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ORIGINAL PAPER

Acetabular fracture types vary with different acetabular version

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Abstract
Purpose Acetabular fractures typically occur in high energy trauma. Understanding of the various contributing biomechanical factors and trauma mechanisms is still limited. While several investigations figured out what role femoral position during impact plays in distinct fracture patterns, no data exists on the influence of acetabular version on the fracture type. Our study was carried out to clarify this issue.
Methods Radiological data sets of 192 patients (145 male, 47 female, age 14–90 years) sustaining acetabular fractures were assessed retrospectively. The crossover ratio of the crossover sign and presence or absence of the posterior wall sign and ischial spine sign were used to determine acetabular retroversion on conventional radiographs. Acetabular version in the axial plane was measured on a computed tomography (CT) scan. Statistics were then performed to analyse the relationship between the acetabular fracture type according to the Letournel classification and acetabular version.
Results A significant difference (p=0.029) in acetabular version was found between fractures of the anterior [mean equatorial edge (EE) angle 19.93°] and posterior (mean EE angle 17.53°) acetabulum in the CT scan. No difference was shown on the measurements on conventional radiographs.
Conclusions Acetabular version in the axial plane has an influence on the acetabular fracture pattern. While more anteverted acetabula were frequently associated with anterior fracture types according to the Letournel classification, retroversion of the acetabulum was associated with posterior fracture types.

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Introduction

Acetabular fractures are characteristic injuries in high energy trauma victims. The incidence was reported to be about 3/100,000 per year [1] and an association with pelvic ring fractures was shown in up to 24 % [2, 3]. The different acetabular fracture patterns and the proposed treatment strategies are well reflected in the widely used classification of Letournel and Judet [4]. The relative incidence of the different fracture types has been carefully analysed based on large trauma databases [5–7]. However, the understanding of the contributing biomechanical factors and trauma mechanisms which lead to each distinct fracture pattern is fundamental. While early observational and biomechanical studies highlighted the effect of femoral positioning and force transmission on acetabular fracture types [4, 8–10], the role of anatomical variations in pelvic shape/orientation have not yet been elucidated. Acetabular orientation has proved to play a major role in degenerative pathways of the hip [11–16]. In contrast—to the best of our knowledge—no data is available investigating the influence of the acetabular version on different acetabular fracture types according to the Letournel classification. Our study was carried out to clarify this issue.

Materials and methods

Patients

Conventional anteroposterior (AP) pelvic radiographs and pelvic computed tomography (CT) scans of patients admitted to the R Adams Cowley Trauma Center, Baltimore, MD, USA, were reviewed from the electronic radiological trauma database. Of a total of 651 patients with pelvic injuries 192 (29.5 %) sustained acetabular fractures. All patients met the inclusion criteria, of which 145 were male and 47 female (76/24 %) with an age range between 14 and 90 years (median 42.5 years). All of the subjects had conventional radiographs of the pelvis obtained in a correct standardised radiographic technique and corresponding CT scans of the pelvis. Institutional Review Board approval was obtained for this study.

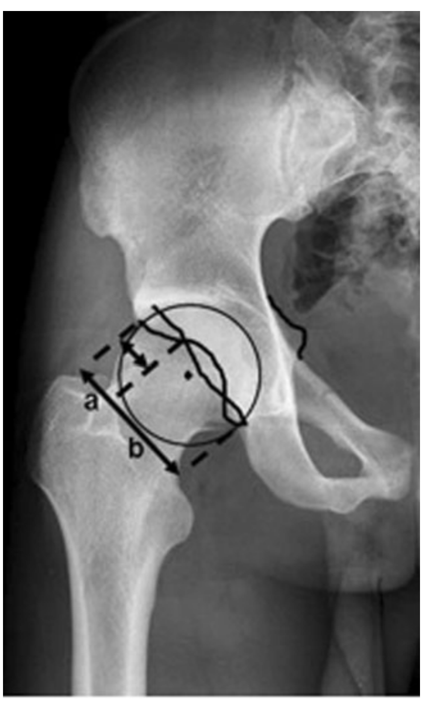

Fig. 1 The following measurements representing acetabular retroversion on the conventional AP radiograph are indicated: crossover ratio (a/b in %) of the crossover sign, positive posterior wall sign and positive ischial spine sign

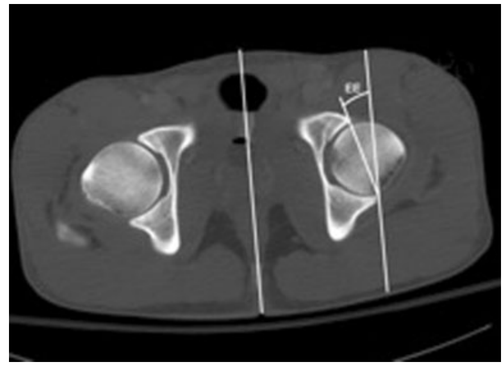

Fig. 2 Axial CT scan at the level of maximum femoral head diameter: the equatorial edge (*EE*) angle indicates the acetabular version. In this case wide anterior opening results in a positive value (+16°)

Validation of radiographs

To reduce potential error, only AP pelvic radiographs which revealed (1) alignment of the tip of the coccyx with the middle of the symphysis and (2) a distance between the sacrococcygeal joint and the symphysis less than 32 mm in men and 47 mm in women according to the criteria of Siebenrock et al. [17] were assessed, since rotation in the sagittal and axial plane of the pelvis may significantly change outcome measurements of coxometric parameters [18].

False rotation in the frontal plane was corrected electronically with the picture archiving and communication system (PACS) imaging program, and therefore such radiographs were also included.

Measurements on radiographs

Commonly used roentgenological parameters indicating acetabular retroversion were measured as previously reported [19–21]: The crossover ratio or crossing grade (X-grade) of the crossover sign and presence or absence of the posterior wall sign and ischial spine sign were assessed (see also Fig. 1). Measurement values were only included if the fracture pattern allowed correct assessment. In all other cases measurements were performed on the non-injured

Table 1 Subsumption of fracture types

Fracture groups	Fracture types according to the Letournel classification
A	Anterior wall; anterior column
P	Posterior wall; posterior column; post. wall + post. column
T	Transverse type; ant. column + post. hemitransverse; transverse + post. wall; T-shaped; both columns

Table 2 Descriptive analysis of nominal variables

Variable	Fracture group	*n* obser.	*n* pos.	% pos.	*n* neg.	% neg.
Spina sign	A	39	16	41.0	23	59.0
	P	67	24	35.8	43	64.2
	T	74	37	50.0	37	50.0
Posterior wall sign	A	38	8	21.1	30	79.0
	P	70	14	20.0	56	80.0
	T	73	9	12.3	64	87.7

contralateral side of the pelvis. All values of conventional radiographs were obtained using digital measurement tools of the PACS imaging program.

Validation of CT scans

With the "localiser" image of the CT scan the same criteria were applied as for the conventional AP radiographs, and thus correct patient positioning could be achieved. Using the PACS imaging program rotations in the axial plane could be corrected. Rotational fault in the frontal plane up to 5° showed to not influence further measurements [20]. All sets of CT scans not meeting these criteria were not further assessed.

Measurement on CT scans

With a previously described measurement technique [20], acetabular version using the acetabular opening or equatorial edge (EE) angle at the maximum diameter of the femoral head in the axial plane was measured (Fig. 2). According to Reynolds et al. [12], who originally described a similar measurement technique, the angles were termed positive if the acetabulum opened anteriorly and negative if it opened posteriorly. As in the conventional radiographs, measurement values were only included if the fracture pattern allowed correct assessment. In all other cases measurements were obtained from the non-injured contralateral side.

Table 3 Descriptive analysis of continuous variables

Variable	Fracture group	*n* obser.	Min.	Mean	Max.	95 % CI
Crossing grade (of CO sign) (%)	A	58	0	12.90	49.65	8.37–18.30
	P	91	0	15.00	73.21	11.25–18.75
	T	91	0	15.27	52.57	11.73–18.67
EE angle (°)	A	51	3.30	19.93	34.50	17.97–21.89
	P	79	5.00	17.06	27.60	15.90–18.82
	T	79	5.60	17.53	28.40	16.00–18.58

Table 4 Bonferroni-Holm corrected *p* values for pairwise comparisons of the EE angle

	P	T
A	0.029	0.047
P	–	0.83

Fracture classification

All acetabular fractures were primarily allocated to one of the fracture types according to the Letournel classification [4]. To strengthen the statistical analysis in terms of avoiding too many subgroups, we reduced the ten different fracture types to three superordinated groups (Table 1). Group A consisted of the anterior wall and the anterior column fractures. In group P the posterior wall, the posterior column and the combination of posterior wall + posterior column fractures were included. The third group (T) comprised all transverse type fractures (transverse type/anterior column + posterior hemitransverse/transverse + posterior wall/T-shaped/both columns).

Statistical analysis

To compare patient-specific variables between the levels of the variable group we calculated *p* values with the Kruskal-

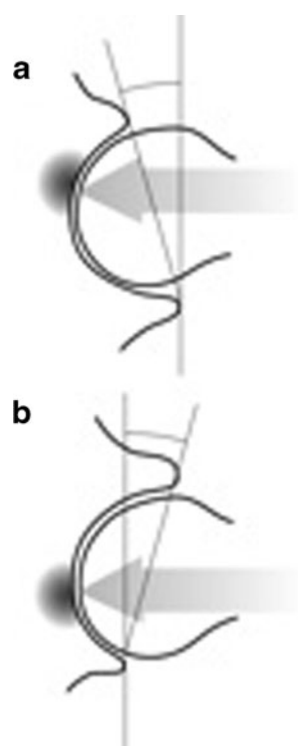

Fig. 3 Constant force vector trough the femoral head in an anteverted acetabulum results in anterior force impact (**a**). Same force vector in a retroverted acetabulum shows posterior impact (**b**)

Wallis test for continuous variables and Fisher's exact test for nominal variables. For proportions the Wilson confidence interval (CI) and for means the CI based on t distribution were calculated. For potentially both sided measurements such as X-grade and EE angles, dependency of the measurements was taken into account and generalised least square (GLS) models were used for this. The p values for global testing and Bonferroni-Holm corrected p values for pairwise comparison were computed. CIs for group means and standard errors were calculated using a GLS model [22, 23]. All CIs were computed using a confidence level of 95 % and all tests were computed at a significance level of alpha=0.05 for global testing. Complete statistical analysis was performed by a biostatistician consultant.

Results

Descriptive analysis showed the following distribution of the acetabular fractures: group A $n=40$ (20.8 %), group P $n=75$ (39.1 %) and group T $n=77$ (40.1 %). CT-based measurements of the acetabular version showed significant differences between group A compared with both groups P and T. The mean EE angle was 19.93° (95 % CI 17.97–21.89) in group A, 17.06° (95 % CI 15.90–18.32) in group P and 17.53° (95 % CI 16.00–18.58) in group T ($p=0.029$ A/P and $p=0.047$ A/T). In contrast, none of the measurement parameters based on the conventional radiographs, such as the crossing grade, posterior wall sign or the ischial spine sign, showed significant differences between the groups. For detailed analysis see also Tables 2, 3 and 4.

Discussion

Understanding of the contributing factors to the different acetabular fracture patterns is still limited. Observational and biomechanical investigations conducted over the past half century have shown the relationship between the femoral position and rotation, and the resulting force distribution inside of the acetabulum [4, 8–10]. For example, Judet et al. stated that hip flexion of 60° at the time of impact causes a postero-superior fracture, while hip flexion of 90° would cause a fracture of the posterior rim, and hip flexion of 115° should result in a fracture of the posterior horn [4].

While the architecture of the proximal femur and pelvis was found to have an influence on the risk and type of hip fractures [24, 25], the role of the acetabular orientation and geometry in fracture pathogenesis of the acetabulum itself remains unclear.

Our results show that the orientation of the acetabulum in the axial plane may influence the occurrence of a distinct fracture pattern. The significant differences in acetabular version between the anterior fracture types in group A and the posterior fracture types in group P indicate the effect on the fracture mechanism. Considering that the majority of cases of acetabular fractures are caused by high velocity vehicular crashes, femoral impact to the acetabulum usually is transmitted in a flexed adducted (sitting) position. Assuming a constant vector of force through the femoral head, variation in acetabular version results in different points of impact and therefore could explain a possible pathomechanism leading to more anteriorly or more posteriorly oriented fracture patterns (Fig. 3).

However, no quantitative conclusion about contribution of the acetabular version to the acetabular fracture type can be drawn by our study. Neither can a statement be made how acetabular orientation in the frontal or sagittal plane may influence a distinct fracture pattern. Further investigations are mandatory to promote a better understanding of the multifactorial pathogenesis of acetabular fractures.

Conclusion

Our results demonstrate that acetabular version in the axial plane has an influence on the fracture pattern. While more anteverted acetabula more frequently lead to anterior fracture types according to the Letournel classification, retroversion of the acetabulum is associated with posterior fracture types.

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