Case Report
Treatment of unstable pelvic ring injuries with an internal anterior fixator: initial clinical series

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Abstract: Objective: To investigate the clinical effectiveness of minimally invasive subcutaneous pedicle screw and rod system in treatment of anterior pelvic ring injury. Methods: Altogether, 28 patients (17 men, 11 women; average age 39.8 years, range 19-68 years) with pelvic ring fractures were treated using a subcutaneous internal anterior fixation device composed of supra-acetabular spinal pedicle screws and a subcutaneous connecting rod (INFIX). Causes of injuries were traffic accidents (n=15), falling from a height (n=7), and crushing (n=6). The injuries were rated according to Young-Burgess and AO/OTA classifications: APCII or 61-B1 (n=3), LCI or 61-B2.1 (n=8), LCII or 61-B2.2/61-B2.3 (n=11), VS or 61-C1/61-C2 (n=6). Two pedicle screws were inserted bilaterally at the mid-ilia. The precontoured rod was tunnelled subcutaneously from one screw to the other. The caps of the pedicle screws were then tightened. For stable posterior ring fractures, only the anterior pelvic ring was stabilized with the device. For unstable posterior ring fractures, posterior injuries were addressed first, followed by anterior injuries. Results: Follow-up was 6-12 months (average 8.7 months). All patients tolerated the device well. All fractures healed within 3 months, without loss of reduction. There were no surgical-site infections and no loosening of the internal fixation. Femoral cutaneous nerve injuries were bilateral in seven patients and unilateral in five. All recovered within 3 months postoperatively. Conclusions: Advantages of this technique include its minimally invasive nature, stable fixation, and acceptable complications. It is an ideal method for stabilizing anterior pelvic ring fractures.

Keywords: Pelvis, fracture fixation, internal, surgical procedure, minimally invasive

Introduction
Unstable pelvic ring injuries are usually associated with high energy trauma. The incidence of pelvic ring injuries in trauma patients is reported to vary from 3% to 8% [1]. The treatment of unstable pelvic ring injuries has remained a major challenge in modern orthopaedic reconstructive surgery, especially in patients with multiple injuries. Treatment of unstable pelvic fractures often requires fixation of both anterior and posterior pelvic rings simultaneously. Most often, Surgical options for the fixation of anterior pelvic ring such as external fixation and open reduction with internal fixation have been advocated while the posterior pelvic lesion has been fixed [2, 3].

The external fixator is the most commonly used treatment for surgical stabilization of the anterior pelvic ring in emergency situations [3]. The anterior pelvic external fixator can be used quickly and easily to stabilize disrupted pelvic ring. The external fixator is now common for temporary and initial stabilization and also for definitive treatment in combination with posterior fixation depending on the pelvic injury pattern [4]. Riemer [5] showed that external fixation of the pelvis and early mobilisation of the patient reduced mortality from 43% to 6%. Unfortunately, many of clinical complications associated with the external fixator include pin tract infection with possible abscess formation and osteomyelitis, loss of reduction, aseptic loosening, impingement, and nerve damage [3]. And the anterior pelvic external fixator limits patient limitation of activities of daily living, such as sitting, lateral decubitus, lying prone and walking. Patients usually complain of significant discomfort.
Open reduction and internal fixation with a plate may also be used for parasymphyseal or rami fractures. Plate fixation of the anterior pelvic ring can provide a stable outcome, but there may be great surgical trauma which include blood loss and soft tissue complications. So, to improve patients comfort and minimize the complications and invasive surgery, we applied a novel technique termed the anterior subcutaneous internal fixator (INFIX) which consisted of single supra-acetabular pedicle screw placed on either side and a subcutaneous rod connected the screws to treat the anterior pelvic ring injuries in our center from July 2013 to June 2015 [6, 7].

Patients and methods

A total of 28 patients (17 men, 11 women; average age 39.8 years, range 19-68 years) were enrolled in this study. Traffic accidents (n=15), falls (n=7), and crushing (n=6) were responsible for the injuries. At admission, all of the patients underwent anteroposterior (AP) and inlet and outlet plain radiography of the pelvis as well as computed tomography with three-dimensional (3D CT) reconstruction. The injuries were rated according to the Young-Burgess classification and the AO Foundation and Orthopaedic Trauma Association (OTA/AO) classification [8, 9] as follows: APCII (or OTA 61-B1), n=3; LCI (or OTA 61-B2.1), n=8; LCII (or OTA 61-B2.2/
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61-B2.3), n=11; and VS (or 61-C1/61-C2), n=6, respectively. Eight patients (four extremities) also had fractures in other locations. Another four patients had thoracolumbar spine fractures as well. Two patients also had urethral disruption, for which suprapubic cystostomy was performed on the day of admission (Table 1). The mean interval from injury to surgery was 6.3 days (range 1-36 days).

Surgical methods

Surgery was performed under continuous epidural anesthesia. The patient was positioned supine on a fluoroscopy-equipped operating table. A 3-cm longitudinal incision was made between the region of the anterosuperior and inferior iliac spine. For 15 patients who were still in the early stages of this study, the lateral femoral cutaneous nerve was routinely dissociated and then protected during dissection. In contrast, in 13 patients with conditions in later stages, this nerve was not dissociated. After the medial iliac periosteum was stripped, a port was created using a spreader between the anterosuperior and inferior iliac spine under fluoroscopic guidance. A pedicle screw (6.5-mm-diameter, 50-mm-long) was introduced along the inner and outer iliac plates. The operation was then performed on the contralateral side using the same method. A subcutaneous tunnel was made from one iliac crest incision to the other side between the fatty layer and the deep fascia layer using long, oval forceps to achieve the subcutaneous connection between the bilateral iliac crests. A pre-bent connection rod was placed via the subcutaneous tunnel into the U-shaped grooves at the ends of the bilateral pedicle screws. For a lateral compression (LC) fracture, the end cap of the screw at one side was locked first. Then, the end cap at the other side was locked in a state of distraction to allow reduction of the overlapped pubic rami. For anteroposterior compression (APC) fractures, the end cap of the second pedicle screw should be locked under pressure to allow fracture reduction. The ends of the screws should be slightly above, or close to, the sartorius muscle but slightly below the anterosuperior iliac spine to avoid their irritating the skin or compressing the iliac vessels, the bladder, or the spermatic cord underneath them. If the separation of the pubic symphysis was >2.5 cm, a 3-cm transverse incision was made above the pubic symphysis before this operation. After reducing the pubic symphysis, it was fixed using two screws and wire (or plate). The instruments necessary (Wego, Shangdong, China) for INFIX and internal fixation are shown in Figure 1.

For APCII, LCI, and LCII (partial) fractures, fixation of the anterior pelvic ring with INFIX alone is sufficient because the posterior ring is relatively stable. For LCII (partial), LCIII, APCIII, or VS fractures, the posterior ring should be fixed first, followed by fixation of the anterior ring. During the surgery, the location of the screw-rod system should be identified by fluoroscopy to prevent the screw from entering the acetabulum.

Postoperative rehabilitation and follow-up

After the surgery, all patients started flexion and extension exercises of the affected limbs while still in bed. Before fracture healing, the affected limb could only partially bear weight (up to 20 kg). After the fracture healed (10-12 weeks after surgery), the patients could undertake complete weight bearing. The patients underwent radiographic examinations on a monthly basis until the fracture healed. During follow-up, the patients were asked about their tolerance to INFIX (had the surgery affected their ability to sit comfortably, was there lateral decubitus comfort, could they lie prone, walk, squat) or had the screw end and connection rod irritated the skin and thus caused discom-
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Statistical analysis

The statistical analysis was performed using SPSS 17.0 software. Chi-squared test was used to analyse the lateral femoral cutaneous nerve injury between dissociation group and non-dissociation group. Significance level was set at $P<0.05$.

Results

The time consumed for fixation of the anterior ring ranged from 18 to 35 min (mean 24 min). The intraoperative blood loss was 5-30 ml (mean 15 ml). Patients were followed up for 6-12 months (mean 8.7 months). In one patient with an LCII fracture, the anterior ring was not adequately dilated, and the overlapped pubic rami were not completely reduced. In a patient with an APCII fracture (separation of the symphys pubis and fracture of the right pubic ramus), the patient was transferred to our department 1 month after the injury because of bladder rupture and a urinary tract infection. After the surgery, the pubic ramus was not completely reduced. Another patient with a VS fracture visited our department 3 weeks after the injury. Following the surgery, the sacroiliac joint was not fully reduced, with 1-cm upward dislocation. Three months later, the fractures were healed in all patients without any loss of reduction.

All of the patients tolerated the treatment well. Sitting, lateral decubitus, being prone, walking, and squatting were good after surgery. The patients could palpate the subcutaneous connection rod and the end cap of the screw but without discomfort. No patient developed a wound infection, loosening of the internal fixator, or heterotopic ossification. Other possible unfavourable outcomes (e.g., wound infection, ossifying myositis, loosening of the internal fixator, injury of the lateral femoral cutaneous nerve) were also recorded.

Table 2. Lateral femoral cutaneous nerve injury: dissociation group vs. non-dissociation group

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of injured nerves</th>
<th>Number of non-injured nerves</th>
<th>$\chi^2$</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissociation</td>
<td>10</td>
<td>20</td>
<td>0.0102</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Non-dissociation</td>
<td>9</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
<td>37</td>
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</table>

The lateral femoral cutaneous nerve was injured bilaterally in seven patients and unilaterally in five. The injury mainly manifested as anterolateral thigh numbness on the injured side. The symptoms disappeared within 3 months after surgery. The $\chi^2$ test showed that there was no statistical difference between the dissociation and non-dissociation groups ($P>0.05$) when the lateral femoral cutaneous nerve was injured (Table 2). The internal fixator was removed within 6 months after surgery in 12 cases. None of the removal procedures was due to discomfort. Typical cases are shown in Figures 2A-E and 3A-E.

Discussion

Advantages and disadvantages of previously described fixation methods for anterior pelvic ring fracture

Treatment of unstable pelvic fractures often requires fixation of both anterior and posterior pelvic rings. The posterior ring is frequently fixed with sacroiliac screws, plates, or sacral rods, whereas the anterior ring is often fixed with plates, percutaneous iliosacral screws, or external fixation. If only the anterior ring requires fixation, the external fixator can be used for the final fixation.

The external fixator is a simple, effective tool for anterior ring fixation and has been widely applied. It is associated with many complications, however, that may affect the patients' daily activities (e.g., sitting up, rolling over, standing), which further increases the difficulty of nursing the patient. In patients with accompanying spinal fractures, subsequent surgery will be needed, which makes treatment even more difficult. It has been reported that the pin track infection rates after application of a pelvic external fixator ranges from 2.5% to 50.0% [1, 10], whereas the incidence of aseptic loosening ranges from 0% to 19% [11, 12]. In patients with unstable pelvic rotation, loss of reduction occurs in 0%-33% after application of a pelvic external fixator alone [13-15]. In patients with vertical instability, loss of reduction was 95% after application of a pelvic external fixator alone [3, 15]. The concurrent appli-
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Figure 2. A 52-year-old man with an anteroposterior compression fracture (i.e., APCII, 61-B1 type) (separation of symphysis pubis and fracture of the right pubic ramus) after a car accident. The patient was transferred to our department 1 month after the injury because of bladder rupture. A. Preoperative radiograph. B. Preoperative three-dimensional imaging. C. Postoperative radiograph. D. Postoperative skin incision. E. Radiograph following removal of the internal fixator 7 months after surgery.

Figure 3. A 45-year-old man with a VS pelvic fracture (i.e., 61-C2 type) accompanied by a left femoral shaft fracture after falling from a height. He was transferred to our department 3 weeks after the injury. A. Preoperative three-dimensional imaging. B. Computed tomography shows “whirl-like” fractures. C. Postoperative radiograph. D. The incision is well healed. E. Bone healing was achieved 3 months after the surgery. The internal fixator was removed during the 6th postoperative month.
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cation of posterior ring fixation decreased the loss of reduction rate to 0%-8% [1, 12, 14].

Plates achieve the best stability for fixation of an anterior pelvic ring, but this method is often accompanied with greater surgical trauma. In recent years, plate fixation for anterior pelvic ring fracture is often performed using the Stoppa incision, which enables fixation of bilateral pubic rami with a single incision. Recent literature suggests, however, that for unilateral anterior column fractures the conventional ilioinguinal incision shows no significant difference from the Stoppa incision in terms of intraoperative blood loss and postoperative function [16]. The “pelvic bridge” technique, which fixes the anterior ring by connecting the anterosuperior iliac spine and pubic symphysis via a subcutaneous plate, proposed by Hiesterman [17], could decrease surgical trauma. This method has shown good effectiveness in fixing the unilateral anterior ring. For bilateral pubic rami fractures, however, two plates must be fixed at the pubic symphysis in an overlapping manner, which is particularly difficult to perform. Furthermore, this method does not exert pressure on or dilate the anterior ring, and removing the plate(s) is extremely difficult after soft tissue grows into the empty screw holes.

Features of the anterior subcutaneous internal fixator

In light of the fact that the pedicle screw-rod system could be used to treat the posterior ring fracrure, Kuttner [6] used the same device to perform fixation of the anterior pelvic ring in 19 patients with unstable pelvic fractures and achieved good effectiveness. The authors named it the anterior subcutaneous pelvic internal fixator. In 2011, Vaidya [7] applied the same method and successfully treated 24 patients with unstable pelvic fractures. They named the technique INFIX. This method avoids common complications (e.g., pin tract infection, aseptic loosening) associated with the external fixator. More importantly, it makes nursing easier and the patients more comfortable. In our series, follow-up showed that the INFIX system had no impact on patients’ sitting, lateral decubitus, lying prone, or standing. The patients could palpate the end cap and connection rod but usually were not aware of their presence. There was no request to remove the system because of discomfort.

The INFIX system is particularly useful in obese patients [7]. Abdominal distension often exists in these patients. Thus, the distance between the connection rod of the external fixator and the pelvis must be increased (up to 15 cm) to avoid any effect on respiration by abdominal compression, which would decrease the stability of the external fixator [1]. According to Vaidya [11, 18], the ideal location of the connection rod of the INFIX system would be in the “bikini region” which was formed by the two inguinal creases and the symphysis pubis and superiorly by a fold of the abdominal tissue. This area is relatively stable when standing or sitting with relatively little mobility. When located in this region, the connection rod has less impact on patients’ activities. Mason [1] argued that the INFIX system was preferred in patients with pelvic fractures accompanied by abdominal injury because it would not affect the required abdominal surgery. However, the INFIX system is not feasible for patients with haemodynamic instability because it must be performed under fluoroscopic guidance and is quite time-consuming.

The INFIX system can simultaneously fix bilateral fractures of the pubic rami. In patients with bilateral or unilateral fracture of the pubic rami accompanied by separation of the pubic symphysis, the latter could be fixed with a plate or two screws and wire via a small incision above the pubic symphysis. Then, fixation of bilateral fractures of the pubic rami could be undertaken using the INFIX system. Although the INFIX system can replace plates or external fixators for fixation of a pubic ramus fracture, plate fixation is recommended for patients with obvious separation of the pubic symphysis alone because it would result in less re-separation [6, 7].

Biomechanical properties of the INFIX system

In recent years, some authors have proposed changing the pin site of the external fixator from the iliac crest to the supra-acetabular region, which has higher bone density, thereby increasing the stability of the fixation [14]. Although the pin site is similar to that of the INFIX system, the external fixator has a longer arm of force and thus poorer stability. Vigdorchik [19] created a model pelvis with a simulated anterior posterior compression type III injury. All of the posterior sacroiliac joints were fixed with sacro-
iliac screws, and the anterior rings were fixed with the INFIX system, a supra-acetabular external fixator and plate fixation respectively. Comparison of the stability for these techniques showed that, under the effect of 200 N external force, displacement of the pubic symphysis was 9, 20, and 0.8 mm, respectively, indicating that the stability achieved by the INFIX system was almost twice as stiff as the supra-acetabular external fixator (10.5% vs. 5.6%).

The biomechanical testing performed by Vaidya [20] demonstrated that, with application of the INFIX system, monoaxial pedicle screw system was stronger (360 N) than polyaxial devices (157 N) which failed if distracted greater than 4 cm in failure testing. However, during application of the uniaxial system, the rotation angles of the screws must be adjusted frequently, and the rod must be bent repeatedly, which can be quite time-consuming. Universal pedicle screws were applied in 15 of our patients, among whom no one experienced loss of reduction, suggesting that the strength of the universal pedicle screws was sufficient.

The main disadvantage of the INFIX technique is its relatively high incidence of the injury to the lateral femoral cutaneous nerve, mainly manifesting as anterolateral thigh numbness on the injured side. Among the 26 patients in our series, 15 routinely underwent dissociation of the lateral femoral cutaneous nerve during the surgery (dissociation group). Among them, six had an injured lateral femoral cutaneous nerve on 10 sides (33.3%). Later, as we became more familiar with the surgical operation and anatomical structures (further along the learning curve), we did not perform dissociation of the lateral femoral cutaneous nerve during the surgery in 13 patients (non-dissociation group), among whom six patients developed injury of the lateral femoral cutaneous nerve on nine sides (34.6%). These injuries, however, resolved spontaneously within 3 months after surgery in all of the patients. The χ² test showed that there was no statistical difference between the dissociation and non-dissociation groups. Thus, dissociation of the lateral femoral cutaneous nerve during the surgery did not decrease the injury rate. In addition, Vaidya [11] reported that temporary irritation of the lateral femoral cutaneous nerve was observed in 30% of patients being transient, and permanent injury occurred in only one patient. Thus, they did not mentioned whether or not dissociation of this nerve during the operation. Finally, extra care needs to be taken not to injure the lateral femoral cutaneous nerve when removing the internal fixators.

In summary, the INFIX system provides a novel, minimally invasive, internal fixation method for fractures of the anterior pelvic ring. It involves little surgical trauma and thus has less impact on patients’ daily activities, especially obese patients. The INFIX system can be applied separately in patients with a stable posterior ring. In those with an unstable posterior ring, however, the posterior ring should be fixed first, followed by fixation of the anterior ring with the INFIX system.

Disclosure of conflict of interest
None.

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