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ORIGINAL ARTICLE

Analysis of acetabular version: Retroversion prevalence, age, side and gender correlations

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Abstract *Introduction:* Studies using conventional radiographical signs and computerized tomography (CT) for retroversion of the acetabulum have reported a prevalence of up to 25%. The purpose of this study was to provide a detailed report on acetabular version, gender, age and side differences in a large cohort.
Materials and methods: A total of 404 patients receiving a whole-body CT scan, aged between 16 and 40 years, have been included in the study. The measurement was performed in the transversal plane on three levels: cranial, central and caudal.
Results: The retroverted acetabulum on all three levels had a prevalence of 0.25% (95% confidence interval 0–0.7%). The average central anteversion in men was 16.46° (±4.42) and that in women was 19.31° (±5.04) ($p < 0.001$). Version increases with age, but a cluster analysis showed this to be a trend ($p = 0.068$).
Conclusion: Women have a higher average acetabular version than men. Retroversion in a young adult population has a low prevalence when measured with conventional CT. About a tenth of the population has a significantly different contralateral acetabular version.
The translational potential of this article: Global acetabular retroversion has a much lower prevalence than previously reported.

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Introduction

The orientation of the acetabulum in the horizontal plane is anatomically called version [1,2]. Anatomical orientation of the acetabulum is around 20° anteversion [3,4]. In cases where the version is posterior to the horizontal plane, the acetabulum is retroverted [5]. This morphological feature has been proposed to contribute to a number of pathologies of the hip joint. It has been linked to the development of early osteoarthritis [6,7]. A correction of retroversion has been shown to prevent early osteoarthritis [8] and increase survivorship of the hip joint [9,10] with excellent overall results [11]. A retroverted acetabulum has been shown to contribute to more acetabular fractures, and it also influences the type of the fracture [12] because of the increased load on the posterior column. Stress fractures of the femoral head are also more common in retroverted acetabula because of the prominent anterolateral wall which impinges the femur [13,14].

Several radiologic markers are used to quantify the retroversion, the crossover sign (COS), posterior wall sign (PWS) and ischial spine sign. Initially verified as a reliable sign to measure retroversion [15] and used to report very high incidences, the COS in the meantime has been shown to overestimate retroversion because of the geometry of the pelvis and the angle of the radiologic beam [16]. Currently, when using conventional radiology to diagnose retroversion, the presence of all three signs must be fulfilled [17]. Conventional radiology does not allow a correct measurement of the angle.

For this reason, some studies using computerized tomography (CT) were conducted. They use different definitions of acetabular retroversion, thus providing confusing results. Perreira et al. [18] measured on seven levels of the acetabulum and found retroversion only on the two most cranial levels at 7% and 2%, based on 100 acetabula but reported a 7% prevalence of retroversion. A study by Larson et al. [19] on 474 hips found the prevalence of cranial retroversion that would have a positive COS to be 15%. Wassilew et al. [20] reported 24% of the cohort to have a positive COS. Contrary to the CT studies, Tannenbaum et al. [21] used a goniometer to measure acetabular version on three levels and found 0% of globally retroverted acetabula.

The purpose of the study was to provide a detailed report of the acetabular version in a young population using CT scans.

Materials and methods

This study is a Level III prognostic study. The authors' institutional ethical board has approved the study (0711/2017). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

The patient cohort was collected using a retrospective search of polytraumatised patients treated in the authors' emergency room between January 2013 and January 2018. The inclusion criterion was patients aged between 16 and 40 years. The exclusion criteria were a diagnosis of pelvic, spinal and femoral fractures, hip dysplasia, acetabular protrusion, previous hip, pelvic or spinal surgery, and technically insufficient scans. Fractures have been diagnosed and excluded. The diagnosis of dysplasia was made on the frontal plane CT slices through the center of the femoral head, based on measurements of the lateral center-edge angle and the acetabular index. A lateral center-edge angle of $<25^\circ$ and acetabular index of $> 10^\circ$ were defined as indicating dysplasia. Acetabular protrusion was defined as crossing of the outline of the femoral head beyond the ilioischial line resulting in a femoral head extrusion index of ≤ 0.4. Patients' gender, age and race were recorded.

After an initial clinical assessment, the patients were moved to the adjacent CT room in the emergency admission room and slid onto the CT table. The patients remained in a supine and straight position during this time, regardless of the use of a vacuum mattress. The scans were performed using a 64-slice Siemens Somatom Definition AS (Siemens Healthineers, Erlangen, Germany). On completion of the scan, a radiology technician set the frontal, transversal and sagittal planes to account for any tilt of the patient on the table and created the CT images in 2-mm slices in all three planes.

Transversal scans were used to measure the acetabular version. The measurements were performed using Agfa IMPAX EE (Agfa-Gevaert N.V., Mortsel, Belgium) by two examiners, a specialist in orthopaedic surgery and a doctoral candidate trained in the radiological department specifically for this task.

A total of three measurements were taken per acetabulum using a previously described method [21]: the cranial version, the central version and the caudal version. The reference line was drawn through the pubic symphysis and the middle of the sacrum (Fig. 1). The cranial, central and caudal levels of the measurements and their transversal plane counterparts are shown in Fig. 2.

Retroversion was defined as a negative angle of the measured version of the acetabulum with regard to the reference line. The bilateral difference was calculated as a difference between central versions for each patient.

The distribution of all three measurements and the average version was analysed using a two-step cluster analysis. First, a hierarchical cluster analysis of version on all three levels and side differences was performed to

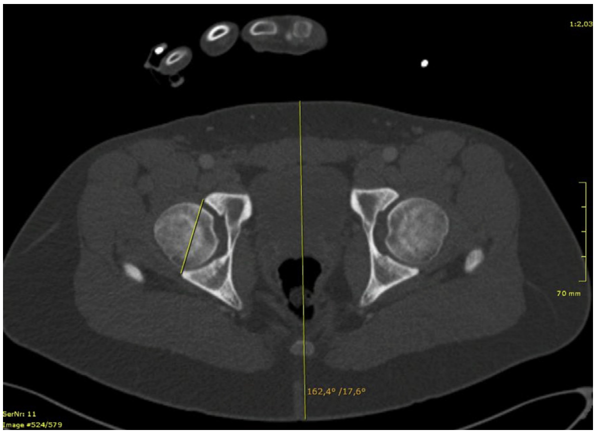

Figure 1 Measurement of acetabular version: angle between the reference line and the line drawn through to the most lateral, anterior and posterior wall.

determine the number of clusters after which a k-step cluster analysis was performed to identify the cases in each cluster. Age groups were calculated using the same two-step cluster analysis. Groups for the bilateral difference in version were also calculated using this two-step cluster analysis. Statistical difference between the cluster groups was calculated using analysis of variance. The correlation between version and age has been calculated using linear regression, and the correlation between gender and version, using point-biserial correlation. The confidence interval (CI) for prevalence was calculated using Wald intervals. Interobserver reliability was calculated using the intraclass correlation analysis. Statistical analysis was performed using SPSS 24 (IBM, Armonk, NY, USA).

Results

After applying the inclusion criteria, 580 CT scans were analysed. A total of 176 scans were excluded, which left a total of 404 CT scans (808 acetabula) included in the study. There were 118 women (29.2%) and 286 men (70.8%). A total of 375 patients were Caucasians (92.9%), and 29 patients were of Middle Eastern descent (7.1%). The average patient age in the cohort was 27.8 ($\pm$7.0) years. The average age of women was 27.0 $\pm$ 6.9 years and that of men was 27.3 $\pm$ 6.85 years without a difference between the groups ($p = 0.704$). The average central version was 17.3° ($\pm$4.8), range −7.4 to 28.6°. The average cranial version was 16.45° ($\pm$4.3), range −8° to 26.3°, and the average caudal version was 18.8° ($\pm$4.9), range −3° to 29.1°. Interobserver agreement was 0.93 for all measurements. The average central version in men was 16.5° ($\pm$4.4) and that in women was 19.3° ($\pm$5.0) with a statistically significant difference ($p < 0.001$). Overall, version increased with age ($p = 0.028$). Average bilateral version difference was 1.1° $\pm$ 2.0°. It has been demonstrated that there was no correlation to gender ($p = 0.994$), age ($p = 0.325$) or average anteversion ($p = 0.440$).

There was only one retroverted acetabulum on all three levels in a 21-year-old Caucasian man. This patient's cranial version was −8°, central version was −7.4° and caudal

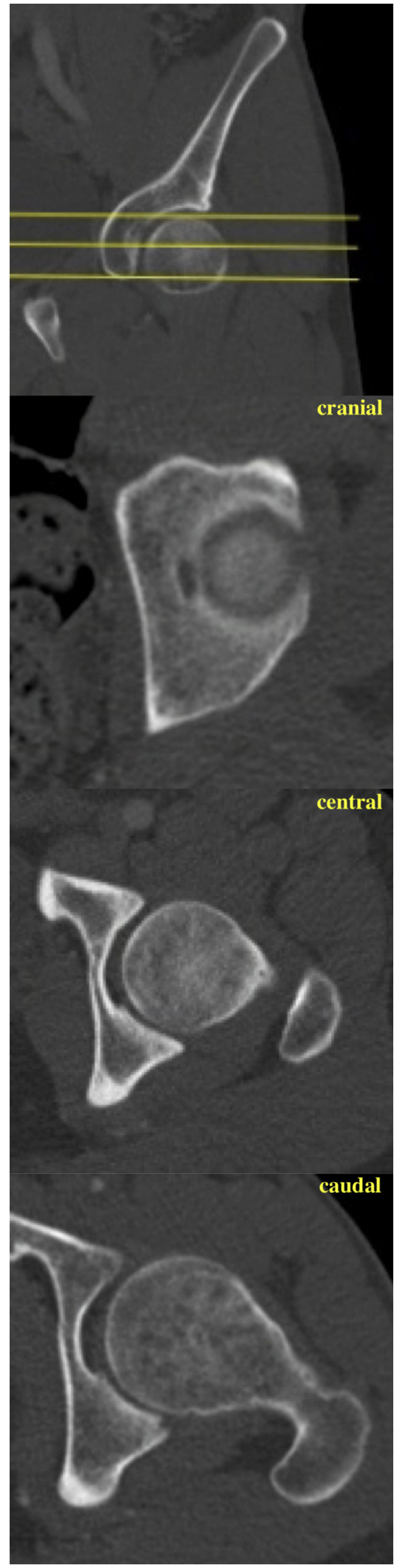

Figure 2 Coronal depiction of three measured levels of the acetabulum with their transversal counterparts.

version was −3°. Additional four patients had a retroversion on the cranial level to a maximum of −2°. Central and caudal retroversion was only observed in that one patient. The prevalence of complete acetabular retroversion in this cohort is 0.25% (95% CI 0–0.7%) and that of cranial retroversion is 1.24% (95% CI 0.2–2.3%).

A two-step cluster analysis of the distribution of version on all levels created five groups, as found in Table 1. The differences in version between the groups were statistically significant ($p < 0.001$) with a considerable proportion of the patients (69.4%) in the two groups around the average version. There was no statistical significance between age and cluster groups ($p = 0.066$). The two cluster groups with higher versions had a higher percentage of women ($p < 0.001$). Using the same cluster values, distribution of cranial and caudal version was calculated and is shown in Tables 2 and 3, respectively.

A two-step cluster analysis of age distribution created four groups, found in Table 4. The differences in version between the groups were statistically significant ($p < 0.001$). However, the overall correlation between age groups and the version was not observed ($p = 0.068$).

A two-step cluster analysis of the bilateral difference in version created two groups. The first group was from 0° to 2.7° with 348 patients (86.1%), and the second was from 2.8° to 13.8° with 56 patients (13.9%). A total of 42 patients (10.4%) were outside of the 95% CI for the bilateral difference in the version at 4°.

Discussion

This study shows that a young population has a low prevalence of complete acetabular retroversion at 0.25% and a prevalence of cranial retroversion at 1.24% when measured with conventional CT. It also shows that women have higher average anteversion than men. Anteversion has demonstrated an increasing trend with age, without a statistical significance. Finally, a tenth of the cohort has a bilateral difference in version greater than two standard deviations of the cohort average.

The prevalence of both complete and cranial acetabular retroversion in this study is much lower than in comparable studies using CT scans [18–20]. This difference is due to the definition of retroversion used in those studies and due to the technical measurement—the presence of COS calculated from a CT scan. Perreira et al. [18] define retroversion as cranial retroversion and report a prevalence of 7%. Larson et al. [19] use a COS equivalent as a definition of retroversion on a clock-based model from a CT scan and report 15% retroversion. Wassilew et al. [20] report 24% prevalence, also using the COS, and report that a combination of a positive COS and PWS was only observed in 1% of the cohort but still define retroversion as a positive COS. Contrary to these reports, Tannenbaum et al. [21] report a 0% prevalence but define global version as an average of all three versions. The average versions for these studies are very similar: the study by Perreira et al. [18] had 21.3°± 5.8°, the study by Wassilew et al. [20] had 18.0°± 4.7°, the study by Tannenbaum et al. [21] had 17° ± 9° and this study has 17.3° ± 4.8°, with the same being true for the ages. These similarities suggest that the population demographics are similar, but the definition of retroversion and measurements differs. The presence of COS can determine focal retroversion but is very sensitive to small changes in tilt, rotation and beam direction [16]. The main culprit for this false positivity is the presence of an anterior inferior iliac spine [16]. If only radiographic signs are to be used, then the combined presence of COS, PWS and ischial

Table 1 Cluster analysis of central version distribution.

Cluster	Central version distribution (°)	Mean central version of all acetabula (°, ±SD)	Number of patients (%)	Number of men (%)	Mean age (±SD)	Cluster p value
1	Retroversion	−8.0	1 (0.3%)	1 (100%)	20.9	<0.001
2	5.6 to 13.2	10.7 (1.9)	83 (20.5%)	70 (84.3%)	26.2 (6.1)	<0.001
3	13.7 to 17.8	15.9 (1.4)	136 (33.7%)	107 (78.6%)	27.1 (6.9)	<0.001
4	18.2 to 23	20.2 (1.3)	144 (35.7%)	91 (63.9%)	27.3 (7.0)	<0.001
5	23.0 to 28.6	25.7 (2.5)	40 (9.9%)	15 (37.5%)	28.9 (7.8)	<0.001
Total	−8 to 28.6	17.3 (4.8)	404 (100%)	286 (70.8%)	27.8 (7.0)	

SD = standard deviation.

Table 2 Cluster analysis of cranial version distribution.

Cluster	Cranial version distribution (°)	Mean cranial version of all acetabula (°, ±SD)	Number of patients (%)	Number of men (%)	Mean age (±SD)	Cluster p value
1	Retroversion	−1.8 (0.3)	5 (1.2%)	5 (100%)	22.4 (2.3)	<0.001
2	5.6 to 13.2	8.3 (1.2)	140 (34.7%)	110 (78.5%)	27.2 (6.4)	<0.001
3	13.7 to 17.8	14.3 (1.6)	201 (49.8%)	139 (69.1%)	27.1 (5.2)	<0.001
4	18.2 to 23	19.8 (1.3)	43 (10.7%)	27 (62.8%)	27.6 (3.4))	<0.001
5	23.0 to 28.6	23.7 (2.5)	15 (3.7%)	5 (33.3%)	28.1 (3.7)	<0.001
Total	−7.4 to 28.6	15.4 (3.2)	404 (100%)	286 (70.8%)	27.8 (7.0)	

SD = standard deviation.

Table 3 Cluster analysis of caudal version distribution.

Cluster	Caudal version distribution (°)	Mean caudal version of all acetabula (°, ±SD)	Number of patients (%)	Number of men (%)	Mean age (±SD)	Cluster p value
1	Retroversion	−3	1 (0.3%)	1 (100%)	20.9	<0.001
2	5.6–13.2	12.1 (1.0)	82 (20.3%)	67 (81.7%)	27.5 (6.4)	<0.001
3	13.7–17.8	16.6 (1.1)	187 (46.3%)	145 (77.5%)	27.2 (5.2)	<0.001
4	18.2–23	20.5 (1.4)	85 (21.0%)	49 (57.6%)	27.3 (3.4))	<0.001
5	23.0–31.4	27.7 (2.4)	49 (12.1%)	24 (48.9%)	26.9 (3.7)	<0.001
Total	−3–31.4	22.2 (4.2)	404 (100%)	286 (70.8%)	27.8 (7.0)	

SD = standard deviation.

Table 4 Cluster analysis of age distribution.

Cluster	Age distribution (years)	Average age (years, ± SD)	Number of patients (%)	Number of men (%)	Average version (°, ±SD)	Cluster P value
1	16.0–22.7	20.0 (1.5)	146 (36.1%)	107 (73.3%)	16.7 (4.7)	<0.001
2	22.8–28.4	25.5 (1.6)	94 (23.3%)	61 (64.9%)	17.6 (4.6)	<0.001
3	28.5–34.3	31.6 (1.7)	77 (19.0%)	56 (72.3%)	17.3 (5.4)	<0.001
4	34.4–39.9	37.2 (1.7)	87 (21.5%)	62 (71.3%)	18.0 (4.7)	<0.001
Total	16.0–39.9	27.8 (7.0)	404 (100%)	286 (70.8%)	17.3 (4.8)	

SD = standard deviation.

spine sign should be used to define retroversion [17]. Instead of using radiographic counterparts, this study reports direct measurements on all levels to avoid confusion in the definition, thus avoiding over-reporting seen in other studies.

Our findings support previous findings that women have an increased average version compared with men [21]. The precise implications of this difference are yet to be determined because women were previously believed to have a higher incidence of femoroacetabular impingement [21]. These differences have also been refuted in the meantime [22]. Women also have a higher incidence of hip osteoarthritis [23]. There are several theories as to why there is a difference in anteversion, all yet to be confirmed. One proposed mechanism is increased pelvic flexion in women because of weaker abdominal muscles [21]. Pathoanatomic variations, such as coxa profunda, acetabular protrusion and femoral retroversion, of the hip are under-investigated, and their prevalence in men and women is mostly unknown; subsequently, their potential respective roles are unknown [21].

Finally, the bilateral difference in version larger than two standard deviations (4°) was seen in 10.4% of the cohort. To our knowledge, this has not been reported before in any study. Although patients get bilaterally assessed for hip pain, patients with low anteversion should be assessed with a CT scan because radiographs are technically not capable of distinguishing these small differences, which can result in overlooking a retroverted contralateral acetabulum.

There are several limitations to this study worth noting. First, the population analysed was trauma patients, the majority of them being men. This is also a more general population and not a specific hip pain population. However, this exact demographic is ultimately undergoing a peri-acetabular osteotomy because of this very reason [11]. The cut-off at 40 years can be viewed as a potential limitation. The increasing prevalence of osteophytes with age would skew the measurements substantially, and more importantly, older patients' consequences of retroversion are treated with a total hip replacement and not with a peri-acetabular osteotomy [24]. Second, although the position of the patient on the CT table was rigorously controlled to avoid secondary damage to the patients and the scans were adjusted for malposition of the patient, the primary purpose of these scans was to detect a fracture so that pelvic tilt was not controlled for specifically. The average versions and the distribution are within one degree of studies controlling pelvic tilt [20,21], suggesting that variation in pelvic tilt does not affect the overall measurements in a significant manner.

Conclusion

Women have a higher average acetabular version than men. Retroversion in a young adult population has a low prevalence when measured with conventional CT. About a tenth of the population has a significantly different contralateral acetabular version.

Conflicts of interest

A.K. has received research support from Implantcast. T.J.H. has been paid for presentations for Smith & Nephew, Zimmer Biomet and Implantcast. He has received research support from Smith & Nephew, Zimmer Biomet and Implantcast. He is a consultant to Smith & Nephew. M.D.S has been paid for presentations by Smith & Nephew and DePuy. All other authors have no conflicts of interest to declare.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jot.2019.01.003.

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