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ORIGINAL STUDY

Prevalence of acetabular dome retroversion in a mixed race adult trauma patient population

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The goals of the present investigation were to identify the prevalence of acetabular dome retroversion in a mixed race population, to quantify the average amount of cross-over ratio, and to determine normative values.

The presence of the cross-over sign and its overlap ratio was assessed for 2,925 hips meeting strict radiographic criteria of the pelvic radiograph.

Fifty-two percent of the hips had no cross-over sign whereas 48% had at least a minimal amount of overlap of the anterior and posterior acetabular wall. Analysis of only those hips with positive cross-over sign revealed a mean cross-over ratio of 26% ± 11% (range : 3 to 93). Forty-two percent of the patients had no cross-over on either side, 18% on one side, and 40% on both sides.

The presence of the cross-over sign is more common than previously expected. Further studies will be necessary to determine the risk of pathological abnormality and to correlate symptoms to crossover ratios. Surgery should not be based solely on the finding of a cross-over sign without clinical correlation.

Keywords : acetabulum ; cross-over ; hip ; impingement ; retroversion ; surgical dislocation.

INTRODUCTION

Decision making for femoroacetabular impingement relies – among other factors – on antero-posterior (AP) view pelvic radiographs as the gold standard of imaging, not only for diagnostic purposes but also for intraoperative and postoperative assessment of correction. A retroverted acetabular dome corresponds to anterior over-coverage of the femoral head and is characterised by the cross-over sign (COS), visible on the AP view pelvic radiograph (*5,6,12,14*). Among surgeons acquainted with femoroacetabular impingement surgery, this sign is considered an important factor when selecting

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patients for surgery (*3-5,8,12-14*). Depending on the pathological finding, surgery can consist of periacetabular osteotomy or surgical hip dislocation and then trimming of the acetabular rim, trimming of the femoral neck, or both (*1,3,7,13*).

The presence of radiographic abnormalities has been correlated with clinical, operative, and histological findings (*4,5,9,15*). Also, several series have reported the mid-term follow-up of patients undergoing femoroacetabular impingement surgery (*1,10, 11*). Despite the frequent use of the COS as an indicator of pathological retroversion of the acetabulum, little data are available regarding the overall prevalence of this finding in the general population.

Although the prevalence of acetabular retroversion recently was reported (*2*), the series included exclusively Asian patients undergoing hip joint evaluation at a single hospital. The data therefore might not represent the prevalence in other races, and the overall prevalence including the asymptomatic population remains unknown. Knowledge of normal values of acetabular dome retroversion is relevant because it could have an impact on indications and surgical decision making for preservation of the hip. Improved understanding and awareness among orthopaedic surgeons regarding acetabular anatomy could lead to earlier identification and subsequent treatment of patients at risk. The goals of the present investigation were to identify the prevalence of acetabular dome retroversion in a mixed race population, to quantify the average amount of acetabular dome retroversion, and to determine normative values based on age, gender, and race.

MATERIALS AND METHODS

The investigation was approved by our institutional review board. Prospectively collected trauma registry information was reviewed to retrospectively identify consecutive patients admitted to our Level I trauma center. Patients who underwent screening AP view pelvic radiography as part of the diagnostic workup or perioperative controls were identified. Many patients had multiple pelvic radiographs obtained for assessment. The radiography sets of 2,964 patients (5,928 hips) met the inclusion criteria. A radiographic review of the AP view pelvic radiographs was then conducted.

Next, we analysed each patient's set of radiographs to rule out positional artefact.

Axial plane rotation of the pelvis could falsify measurements by increasing the cross-over on the side turned away from the source and vice versa. We assessed axial plane alignment by verifying that the os coccyx or the lumbar spinous processes were perfectly aligned with the symphysis (within the midline ± 5 mm).

Sagittal plane rotation of the pelvis could falsify measurements by increasing cross-over on both sides with increasing inclination (more of an inlet view) and diminish the cross-over with extension of the pelvis (more of an outlet view). We assessed sagittal plane alignment by applying the strict criteria set by Siebenrock *et al* (*14*) for pelvic tilt in the process of selecting proper pelvic radiographs for inclusion in the study. To minimise the chance of false positive cross over sign, the distance between the symphysis and sacrococcygeal joint had to measure less than 32 mm in men, and 47 mm in women. All radiographs not meeting these criteria (*14*) were excluded from the study. Pure frontal plane rotation was less of an issue because all measurements were obtained in the frontal plane. For this reason, only sagittal and axial plane rotations had to be perfect.

Additionally, both the anterior and posterior acetabular walls had to be visualised, intact, and recognisable. Pelvic radiographs not meeting any of these criteria were also excluded from the study and were not further analysed. The presence of osteoarthritis or pelvic/acetabular trauma did not exclude radiographs from the assessment as long as the criteria mentioned above were present. In the case of pelvic ring or acetabular injury, the two sides of the pelvis were reviewed independently. If the radiographic criteria were met and the acetabulum could be measured on the non-injured side, that side was included in the investigation.

The radiographic assessment was carried out by four authors trained in reading the characteristic signs associated with acetabular retroversion prior to the study. The presence of a COS (*5,6,12,14*) was recorded. Unlike prior investigators, however, any amount of overlap between the anterior and posterior acetabular walls was determined a 'positive' COS.

Siebenrock *et al* (*14*) proposed quantifying the COS. Two measurements were therefore performed. The first measurement (A) extended from the lateral border of the acetabulum to the cross-over point, and the second measurement (B) extended from the lateral border of the acetabulum to its posteroinferior border. We calculated the ratio of A :B and called it the *overlap ratio of the COS* (fig 1).

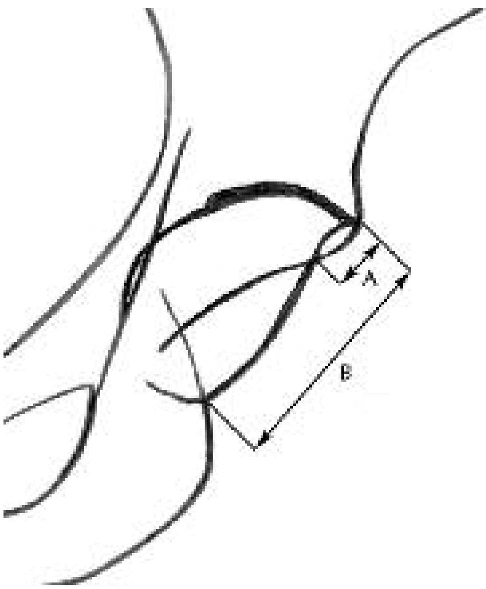

Fig. 1. — The cross-over ratio (amount of overlap) was calculated as the ratio of distance A (extended from the lateral border of the acetabulum to the cross-over point) and distance B (extended from the lateral border of the acetabulum to its posteroinferior border).

We collected patient demographic factors, including age, gender, and race. Patient race, if clearly categorisable, was gathered from patient charts, entered at the time of admission and was recorded as Caucasian, Hispanic, African-American, or Asian.

Statistical analyses

Continuous data were presented as means ± standard deviations and were compared among groups by using the Mann-Whitney test. Correlations between values at both sides were computed by using the Spearman rank correlation technique. Nominal data were presented as numbers or percentages and were compared among groups by using Fisher's exact test. Logistic regression was used to analyse the presence of cross-over with age. Additionally, 100 AP pelvic radiographs were randomly selected to perform an interrater reliability testing and restricted likelihood estimations were obtained.

SPSS 13.0 software (SPSS Inc., Chicago, IL) was used for statistical analyses ; p values < 0.05 were considered statistically significant.

RESULTS

Of the original 2,964 patients, most of whom had multiple sets of pelvic radiographs available (up to 10 AP pelvic radiographs per patient), we excluded 1,639 patients altogether (55%) because they did not meet the radiographic inclusion criteria on any of their multiple radiographs. This left 1,325 patients who met the strict radiographic inclusion criteria at least on one of their AP view pelvic radiographs and in whom both hips were well visualised and could be accurately measured. In 275 further patient sets of radiographs that met the criteria, only one side could be measured because of trauma or artefact. Therefore, of the original 5,928 hips in 2,964 patients, we were left with a total of 2,925 hips in 1,600 patients that were further investigated. The demographics of the patients selected for this study are presented in table I.

Overall retroversion measurement did not show a Gaussian distribution but rather a bimodal distribution (mixed equicontinuous-discrete random variable) (figs 1, 2). When all the hips were analysed together, a mean cross-over ratio of 12% ± 15% (range : 0 to 93) was found. Because of the bimodal distribution, the patients with no COS (0 to 1% cross-over ratio, n = 1508 hips, 52% of hips) were excluded in a second step of the analysis and the remaining patients (with > 1% cross-over ratio, n = 1,417, 48% of hips) were analysed separately. Analysis of only those hips with a positive COS revealed an approximate Gaussian distribution with a mean cross-over ratio of 26% ± 11% (range : 3 to 93) (fig 3).

We then investigated the symmetry. For the 1,325 patients for whom measurements could be obtained on both sides, a correlation of cross-over ratios of r = 0.61 with p < 0.001 was found. Of the patients for whom both sides could be evaluated (n = 1,325), 557 (42%) had no cross-over on either side, 239 (18%) had unilateral COS (evenly divided between right and left), and 529 (40%) had positive COS bilaterally. When only the patients with bilateral positive COS were compared, no statistically significant difference of the cross-over ratios measured could be found between left and right sides (p = 0.607).

Table I. — Demographic data for patients included in final analysis

	No cross-over left	Cross-over left
No cross-over right	42%	9%
Cross-over right	9%	40%

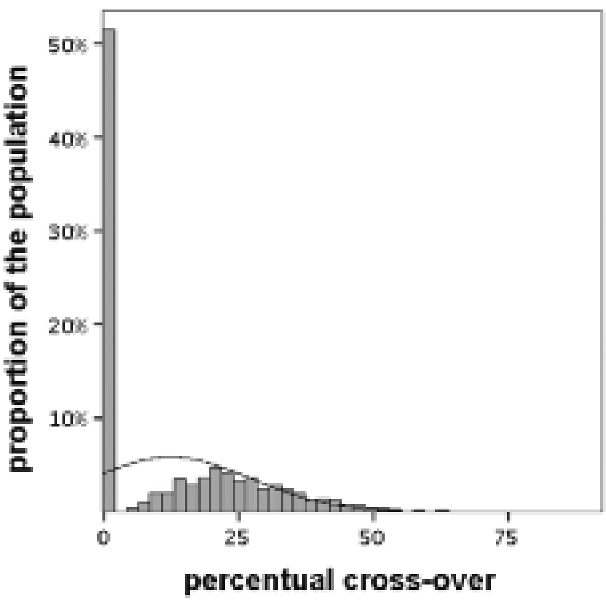

Fig. 2. — Bimodal distribution (mixed equicontinuous-discrete random variable) of all the 2,925 hips together. Note that approximately 50% of the hips have no crossing, whereas the remainder have cross-over and show a Gaussian distribution.

Sex seems to play a role for the presence of cross-over. Cross-over was present in 52% of men (48% < 1% cross-over), whereas only 45% of women presented with cross-over. This difference was statistically significant ($p = 0.0004$ and $p = 0.032$, respectively).

A negative correlation between age and cross-over ratio was found ($r = -0.319$ for the right side, $r = -0.275$ for the left side, $p < 0.001$). Older people were significantly more represented in the group without COS (< 1% cross-over ratio, $p < 0.001$). The scattergram (fig 3) and the age-grouped representation (fig 4) show that it is not the actual cross-over ratio that diminishes but that the prevalence of COS is lower in older people. Logistic regression

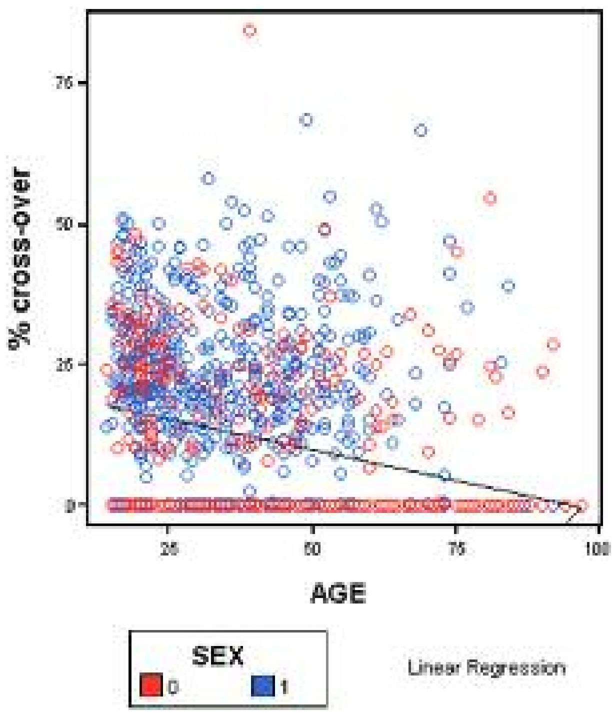

Fig. 3. — Regression analysis for percentage of cross-over and age. Note that the prevalence of cross-over ratio seems to diminish with age. The prevalence is higher in younger patients.

analysis ruled out confounding by higher female gender prevalence in older patients. The effect of age on the presence of COS or cross-over ratio was found to be independent of gender. Odds ratio calculations showed that a relative risk exists ; with every 10 years of increase in population age, the prevalence of COS drops by approximately 30% (or 4% per year) (fig 3).

Demographic information on patient race was available in only 1070 of the 1,600 patients (67%). The age distribution curve was similar for all races. Patient race (Caucasian, Hispanic, African-American, Asian) was not found to statistically influence the presence of the COS or the cross-over ratio. When right and left hips of each patient were compared for symmetry for each patient race separately, no difference was noted, with one exception. In the patients of Asian descent, only 25% of the right hips showed cross-over whereas 50% of the left hips did. Because of the low number of patients

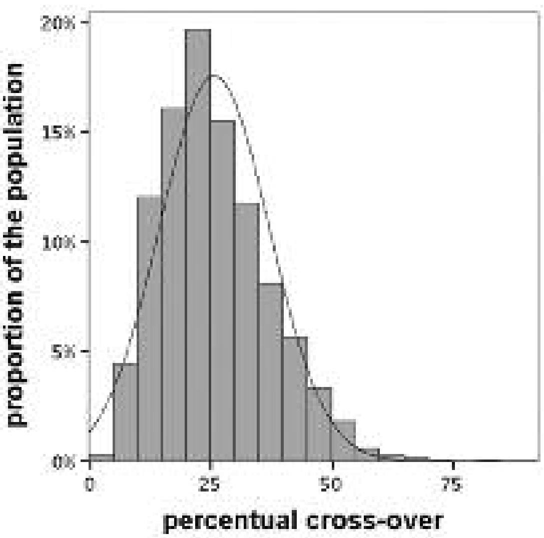

Fig. 4. — Gaussian distribution of the hips with COS (n = 1,417). In the hips with cross-over, the mean value was 26% (range : 3 to 93 ; SD : 11%).

(n = 40) clearly identified as being of Asian descent, this difference was not further statistically analysed.

Based on the 100 radiographs randomly selected for interrater comparison, an interrater reliability of r = 0.92 with a restricted maximum variance estimation of 0.06% was found.

DISCUSSION

The present study, to the best of our knowledge, is the first to describe not only the presence of COS but also the cross-over ratio of the acetabular dome in a large mixed race patient population. Our center admits trauma patients who are older than 15 years and is a Level I referral center tending to admit patients with high-energy trauma. Screening AP view pelvic radiographs and dedicated pelvic radiographs are routinely obtained. We used the strict radiographic criteria for correct imaging of the pelvis as described by Siebenrock *et al* (*14*). The patient population in our study might therefore constitute a more valid representation of the general adult population. Unlike previous studies, however, we determined even the smallest amount of cross-over ratio to represent a 'positive' cross-over sign, and quantified that sign as a ratio. The high prevalence of COS found in this study might therefore not necessarily be compared to the findings of other investigators.

The presence of acetabular retroversion recently was reported to be 6% in a normal population and 20% in a patient population with radiographic presence of arthritis of the hip (*2*). That study included patients from a single institution, all of Asian descent, and it was not clearly stated why all the patients underwent radiographic hip evaluation. The assignment of the patients into subgroups in that study was based on the radiographic presence of osteoarthritis alone. Categorical yes-or-no assessment of COS did not asses its magnitude (cross-over ratio), and no information is given on how much overlap of anterior and posterior acetabular wall was determined to be a 'positive' COS. It is therefore possible that the study included patients with high cross-over ratios in the COS group and that patients presenting with only very proximal cross-over of low value might have been assigned to the no COS group. The data therefore might not represent the true prevalence of COS in the general population (i.e., including those not suffering from hip pathological abnormalities) and might not apply to other races.

The number of patients presenting with cross-over was larger in our study compared with the findings presented by Ezoe *et al* (*2*). The most likely explanation is that small cross-over ratios were recorded as positive COS in our study. Differences in age and race are also noted. The patient population in the study by Ezoe *et al* (*2*) was relatively young, with a mean age of 34.9 years in the normal group. Differing results could be caused by the mixed races in our study, compared with Asian patients in the other. The relatively small number of Asian patients in our study population may explain the absence of a statistical difference in the prevalence of the COS between Asian patients and patients of other races.

The prevalence of COS was surprisingly high, and especially so in younger subjects. The finding of a decreased prevalence of the COS in older patients was unexpected. The effect of age on the

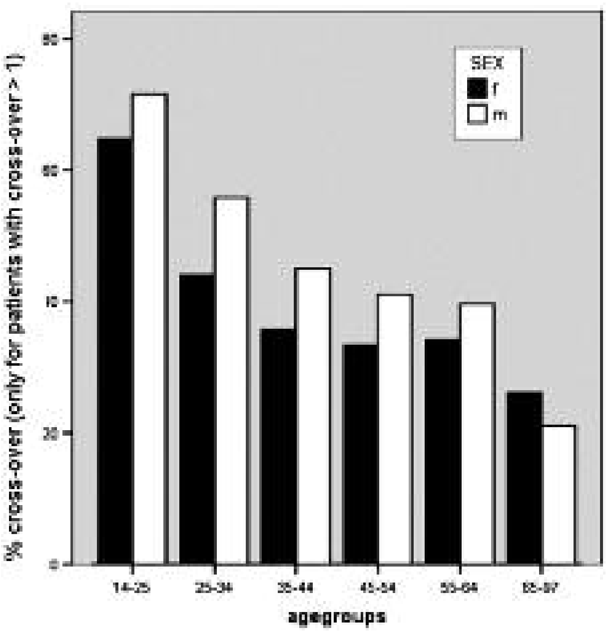

Fig. 5. — Graphic representation of cross-over overlap ratio (only patients with cross-over depicted), shown in age groups of 10 years. Note the constant drop in prevalence from one 10-year block to another.

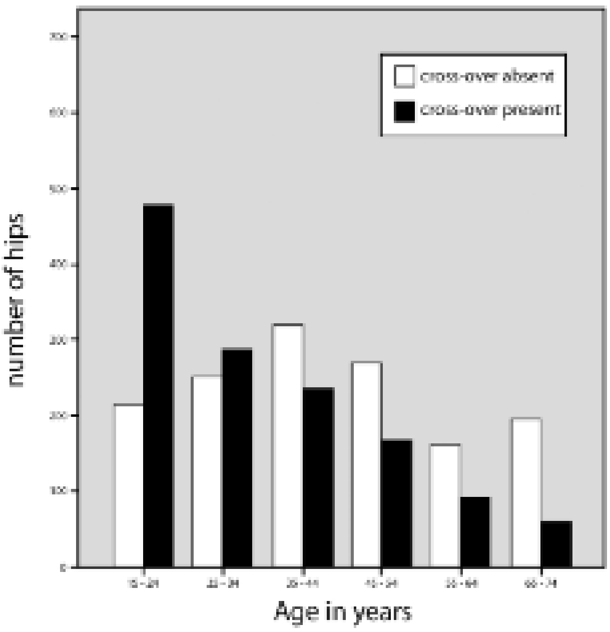

Fig. 6. — Number of hips with and without presence of the cross-over sign (independent of overlap ratio), shown in age groups of 10 years.

presence and magnitude of retroversion was found to be independent of gender in the older age groups, and acetabular retroversion was less frequent in women. A remodelling processes leading to a more "normal" version of the acetabulum is highly unlikely. One possible explanation might be that the phenomenon is becoming more frequent compared with some decades ago (fig 3). Another explanation is that radiographic positioning in the older patient may be subtly affected by stiffness in the lumbar spine and lumbosacral junction, functionally flexing the pelvis relative to the position in younger patients. This could possibly result in "false negative" COS. The Siebenrock criteria for radiographic positioning may be insufficiently strict to prevent false negatives based on subtle changes in positioning in the sagittal plane. Further correlation between the COS on plain films and the finding of retroversion on CT scans in this patient population is forthcoming.

A major limitation of this investigation is that we do not have any data on the patients' symptoms. We therefore cannot tell, where the cut-off between asymptomatic hips (presenting with small amount of cross-over ratio) and the actual pathology (symptomatic hips with greater amount of cross-over ratio). Another limitation is the very high number of radiographs excluded from the study due to inappropriate exposure. As we were aware of this possible selection bias, the number of patients/radiographs evaluated for inclusion was maximally increased in order to still get a representative cohort.

In conclusion, 52% of the hips in our study had no retroversion of the acetabular dome, whereas 48% had at least a minimal amount of cross-over ratio. The finding of acetabular retroversion represented by COS on AP view radiographs of the pelvis might therefore be much more common than earlier expected. Based on these normative values, further studies will have to compare the subtle radiographic findings of cranial acetabular retroversion, determine the risk of pathological abnormality and correlation to symptoms. Ideally, and especially with cross-over ratios of small amounts, they would determine a cut-off cross-over ratio where the acetabular retroversion can be determined to be pathological.

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