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CLINICAL INVESTIGATIONS

Coronal Acetabular Fractures: The Anterior Approach in Computed Tomography-Navigated Minimally Invasive Percutaneous Fixation

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Abstract

Purpose: To demonstrate the technical feasibility of the anterior approach to the coronal roof component of carefully selected acetabular fractures in computed tomography (CT)-navigated closed reduction and percutaneous fixation (CRPF).
Methods: Four patients with nondisplaced or slightly displaced coronal fractures of the acetabular roof were treated with percutaneous screw fixation. Screws were implanted over guidepins placed under CT navigation. Mean clinical and radiological follow-up was 16 months.
Results: All screws could be placed as intended. There were no peri- or postoperative complications. Radiological follow-up showed primary osseous union. Clinical results were excellent according to a median Merle-d'Aubigné score of 18.
Conclusion: Nondisplaced or slightly displaced coronally oriented fractures of the acetabular roof can be treated by minimally invasive percutaneous CT-navigated fixation through an anterior approach that does not endanger the sciatic nerve. Early clinical results are encouraging. Close cooperation between trauma surgeons and radiologists and careful selection of cases is mandatory.

Key words: Acetabulum, fractures—Interventional procedures—Computed tomography guidance—Closed reduction and percutaneous fixation

Fluoroscopically guided or computed tomography (CT)-guided closed reduction and percutaneous fixation (CRPF) of pelvic ring fractures have been reported several times [1–3]. These reports deal with sacroiliac or superior pubic ramus fractures which do not involve the articular surface of the hip joint. Until recently, treatment of articular fractures has been considered the domain of open reduction and internal fixation (ORIF). Gay et al. [4] demonstrated that CRPF also can be employed successfully in selected articular acetabular fractures through a posterior approach dorsolateral to the greater sciatic notch.

We present four patients with a coronally oriented main acetabular fracture component treated with CT-navigated CRPF through a new anterior approach via the anterior inferior iliac spine that to our knowledge has not been previously described.

Materials and Methods

Injuries

Four patients were treated with CT-guided CRPF between 28 April, 1996 and 12 March, 1997. Their ages ranged from 36 to 50 years (mean 39 years). The underlying trauma, associated injuries, and classification according to the system of the Association for the Study of Internal Fixation (AO/ASIF) [5] are listed in Table 1. According to the AO/ASIF classification, patient 2 had a partial articular fracture and the others had complete articular fractures. Each patient had a coronally oriented fracture component in the acetabular roof amenable to percutaneous screw fixation. Only patient 3 had trauma-related neurological symptoms.

Patient Selection

Patients were considered eligible for CRPF if their fractures exhibited no to moderate dislocation, no step in the articular surface, and if no more than two main fragments had to be united. Comminuted fractures with or without free intraarticular bodies were excluded from CRPF and treated with conventional open surgery. Informed consent was obtained from every patient. Patient 4, who had a comminuted fracture of the acetabular rim, initially refused ORIF.

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Table 1. Clinical data

Patient no.	1	2	3	4	Median
Sex	Female	Male	Female	Male	
Age (years)	50	43	36	37	37
Trauma	Fall from horse	Suicidal fall from first floor	Suicidal fall from eighth floor	Ran into wall on inline skates	
AO/ASIF classification	62 C1.1	62 A3.2 a1	62 C2.3 a2	62 C2.3 a3	
Associated injuries	Complex pelvic ring fracture	Superficial lesion of spleen, fracture of clavicle	Complex pelvic ring fracture, cystic and splenic rupture, hematothorax	None	
Neurologic symptoms			Transient hypoesthesia left S1 root and conus contusion		
Time to operation (days)	2	3	4	2	3
Duration of operation (min)	120	150	90	105	113
Time to partial weight-bearing ambulation (20 kg) (days)	1	5	8	1	3
Time to full weight-bearing ambulation (weeks)	7	7	7	7	7
Postoperative hospital stay (days)	2	9	44	8	9
Complications	None	None	None	None	
Follow-up (months)	24	20	6	12	16
Merle-d'Aubigné score	18	17	18	18	18

He consented, however, to CRPF of the main fracture line in his acetabular roof (Fig. 1). The patients were consecutive in the sense that only they fulfilled the inclusion criteria set out above.

Imaging

Imaging was done on a spiral CT scanner (GE Hispeed Advantage, GE Medical Systems, Milwaukee, WI, USA; imaging parameters 120 kV, 250–280 mA, slice thickness 5 mm, pitch 1.5, slice increment 2.5 mm). Three-dimensional surface reconstructions as well as multiplanar reconstructions were done in all cases.

Surgery

Based on imaging information and the clinical situation a surgical plan was devised that stated the intended position of screws. Screw position was chosen to be as close to perpendicular to the fracture line, to the hip joint, and to the acetabular midline as possible. Total screw length was chosen so that the screws could reach the far cortex for good purchase. Thread length (either 16 or 32 mm) was adapted to the size of the more distant fragment.

Surgery was done in a modified CT suite with two clean-air inlets above the CT table that is approved for minimally invasive surgery by the hospital's commissioner of hygiene. It was performed with the patient in the supine position and under general anesthesia.

For placement of guidepins we used our CT navigation system. CT navigation is interactive targeting combining anatomical data from CT imaging and geometrical data from dynamic tracking of instruments for instantaneous visual feedback. This particular system was developed in-house and employs a three-dimensional optical digitizer to directly show the spatial position of the AO/ASIF surgical drill overlaid onto the CT images taken previously. It is functional immediately after imaging and allows seamless integration of additional intraoperative images [6, 7].

Kirschner wires were first placed about 5–10 mm into the near cortex. Since the small radius of the iliac spine may lead to a sliding of the guidepin on the outer cortex it was perforated at the appropriate position with the guidepin perpendicular to the outer surface. The guidepin was then turned in the desired direction. This problem is greatly diminished with the new 2.8 mm AO/ASIF guidepins which have a very sharp, pointed tip.

The position of the guidepin was then controlled with intraoperative CT scanning and its direction was extrapolated to the target position with the standard measuring functions of the CT console. The residual drilling depth to the far cortex was also determined in this step and marked on the guidepin with a stopper. Guidepins were drilled into the bone until the stopper was level with the skin entry site. Unlike Gay et al. [4] we did not use a second Kirschner wire for stabilization of the fragments. Definitive total screw length according to final guidepin position was again calculated as the distance from near to far cortex minus the width of fracture gap plus 5 mm for screw head and washer. Cannulated screws were then implanted over the guidepins. Two screws were used for prevention of secondary rotation and better fracture compression. In patients 1–3, 2.0-mm wires and 7.0-mm cannulated cancellous AO/ASIF screws were used, which required drilling a glide hole with a cannulated drill before insertion. In the fourth patient we applied 2.8-mm guidepins and self-drilling as well as self-cutting 7.3-mm cannulated cancellous AO/ASIF screws not requiring a predrilled glide hole.

Follow-Up

The mean last follow-up, including a full clinical investigation with history taking and physical examination, erect pelvic radiography, and pelvic CT in all patients, was at 16 months (see Table 1). Clinical result was assessed with the score proposed by d'Aubingé and Postel [8]. This score rates the range of hip joint motion,

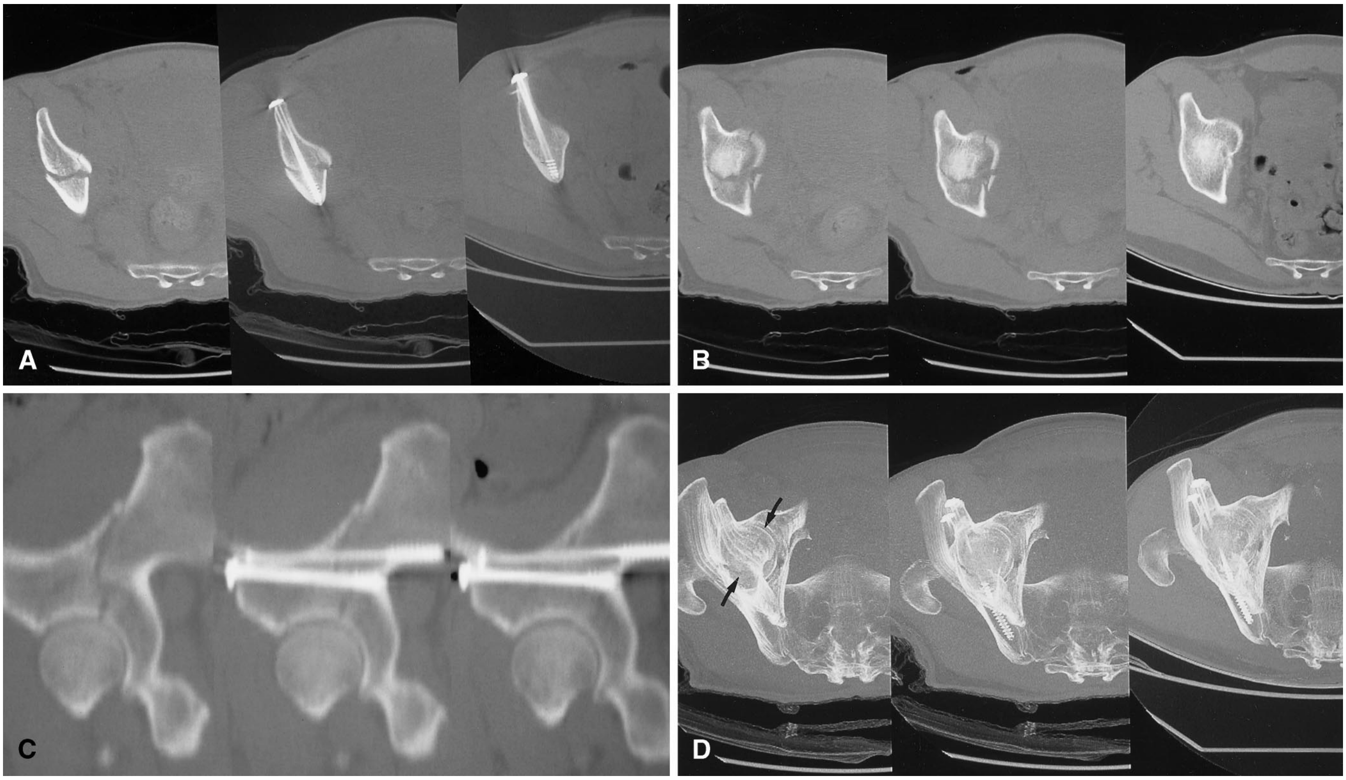

Fig. 1. A 37-year-old inline-skater ran hip-first into a wall while trying to avoid a pedestrian. The fracture had organo-coronal orientation (AO/ASIF 62 C2.3 a3) and was fixed with two screws placed in an organo-sagittal plane. There was an excellent clinical and radiological result. Each row of images (GE Hispeed Advantage; imaging parameters 120 kV, 280 mA, slice thickness 5 mm, pitch 1.5, slice increment 2.5 mm) shows, from left to right, the situation immediately before, immediately after, and 1 year after screw fixation. **A** Serial axial images at the height of the lower screw demonstrate primary osseous union. Note the exact fit of the cancellous bone lag screw with washer, short 16-mm thread adapted to the size of the posterior fragment, and position of the screw tip at the far cortex. **B** Serial axial images at the level of the acetabular roof. Besides the main fragments divided by the transverse fracture line there are several smaller fragments of the acetabular rim, two of which are located medially. Complete osseous union occurred after 12 months. **C** Position of the main and marginal fracture line as well as the positioning of the lag screws at and just above the sciatic notch is well appreciated in these parasagittal reconstructions. The fracture has closed at the joint level immediately after fixation. **D** Craniocaudal maximum intensity projections demonstrate the three-dimensional extent of the fracture across the roof. In the preoperative image (left) the fracture line is visibly traversing the femoral head from dorsolaterally to ventromedially (arrows). The immediate postoperative control (center) shows closure of this tectal portion of the fracture line. Only the lateral extension is still visible. Twelve months later (right) both the central and lateral portion of the fracture line have disappeared.

walking distance, and pain on a scale of 1–6 points each. The sum of the three individual ratings ranges between 3 and 18 points, with 18 points indicating an excellent functional result.

Team Approach

Most steps of the process, from patient selection to follow-up, were done by a team of radiologists and trauma surgeons. Clinical examination and clinical care were done by the surgeons, whereas image reading was the job of the radiologists. During the intervention itself all team members did everything interchangeably.

Results

All guidepins and hence screws could be placed with the navigation system as intended, displaying less than 2° angular deviation as measured by electronically overlaying the final guidepin position with the initial surgical plan. Closure of the fracture gap was achieved in all cases as shown by intraoperative CT imaging. No guidepin or screw penetrated the posterior cortex. Screw purchase was subjectively rated as very good by two experienced trauma surgeons (P.M., P.R.). No intraoperative complications, procedure-related morbidity, or mortality were observed. Blood loss was immeasurably small in all cases. There were no instances of infection or repeat surgery. No iatrogenic neurological injuries occurred.

Clinically, all patients did well as far as the acetabular fracture is concerned. Two patients were mobilized with partial weight-bearing the day after surgery, whereas one of the two patients who had attempted suicide could not cooperate (patient 2) and the other was still acutely suicidal (patient 3). Total length of hospital stay ranged from 4 to 48 days (median 9 days). Patient 3, who was hospitalized for 48 days, could not be mobilized normally and was discharged earlier because of her suicidality. At last clinical follow-up, three patients were pain-free and showed a full range of motion of the affected hip. Patient 2 complained of occasional pain when walking more than 2 km. The median Merle-d'Aubigné score [8] was 18.

Radiography and CT both showed primary osseous union and a correct position of the screws (Fig. 1). No heterotopic soft-tissue ossification was observed during follow-up.

Discussion

Because anatomic reduction has been shown to prevent premature posttraumatic arthrosis in displaced acetabular fractures [9]. Such fractures are normally treated with open reduction and percutaneous fixation (ORIF). There is, however, a significant procedure-related morbidity associated with ORIF of acetabular fractures: iatrogenic sciatic nerve injury in 6.3%–22% of cases [10], intraoperative blood loss of between 1000 and 2000 ml [11], local postoperative infections in about 2%–4% of cases [12], and relevant heterotopic ossifications in up to 20% of cases [13–16]. The ilioinguinal approach, which carries the least number of complications, does not visualize the interior of the hip joint [11], making reduction difficult. There are also general complications such as pulmonary embolism, adult respiratory distress syndrome, or multiorgan failure [17]. When surgery has to be delayed because of the local or general condition of the patient, the level of complications will increase and the results will deteriorate [18]. All in all, acetabular surgery can be considered one of the greatest challenges in fracture surgery [12]. These facts favor conservative treatment in nondisplaced or only slightly displaced fractures, because the ratio of risk to benefit and the complexity of surgery may not be justified in these cases.

Conservative treatment is successful in nondisplaced or marginally displaced fractures but requires extended periods of immobilization and traction with their associated morbidity [19]. Normally, patients have to remain immobilized in bed for at least 3 weeks before being able to ambulate with a load of 20 kg [20].

A minimally invasive approach that in selected cases had the advantages of early ORIF without relevant operative trauma could possibly reduce immobilization-related morbidity for the conservative group without adding the procedure-related morbidity the surgical group normally experiences. This approach would have to comprise closed or minimal access reduction and percutaneous fixation.

Good results and a marked decrease in morbidity in complex acetabular fractures are reported using special forceps for indirect reduction through single nonextensile exposures [21]. Starr et al. [22] used a small surgical exposure for open reduction and performed the subsequent fixation percutaneously, effectively performing open reduction and percutaneous fixation (ORPF), the link between ORIF and CRPF.

Reaching and maintaining closed or indirect reduction is, in our experience [3], by far the most difficult problem in CRPF and it is not solved yet for the case of acetabular fractures. Since there is neither direct visualization nor direct manipulation, appropriate intraoperative imaging, preferably CT, eventually in combination with endoscopy, has to replace direct sight. The routine means of closed reduction are placement, manipulation, traction, and external fixation.

Percutaneous fixation is a problem that is principally solved with navigation techniques [6, 7, 23]. Navigation systems like the one developed by us allow the placement of screws with high precision in arbitrary directions so that there is almost no danger of perforation into the hip joint [24]. The additional possibility of intraoperative imaging controls allows detection of a possible mismatch between virtual and actual reality, closing the feedback loop between action and result. The system has also been used successfully in a number of other pelvic fractures, notably in iliosacral screw fixation, as well as in biopsy and drainage procedures. Though still a prototype, it has reached a satisfactory level of robustness and user-friendliness. Unlike CT fluoroscopy it allows the use of substantial hardware, such as a surgical drill, it supports arbitrary target-paths, and it does not use radiation during the therapeutic action.

Gay et al. [4] demonstrated that in nondisplaced or minimally displaced acetabular fractures CRPF is feasible with good clinical results. They chose a posterior approach to the acetabular roof. As the sciatic nerve lies immediately posterior to the acetabulum, direct access in the long axis of the acetabular roof is prohibited and an oblique dorsolateral route to the acetabulum is used. This leads to a rather acute angle between the coronal fracture line and the screw axis, thereby reducing fracture compression and producing a shearing force along the fracture line. Another possible consequence is a marginal position of the screws in one fragment or both, potentially leading to further fragmentation.

In the small series presented here, four patients with nondisplaced or minimally displaced acetabular fractures were treated through an anterior approach. The patients were in the supine position, which eases surgical as well as anesthetic access. Since there is no vital anatomic structure ventrolateral to the anterior inferior iliac spine, guidepins can be placed safely in the long axis of the acetabulum.

Two screws were always inserted to ensure better fixation and prevention of secondary rotation. Due to the placement of screws perpendicular to the coronal fracture, good fracture compression was achieved. The risk of damaging the sciatic nerve is nominal if the drilling depth and screw length are measured correctly and followed closely.

The limitations to the anterior approach are a posterior fragment that is too small to accommodate the thread of a screw 16 mm in length and 7.3 mm in diameter, or a fracture line too sagittally oriented. The first may not need fixation at all. The rare organo-sagittal fracture can be reached through an anterolateral approach but will require ORIF in most cases. The selection of cases and all aspects of the procedure itself—planning, navigation, screw insertion—were done by a surgical-radiological team.

We did not see any intraoperative or postoperative local or general complications due to the minimally invasive approach. Clinical and radiological midterm results are encouraging. All patients had an excellent midterm functional result, probably predictive of an equally good long-term result [25].

In conclusion, we have demonstrated that the anterior approach in CT-navigated CRPF of nondisplaced or slightly displaced coronal fractures of the acetabular roof is feasible. Prospective studies comparing ORIF, conservative treatment, and CRPF, as well as their clinical and cost-effectiveness, are now warranted. Furthermore, we are currently planning a new type of image-guided therapy room that will allow us to combine minute open reduction with minimally invasive fixation and to generalize this approach to other parts of the skeleton.

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