical aspect is the contour of the connecting rod. Placing a straight rod between the pedicle screws would place the majority of the rod in an intrapelvic location, placing the external iliac vessels and the bladder at high risk for injury. Contouring the rod with an anterior curvature increases the distance between the vessels and the rod and allows for extraabdominal placement.

The entry point for the screws was 2.4 cm from the superior rim of the acetabulum. Haidukewych et al. [4] previously noted the hip capsule extends, on average, 16 mm above the joint, and supraacetabular external fixation pins should be placed at least 2 cm away from the superior rim of the acetabulum to prevent joint capsule

penetration and the potential development of septic arthritis. In our series, the entry point for the pedicle screws ranged from 1.4 cm to 3.5 cm; seven of 26 pins were within 2 cm of the hip, but no patients developed joint infection. We believe placement of the implants in a subcutaneous position decreases the risk of infection despite the potential for capsular penetration. Solomon et al. [16] also noted the variability of the hip capsule thickness and its proximal extension allows for penetration of the capsule without necessarily penetrating the hip [16].

The screws used in this series were 6.5 to 8.5 mm in diameter and were 60 to 90 mm in length and were within bone for an average distance of 5.9 cm. Maximizing the length of the screws in this application may not be critical, perhaps as a result of the large diameter of the screw, the density of the supraacetabular bone, or the limited loads placed across the fixator itself when combined with posterior pelvic fixation.

In our series, one patient developed superficial wound breakdown. The incisions over the screw heads both demonstrated serous drainage that resolved with irrigation, débridement, and hardware removal approximately 9 months after implantation. The screw heads are typically located in the lower abdominal crease, which can make the screw heads relatively superficial. Although the components of the internal anterior fixator are similar to those used in triangular osteosynthesis [12, 15], the anterior location and more recessed location of the pedicle screws are the likely explanation for the decreased implant-related complication rate compared with that procedure.

In conclusion, we quantified the location of several critical pelvic anatomic structures with respect to a novel pelvic internal fixator using measurements made from postoperative CT scans. The components of the internal anterior fixator, when placed using the previously described standard technique, are in close proximity to critical soft tissue structures, and careful adherence to the surgical technique should be used.

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