Technical Note

Percutaneous screw fixation for the acetabular fracture with quadrilateral plate involved by three-dimensional fluoroscopy navigation: Surgical technique

Zhiyong Ruan, Cong-Feng Luo*, Bing-Fang Zeng, Chang-Qing Zhang

Department of Orthopaedics, Shanghai Sixth People's Hospital, Shanghai Jiao Tong University, School of Medicine, Shanghai 200233, China

Article history:
Accepted 5 August 2011

ABSTRACT

Background: The percutaneous three-dimensional (3D)-fluoroscopic-navigated screw directing to the quadrilateral plate was attempted.

Materials and methods: Five patients with acetabular fractures were treated by 3D navigated percutaneous screw. The quadrilateral plate was involved in all the patients. The Arcadis 3D (ARCADIS Orbit 3D®; Siemens AG Healthcare Sector, Erlangen, Germany) and computer navigation system (styrker navigation system) were employed, screwing trajectory was attempted to anchor the quadrilateral plate perpendicularly to the fracture line and close to the joint cartilage as much as possible. Parameters including fracture gap closure (P1), distance to the joint cartilage (P2), angulations between the screw and the fracture line (P3), were measured with the software installed on the machine of Arcadis 3D.

Result: Seven screws were inserted with the use of 3D fluoroscopic navigation. The quadrilateral plate was hold by percutaneous screws. The closure of fracture gap was achieved in 3 patients by 2–3 mm. The nearest distance from the screw to the joint cartilage was ranged from <1 mm to 6 mm. The angulations between the screw and the fracture line was 80–90° in three patients, it was 60° and 65° respectively on the rest two patients. All patients felt pain free 1 week after the operation. No complication was noted postoperatively.

Conclusion: The surgical technique of percutaneous screwing for the acetabular fracture with three-dimensional fluoroscopy-based navigation was demonstrated.

© 2011 Elsevier Ltd. All rights reserved.

Introduction

Percutaneous screw fixation (PSF) is gaining great popularity in the treatment of pelvic and acetabular fracture due to minimal soft tissue damage.10,16,17,19,20 It is easy to reduce quadrilateral plate but it is difficult to fix it. The screw directed to the quadrilateral plate in a reduced position was a great challenge, which was described as “Magic screw”.21

With the help of the navigation system, the procedure of PSF was simplified and the radiation was reduced remarkably.17,19 Recently the intra-operative three-dimensional (3D) fluoroscopy (Arcadis Orbit 3D) is commercially available in many trauma centres, in which the intra-operative 3D imaging could be transferred to the navigation system simultaneously, that is so-called direct 3D fluoroscopy navigation because the “registration” step has been eliminated.4,5,12,23 We reported on five acetabular fracture patients with percutaneous 3D-fluoroscopic-navigated screw treatment, in which the screws were directing to the quadrilateral plate. This technique was few reported in the English literature.

Patients

Five patients with acetabular fractures were treated by percutaneous 3D navigated screw fixation in our surgical team from September 2008 to March 2009 (Table 1). The patients indicated for 3D navigated screw fixation in our group were those for whom the early non-weight-bearing activity was critically required. The patients were poly-trauma patients and elderly patients, in which the surgery was performed to avoid prolonged bed rest and to achieve a stable fracture in no weight-bearing activities. Two patients were poly-trauma patients with associated injuries. The other patients were elderly patients. Four patients sustained the fracture in a vehicle accident, and the other was caused by a fall. There was no lesion to the sciatic nerve. Three fractures in left acetabulum and two in the right. Three fractures were sagittal in orientation. The other two had coronal fractures through the roof. According to the Letournel classification, there was one patient of the posterior wall fracture. Two patients of high anterior column acetabular fracture, this coronal plan fractures transverse the superior weight-bearing dome of the acetabulum, exiting through the iliac wing. Another two patients had transverse acetabular fractures on the acetabular dome. These fracture lines was depicted on the CT images of the acetabular dome, which was...
presented in Table 2. None of the patients had bone fragments within the hip joint. The surgical plan regarding to the screws’ entry point and trajectory was designed preoperatively based on preoperative CT (Figs. 2 and 3).

Surgical technique

Surgery was performed under general anaesthesia 2–5 days after the injury. The senior surgeon (CF LUO) performed the operations. During surgery, the patient was placed supine on a radiolucent table.

Arcadis 3D (ARCADIS Orbig 3D; Siemens AG 43 Healthcare Sector, Erlangen, Germany) and navigation system (stryker navigation system) were connected. The patient tracker was installed in the patient’s pelvic crest. Another tracker was installed on the drill sleeve and registered with the navigation system.

Calibrate cage was mounted on the C-arm of the Arcadis 3D for registration. It was confirmed that there was no collision and the reference trackers were always traceable by the camera during the rotation of the C-arm. The operated hip joint was centred on the lateral and anterior/posterior fluoroscopy. The operative area was draped carefully for fear of possible contamination during the rotation of the C-arm. The 100 fluoroscopic images were created during the 190 rotation of the 3D C-arm and the image set was sent to the navigation system automatically. The direct 3D fluoroscopy navigation was working after a short period of calculation. The surgical setup was presented in Fig. 1.

The skin was stabbed and the drill sleeve was then inserted to the bone surface close to the area of interesting. Multiplanar images were available then. The multiplanar images were dynamically altered correspondingly according to the alteration of the drill sleeve. The extending green dot line was the virtue of the screwing trajectory (Fig. 2).

The guide pin was then inserted within the drill sleeve once the screw trajectory matched the preoperative surgical plan. Its position was validated with conventional 2D fluoroscopy. The length of the guide pin was then measured and an AO Synthes® cannulated screw was inserted through the fracture interface, finally the screw and the fracture reduction was examined by 3D fluoroscopy again. Parameters were measured by the software installed on this 3D fluoroscopic machine (Fig. 3). The parameters consisted of the fracture gap closure (P1); the nearest distance to the joint cartilage (P2); the angulations between the screw and the fracture line (P3).

Patients were allowed to perform no weight-bearing exercises on the first day post-operation. All patients were followed up regularly.

Result

It was found that with the use of the 3D fluoroscopy navigation, precise placement of the percutaneous screw was achieved as Fig. 4 presented, which was unbelievable with the traditional methods. The soft tissue damage was minimal, no significant blood loss. Seven screws were successfully inserted into the roof of the

<table>
<thead>
<tr>
<th>Number of patients</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (M/F)</td>
<td>3/2</td>
</tr>
<tr>
<td>Mechanism</td>
<td>Fall</td>
</tr>
<tr>
<td></td>
<td>MVA 4</td>
</tr>
<tr>
<td>Prefactured mobility</td>
<td>Independent 5</td>
</tr>
<tr>
<td>Fracture line on the acetabular roof</td>
<td>Sagittal in orientation 3</td>
</tr>
<tr>
<td>Coronal in orientation</td>
<td>Time to surgery (days) 2–5</td>
</tr>
<tr>
<td>Mean duration of the first screwing (days) 20 (10–35 min)</td>
<td></td>
</tr>
<tr>
<td>Complications</td>
<td>0</td>
</tr>
<tr>
<td>Mean follow up (years) 1 year</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1. The setup of the percutaneous screw fixation on acetabular roof fracture.

Table 1
Pre intra and postoperative data of five patients.

<table>
<thead>
<tr>
<th>Fracture line (CT on dome)</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
<th>Case 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Letournel classification</td>
<td>High anterior column a cetabular fracture</td>
<td>High anterior column acetabular fracture</td>
<td>Transverse acetabular fracture</td>
<td>Fracture of the posterior wall</td>
<td>Transverse acetabular fracture</td>
</tr>
<tr>
<td>Fracture gap closure</td>
<td>3 mm</td>
<td>–</td>
<td>2 mm</td>
<td>2 mm</td>
<td>–</td>
</tr>
<tr>
<td>Angulations</td>
<td>80°</td>
<td>60°</td>
<td>86°</td>
<td>89°</td>
<td>65°</td>
</tr>
<tr>
<td>Distance to joint</td>
<td>1 mm</td>
<td>3 mm</td>
<td>5 mm</td>
<td>&lt;1 mm</td>
<td>5 mm</td>
</tr>
<tr>
<td>Number of screw</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
acetabulars with 3D fluoroscopic navigation. The quadrilateral plate was anchored by screw. The measurement parameters were presented in Table 2, the closure of the fracture gap was achieved in 3 patients by 2–3 mm. The fracture gap was unchanged in 2 patients. The nearest distance from the screw to the joint cartilage was ranged from <1 mm to 6 mm. The angulations between the screw and the fracture line was 80–90° in three patients, the other two were 60° and 65° respectively. The mean operation time for the acetabular roof screw was 20 min on average (range 10–35 min), fluoroscopy time was 45 s on average (range 43–47 s). All patients felt pain free 1 week after the operation. No complication was noted postoperatively.

**Discussion**

Two-dimensional (2D) fluoroscopic navigated PSF was widely accepted in the fixation of pelvic fracture.3,7,22,26 However due to the fact that the acetabular socket is a complex three-dimensional structure, and the standard Judet obturator and iliac views were frequently unachievable during surgery, the traditional two-dimensional fluoroscopy was of limited value regarding to the detection of a fracture line and the screws’ position in acetabular socket.1,11,15 Since the acetabular dome on plain radiography is a composite view of a narrow area, the axial imaging is necessary to visualize the fracture line in this region. It was therefore recommended to use the intraoperative 3D fluoroscopy to evaluate the fracture line and the screws around as well.1,15

Open reduction and internal fixation for acetabular fracture has traditionally required large surgical exposures. These exposures can be associated with significant complications. For example, the prevalence of iatrogenic injury to the sciatic nerve with a fracture of the acetabulum was reported to be 5–6%9 and injury to the femoral nerve was also reported in some cases.8 It was even suggested to visualize the acetabular fracture directly by surgical dislocation of hip joint for assurance of the anatomic reduction for this intra-articular fracture.24 Therefore the decision whether to operate on individual cases is often not straightforward. The various issues related to which fractures be treated non-operatively, how fixation can be achieved with minimal risk to the patient, or when a total hip replacement is more appropriate, are multifactorial. With traction or temporary external fixator, after confirmation of adequate reduction by fluoroscopy, the open surgery might be replaced in many selected cases by the use of the percutaneous screw fixation, which has been proved to be a safe and effective alternative to formal surgery, with a low anticipated complication rate and excellent outcome.8

From a review of the literature,16,18 the indications based on expertise are following: nondisplaced (1–3 mm) but potentially unstable fractures involving the weight-bearing dome; the transrectal transverse fractures with roof arcs measuring less than 45°; slightly displaced fractures (3–5 mm) with gap
displacement that could be reduced with percutaneously placed lag screws; the displaced simple fractures that may be reducible with minimal open surgery; cases where soft tissue damage precludes open surgery, or where medical co-morbidities are severe and the risk of open surgery with major blood loss is too high; another less common situation is the undisplaced fracture in an unreliable patient, where minimal fixation may avoid secondary displacement.

Fig. 3. Case 1: The top-left photo was the preoperative CT scan on the dome, in which a fracture gap with 4 mm and a slight mal-rotation was presented. The fracture line was manually depicted with black line. The top-right picture was the working picture of the 3D fluoroscopy navigation, in which the screw’s trajectory was designed according to the fracture line. The bottom photos were the second 3D fluoroscopy images, which was used to check the position after screw fixation. The angulations between the screw and the fracture line was about 80° and the nearest distance from screw to the joint surface was 1 mm, the fracture gap was closed by 3 mm and the slight mal-rotation was also be corrected in some degree.

Fig. 4. Case 4: A patient with acetabular fracture on the poster wall was presented, in which the direct 3D fluoroscopy navigation was used to guide the screwing. The photos of the posteroperative CT scan, X-ray and intraoperative 3D fluoroscopy presented two perfect screws. Two screws were inserted perpendicular to the fracture line, the fracture gap was closed, the nearest distance from the joint cartilage to the screw was less than 1 mm, the patient was pain free the day after operation and encouraged to no weight-bearing practice immediately.
Navigated acetabular percutaneous screw was also indicated in the acetabular fractures which could be reduced closely, and the slight displacement was tolerated. To the authors’ view, the elderly patients and the poly-trauma patients were much more indicated for this technique. The patients in current study were considered to be unwise for the conservative management and would be benefited by percutaneous screw fixation. Percutaneous stabilization of these fractures could prevent late fracture displacement and allow beneficial early mobilization of these patients. It was essential for the elderly patients and poly-trauma patients for which the general condition is not allowed a huge surgery. This small surgical procedure can help nursing and also allows early walking with crutches. In addition, later total hip replacement is more suitable for the elderly patients with degenerative hip joint, the intact soft tissue around the hip joint is vital for the later outcome if the total hip replacement is scheduled.

Apart from minimal soft tissue damage, potentially less complications and less operation time, the advantage of intraoperative 3D imaging on acetabular fracture is that it can save the patients and surgeons from uncertainty relating to the quality of reduction and implant position. Meanwhile, we also saw the possibility to improve the quality of reduction and fixation by perfect screw trajectory because the fracture line was best seen in multiplanar reformaion imaging (MPR). The fracture gap might be closed in some degree, and the malrotation of the fracture might also be reduced by some degree if the screws were placed perfectly (Fig. 3). Theoretically it could lead to a superior long-time outcome.

Percutaneous screwing with a CT-based navigation was reported on several clinical cases. However, the logistic and disinfection management of the CT suit is problematic for trauma surgery. If the 3D fluoroscopy imaging was achieved in the surgery, at the same time the 3D (Arcadis 3D) navigation was taking effect immediately. So it was really convenient to execute the 3D fluoroscopy navigation at the same procedure.

The imaging coverage of the Arcadis 3D was a cube image (12 cm × 12 cm × 12 cm) and the multiplanar imaging were dynamically altered relatively. The entry point of guider pin was critical. If it is not close to the area of interesting, the imaging on the screen is defected. Orientation is impossible due to this defected image. Therefore, the straightforward location of the entry point and an appropriate precautious plan for the screw trajectory was definitively essential to reduce the operation time and improve the screw fixation.

From the aspect of the author's experience, the real-time interactive nature of such displays is particularly helpful. The expertise on open acetabular surgery and the capability of interpreting dynamic slice imaging of acetabulum to a three-dimensional structure is mandatory. The procedure must be carefully planned so that the path of the screw would not injure the sciatic nerve and gluteal artery. The surgery depends on the structural orientation during surgery and the appropriate preoperative plan for the screw trajectory with reference to the fracture line.

Conclusion

The percutaneous screwing for the acetabular roof fracture with the 3D fluoroscopy navigation system was clinically feasible, in which a quadrilateral plate could be anchored by percutaneous screw and it was possible to reduce the fracture gap by some degree with this technique.

Conflict of interest statement

We declare that we have no financial and personal relationships with other people or organizations that can inappropriately influence our work.

References
