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Mapping of 238 quadrilateral plate fractures with three-dimensional computed tomography

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ABSTRACT

Purpose: The primary goal of this study is to create a frequency map of a series of the quadrilateral plate fractures, explore the characteristics of fracture map and to further propose a new classification.
Methods: We used a consecutive series of 238 quadrilateral plate fractures to create 3-dimensional reconstruction images, which were superimposed and oriented to fit a model hemipelvis template by aligning specific pelvis landmarks. Fracture lines were identified and traced to create a quadrilateral plate fracture map.
Results: Fracture location corresponded with fracture line distribution. Of 238 fractures that met the criteria for inclusion, most fractures involved the "A + B" zone (n = 156; 65%), whereas the remaining minority of the fractures involved the "A" zone (n = 59; 25%) and the "B" zone (n = 23; 10%). Correspondingly the incidence of C-type fracture ("A + B"zone) was significantly higher than that of A-type fracture and B-type fracture. Additionally the most common pattern was demonstrated by coexisting fracture lines; nearly half (48%) of the fractures involved the upper section of the quadrilateral plate traversing both zones, 46% traced almost vertically to the arcuate line, and 25% extended to the posterior aspect. Furthermore, the high fracture line intensity (n = 172; 74%) formed a Gun-shaped pattern, which pointed to the ischial tuberosity.
Conclusions: The map shows that the comminution is prone to traverse the quadrilateral plate in the sagittal direction among nearly two-thirds of all fractures. Moreover, Surgically treated quadrilateral plate fractures display very common patterns. The most common pattern is the upper fracture in nearly half of the fractures. Knowledge of these patterns can aid surgeons during diagnosis, preoperative planning, and execution of surgical strategies.

Introduction

Management of acetabular fractures remains a challenge for orthopedists [1]. Acetabular fractures are rare fractures with an incidence of 3/100,000/year [2]. The majority of acetabular fractures are of high-energy injury mechanisms and tend to draw in injury to neighboring organ systems. However low impact fractures in elderly patients has significantly increased with the increasing prevalence of osteoporosis, which are most commonly combined with quadrilateral plate fractures.

Quadrilateral plate fractures represent a heterogeneous group of acetabular fractures. As a thin relatively bony structure, medial migration of quadrilateral plate with central fracture dislocation of the hip is reported to be more common in the osteoporotic acetabular fractures [3–6]. Success to restore the buttressing function of the medial wall and prevent protrusion of the femoral head are imperative for optimal outcome. Currently Some quadrilateral plate fractures can be reduced indirectly along by reduction and stabilization of column fractures.

However, despite improvement in surgical technique and various implants, it can be difficult to achieve congruous hip with a comminuted or free floating medial wall fracture. More importantly, there is no practical classification system specially for quadrilateral plate fracture in the existing literature, which affects the treatment of fractures in the quadrilateral plate to some extent. And accurately ascertaining the fracture type, selecting the appropriate surgical approach and proper internal fixation are all paramount in the success of surgical treatment of acetabular fractures.

Therefore, after having studied the imaging data of a large number of patients with quadrilateral plate fractures and considering the anatomical characteristics of the quadrilateral

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plate and distribution of fracture lines, we put forward a specialized classification system for fractures in the quadrilateral plate in order to help them understand Letournel classification.

Materials and methods

Patient cohort

At one level I trauma center, a search in the hospital database showed three hundred and thirty patients with acetabular or pelvic fractures were admitted into the trauma department from January 2009 to May 2017. Inclusion criteria was as follows: (1) Age greater than or equal to 18 years; (2) Fractures involving the quadrilateral plate; (3) Complete imaging information, including X-ray and Computer Tomography assessments. Exclusion criteria included: (1) fracture lines or anatomical landmarks obscured by foreign bodies; (2) severe comminuted fractures which were difficult to determine fracture line conditions; (3) poor quality CT data.

Fracture mapping

Digital Imaging and Communications in Medicine (DICOM) format data of the CT scans that had been selected was obtained from the Picture Archiving Communications System(PACS)database and then imported into the 3D Slicer (version 4.7.0; Boston, MA, USA). 3D Slicer is a free software for the analysis and visualization of medical images. We then went on to use the "volume rendering" function in the software to generate a three-dimensional reconstruction of the pelvis, further rotating and cropping to form a hemipelvis, and to fully expose the quadrilateral plate. A standard pelvis was selected and the same method was applied to form a left hemipelvis model for reference use. Selection of a 3DCT view was based on sufficient evaluation of all of the images available, and these views that allowed the best visualization of the quadrilateral plate in the plane represented by the standard hemipelvis were collected for each patient. All CT scans had a slide thickness between 0.62 mm and 1.25 mm.

Utilizing the method of Cole et al. [7] and Armitage et al. [8], the aforementioned hemipelvis images can be imported into Macromedia Fireworks MX software (Macromedia Inc, San Francisco, CA, USA) for supplementary processing. The Macromedia Fireworks MX has been developed to edit bitmap images and enables creation of fracture maps. The hemipelvis model was uploaded into the software along with the patient's reconstructed hemipelvis images. Proper alignment and normalization were done by aligning specific pelvis landmarks—namely, the arcuate line, ischial spine and ischial tuberosity, which were respectively regarded as the reference line and point. Through fully assessing the imaging data of each patient, the true shape of the fracture line can be restored to the greatest extent. Once proper anatomical alignment was obtained, fracture lines were identified and were traced on top of the hemipelvis model (Fig. 2). Then images of each hemipelvis were graphically superimposed to create a compilation of fracture lines on the hemipelvis model serving as a representation of the osseous anatomy. This overlapping of all fracture patterns resulted in the creation of a quadrilateral plate fracture map. (Fig. 3B). The hemipelvis model that we used was a left hemipelvis. For right hemipelvis, the images were flipped horizontally to obtain corresponding mirror images.

In addition, Zones were defined on the basis of pelvic anatomy and/or key muscular origins and insertions (Fig. 3A). With use of the definitions of relevant zones, all fractures were categorized according to the zones at which they implicated the quadrilateral plate. The overlap of all major fracture lines resulted in a frequency diagram based on the density of fracture lines. In this way, a frequency diagram based on the density of zones of impaction or comminution was created. With qualitative and quantitative assessment of fracture map, zone vulnerable to comminution was further determined. All fracture line interpretations were verified by a trauma fellow and a fellowship-trained trauma surgeon.

Data analysis

The analysis of the fracture maps was descriptive. Patient characteristics were summarized with frequencies and percentages for categorical variables and with means and standard deviations for continuous variables. The fracture maps were assessed for recurrent patterns of fracture lines and zones of comminution.

Results

A total of 232 patients met the inclusion criteria, among which were 164 male patients and 68 female patients, with an average age of 43 years. Besides, six patients had bilateral fractures. 230 patients underwent surgery, and the remaining 2 patients were conservatively treated due to poor general condition and severe coronary heart disease. The most common injury mechanism was motor vehicle collision (Table 1).

The line between ischial spine to iliopubic eminence just divided the quadrilateral plate into two parts : the rear aspect ("A"zone) and the anterior aspect ("B"zone) (Fig. 3A). All 232 subjects contained 238 major fracture lines, which amounted to 238 fractures. Fifty-nine (25%) had a component involving the "A" zone, and twenty-three fractures (10%) exited or entered the "B"zone, and one hundred and fifty-six (65%) traversed both zones of the quadrilateral plate ("A + B"zone) in the sagittal direction (Fig. 3D). Correspondingly the fracture in "A" zone was defined as A-type fracture, those involving "B" zone defined as B-type fracture, and those traversing both zones ("A + B") as C-type fracture. Apparently, the incidence of C-type fractures was highest (Fig. 3D).

Consistent fracture lines were identified and deemed major fracture lines by critically reviewing all these images. On the basis of the initial overall patterns (i.e., the fracture lines), the findings were divided into three groups: (1) the upper border with the fracture traversing both zones, (2) the medial section with the fracture tracking approximately perpendicularly to the arcuate line, and (3) the rear section with the fracture extending from

Table 1
The demographics of subjects.

Variable	All patients (n = 232)
Mean age (SD),year	43 (12)
Sex, n (%)	
Men	164 (71)
Women	68 (29)
Side of injury, n (%)	
Right	104 (45)
Left	122 (52)
Bilateral	6 (3)
Treatment, n (%)	
Operative	230 (99)
Conservative	2 (1)
Injury mechanism, n (%)	
Motor vehicle collision	129 (56)
Fall from height	81 (35)
Others	22 (9)

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