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Original Research

Effect of the Innominate Bone Horizontal Rotation on Acetabular Version: A Retrospective Radiological Study on a Middle Eastern population

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Abstract

Background: The impact of acetabular horizontal rotation on the development of femoroacetabular impingement and subsequently osteoarthritis is well-studied in the literature. However, there is not a clear relationship between the rotation of the hemipelvis and the version of the acetabulum.

Purpose: The purpose of this study was to evaluate the influence of the rotation of the hemipelvis on the version of the acetabulum.

Methods: Through a retrospective study, three-dimensional reconstructions of high-resolution CT (computed tomography) scans of 154 patients receiving pelvic scans for non-orthopedic causes were selected from our institution's database. The horizontal rotation of the different parts of the hemipelvis was evaluated using the following parameters: superior iliac spine angle (SIS), inferior iliac spine angle (IIS), roof edge angle (REA), equatorial edge angle (EEA) and ischiopubic angle (IPA).

Results: The results showed a significant positive correlation between the different angles of the innominate bone and the version of the acetabulum such as when the proximal innominate bone rotates, the cranial part of the acetabulum rotates in the opposite direction. Increased anteversion angles in females compared to males were also observed.

Conclusion: The observations suggest that, in an asymptomatic population, the acetabulum should not be considered a separate entity independent from the rest of the innominate bone and that the version of the acetabulum correlates with the rotation of the hemipelvis.

Keywords: Acetabular version, Computed tomography, Hemipelvis, Hip joint, Horizontal rotation, Innominate bone

Introduction

Acetabular orientation is well understood in the physiological as well as in various pathological conditions [1-6]. Its effect on hip biomechanics as well as the resulting cranial focal over-coverage secondary to different horizontal rotations of the acetabulum are commonly studied topics in the current literature [7-9]. However, the relationship between the rotation of the acetabulum and the innominate bone in the horizontal plane is a rarely discussed topic [10-14]. The current literature focuses mainly on the orientation of the acetabulum in certain pathologies but omits to examine the orientation of the whole innominate bone in these entities [15-16].

To our knowledge, only two articles studied the relationship between the three-dimensional orientation of the innominate bone and that of the acetabulum. In addition, a very limited number of studies focused on the pathologic changes of the whole pelvis or hemipelvis in developmental dysplasia of the hip (DDH) without mentioning the acetabulum [10-14].This restricted number of studies limits our understanding of hip physiology and consequently the pathogenesis of various hip disorders such as femoroacetabular impingement (FAI). The impact of acetabular horizontal rotation (which is anatomically known as version), more specifically cranial retroversion of the acetabulum, on the development of FAI and subsequently osteoarthritis, is a well-established entity [7,9,15-21]. However, a clear relationship between the rotation of the hemipelvis and the version of the acetabulum hasn't been established. Thus, the aim of this research article is to evaluate the influence of the innominate bone rotation on the acetabular version based on the three-dimensional (3D) reconstruction of computed tomography evaluation.

Materials & Methods

Patients' selection

This research has been approved by the Saint Georges Hospital University Medical Center institutional review board. This is a retrospective study that used supine CT scans of the pelvises of 154 patients who were examined for non-orthopedic causes at one single institution between January and May 2016. Six patients were excluded from the study due to gross deformities of their pelvises.

The remaining group consisted of 78 females and 70 males, with respective mean ages of 59.2 and 56.

Imaging and measures

The investigations were fulfilled with a "General Electric LightSpeed 64" multidetector CT scanner. The slice thickness of the accepted scans was 0.625 to 1.25 mm (peak kV = 120 kV and average exposure = 260 mA). Each examination was afterward processed with the 3D software (Amira, Thermo Fisher Scientific) which generated a volumetric representation of the basins. The measurements of the angles between the different lines were processed using the ImageJ software.

The following angles were measured on the axial cuts of the CT scans:

(1) The Roof Edge Angle (REA) (also known as apical acetabular anteversion angle) is measured in the axial plane passing through the most proximal part of each femoral head. It is the angle formed between a line passing through the most lateral points of the anterior and posterior acetabular walls and the perpendicular to the line joining both ischial spines. A negative angle indicates a cranially retroverted hip.

(2) The Equatorial Edge Angle (EEA) (Figure 1) is measured in the same way as the roof-edge angle is measured, but the axial plane passes through the center of each femoral head.

On the 3D-reconstructed pelvises using the following anatomical landmarks, 3D lines were drawn on each hemipelvis:

1) A line connecting the anterior to the posterior superior iliac spines (SIS)

2) A line connecting the anterior to the posterior inferior iliac spines (IIS)

3) An ischiopubic line connecting the pubic tubercle to the ischial tuberosity (IPL)

Figure 2 represents the different above mentioned points on the pelvis and the lines that connect each pair of points.

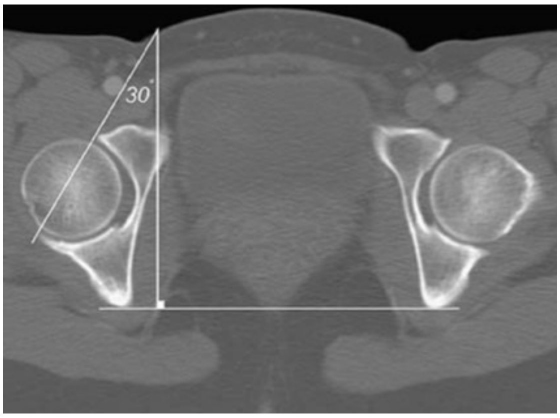

Figure 1: Equatorial edge angle (EEA) measured at the level of the femoral head center using axial CT scan cuts.

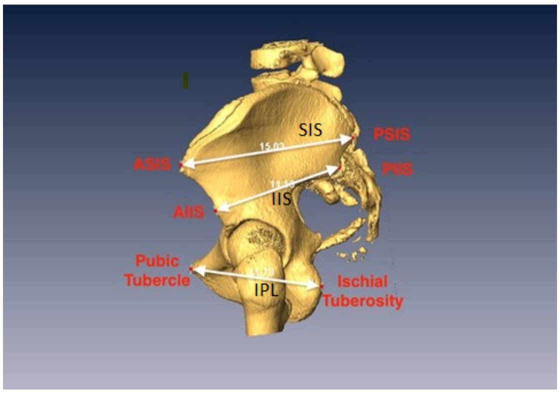

Figure 2: Laterally viewed reconstructed pelvis showing the SIS, IIS & IPL lines.

The reconstructed pelvis' position was standardized in three planes to correct for any rotations that may affect the measurements. Each pelvis was positioned in the position suggested by Kendall and McCreary, which is the neutral standing position of the human pelvis. In the coronal plane, the ASIS were aligned horizontally, and in the sagittal plane, the two ASIS and the most anterior aspect of the pubic symphysis were aligned in the same vertical plane. In the axial plane, the pelvis was placed vertically to a line connecting the middle of the sacrum to the pubic symphysis [22-23].

After correcting the rotation in the different planes, the 3D pelvis was rotated to be viewed superiorly (Figure 3) with the anterior superior iliac spines and the anterior aspect of the pubic tubercles in the same plane.

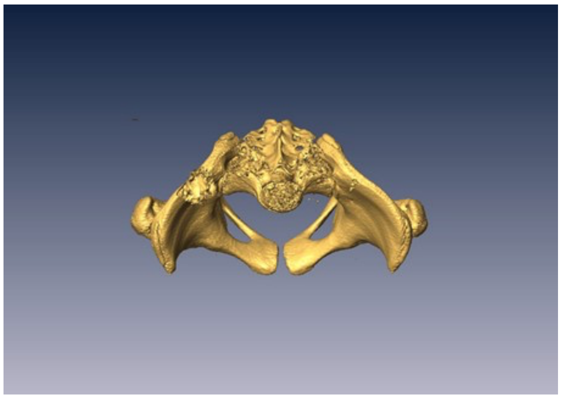

Figure 3: 3D reconstructed pelvis viewed superiorly

Next, a line bisecting the pelvis in half was drawn passing through the pubic symphysis anteriorly and the center of the sacrum posteriorly, this was labeled as the reference line.

The angles formed between the above-mentioned drawn lines and the reference line were measured using the ImageJ software [24].

The resulting angles were:

1) SIS angle: the angle formed by the intersection of the line connecting the anterior and posterior iliac spines with the reference line, which corresponds to the iliac opening angle. (Figure 4)

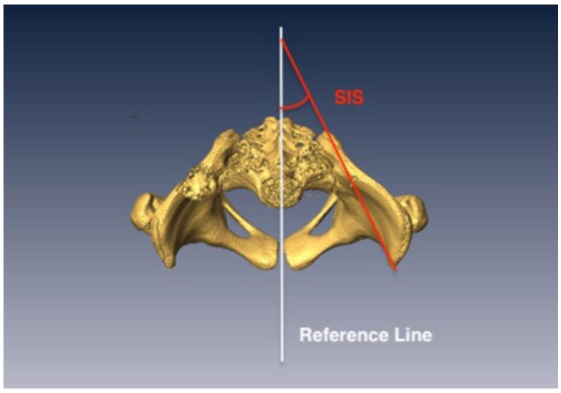

Figure 4 Drawings of the SIS and the reference line on the 3D reconstructed pelvis

2) IIS angle: the angle formed by the intersection of the line connecting the anterior and posterior inferior iliac spines

with the reference line.

3) IPL angle: the angle formed by the intersection of the ischiopubic line with the reference line, which corresponds to the iliac closing angle.

The different angles correspond to the rotations of the proximal (SIS, IIS) and distal (IPL) segments of the hemipelvis in the axial axis.

Statistical analysis

All data were processed with the use of SPSS 26.0 software. Descriptive statistics (mean and standard deviation) were determined for each of the above variables. Continuous parametric data were assessed using the Pearson product-moment correlation. As for the comparison of the means of the different groups, the independent t-test was used. The significance for all tests was set at $p < 0.05$. All measurements were executed by a single observer. The repeat measurements of 38 hemipelvises were conducted in a blinded manner by the initial observer and a second observer. Inter- and intra-observer reliability was determined through the use of intraclass correlation coefficients (ICC). The results were interpreted as follows: ICC > 0.80 excellent reliability, 0.61–0.80 substantial reliability, 0.41–0.60 moderate reliability, 0.21–0.40 fair reliability, and <0.20 poor reliability [24].

Results

The results showed a normal distribution of the data. The sample population consisted of 78 females and 70 males. The percentage of retroverted hips in the sample was 20.61% (Figure 5).

When compared to males, females had statistically higher version angles at the level of the roof edge angle and the equatorial edge angles shown in Table 1. The average values with the minimum, maximum, and standard deviations are presented in Table 2.

The means of the different pelvic angles in anteverted and retroverted hemipelvises are shown in Table 3, which reflect increased SIS, IIS, IPL, REA, and EEA

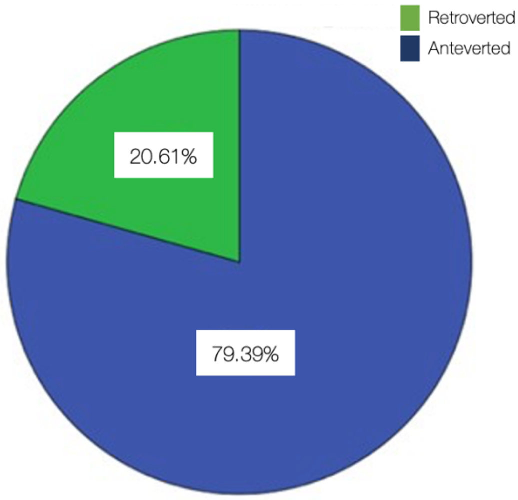

Figure 5 Prevalence of anteverted and retroverted hips

in the anteverted group. Signifying that the acetabulum was anteverted when the cranial hemipelvis was

externally rotated (represented by higher values of SIS, and IIS).

Table 4 displays the presence of a statistically significant positive correlation between the REA with SIS, IPL, and EEA.

Intraclass correlation coefficients indicated excellent intra-observer agreement (0.92) and inter-observer agreement (0.86) between the two observers.

Discussion

The morphology of the hip joint and its variance in the various hip pathologies has been extensively studied. On the other hand, just a limited number of articles have examined the relationship between the pelvic shape with the morphology of the acetabulum [10,11,13,14].

The percentage of retroverted hips was found to be 20.61% which is in the range described in the literature being 7% to 24% [25-27]. Also, the results showed increased acetabular anteversion in females which is in accordance with the existing findings in the literature [26,28]. Kumeta et al. in their study of CT scans showed that in DDH patients, there is medialization of the proximal of the

Table 1: Roof Edge Angle (REA) and Equatorial Edge Angle (EEA) Means in Females and Males. N: sample size

	Gender	N	Mean	Standard Deviation	Standard Error Mean	P-Value
Roof Edge Angle	Female	156	13.3983	13.07896	1.04715	0.002
	Male	140	8.7289	13.19195	1.11492	
Equatorial Edge Angle	Female	154	22.9353	7.40003	.59631	0.000
	Male	136	19.2248	5.97113	.51202	

Table 2: Population demographics and respective measurements

	Minimum	Maximum	Mean	Std. Deviation
Gender	1	2	1.47	.500
Age	20	90	58.10	18.475
SIS	15.54	42.82	27.3691	4.45256
IIS	16.51	32.86	23.5398	3.06719
IPL	3.99	45.89	29.6146	4.58453
REA	-22.40	46.50	11.1898	13.31658
EEA	1.03	41.30	21.1952	7.00619

Table 3: Means of SIS, IIS, IPL, REA & EEA in the Anteverted & Retroverted Groups

	Acetabular Version	N	Mean	Standard Deviation	Standard Error Mean	P Value
SIS	Anteverted	235	27.7106	4.49466	.29320	.07
	Retroverted	61	26.0534	4.05832	.51962	
IIS	Anteverted	235	23.6133	3.15028	.20550	.381
	Retroverted	61	23.2566	2.72888	.34940	
IPL	Anteverted	235	29.8740	4.67899	.30522	.04
	Retroverted	61	28.6154	4.08377	.52287	
Roof Edge Angle	Anteverted	235	16.5876	8.71258	.56835	.000
	Retroverted	61	-9.6049	4.70007	.60178	
Equatorial Edge Angle	Anteverted	232	21.6264	7.05395	.46311	.031
	Retroverted	58	19.4705	6.59113	.86546	

Table 4 Correlations Between REA with Age, SIS, IIS, IPL & EEA.
** Correlation is Significant at the 0.01 level (2-tailed).
* Correlation is Significant at the 0.05 level (2-tailed)
Abbreviations: superior iliac spine angle (SIS), inferior iliac spine angle (IIS), roof edge angle (REA), equatorial edge angle (EEA) and ischiopubic line (IPL), Pearson Correlation (P), Sig. (2-tailed) (S), Sample size (N).

		SIS	IIS	IPL	EEA
REA	P	.154**	.032	.137*	.228**
	S	.008	.589	.018	.000
	N	296	296	296	290

ilium termed an "inward wing ilium" with lateralization of the femoral head [11]. Whereas Suzuki et al., by examining the pelvic MRIs of 8 infants with CDH (congenital dislocation of the hip) concluded that the whole pelvic wing rotates and twists medially in the affected hemi-pelvises [12]. They also concluded that the increased anteversion of the iliac bone will lead to anteversion of the acetabulum without any actual measurements of the acetabular version. This conclusion was not in accordance with the findings of our study.

In 2011, Fuji et al. examined the horizontal rotations of different parts of 122 pelvises in asymptomatic and DDH patients. They found that there is greater internal rotation of the hemipelvis in the DDH group and that retroverted hips had externally rotated innominate bones from the level of the ilium to the ischiopubic ramus when compared with the anteverted hips [10].

Musielak et al. by assessing 3D reconstructed pelvises concluded that when the iliac opening angle increases (external rotation of the ilium) acetabular anteversion increases [14].

Hence, only two articles studied the horizontal rotations of the different parts of the pelvis and their relationship to the acetabular version. One article concluded that the acetabulum rotates in the same direction as the innominate bone, and the other study had opposite findings [10,14].

The study of Musielak et al. contained only 62 all-male acetabula, and the study done by Fuji compared 82 dysplastic hips to 40 control hips and all were females. Our research was conducted on 296 male and female hemipelvises, thus, having the biggest number of asymptomatic examined hemipelvises and including both genders.

The horizontal rotations of the innominate bone on the 3D pelvic reconstructions of an asymptomatic Lebanese population were studied, and a positive correlation between the rotation of the cranial part of the innominate bone and the rotation of the acetabulum was found. In other words, when the proximal hemipelvis internally rotates (which is expressed by decreasing SIS, and IIS), an external rotation of the acetabulum occurs which is expressed by a decreased roof edge angle. This reversed dependence on the acetabulum can be explained as a compensatory mechanism. When the proximal hemipelvis internally rotates, the acetabulum retroverts either by a waning posterior acetabular wall to diminish the conflict with the femoral head posteriorly (Figure 6), or by an expanding anterior wall for increased femoral head coverage anteriorly (Figure 7).

However, when the proximal hemipelvis externally rotates the acetabulum anteverts by diminishing the anterior wall for less conflict with the femoral head anteriorly (Figure 8), or by expanding the posterior acetabular wall for increased posterior head coverage as compensation for the external rotation of the innominate bone (Figure 9).

Limitations

There were several limitations to this study. First, the chosen landmarks are anatomic structures and therefore choosing an exact point to represent this structure might decrease the accuracy of the measurements. However, the ICC indicated

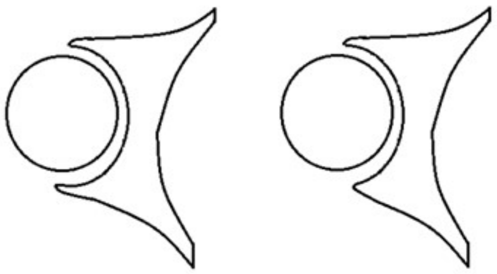

Figure 6 Normal acetabulum (left) compared to diminishing posterior wall (right)

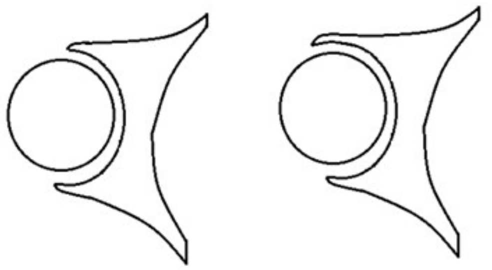

Figure 7 Normal acetabulum (left) compared to expanding anterior wall (right)

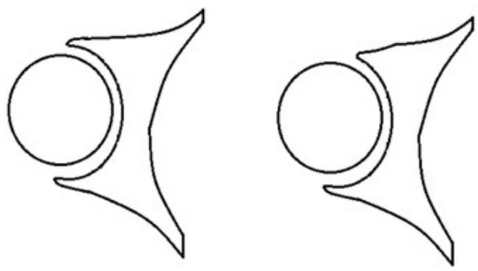

Figure 8: Normal acetabulum (left) compared to diminishing anterior wall (right)

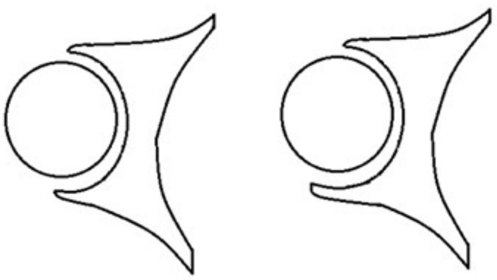

Figure 9 Normal acetabulum (left), compared to expanding posterior wall (right)

However, the ICC indicated excellent intra & inter-observer reliability which indicates that the measuring method is accurately reproducible.

Second, 3D reconstruction programs may decrease the precision of the measurements as surface modifications like smoothing and mesh size reduction affect the accuracy of reconstructions [5,29]. Third, only the effect of the pelvic anatomy and rotations on the acetabular version was studied, whereas the effect of the femoral head was not. It is an established fact that the acetabulum and the femur have a continuous remodeling process and that the development of one is affected by the other [30]. It is our opinion that future research should aim to include the femur and analyze the relationship between these anatomical structures. Fourth, CT measurements in asymmetrical pelvises may be inaccurate due to the difficulty in establishing an accurate pelvic coordinate axis. Moreover, there are not any simple standardized references to place the 3D reconstructed pelvis according to the "x,y,z" axes and to avoid any resulting inaccuracies in the measurements. However, we used the neutral pelvic position as defined by Kendal & McReary in order to imitate the neutral position of the pelvis in a standing person [22].

Conclusion

This study established statistically significant correlations between the horizontal rotations of the innominate bone with that of the acetabulum. The data indicated that when the proximal innominate bone internally or externally rotates, the cranial part of the acetabulum rotates in the opposite direction. It also showed that females have increased acetabular version angles compared to the male population. These findings can have clinical importance, as the establishment of future innominate bone rotation signs can be indirect indicators of the acetabular version and help in the early diagnosis of certain pathologies such as FAI.

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