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Full Paper

MULTIPLANAR RECONSTRUCTED CT STUDY OF NORMAL ACETABULUM – INCLINATION ANGLE, ANTEVERSION ANGLE AND ACETABULAR DEPTH

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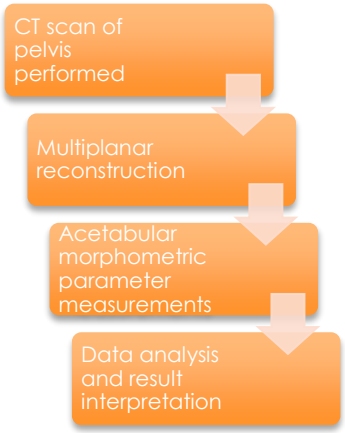
Graphical abstract



Abstract

Knowledge of acetabular morphometry parameters namely acetabular inclination and anteversion angles beside acetabular depth aid surgeons to accurately plan hip replacement procedure. The current hip implants designed based on Caucasian population which may not accurately match morphologic features of our population. Our objective is to determine normal acetabular morphometric parameters from CT scans of Malay patients in Hospital Universiti Sains Malaysia and compare gender and age group differences. A cross-sectional study was done within 18 months duration from November 2010 till May 2012. A total of 133 samples collected and divided into four age groups. Mean and standard deviations for all parameters were determined. No significant difference between acetabular parameters among males and females ($p>0.001$). Significant difference between age groups noted, mainly in group 1 (18 to 30 years) with group 4 (51 to 60 years) in all parameters. As for conclusion, no significant parameter differences between genders, hence no indication for gender or population specific hip implants. Significant differences noted when parameters compared between age groups, especially between the two extremes of age groups.

Keywords: Acetabular morphometry, CT scan, hip replacement

Abstrak

Parameter morfometri soket pinggul seperti sudut kecondongan, sudut versi dan kedalaman soket membantu pakar bedah merancang prosedur penggantian sendi pinggul dengan tepat. Prostesis terkini direka berdasarkan populasi di Eropah yang mungkin tidak sesuai dengan parameter populasi kita. Objektif kami ialah mengukur parameter morfometri soket pinggul pesakit Melayu yang menjalani pemeriksaan CT skan di Hospital Universiti Sains Malaysia seterusnya membandingkan antara jantina dan kumpulan umur. Kajian keratan rentas telah dijalankan dalam tempoh 18 bulan bermula November 2010 sehingga Mei 2012. Sejumlah 133 sampel dikumpulkan dan dibahagikan kepada 4 kumpulan. Min dan sisihan piawaian bagi kesemua parameter telah diperoleh. Tiada perbezaan ketara antara parameter lelaki dan perempuan ($p>0.001$). Perbezaan yang ketara dilihat antara semua kumpulan umur, terutamanya kumpulan umur 18 ke 30 tahun dengan kumpulan umur 51 ke 60 dalam kesemua jenis parameter. Kesimpulannya, tiada perbezaan ketara parameter antara jantina, maka tiada keperluan pembuatan prostesis sendi pinggul yang khas untuk jantina dan populasi kita. Perbezaan ketara dilihat apabila perbandingan antara kumpulan umur, terutama antara kumpulan-kumpulan umur yang ekstrim.

Kata kunci: Morfometri soket sendi pinggul, CT skan, pembedahan penggantian sendi pinggul

1.0 INTRODUCTION

Total hip arthroplasty (THA) is one of the most commonly performed and successful orthopaedic procedures available [1]. In United States alone, 200,000 to 250,000 THAs performed per year [2]. Surgeons have to select from vast array of different commercially available prostheses in the current market. Despite the variety of choices, these prostheses share common biomechanical goals, structural materials and also complications [3].

Complications that may arise in cases of prosthesis failure include prosthesis loosening, infection, dislocation, malalignment, instability, fracture, cement extrusion and heterotopic bone formation. Poor positioning of the acetabular component of a hip prosthesis is associated with dislocation and limitation of motion.

Hence, the need of proper pre-operative planning prior to THA is very important in order to minimize, if not to avoid the unfavourable implications of prosthesis failure. Pelvic radiographs have long been the mode of qualitative assessment of the acetabulum [3]. However, it is not accurate enough to give the precise information regarding the acetabulum, which is a rather more complex structure. Multi detector computed tomography (MDCT) is an alternative in assessing the hip joint pre-operatively. It is well established that three-dimensional CT (3DCT) techniques produce accurate visualization of bony anatomy, and allow accurate angular and linear measurements in an infinite variety of planes [4]. Multi-planar reconstructed CT image gives more advantage in assessing the acetabulum. It is easily available and allows visualization of the acetabulum in three planes simultaneously.

In this study, our aim was to determine the important normal acetabular morphometric parameters in Malay patients in HUSM. We were also interested in studying the age as well as gender differences of these parameters. Hopefully the outcome of this study would be beneficial to the field of joint replacement and hip implant industry.

2.0 METHODOLOGY

This cross-sectional study was a study of acetabular morphometry using multiplanar reconstructed images from non-orthopaedic indicated CT scans of Malay patients aged 18 to 60 year old, which included the pelvis in Hospital Universiti Sains Malaysia (HUSM). Patients with previous trauma to the hip, previous hip operation, severe degenerative disease of the hip and congenital hip abnormality were excluded. This study was conducted within a period of 18 months, from November 2010 till May 2012. Ethical approval for this study was obtained from the university ethics committee.

A total of 133 patients, hence 266 hips were included in this study. All CT scan examinations were performed using Siemens 128 slice MDCT scan Somatom Definition AS according to preset protocols in our department. The 1.0 mm slice images were reconstructed into multiplanar images on the Multimodality Workstation using the 3D application software. There were three morphometric parameters measured namely the acetabular inclination angle, acetabular anteversion angle and the acetabular depth. Before any measurement was made, a series of anatomic planes were defined for each pelvis [5].

a) **Standard coronal plane (SCP)** – the plane formed between both anterior superior iliac spine (ASIS) points and pubic symphysis.
b) **Pelvic axial plane (PAP)** – the plane passing through both ASIS points and positioned perpendicular to SCP.
c) **Sagittal plane (SP)** – the plane that passes through the sacral midpoint, runs through the center of pubic symphysis, and is perpendicular to the SCP and PAP.
d) **Acetabular equatorial plane (AEP)** – the plane that intersects the acetabular center and is parallel to PAP; perpendicular to SCP.
e) **Acetabular coronal plane (ACP)** –the plane that intersects the acetabular center and is parallel to SCP.

The acetabular inclination angle was measured on coronal oriented plane, which intersects the acetabular center and is parallel to SCP. The angle is formed between two lines drawn from the acetabular teardrop to the most lateral acetabular margin and a horizontal line on a plane parallel to the PAP at the level of the acetabular tear drop (Figure 2.1(a)).

The acetabular anteversion angle was measured on the axial plane (parallel to the PAP) at the level of AEP. The anteversion angle is formed by a line between the anterior and posterior acetabular ridge and a reference line drawn parallel to the SP (Figure 2.2 (b)).

The acetabular depth was measured as the maximum perpendicular distance from the dome of acetabulum to a line drawn connecting the anterior and inferior acetabular margins or face of the acetabulum at the level of AEP (Figure 2.3(c)).

Data entry and analysis were performed using Statistical Package for Social Sciences (SPSS version 18) software programme. Socio-demographic data was analysed using descriptive analysis where tabulation and graphical analysis were performed. The mean and standard deviation were calculated from the

data obtained from morphometric parameters of the patients. For comparison of the gender differences, independent t-test was used to determine the morphometric parameter differences between male and female. For the age group differences, analysis of variance (ANOVA) was used to determine the differences between the age groups. For the entire test, *p* value of less than 0.05 ($p < 0.05$) was taken as significant. Results were expressed as mean ± standard deviation (SD).

3.0 RESULTS AND DISCUSSION

From the 133 patients, 52 (39.1%) subjects were males and 81 (60.9%) were females. The patients were divided into 4 age groups as listed in Table 1.

Table 1 Numbering of age groups

Group	Age range (years)
1	18 - 30
2	31 - 40
3	41 - 50
4	51 - 60

Table 2 Mean, standard deviation and value range of all the morphometric parameters

Acetabular Morphometric parameters	Minimum	Maximum	Mean (SD)
Right Inclination (°)	30.67	47.33	38.14
Left Inclination (°)	26.00	47.67	(3.85)
Right Anteversion (°)	10.33	35.00	38.28
			(3.91)
			19.96
			(4.89)
Left Anteversion (°)	10.00	32.67	19.50
			(4.53)
Right depth (cm)	1.73	3.68	2.56
			(0.30)
Left depth (cm)	1.72	3.53	2.53
			(0.31)

The mean and standard deviation and range of all the parameters are listed in Table 2. There was no significant difference between the means of male and female acetabular morphometric values bilaterally (*p* value >0.001). All the acetabular morphometric values show significant difference among all the age groups after one-way Analysis of Variance (ANOVA) test performed. On further statistical analysis, the morphometric parameters show the most significant difference when the extremes of age group are compared, between group 1 (18-30 years) with group 4 (51-60 years) on both right and left sides.

Our study has successfully determined all morphometric parameters of the acetabulum. They were measured via the multiplanar reconstructed images and the measuring technic was simple and readily reproducible.

All subjects were Malays, which is the majority ethnic group in Kelantan. Male and female pelvis is well known to be different with their unique characteristics. They are different due to the functional needs of each gender. These differences are also one of the valuable information in determining the sex of an unrecognized body in forensics. However, our study revealed that there was no significant difference in the selected acetabular morphometric parameters in the context of gender differences.

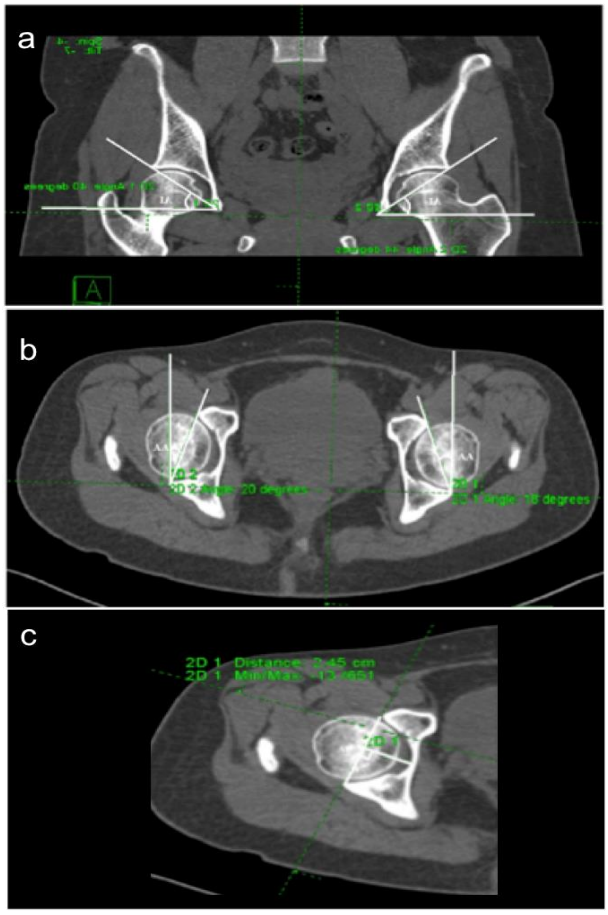


Figure 2.1 Measurement of the (a) Acetabular inclination angle (b) Acetabular anteversion angle (c) Acetabular depth on the Siemens workstation.

Our study has proven that there were statistically significant differences between designated age groups. In short, the significant difference was more obvious in the extremes of age groups, namely the 18 – 30 years with the 51 – 60 years age group.

A study done by Umer *et al* (2006) in the Singaporean population, a total of 261 asymptomatic patients with the age range of 16 to 99 years of age were included [6]. This number of subject as well as its

age range was relatively bigger than ours. However, the race of the subjects was not mentioned. Other studies which were done elsewhere such as in the United States by Maruyama *et al* (2001) in Cleveland and Murtha *et al* (2008) in Pennsylvania, a total of 100 and 42 pelvises respectively were studied with equal sex distribution [7,8]. Five subjects were younger than 40 years of age and 10 were older than 70 in Maruyama's study. It is worth noting that 20% of the subjects in the study done by Maruyama *et al* were African-Americans [7]. Stem *et al* conducted a CT scan based study in Florida on 100 pelvic CT scans [9]. They included subjects aged between 18 and 88 years, which exceeded our age limit. All the mentioned study from the United States included subjects from the far extreme age. We purposely excluded the subjects more than 60 years of age to avoid the effect of degenerative changes to the acetabular morphometry.

A few other example studies done in Asia were by Han *et al* (1998) in South Korea and Saikia *et al* (2010) in India [10,11]. Han *et al* included a total of 591 normal adult hips in the form of pelvic radiographs [10]. A total of 18.6% of the patients were over 70 years old and they included patients with trauma. However, Saikia *et al* only included normal hips in patients up to 66 years of age [11]. The interesting fact about this study is the inclusion of all the tribes in Northeastern India, which was divided into either Mongoloids or Caucasoids. Mongoloids were characterized by wide and short face, projecting cheekbones, low broad nose and short in stature. Caucasoids have long head, high forehead, narrow face, long and narrow nose and generally taller than Mongoloids [11]. All the qualitative and subjective assessment of the features has made the study complicated and less accurate.

Our study also revealed that there was no difference between all the morphometric parameters compared to other studies. The value of right acetabulum inclination angle for our study ranged from 30.67° to 47.33°, with the mean value of 38.14° (10.26). Left acetabulum angle ranged from 26.00° to 47.67°, with the mean of 38.28° (3.91). From a study done by Maruyama *et al* in the Pennsylvania (USA), they reported acetabular inclination angle of 38.9° in females and 37.8° in males [7]. A Korean study reported the average value of 37.0° (3.7) for the inclination angle [10]. From a study done in Northern India, Saikia *et al* reported that the mean acetabular inclination angle was 39.2° [11]. Last but not least, from a study done in our neighbouring country Singapore, the mean inclination angle was 39.46° [6].

Mean value of right and left anteversion angles for our study were 19.96° (4.89) and 19.50° (4.53) respectively. It ranged from 10.33° to 32.67° for right anteversion and 10.00 to 32.67° for left anteversion angle. In comparison with other different previous studies, our results were not significantly different from theirs. Maruyama *et al* reported mean acetabular anteversion angle of 19.9° (6.6), with 21.3° (7.1) in females and 18.5° (5.8) in males [7]. From another study done in Northern India, Saikia *et al* reported that the mean acetabular anteversion angle was 18.2° [11].

As for the right and left acetabular depths, the value ranged from 1.73 cm to 3.68 cm and 1.72 cm to 3.53 cm respectively. The mean values of right and left acetabular depths were 2.56 cm (0.30) and 2.53 cm (0.31) respectively. Saikia *et al* reported mean acetabular depth of 2.5 cm in the Northern Indian population [11]. However, from a study done on Korean adults, they reported acetabular depth values that were significantly different from ours and other studies [10]. However, they used pelvic radiographs that are less accurate compared to CT scan of the pelvis.

From this study, the results clearly showed no statistically significant differences when all the acetabular morphometric parameters compared between corresponding sides in male and female. There were several previous studies that also compared the gender differences involving the hip and obtained comparable result to our study. The nearest study comparable to our population was based in Singapore done by Umer *et al*. The acetabular inclination angle was found to be not significantly different between gender ($p>0.05$). Since this study was done to the Singaporean population, this might imply that there was no significant difference in acetabular parameters between genders. However, acetabular anteversion angle and acetabular depth were not studied [6].

Saikia *et al* studied the hip joint parameters of the Northeastern population in India in 2010. They also showed that there was no significant difference in the mean of parameters of the hip joint with our study. In addition, they also included the center edge angle, neck shaft angle, neck anteversion angle, joint space width and vertical diameter of femoral head. Only the femoral neck version angle showed significant difference in their study [11].

There were studies that show significant difference of the acetabular morphometric parameters. In a study done in the South Korea by Han *et al* (1998), the results showed significant difference of acetabular inclination angle and depth in between gender ($p<0.01$) [10]. A study done in the United States by Maruyama *et al* in 2001 from skeletons of an unclaimed dead in Cleveland area revealed that there were significant difference between acetabular inclination and anteversion angles between genders. The acetabular inclination and anteversion angles were significantly larger in females ($p=0.002$ and $p=0.038$ respectively) [11]. Mixed conclusion made by Stem *et al* from their study of acetabular anteversion and inclination in the state of Florida of United States in 2006. They reported significant difference between gender in acetabular anteversion angle but not with inclination angle [9].

An example of a study in 100 consecutive Caucasians by Henry *et al* in 2010 reported that there was no difference in acetabular inclination angle in between genders. However, in contrary with our study, the acetabular anteversion angle was significantly

larger in females with the mean of 23° (range 10-53°). In addition, they also reported that there was no significant difference between right and left hip parameters [12].

The possible reason why there was no significant difference between male and female acetabulum in the study population is the impurity of the Malay race. In this study, we used this inclusion criterion loosely. It is now difficult to have a pure Malay patient since the mixed marriage across ethnicity causes impurity of the Malay race.

Since our study did not show any significant difference between the male and female gender, there was no indication of manufacturing different set of prosthesis for different gender. In other studies discussed above, there were notions for gender specific implants according to the morphometric characteristics. Currently there are gender specific implants manufactured in the industry. However, no proper randomized, prospective studies that compares patients who have these implants to those who do not [13].

4.0 CONCLUSION

As for conclusion, there was no significant difference between of the mean and range of findings of all the acetabular morphometric parameters with data from other studies. Apart from that, no significant difference noted in the morphometric parameters between genders but there were significant differences between all age groups. On further analysis, the two extremes of age group, which are group 1(18 to 30 years) and group 4 (51 to 60 years) showed the most significant difference. Above all, there was no indication for a population or gender specific prosthesis.

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