Archives of Orthopaedic and Trauma Surgery (2019) 139:489–496
https://doi.org/10.1007/s00402-018-3094-7

TRAUMA SURGERY

Minimally invasive internal fixator for unstable pelvic ring injuries with a pedicle screw–rod system: a retrospective study of 23 patients after 13.5 months

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Received: 30 May 2018 / Published online: 8 December 2018

Abstract

Purpose Pelvic ring fractures are challenging injuries and require effective treatment due to the frequently compromised patient condition. The aim of this study was to evaluate the outcome of unstable pelvic ring injuries treated with a minimally invasive pedicle screw–rod system.

Methods Retrospective analysis was performed for patients with an unstable pelvic ring injury that were treated with a minimally invasive anterior internal pelvic fixator (INFIX) with or without a posterior pedicle screw–rod fixator (6/2012–4/2015). The quality of reduction was evaluated by the Tornetta and Matta criteria and the clinical outcome was evaluated by the Majeed scores. Further evaluation included the operation time, intraoperative blood loss, and complication rate.

Results A total of 23 patients (12 males and 11 females) with a mean age of 37.6 years (range 10–65 years) and a follow-up of 13.5 months (6–27 months) were evaluated. The Tile classification showed 13 type B (B1 = 6, B2 = 4, and B3 = 3) and 10 type C (C1 = 7 and C2 = 3) fractures. Mean operation time and intraoperative blood loss were 24.8 min (20–30 min) and 20.4 ml (16–29 ml) for an anterior INFIX ($n = 13$), and 60 min (45–70 min) and 150 ml (115–168 ml) when combined with a posterior pedicle screw–rod fixator ($n = 10$). Quality of reduction was excellent in 13, good in 6, and fair in 4 patients, with no signs of heterotopic ossification. Clinical results after 6 months were excellent in 14 patients, good in 6, fair in 2, and poor in 1. Unilateral thigh paresthesia was seen in 2 patients which resolved after implant removal.

Conclusions The INFIX appears to be a safe and minimally invasive surgical technique which can effectively be combined with posterior pedicle screw–rod fixation. It also can be applied for the definitive treatment of vertically and/or rotationally unstable pelvic ring injuries, especially in severely compromised patients with a high mortality risk.

Keywords INFIX · Pelvic ring injury · Internal fixator · Minimally invasive · Pedicle screw–rod

Introduction

The use of anterior pelvic external fixation (EXFIX) is an established technique for rotationally unstable pelvic ring injuries and can also be combined with a supplementing posterior fixation [1–3]. However, EXFIX is associated with some complications including pin-tract infections, osteomyelitis, aseptic loosening, loss of reduction, restrictions in obese patients, difficulties in nursing care, and mobilization [4–7].

Minimally invasive anterior internal pelvic fixator (INFIX) was developed from spine instrumentation and has recently been introduced to avoid adverse events of an EXFIX. It combines the established biomechanical principles of an EXFIX and involves percutaneous placement of supra-acetabular pedicle screws connected by a spinal instrumentation rod. In vitro studies even postulate a superior stability of the INFIX, which is referred to the shorter lever arm of the construct [8, 9]. Clinical trials reported good results in terms of fracture reduction, patient mobility, functional outcome, and low complication rates [8, 10–13].

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Specific complications of the INFIX included lateral femoral cutaneous nerve irritation (LFCN), heterotopic ossification (HO), and femoral nerve palsy [14–16].

Clinical studies also demonstrated the effective application of an anterior INFIX for unstable posterior pelvic ring injuries when combined with an appropriate posterior fixation device [10, 13]. Different techniques are currently used to restore the stability of posterior pelvic ring injuries, such as fracture and/or sacroiliac disruption, including transiliac sacral rods, anterior sacroiliac joint plates, posterior locking compression plate (LCP), and percutaneous sacroiliac screws [17–20]. In addition, biomechanical studies revealed clear differences regarding the stiffness [21]; the clinical superiority of one surgical technique remains unproven. Nevertheless, it is well known that these techniques go along with a varying risk of complications, including neurovascular injuries or a relatively high surgical trauma [22, 23].

With reference to the good results of the anterior INFIX, minimally invasive pedicle screw–rod fixators have recently also been applied for unstable posterior pelvic ring injuries [15]. This posterior fixator involves a rod and pedicle screw system between the S1 vertebra and the ilium [24] or a transiliac internal fixator (TIFI) [23]. Currently, only a few data are available which evaluate the clinical and radiological outcome of this posterior INFIX technique.

The current study, therefore, evaluated the clinical and radiological outcome of unstable pelvic ring injuries using the INFIX technique in combination with and without posterior pedicle screw–rod fixation.

Methods

The records of our hospital trauma data base were retrospectively screened from June 2012 to April 2015 to identify all consecutive patients treated by the anterior INFIX. The study was approved by the Ethics Committee of our University and conducted in accordance with the Helsinki Declaration of 1975 as revised in 2013.

Inclusion criteria were (1) unstable pelvic ring injuries and (2) treatment with an anterior INFIX in combination with and without posterior pedicle screw–rod fixation and (3) a minimum follow-up of 6 months. Patients were excluded if (1) supra-acetabular fracture impaired the stabilization of screw insertion, (2) preexisting altered skin condition and/or infection at the surgical side, or (3) hernias at the surgical side.

Radiological assessment included pre- and postoperative anteroposterior, inlet and outlet pelvic radiographs. Preoperative assessment also included a pelvic computed tomography (CT) scan with a three-dimensional (3D) reconstruction to fully assess the pelvic ring injuries. The types of pelvic fractures were classified according to Tile [25]. Patient demographics and characteristics are shown in Table 1.

The radiological and clinical outcome was evaluated after a minimum of 6 months following surgery. The records and radiographs of all patients were reviewed, and all complications such as heterotopic ossification, infection, nerve palsy, and paralysis were retrieved. Perioperative blood loss and time to surgery were extracted from the surgical reports.

The fracture reposition and healing was analyzed on the three standard radiographs. The results was graded by the maximal residual displacement measured on the three standard views of pelvic radiographs using the criteria defined by Tornetta and Matta: reduction from 0 to 4 mm was classified excellent, 5 to 10 mm as good, 10 to 20 mm as fair, and more than 20 mm as poor [26].

The functional results were measured using an established scoring system described by Majeed [27], which is based on the clinical findings including pain, work, sitting, sexual intercourse, and standing. The latter is further divided into the usage of walking aids, the gait unaided, and the walking distance. A score from 100 to 85 is classified as excellent, 84 to 70 as good, 69 to 55 as fair, and less than 55 as poor [27].

Preoperative protocol

After admission, patients with unstable vital signs first underwent shock management and first-line treatment of the combined life-threatening injuries. Until definitive surgical fixation of the pelvis was possible, patients with a Tile B-type fracture were treated with a pelvic belt suspension traction to stabilize the pelvis and reduce the bleeding. Patients with C-type fractures were treated with a pelvic belt suspension traction and skeletal traction through the femoral condyle.

Surgical technique

Pelvic fractures classified as rotationally unstable and graded as Tile B type were solely treated with the anterior INFIX. A 2–3 cm longitudinal incision is made centered over the anterior inferior iliac spine (AIIS). Blunt dissection is performed to protect the lateral femoral cutaneous nerve (LFCN), which often crosses the surgical field. The interval between the tensor fascia lata muscles and sartorius is identified to gain access to the AIIS. The starting point for the pedicle awl is chosen just proximal to the insertion of the rectus femoris tendon to open the cortex. A pedicle finder was used to identify the bony corridor between the inner and outer cortices of the ilium, as the approach introduced by Vaidya et al. [8]. A polyaxial pedicle screw [Medontic sofamor (USA)] was inserted in the tunnel (approximately 30° outward and 20° backward tilt) with an appropriate

Table 1 Patient demographics and characteristics [mean (SD)]

Variable	($n=23$)	Range or percent
Socio-demographic		
Age (years)	37.6 ± 11.6	10–65
Gender (women/men)	12/11	52.2/47.8
Ant. INFIX/ant. INFIX and post. fixation	13/10	56.5/ 43.5
Operation time: ant. INFIX (min)	24.8 ± 4.8	20–39
Operation time: ant. INFIX and post. fixation (min)	60 ± 6.4	45–70
Blood loss: ant. INFIX (ml)	20.4 ± 3.4	16–29
Blood loss: ant. INFIX and post. fixation (ml)	150 ± 17.8	102–168
Time from injury to operation (days)	7 ± 2.7	3–13
Hospitalization time (days)	15.1 ± 5.9	6–34
Follow-up in months	13.5 ± 5.6	6–27
Mechanism of injury		
Traffic accidents	15	65.2
Fall from height	3	13
Heavy pound injuries	4	17.4
Crush injuries	1	4.4
Concomitant injuries		
Hemorrhagic shock	6	26.1
Urinary injuries	9	39.1
Chest injuries	2	8.7
Brain injuries	2	8.7
Multiple thoracolumbar	3	13
Multiple extremity fractures	2	8.7
Sacral plexus injury	1	4.4
Lumbar fracture and paraplegia	1	4.4
Other combined fractures	4	17.4
Pelvic fracture type (Tile)		
Type B1	6	26.1
Type B2	4	17.4
Type B3	3	13
Type C1	7	30.5
Type C2	3	13

length. According to the local body habitus, we used screws between 75 and 110 mm in length and 7.5 mm in diameter in this series. Besides, it was ensured that the pedicle screw head was at the level of the sartorius muscle or above the deep fascia to avoid compression on the femoral nerve and inguinal ligament. The procedure was identically performed at the contralateral side.

Then, a 6 mm precontoured titanium rod with an anterior bow was tunneled subcutaneously for connecting the pedicle screw heads. The curve of this rod is estimated by laying it flat on the belly between the two pedicle screws and cut to the appropriate length. Reduction of Tile B pelvic ring injury was achieved by compression or distraction over the rods, and when appropriate, the screw head was locked. The quality of reduction and implant position was finally ensured with intraoperative fluoroscopy in anteroposterior, and inlet and outlet views (Fig. 1).

Pelvic fractures classified as rotationally and vertically unstable which were graded as Tile C type were treated with the anterior INFIX combined with pediculoiliac screw fixation for sacroiliac joint disruptions. First, the patient was placed in the supine position for the reduction of vertical pelvic displacement and the anterior INFIX was performed immediately. Before tightening the rods to the screws, vertical displacement of the posterior ring was gently reduced by manual traction of the screw. Once the reduction was achieved under the C-arm fluoroscopic X-ray, the patient was placed in the prone position. A 6 cm paramedian incision was made at the S1 level for exposing the posterior superior iliac and the S1 facet. A pedicle screw with 6.5 mm in diameter and 4 cm in length was inserted in the ipsilateral S1 pedicle, and an iliac screw with 7.5 mm in diameter and 7 cm in length was inserted between the inner and outer cortices of the ilium aiming from the posterior superior iliac

spine towards the AIIS. A short 6 mm-diameter titanium rod was used for connecting the pedicle screw–iliac screw heads and was cut to the appropriate length (Fig. 2).

In patients with a sacral fracture disrupting the insertion point of the S1 pedicle screw, the transiliac internal fixator (TIFI) was used. For this technique, bilateral 3 cm incisions were made along the posterior superior iliac spine (PSIS). The osseous entry point was located 1 cm cranial to the PSIS at the medial side of the dorsal iliac crest. The pedicle finder was used to create a bony tunnel toward the AIIS. Two iliac screws with 7.5 mm in diameter and 70 mm in length were inserted into the dorsal iliac crest bilaterally. A 6 mm precontoured titanium rod was inserted subfascially to connect the two screws. Before tightening the screw caps, compression or distraction was applied to achieve reduction according to the characteristics of the posterior ring injuries. The quality of reduction and implant position was ensured with intraoperative multiplanar fluoroscopy (Fig. 3).

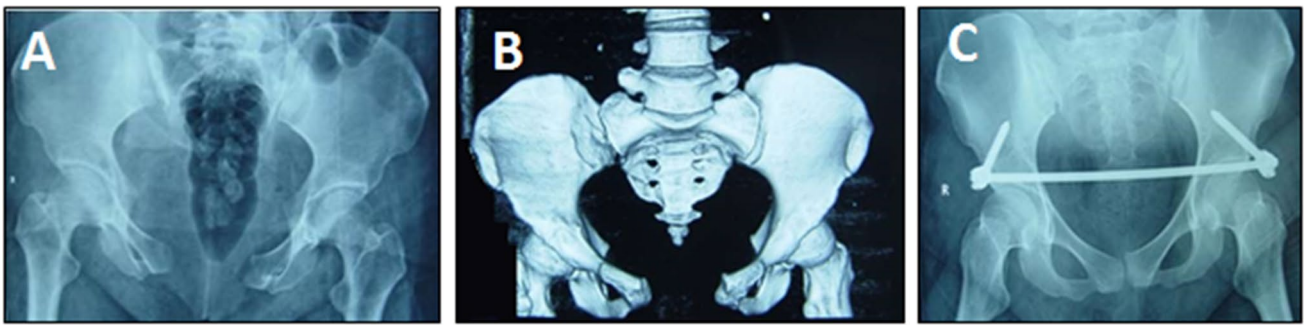

Fig. 1 A 25-year-old female with an injury from a heavy weight. **a** A rotationally unstable (Tile B type) pelvic fracture. **b** 3D computed tomography scans and **c** after stabilization with an anterior INFIX

Fig. 2 A 37-year-old male patient with traffic accident. **a** A vertically and rotationally unstable pelvic fracture with sacroiliac joint dislocation (Tile C type). **b** 3D computed tomography scans and **c** after stabilization with an anterior INFIX in combination with a posterior S1 pediculoiliac screw fixation

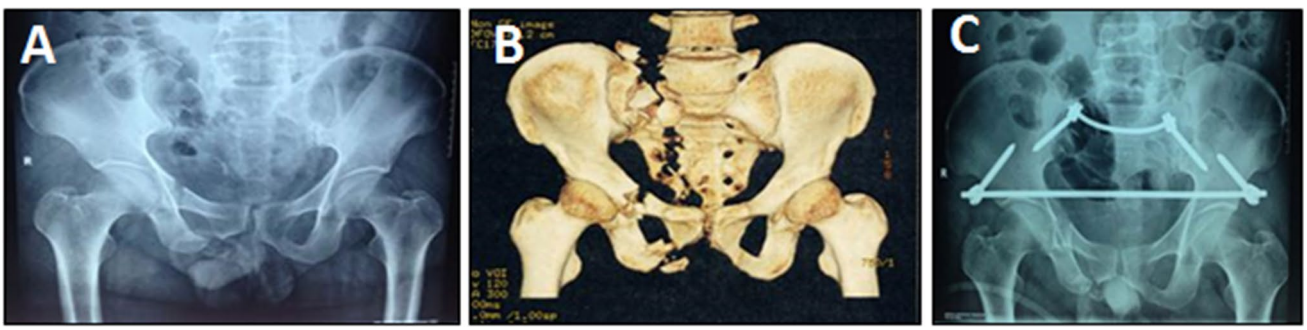

Fig. 3 A 48-year-old male patient with traffic accident. **a** A vertically and rotationally unstable pelvic fracture with sacroiliac joint dislocation (Tile C type). **b** 3D computed tomography scans and **c** after stabilization with an anterior INFIX in combination with a transiliac internal fixator (TIFI)

During the INFIX, we calculate the loss by subtracting the weight of dry swab from the wet swab. For the INFIX and ILF/TIFI, on one hand, we subtracted the weight of dry swab from the wet swab; on the other hand, we subtracted the volume of water from the total volume of the sucker content.

Postoperative protocol

Patients were not received any standardized treatment for preventing the deep vein thrombosis (DVT) or heterotopic ossification. The postoperative rehabilitation protocol was based on the configuration of the pelvic ring injury and operative technique. Directly postoperatively, all patients started functional exercises of the lower limbs in the bed without weight bearing. Patients were permitted to sit with 90° flexion on the bedside after 1 week and to perform functional exercises of the lower limb with no weight bearing until 4–6 weeks postoperatively. Partial weight bearing with crutches was allowed after 4 weeks for patients with solely anterior fixation and after 6 weeks for those with additional posterior fixation.

Patients were allowed to gradually increase weight bearing and walk without crutches after 2 months when the radiographic follow-up was regular. Removal of the device was planned 3 months postoperatively for patients with anterior ring fixation and 6 months for those with anterior and posterior fixation. The clinical and radiological follow-up was scheduled at 4 and 6 weeks as well as 3, 6, and 12 months postoperatively.

Results

The collective comprised 23 patients (12 males and 11 females) with an average age of 37.6 years (range, 10–65); of which 13 patients are manual workers, 5 drivers, 3 students, and 2 retirees. The mean followed up of all patients was 13.5 months (range 6–27 months). According to the Tile classification, there were 13 type B fractures (6 type B1, 4 type B2, and 3 type B3) and 10 type C fractures (7 type C1 and 3 type C2). The socio-demographic data as well as the mechanism of injury and concomitant injuries are given in Table 1.

All the operations were performed by one experienced trauma surgeon (XH). Thirteen patients underwent only anterior pelvic INFIX. Ten patients underwent both anterior and posterior fixation, of which 8 patients used TIFI and 2 patients used ilio-lumbar fixation. The mean operation time and intraoperative blood loss are given in Table 1. Patient placement and turn over from supine to prone position were not included in the operation time.

All patients were able to walk with full weight bearing after 2 months postoperatively except 1 patient with paraplegia and 2 patients with combined lower extremity fractures. The pelvic fractures healed all after the follow-up between 3 and 6 months. None of the included patients died or was lost to follow-up.

According to the method of Tornetta and Matta, the postoperative radiographic results was good or excellent in 82.61% of the patients with 13 showing an excellent, 6 a good, 4 a fair, and 0 a poor reposition result. According to the Majeed scores, the clinical results at 6 months postoperatively were good or excellent in 86.95% of the patients. Excellent results were observed in 14 patients, good in 6 patients, fair in 2 patients (both combined lower extremity fractures), and poor results in 1 patient (combination of lumbar fracture and paraplegia) (Table 2).

From the patients with Type B fractures, 12 of 13 patients were able to return to their pre-injury occupation after 3 months. One patient failed to return to his occupation due to a combined brain injury with mild residual hemiplegia. From the patients with Type C fractures, 8 of 10 patients returned to pre-injury occupation after 6 months. Two patients were not able to return to his occupation, one due to paraplegia requiring a wheelchair and the other due to a sacral plexus injury with residual numbness and one-sided limping of the lower extremity.

Complications in terms of unilateral anterolateral thigh paresthesia were observed in 2 patients due to LFCN compression which, however, resolved after anterior implant removal. Heterotopic ossification, DVT, or deep wound infection was not observed. None of the patients showed loosening or breakage of internal fixation.

Table 2 Function and radiological outcomes

Variable	($n=29$)	Range or percent
Function outcomes (Majeed scores)		
Excellent	13	56.5
Good	6	26.1
Fair	4	17.4
Radiographic grades (Matta grading scores)		
Excellent	14	60.9
Good	6	26.1
Fair	2	8.7
Poor	1	4.3
Complications		
Unilateral anterolateral thigh paresthesia	2	8.7

Discussion

This study evaluated 23 patients with unstable pelvic ring fractures and found good-to-excellent results in more than 80% when minimal invasive treated with an anterior INFIX or combined with pediculoiliac screw fixation or TIFI. The internal fixator was well tolerated by all patients with a low complication rate of LFCN palsy and heterotopic ossification. Besides, the learning curve for the minimally invasive pedicle screw–rod system was short, offering the advantage to compress and distract the fragments at any stage of the operation before the final stabilization.

The radiographic and functional outcomes in this study demonstrated a high rate of excellent and good results according to the Matta criteria (82.6%) and Majeed scores (87.0%). Our results go well along with the good results which have been documented in multiple studies evaluating the minimal invasive INFIX [10, 15, 23]. Wu et al. evaluated, in a retrospective series of 23 patients, a modified pedicle screw–rod fixator with or without posterior fixation by a transiliac internal fixator. After a mean of 15 months, they found an excellent rate or good rate of 87% according to the radiological Matta criteria and 91.3% according to the clinical Majeed scores [15]. Vaidya et al. performed a retrospective series of 83 patients with an INFIX and an additional posterior fixation, and reported an average Majeed score of 78.8 after a mean of 35 months [10]. Bi et al. found excellent clinical results in 83.3% (Majeed scores) in a series of 24 patients with unstable posterior pelvic ring fractures treated with pedicle screw–rod fixator after a mean of 24.5 months [23].

In accordance to other studies, the minimally invasive insertion of the INFIX system revealed a short operation time and low intraoperative blood loss. These findings are confirmed by Wu et al., who reported a mean operation time of 26.6 min and an intraoperative blood loss of 29.1 ml for anterior ring fixation, compared to 24.8 min and 20.4 ml in our study. For a combined anterior and posterior ring fixation, the mean operation was 50.6 min with a blood loss of 56.8 ml compared to 60 min and 150 ml in this study [15]. In a comparative study for unstable posterior pelvic ring injuries, Bi et al. compared the pedicle screw–rod fixator versus a locking compression plate. They reported superior results for the pedicle screw–rod fixator in terms of the mean operation time (22 versus 38 min) and an intraoperative blood loss (43 versus 161 ml) compared to the locking compression plate [23]. However, it must be noticed that the two previous studies used a modified INFIX system with an additional pedicle screw placed at the pubic tubercle into the inferior ramus.

Although our surgical technique is similar to most of the other studies, we found a clearly lower rate of complications regarding LFCN palsy and heterotopic ossification. Hoskins et al. reported a high proportion of LFCN palsy (57.1%) and heterotopic ossification (42.8%) in a series of 21 patients after a mean of 11.4 months [12]. Vaidja et al. described nerve irritations as well as heterotopic ossification in about 30% of the 91 included patients, compared to 9% (2/23 patients) LFCN irritations and no heterotopic ossification in this study [13]. Nevertheless, our results are similar to another study from Vaidja et al., who reported only 8% (2/24 patients) suffering from LFCN irritations [8]. Furthermore, Shetty et al. found similar to us only 1 patient with LFCN irritations and no heterotopic ossification when evaluating 15 patients with unstable pelvic fractures using the INFIX and percutaneous iliosacral screws [1]. The difference might be explained by differing surgical techniques, especially during preparation and/or inserting of the screws and rods [28].

The good clinical and radiological results of the internal pedicle screw–rod system treating unstable pelvic ring injuries are confirmed by the good results of several in vitro biomechanical studies. One biomechanical study compared the stability of the INFIX versus the EXFIX and plate fixation. The data revealed that the INFIX system was twice as stiff as the EXFIX system at the symphysis pubis, while the plate fixation was stiffer than the INFIX [9]. Dienstknecht et al. found no significant differences in the deformation tolerated by the TIFI compared to the iliosacral screws and ventral plate osteosynthesis [29]. Although the current clinical and biomechanical data support the findings of our study, larger and randomized studies comparing the different treatment options are necessary to draw a definite conclusion regarding the superiority of one single technique.

Further limitations of this study should be acknowledged. First, this was a retrospective evaluation of our initial experience using the INFIX for unstable pelvic ring injuries Tile Type B and C. A prospective study design might give further insights in the limitations and complications of this novel technique as well as its specific indications for application, such as the use in severely injured patients. This also accounts for the need to remove the INFIX after fracture consolidation.

Second, the relatively small collective and the short follow-up might limit our conclusion and requires further comparative studies. Third, our postoperative rehabilitation was relatively strict regarding weight bearing due to the novel technique. Further workup in terms of biomechanical stability as well as finite-element analysis is necessary to compare the different fixation methods and also compare the results to the practical applicability in the clinical routine.

Conclusions

Overall, based on the good clinical and radiological outcomes obtained in this and other studies, the INFIX with or without posterior pedicle screw–rod fixator is a minimally invasive and effective surgical technique, and seems to be applicable for definitive treatment of vertically and/or rotationally unstable pelvic ring injuries. This technique allows a good fracture reduction resulting in a good clinical outcome. Further advantages include the low soft-tissue injury, with a reduced blood loss and operation time as well as the facilitated patient care with a low infection rate.

Funding There was no funding source.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The retrospective study was approved by the Ethics Committee of the local University and performed according to the Declaration of Helsinki.

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