The use of a virtual three-dimensional model to evaluate the intraosseous space available for percutaneous screw fixation of acetabular fractures


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We created virtual three-dimensional reconstruction models from computed tomography scans obtained from patients with acetabular fractures. Virtual cylindrical implants were placed intraosseously in the anterior column, the posterior column and across the dome of the acetabulum. The maximum diameter which was entirely contained within the bone was determined for each position of the screw. In the same model, the cross-sectional diameters of the columns were measured and compared to the maximum diameter of the corresponding virtual implant.

We found that the mean maximum diameter of virtual implant accommodated by the anterior columns was 6.4 mm and that the smallest diameter of the columns was larger than the maximum diameter of the equivalent virtual implant.

This study suggests that the size of the screw used for percutaneous fixation of acetabular fractures should not be based solely on the measurement of cross-sectional diameter and that virtual three-dimensional reconstructions might be useful in pre-operative planning.

Open reduction and internal fixation is the standard treatment for unstable fractures of the acetabulum. Recently, percutaneous screw fixation of the acetabulum has been described as an alternative treatment for both acute fractures and nonunions. Using this technique, the screws are introduced into the anterior and posterior columns through small incisions, and most of their path is intra-osseous. It has been advocated for the treatment of minimally displaced anterior or posterior column fractures without comminution or free fragments in the joint. Safe and accurate insertion of percutaneous screws requires fluoroscopy or three-dimensional reconstruction computer tomography (CT) scans, with or without a computerised navigation system.

We performed a pilot study to determine the accuracy of percutaneous screw insertion into the anterior and posterior acetabular columns of four cadavers with intact soft-tissue envelopes. The specimens were dissected to determine the accuracy of individual screw placement visually, and this revealed that all the screws were adequately placed except for four in the anterior column which penetrated the superior ramus. This prompted us to develop a virtual model to study percutaneous screw insertion in the acetabulum.

Our hypotheses were that the size of the screw is an important factor and that it cannot be determined from cross-sectional measurements of the anterior and posterior columns of the acetabulum. In order to test these hypotheses, we devised a virtual three-dimensional model, to assess the maximum intraosseous diameter of screw that can be inserted into the anterior, and posterior acetabular columns, without cortical disruption. We then measured the cross-sectional diameter of the anterior and posterior columns and compared these to the maximum diameter of a cylindrical implant in a virtual three-dimensional reconstruction model.

Materials and Methods

We performed CT scans, using continuous 3-mm slices on 13 patients with acetabular fractures, and created virtual three-dimensional models from the CT data using image-processing software (AVS, Advanced Visual Systems, Inc., Waltham, Massachusetts). Virtual cylindrical implants were superimposed on the anterior and posterior columns of the intact side of 13 pelvis to determine the maximum diameter which fitted within the cortical margins of each column. In order to determine accurately the optimal implant diameter, the virtual diameter was progressively increased...
until it penetrated the cortical margins of the column. The maximum diameter of the virtual implant was defined as the largest diameter that did not penetrate the cortex of the column regardless of its orientation. Three virtual implant positions were investigated: Implant 1 was directed anterior to posterior from the anterior inferior iliac spine to the sciatic buttress, without penetrating the greater sciatic notch (Fig. 1). Implant 2 was directed inferior to superior from the ischial tuberosity passing through the posterior column to a point approximately 3 cm superior and posterior to the acetabulum (Fig. 2). Implant 3 was directed medial to lateral from the pubic tubercle, passing through the anterior column to a point superior to the acetabulum, and approximately 4 cm posterior to the anterior superior iliac spine, or lateral to medial in the opposite direction (Fig. 3).

Cross-sections of 1 cm of the anterior and posterior columns of the intact side of the virtual three-dimensional reconstruction pelvis, were created and their largest dimensions were measured. The initial virtual cuts were made in the posterior margin of the acetabulum, perpendicular to the anterior surface of the anterior column. The other cuts were parallel to the initial cut as previously described by Ebraheim et al.\textsuperscript{12} Our technique differed only in that the
cross-sectional measurements started at the pubic tubercle and ended at the anterior inferior iliac spine for the anterior column, and started at the ischial tuberosity and ended at the anterior inferior iliac spine for the posterior column.

**Results**

The mean maximum virtual diameter for the three positions was 12.1 mm (10.5 to 13.3) for implant 1, 11.4 mm (9.4 to 13.3) for implant 2 and 6.4 mm (5 to 7.3 mm) for implant 3.

The mean maximum virtual length of screw for the three positions was 194.7 mm (218.7 to 171.9) for implant 1, 96.4 mm (101.6 to 85.9) for implant 2 and 173.2 mm (203.1 to 140.6) for implant 3.

The mean antero posterior diameter in the anterior columns are depicted in Figure 4a. The smallest diameter was 16.5 mm (range 16.5 to 66.9). The mean superior inferior diameter in the anterior columns are depicted in Figure 4b; the smallest diameter was 19.5 mm (range 19.5 to 48.1).

The smallest antero posterior diameter of the posterior column is depicted in Figure 5a. The smallest diameter was 16.5 mm (range 16.5 to 66.9). The mean superior inferior diameter of the posterior column is depicted in Figure 5b; the smallest diameter was 19.5 mm (range 19.5 to 48.1).

**Figure 4a** – The mean anteroposterior diameter of the anterior column in 1-cm cross-sections. **Figure 4b** – The mean superior inferior diameter of the posterior column in 1-cm cross-sections.

**Figure 5a** – The mean anteroposterior diameter of the posterior column in 1-cm cross-sections. **Figure 5b** – The mean superior inferior diameter of the posterior column 1-cm cross-sections.
Discussion
In 1995, Routt et al.\(^7\) reported the results of 26 patients with anterior pelvic ring disruption treated with a retrograde superior pubic ramus screw. Either a 3.5-mm or 4.5-mm cortical screw was inserted after manipulation and reduction. Anatomical constraints prevented screw placement in two patients and in a third patient the screw was misplaced superior to the pubic ramus. The authors acknowledged the risk of cortical penetration with percutaneous screw fixation of anterior column fractures, and cautioned against its use without optimal imaging.

The results of our virtual three-dimensional reconstruction study showed that the maximum mean virtual diameter of screw accommodated by the anterior column was 6.4 mm. This was significantly smaller than the diameters in the other two positions. This supports Routt’s recommendation that only 3.5 to 4.5 mm screws should be used in the anterior column,\(^7\) and corroborates Ebraheim’s\(^12\) conclusion that a narrow margin of safety exists for a percutaneous screw in the anterior column. Furthermore, the results supported our hypothesis that the cross-sectional diameter of the anterior and posterior columns of the acetabulum cannot be used to predict the maximum diameter of percutaneous screws which can be used safely. The cross-sectional diameter measurements, demonstrated that the smallest anteroposterior and superior inferior diameters measured in the anterior column were 16.5 mm and 19.5 mm respectively, but the maximum size of screw accommodated by the anterior column was only 6.4 mm. Similarly, the smallest anteroposterior and superior-inferior diameters measured in the posterior column were 28 mm and 19.7 mm, respectively, but the maximum size of screw accommodated by the posterior column was only 11.4 mm.

The variability of measurements taken from cadaver acetabula is well documented in the literature.\(^15,16\) Nevertheless, we believe that a larger study population would have given more statistical power to our results, and allowed us to study the differences between sub-populations, such as men and women.

In conclusion, this study suggests that the size of screw used for percutaneous fixation of acetabular fractures should not be based on a cross-sectional measurement of diameter. The mean diameter of screw accommodated by the anterior column of the acetabulum was 6.4 mm (5 to 7.3), therefore the use of screws with a larger diameter may violate the bony margin and should only be used after careful evaluation of the dimensions of the anterior column. We suggest that virtual three-dimensional reconstruction might be useful in pre-operative planning for percutaneous screw fixation of acetabular fractures.

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References