Evaluation of the hip joint parameters in Vietnamese people with femoral head avascular necrosis by multi-slice computed tomography

Pham Hong Duc¹, Nguyen Tien Chung², Huynh Quang Huy³, Tran Van Kien⁴

¹Department of Radiology, Hanoi Medical University, Ha Noi, Vietnam
²Department of Internal Medicine, Vietnam University of Traditional Medicine, Ha Noi, Vietnam
³Department of Radiology, Pham Ngoc Thach University of Medicine, Ho Chi Minh city, Vietnam
⁴HungVuong General Hospital, Phu Tho, Vietnam

Corresponding author
Department of Radiology, Pham Ngoc Thach University of Medicine, Ho Chi Minh City, Vietnam;
Email: huyhq@pnt.edu.vn

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ABSTRACT

Background: The purpose of this study was to evaluate some parameters of the hip by the multi-slice computed tomographic system in Vietnamese patients with avascular necrosis of femoral head indicated total hip arthroplasty, which is not known well before but is
important in the hip joint replacement surgery. **Materials and Methods:** Using 32 slice computed tomographic system (MSCT) with reconstructed multiplanar protocol to evaluate parameters of the acetabulum and proximal femur and their relationships in 116 hip joints of 58 patients with avascular necrosis of femoral head. We split 116 hip joints into three groups: early-stage patients group, stage III patients group, and stage IV patients group. The evaluated parameters for each group, include acetabular inclination angle (A.I), acetabular anteversion angle (A.A), acetabular diameter (A.Di), acetabular depth (A.De), femoral head diameter (F.Di), femoral sharp-neck angle (F.Sn) and femoral medial offset (F.O). **Results:** There were significant differences between early stage, stage III and stage IV groups in AA (p=0.04). There were significant differences between male and female of early stage group in AI (p=0.02); FDi (p=0.004); of stage IV group in AI (p=0.02); ADi (p=0.00); ADe (p=0.04); FDi (p=0.005); FSn (p=0.01) with the size of acetabular and femoral head in male was significantly higher than female; except that AI in female of stage IV group was significantly higher than male. There is inverse correlation between age with FDi in three groups (Pearson=-0.41; -0.38; -0.04; respectively and p = 0.04; 0.03; 0.002; respectively). **Conclusion:** The study showed that A.A. of stage IV group was significantly smaller than in the early stage. Generally, FSn of Vietnamese was smaller than other races, but their F.O. was not higher. The values were within a safe range so that the anatomical index can be applied to determine the location of the artificial hip joint in operation. **Keywords:** Hip parameters, Femoral head avascular necrosis, Total hip arthroplasty.

1. **INTRODUCTION**

The hip joint is the most dynamic and impactful joint of the body. The components of the hip joint work together according to a complex mechanical principle, noted by many parameters related to the size and position of the acetabulum and femoral head in three-dimensional assessment (Bhaskar et al., 2017; Gold et al., 2020). Understanding the index of the hip joint, as well as the rules of its activity, is one of the essential factors affecting the success of hip arthroplasty. The choice of size and position of artificial hip joint fitting to anatomy contributing to minimize post-operative complications such as dislocations, loose joint (Dargel et al., 2014; Dawson-Amoah et al., 2018).

Previously, researches on the anatomical hip joint in Vietnam mainly based on X-ray film or dried bone samples, so there were many limitations and inevitable errors. Currently, with the development of multi-slice computed tomography (MSCT) allows the reconstruction of multiple planes and help of computer software. The index of the acetabulum and femoral head is increasingly accurate and simplified (Bankaoglu, 2019). Simultaneously, using multi-plane reconstruction (MPR), it is also possible to simulate the shape, size, and movement of the hip joint as well as the artificial joints in the 3D; so that the situation can be predicted conditions can occur when performing the hip replacement. In diseases that indicate hip replacement, aseptic necrosis of the femoral head is a group of causes at a high rate.

For these reasons, our aim of this study is to evaluate several anthropometric features of the hip joint and the association between the acetabulum and head of the femur in aseptic necrosis of the femoral head by MSCT.

2. **MATERIALS AND METHODS**

**Study population**

A retrospective descriptive study, selected from profile data of 58 patients with femoral necrosis, was diagnosed with MSCT according to the protocol described below. Patients selected as adults (> 20 years old), with normal spine and pelvic structures, no history of hip problems or previous hip surgery, diagnosed confirming aseptic necrosis of femoral head on one or both sides of stage 3 or 4 (The Association Research Circulation Osseous classification of osteonecrosis - ARCO 1993) indicated total hip replacement (Gardeniers JWM., 1993). Information on age, gender, and diagnosis is collected from medical records. The study was conducted at Saint Paul General Hospital; Hanoi between March 2017 and August 2018 after the approval of Ethical Committee of hospital with reference number of 01032017-SPH. Informed consent of patients was obtained.

**Protocol technique and hip index measurements**

Using MSCT Siemens SOMATOM perspective system 32-slice, Siemens Healthcare, Germany. The patient lies on his back, balanced on the table plane so that the iliac crest heights are equal, the legs fully straightened, the thighs - knees - the legs are placed in parallel, rotating in an angle of 10-15 degree. An insert or cuff can put into achieving a standard posture. They were using axial plane sections with a thickness of 0.6 millimeters (mm) from just above the iliac crest to below the tibial tuberosity, reconstructing a 3-dimensional plane to record the index. Besides, a scout views image, a documented protocol procedure, and a total X-ray dose. The measurement is performed on the reconstructed planes: the axial plane is the plane passing through the anteroposterior iliac
crest on both sides, perpendicular to the body axis. The coronal plane is the plane parallel to the anteroposterior axis of the body and perpendicular to the axial plane.

How to determine the index of the joint

On the MPR plane, construct a circle around the femoral head, identify the slice that contains the center of the femoral head on both axial and coronal planes, at that slice, the size of the acetabulum and femoral head is the biggest. Call it the acetabular measurement plane. Measure the acetabular diameter (A.Di), the acetabular depth (A.De), the acetabular inclination angle (A.I), the acetabular anteversion angle (A.A), the femoral head diameter (F.Di), the femoral sharp-neck angle (F.Sn), the femoral medial offset (F.O). On the axial plane, the A.Di is determined as the distance (mm) between the two outermost points of the anterior and posterior border of the acetabular surface. The A.De is the distance (mm) from the midpoint of the acetabular diameter to the deepest point of the acetabular surface. On this plane, based on the circle that constructed before, we get the diameter (mm) of the F.Di. On the axial plane, the line connecting the backmost of the ischium on both sides is called the inter-ischium line. The A.A defined as the angle created by the A.Di and the line perpendicular to the inter-ischium line.

On coronal plane or scout-view, the inter-ischium line performed. The A.I is defined as the angle that is joined by the line from the acetabular outer border through the bottom of the U to the inter-ischium line. On the coronal plane, go through the center of the femoral head, determine the center of the head, the center of the neck (the center of the anterior and posterior wall of the medullary canal of the femoral neck, the axis of the femoral body (the line goes through the two points of the inner and outer medullary canal of 1/3 superior. The F.Sn is defined as the angle that is matched by the femoral neck axis (the line connecting the center of the neck and the center of the femoral head. to the femoral body axis. The F.O is the distance (mm) from the center of the femur to the axis of the femur.

Statistical analysis

The indexesevaluated measured by two radiologists, and then take the average value for statistics. The data is processed by SPSS ver.24.0 (IBM) software, which calculates the average value, standard deviation, interval, distribution properties of quantitative variables, and the ratio of qualitative variables in the study. To test the difference between the average value of the index with gender and with the joints measured, we used the independent sample T-test. To check the average of the index between age groups and between diagnostic groups, we use the One-way ANOVA test. To check the correlation between the mean values of each index, and the relationship with age, using bivariate correlations test, correlation coefficients of Pearson for standard two-tailed significant variables. For quantitative variables that are in the same unit and correlated with each other, use the linear regression test to find the relationship formula. The test has a 95% confidence interval.

3. RESULTS

A total of 116 hip joints of 58 patients with aseptic necrosis of femoral head (51 male and seven female) were measured (Figure 1). Average age is 54.91 ± 10.99 (range 28-85 years). There are 26 joints in stages 0, I, II; 27 in stage III and 63 in stage IV.

Figure 1 MSCT images of a 56-year-old male patient with aseptic necrosis of femoral head

In the I and II stage groups, the morphology of the femoral head and acetabulum are relatively intact. The hip indexes have not changed compared to healthy people so that they can be grouped with stage 0 group (early-stage group). The group of stage 3 had visible necrosis in the C.T. scan, may be collapsed but has not changed the hip joint structure, not narrowed joints or acetabular
injury. Group of stage IV is the heaviest, morphological changes both femoral head and acetabulum, secondary hip degeneration. Therefore, we divided into three stages for comparison and evaluation.

We found that: the A.A shows a statistically significant difference between the early-stage group (16.28 ± 6.89 degrees) and the stage III group (16.65 ± 4.90 degrees) and stage IV group (14.11 ± 6.26 degrees), with p = 0.04 (Table 1). Table 2 presents the mean values for both men and women. For the early-stage group, there was a statistically significant difference in the diameter of the A.Di and F.Di between the sexes with p, respectively 0.02; 0.004. For group IV, there was a statistically significant difference between the sexes in terms of the A.I, A.de, F.Di, and F.Sn with p respectively 0.02; 0.00; 0.04; 0.005 and 0.01. Table 3 shows the correlation between the indexes and patient age. All three groups, including early-stage, stage III, and stage IV groups, had a negative relationship between F.Di and age, with Pearson values of -0.41; -0.38; -0.04 and p are 0.04; 0.03; 0.002.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Mean hip index inpatient with femoral head avascular necrosis of early-stage (0, I, II), stage III, and stage IV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip indexes</td>
<td>Early stage (n=26)</td>
</tr>
<tr>
<td>A.A (°)</td>
<td>42.04±5.05</td>
</tr>
<tr>
<td>A.I (°)</td>
<td>16.28±6.89</td>
</tr>
<tr>
<td>A.Di (mm)</td>
<td>48.24±2.86</td>
</tr>
<tr>
<td>A.De (mm)</td>
<td>24.00±2.66</td>
</tr>
<tr>
<td>A.Di (mm)</td>
<td>43.92±5.65</td>
</tr>
<tr>
<td>F.Sn (°)</td>
<td>128.96±5.65</td>
</tr>
<tr>
<td>F.O (mm)</td>
<td>33.00±5.62</td>
</tr>
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</table>

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<tr>
<th>Table 2</th>
<th>Hip indexes correlated with sexes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip indexes</td>
<td>Early stage Male (n=22)</td>
</tr>
<tr>
<td>A.I (°)</td>
<td>41.62±5.39</td>
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<tr>
<td>p</td>
<td>0.07</td>
</tr>
<tr>
<td>A.A (°)</td>
<td>15.57±6.98</td>
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<tr>
<td>p</td>
<td>0.07</td>
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<tr>
<td>A.Di (mm)</td>
<td>48.86±2.57</td>
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<tr>
<td>p</td>
<td>0.02</td>
</tr>
<tr>
<td>A.De (mm)</td>
<td>25.24±2.36</td>
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<tr>
<td>p</td>
<td>0.11</td>
</tr>
<tr>
<td>F.Di (mm)</td>
<td>44.67±2.03</td>
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<tr>
<td>p</td>
<td>0.004</td>
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<tr>
<td>F.Sn (°)</td>
<td>129±6.05</td>
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<tr>
<td>p</td>
<td>0.68</td>
</tr>
<tr>
<td>F.O (mm)</td>
<td>33.19±5.93</td>
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<tr>
<td>p</td>
<td>0.55</td>
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<tr>
<th>Table 3</th>
<th>Hip indexes correlated with age</th>
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<tbody>
<tr>
<td>Hip indexes</td>
<td>Early stage (n=26)</td>
</tr>
<tr>
<td>A.I (°)</td>
<td>0.23</td>
</tr>
<tr>
<td>A.A (°)</td>
<td>0.36</td>
</tr>
<tr>
<td>A.Di (mm)</td>
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</tr>
<tr>
<td>A.De (mm)</td>
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<tr>
<td>F.Di (mm)</td>
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<tr>
<td>F.Sn (°)</td>
<td>-0.18</td>
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<tr>
<td>F.O (mm)</td>
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4. DISCUSSION

For the A.Di and F.Di

The average index of the A.Di in patients with early-stage compared with groups of stage III and IV, these two indexes are smaller in A.Di and A.De. The indexes for stage IV are also larger than stage III. Compared to the study of Zeng with 100 Chinese hip joints, the A.De was a larger diameter with 56 mm in men and 51.4 mm in women; but the A.De is smaller with 19.4 mm in men and 17.4 mm in women (Zeng et al., 2012). The A.De in our study is also smaller than that of Khalid, with 266 Indian hip joints of 25.6mm (Khalid et al., 2015). The average index of the F.Di at an early stage and the stage III and IV group is smaller than the research results of Nakahara, with 136 Japanese hip joints is 44.9 mm (Nakahara et al., 2011). The A.Di and F.Di at an early stage are generally smaller than in other races. In addition to the reason that the Vietnamese physical body is smaller than other races, it is also due to late necrosis (stage III, IV) that causes necrosis, collapsing, and destruction of the femoral head. This is consistent with pathological reality.

About the shape and location of the acetabulum in the 3D

The A.I at the early stage of our study is larger than that of groups of stages III and IV. Also larger than the Chinese in Zeng’s study was 39.5 degrees (Zeng et al., 2012), Japanese was 37.6 degrees (Nakahara et al., 2011), and Malaysians were 38.14 degrees (Khalid et al., 2015). The average index of the A.I at the early stage was not significantly smaller than that of the stage III group of 16.65 ± 4.90 degrees, but significantly greater than that of the stage IV group (p = 0.04 ). This value is also 19 degrees smaller than the Indians in Maheshwari’s study (Maheshwari et al., 2010); Chinese people are 18.79 degrees (Jiang et al., 2015); Japanese people are 20.2 degrees (Nakahara et al., 2011); and Malaysians of 19.96 degrees (Khalid et al., 2015). Thus, the A.I and A.A in group IV tends to be significantly smaller than that in the early stage.

Correlation between angles and morphology of femoral head

The average index of F.Sn in the early stage group is smaller than that in the stage III group but larger than the group stage IV. It is also smaller than that of Caucasian peoples with 137.43 degrees (Atkinson et al., 2010) and Chinese with 133.02 degrees (Jiang et al., 2015 May). However, the F.Sn in our study was larger than the Japanese with 125.1 degrees (Nakahara et al., 2011). The average of F.O in the early stage group is greater than the group III, IV, but a smaller group of caucasian peoples with 55.36 ± 5.82mm in men and 48.17 ± 5.19mm in women (Atkinson et al., 2010). The F.Sn and F.O play an important role in balancing the hip-bearing arm of the hip; the change of the value of these two indexes after total hip arthroplasty (THA) may be directly affect the patient’s gait, durability of artificial joints and rate of complications.

Application to Vietnamese conditions, currently, most equipment manufacturers use the artifact joint with femoral body angle is 135 degrees, so when THA will have a direct impact on the bearing system of the hip joints on both sides. Therefore, in the future, the next specific research directions may help guide the design of artificial hip joints is more suitable for the anatomical characteristics of Vietnamese people. In our study, although the A.A is highly variable, the mean is still within the similarity to the world. Thus, in THA, anatomical indexes of normal joints can be used to determine the location of artificial joint components. However, in order to achieve this, more research is needed to combine the anteversion angle with a more suitable design in the future.

Difference by gender

In the early group, the A.Di and F.Di in males were higher than that of female, there was a statistically significant difference between sexes, and p was respectively 0.02; 0.004. Similarly, the A.Di, A.De, F.Di, and F.Sn of group IV in males were significantly larger than that of females (p <0.05). Meanwhile, the F.Sn in the male in group IV is smaller than that of females (p = 0.02). The difference between these sexes is similar to that of Nakahara in Japanese (p = 0.006) (Nakahara et al., 2011).

Differences by age

According to research results, there is a negative correlation in all three groups, including early-stage, stage III, and stage IV between the F.Di and age (p <0.05). Thus, the hypothesis is that the older the patient is, the lower the bone quality, the faster the bone resorption occurs, leading to a decrease in the F.Di.

5. CONCLUSION

The study showed that the A.A of group IV was significantly smaller than that in the early stage group. The F.Sn is lower, but the F.O is not higher. These values are within the safe range, so anatomical index can apply to determine the position of artificial joints in
surgery. Understanding these indexes is a prerequisite for further studies, especially the studies on the application of total hip arthroplasty based anatomy for hip disease due to avascular necrosis of femoral head, dysplasia, primary degeneration, or hip injury.

**Abbreviations**

MSCT: multi-slice computed tomography  
A.I: inclination angle  
A.A: acetabular anteversion angle  
A.Di: acetabular diameter  
A.De: acetabular depth  
F.Di: femoral head diameter  
F.Sn: femoral sharp-neck angle  
F.O: femoral medial offset  
MPR: multi-plane reconstruction

**Author’s contribution**

PHD and NTC contributed equally to this article. PHD and HQH gave a substantial contribution in acquisition, analysis, and data interpretation. Each author had a part in preparing article for drafting and revising it critically for important intellectual content. Each author gave the final approval of the version to be published and agreed to be accountable for all aspects of the work, ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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