Cross-sectional Anatomy of Ilium for Guiding Acetabular Component Placement Using High Hip Center Technique in Asian Population

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Background: Many clinical studies have been published involving the use of a high hip center (HHC), achieved good follow-up. However, there is little anatomic guidance in the literature regarding the amount of bone stock available for initial implant coverage in this area of the ilium. The purpose of this study was to evaluate the thickness and width of the human ilium and related acetabular cup coverage for guiding acetabular component placement in HHC.

Methods: A total of 120 normal hips in 60 cases of adult patients from lower extremities computer tomographic angiography Digital Imaging and Communications in Medicine data were chosen for the study. After importing the data to the mimics software, we chose the cross sections every 5-mm increments from the rotational center of the hip to the cephalic of the ilium according the body sagittal axis, then we measured the thickness and width of the ilium for each cross section in axial plane, calculated the cup coverage at each chosen section.

Results: At the acetabular dome, the mean thickness and width of the ilium were 49.71 ± 4.88 mm and 38.92 ± 3.67 mm, respectively, whereas at 1 cm above the dome, decreased to 41.35 ± 5.13 and 31.13 ± 3.37 respectively, and 2 cm above the dome, decreased to 31.25 ± 4.04 and 26.65 ± 3.43, respectively. Acetabular cup averaged coverage for 40-, 50-, and 60-mm hemispheric shells, was 100%, 89%, and 44% at the acetabular dome, 100%, 43.7%, and 27.5% for 1 cm above the dome, and 37.5%, 21.9%, and 14.2% for 2 cm above the dome.

Conclusions: HHC reconstructions within 1 cm above the acetabular dome will be an acceptable and smaller diameter prosthesis would be better.

Key words: Anatomy; Hip; Ilium; Orthopedics; Total Hip Arthroplasty

INTRODUCTION

Reconstruction of acetabular components with a bone defect still challenges to orthopedic surgeons. Ideally, the acetabular component should be placed at the natural hip center as close as possible.¹⁴ However, bone defect in those patients with development dysplasia of hip, acetabular migration superiorly followed by cup loosening, or severe periacetabular osteolysis, may prevent surgeon from placing the cup in a true anatomic hip center for achieving a sufficient contact with the host bone.

Bulk grafting with either femoral head autograft or allograft and cement has been reported to be filled in the location with deficient bone stock and furthermore to be helpful for rebuilding the native hip center²⁷⁻¹⁰ with a successful early follow-up. But long-term follow-up studies have proven a high incidence of aseptic loosening⁹,¹⁰

Most clinical studies demonstrated that using a high hip center (HHC) could obtain good clinical results, especially in those patients with better acetabular bone stock superior to the anatomic hip center.¹¹⁻¹⁵ Obviously, the HHC could offer a chance to achieve better cup coverage with a cementless cup, which ensures initial stability, bony ingrowth, and long-term success in revision acetabular reconstruction.

However, the elevated heights of the rotation center and prostheses survival rate vary from each study. Previous studies claimed that a 1% increase in hip load will occur for displacement 10 mm proximal of the rotation center,¹⁶ proper superior migration of the rotation center will not...
increase hip load dramatically, since the most common reason for surgery failure with the HHC was insufficient coverage of the cup. Anatomical studies concerning the bone stock above the acetabulum are seldom reported. Antoniades and Pellegrini studied cross-sectional anatomy of the ilium from 16 cadaveric hips, claimed that there are substantial anatomic limitations to high hip reconstructions 2 cm above the acetabular dome, however, there were many limitations, and there is also some concern whether the calculations made in people of Caucasian descent can be generalized to Chinese people given that Chinese people generally have a smaller physique than white people.

We therefore, determined the thickness and width of the human ilium by measuring every section in mimics, and we also calculated cup coverage related to every specie thickness and width by a mathematical equation.

**Methods**

**Study subjects**

A total of 120 normal iliums in 60 adult Chinese patients (34 men, 26 women) were chosen from those who received computer tomographic (CT) angiography for diagnosing vascular diseases in Digital Imaging and Communications in Medicine (DICOM) database for this study. The average age was 55.2 years (range, 30–66 years), the average height was 161.5 cm (range, 149–187 cm), and the average weight was 62.7 kg (range, 47–90 kg). Patients were included if they did not have severe osteoarthritis changes in hip and any deformities in the pelvis.

**Computed tomography**

The CT scans were performed previously with a Toshiba brand Aquilion CT scanner (120 kVp; 320 mA; 512*512 matrix; slice thickness, 0.5 mm) at the China-Japan Union Hospital of Jilin University. All patients were placed supine on the scanner with both knees taped to the scanner platform in an extended position with their patellar facing towards the ceiling. The scanning procedure was performed to acquire 0.5 mm CT slices from pelvis to the ankle joint. All the slices were saved as DICOM.

**Landmarks location and measurement**

The DICOM data were imported into Mimics 16.0 (Materialise, Leuven, Belgium) software. The rotational centers of the hips were obtained by drawing spheres to fit the femoral heads [Figure 1]. Every 5-mm increments section of the ilium according the body sagittal axis in coronal plane from the rotational center of the hip to the cephalic [Figure 1a] was marked, then measured the thickness (AB) and width (CD) of the pelvis in each slice [Figure 2]. The first slice was chosen at 25 mm above the rotation center, as the acetabular dome was located the place 25 mm above the rotation center for almost all the patients.

To calculate the acetabular cup coverage rate at different levels above the rotation center, an equation improved from Antoniades and Pellegrini two-dimensional (2D) linear acetabular cup coverage equation was used to estimate the three-dimensional (3D) bony coverage rate of 40-, 50-, and 60-mm acetabular shells [Figure 3].

The cup coverage rate equals to: \[1 - \sqrt{\frac{R^2 - r^2}{R}}\]

**Results**

The results of measured thickness and the width of the ilium are shown in details in Table 1. The width was larger than the thickness in each cross-section, with the maximum difference of at the point 25 mm above the rotation center, which close to the acetabular dome [Figure 2a]. At the acetabular dome, the average thickness and width of the ilium were 49.71 ± 4.88 mm and 38.92 ± 3.67 mm, respectively. Whereas at 1 cm above the dome (35 mm above the rotation center), the average thickness and width were decreased to 41.35 ± 5.13 mm and 31.13 ± 3.37 mm, and at 2 cm (45 mm above the rotation center) above the dome, the average thickness and width were decreased to 31.25 ± 4.04 mm and 26.65 ± 3.43 mm. With the slices went up above the rotation center, the thicknesses and the width of the pelvis were decreased sharply. Considering the cups were placed at 45° inclination, the restricted boundaries of cup coverage were not in accordance to the values of AB but rather the values of CD, since the values of $\sqrt{2AB}$
were bigger than those of CD [Table 1]. The mathematical model [Figure 3] was applied to calculate acetabular cup coverage for 40-, 50-, and 60-mm hemispheric shells, and the average results were 100%, 89%, and 44% at the acetabular dome, 100%, 43.7%, and 27.5% at 1 cm above the dome, 37.5%, 21.9%, and 14.2% at 2 cm above the dome, and 14.9%, 9.0%, and 6.1% at 3 cm above the dome [Table 2].

**Discussion**

In the present study, we determined that the acetabular cup coverage rate varies across each section and individuals, within 1 cm above the acetabular dome being acceptable. Our 3D measurement method may have solved some measurement limitations of the cadaveric approach used previously. The ilium thickness and width reached its peak 25 mm above the rotation center, approximately at the acetabular dome, and decreased quickly to approximately, especially 2 cm above the doom. At that height above the dome, a 50-mm cup would have only 21.9% coverage by our equation calculation. According to our result, a 50-mm cup had only 43.7% coverage at 1 cm above doom. Therefore, it is necessary to apply screws to achieve initial cup stability.

HHC was applied to perform reconstruction of the acetabulum in those patients with peri-acetabular bone defect or osteolysis with good clinical results. However, there were also studies claimed that the risk of loosening was greater if the hip center was raised 30 mm above the teardrop. For now, none of the studies had reported the correlation between the loosening rate and the elevated height of the hip center. In addition, superior-only hip center relocation did not significantly affect the total joint force. Although some surgeons claimed beneficial biomechanical effects of hip center medialization, our results do not recommend the empiric suggestion in HHC, the cup should be moved as medial as possible to improve acetabular component coverage, because our data provided no anatomic basis to ensure that increased medialization of the cup resulted in better bony coverage, moreover, medialization would increase
Table 1: Summary of value of AB and CD every 5-mm increments section of the ilium from 25 to 55 mm above rotational center (mm)

| Items | 25 mm | 30 mm | 35 mm | 40 mm | 45 mm | 50 mm | 55 mm |
|-------|-------|-------|-------|-------|-------|-------|-------|
| CD    | 49.71 ± 4.88 | 45.98 ± 5.36 | 41.35 ± 5.13 | 35.69 ± 4.52 | 31.25 ± 4.04 | 25.89 ± 3.59 | 20.68 ± 3.9 |
| AB    | 38.92 ± 3.67 | 34.33 ± 3.85 | 31.13 ± 3.37 | 28.8 ± 3.2 | 26.65 ± 3.43 | 24.19 ± 4.59 | 21.47 ± 4.69 |
| √2AB  | 55.04 | 48.54 | 44.03 | 40.72 | 37.68 | 34.20 | 30.36 |

AB presents the iliac thickness and CD presents the iliac width.

Table 2: Coverage rates of the different diameter cups 40-, 50-, 60-mm at the level of 5-mm increments section of the ilium from 25 to 55 mm above rotational center (%)

| Cups | 25 mm | 30 mm | 35 mm | 40 mm | 45 mm | 50 mm | 55 mm |
|------|-------|-------|-------|-------|-------|-------|-------|
| 40 mm | 100 | 100 | 100 | 54.8 | 37.5 | 23.8 | 14.4 |
| 50 mm | 89.0 | 60.7 | 43.7 | 30.0 | 21.9 | 14.4 | 9.0 |
| 60 mm | 44.0 | 35.8 | 27.5 | 19.6 | 14.2 | 9.8 | 6.1 |

Larger cup prosthesis may increase the loosening rate as for lower coverage rate of the cup. Moreover, in complicated acetabular reconstruction surgeries, CT scanning will be necessary in performing preoperative planning, since that will provide detailed iliac bony stock situation, quantify the level of the hip center elevated and the stress variation, furthermore achieve good prosthesis survival rate.

References

1. Jasty M, Freiberg AA. The use of a high-hip center in revision total hip arthroplasty. Semin Arthroplasty 1995;6:103-8.
2. Johnston RC, Brand RA, Crowninshield RD. Reconstruction of the hip. A mathematical approach to determine optimum geometric relationships. J Bone Joint Surg Am 1979;61:639-52.
3. Kim DH, Cho SH, Jeong ST, Park HB, Hwang SC, Park JS. Restoration of the center of rotation in revision hip total arthroplasty. J Arthroplasty 2010;25:1041-6.
4. Li H, Mao Y, Oni JK, Dai K, Zhu Z. Total hip replacement for developmental dysplasia of the hip with more than 30% lateral uncoverage of uncemented acetabular components. Bone Joint J 2013:95-B: 1178-83.
5. Zhong C, Cai XZ, Yan SG, He RX. The S-ROM modular stem total hip arthroplasty together with transverse bone dissection inferior to femoral tuberosity for the treatment of Crowe type IV congenital dislocation of the hip. Chin Med J 2011;124:3891-5.
6. Wang W, Guo W, Yue D, Shi Z, Zhang N, Liu Z, et al. Fourth-generation ceramic-on-ceramic total hip arthroplasty in patients of 55 years or younger: Short-term results and complications analysis. Chin Med J 2014;127:2310-5.
7. Tsukada S, Waku M. Bulk femoral head autograft without decortication in uncemented total hip arthroplasty: Seven- to ten-year results. J Arthroplasty 2012;27:437-444.e1.
8. Gill TJ, Sledge JB, Müller ME. The management of severe acetabular bone loss using structural allograft and acetabular reinforcement devices. J Arthroplasty 2000;15:1-7.
9. Kwon LM, Jasty M, Harris WH. High failure rate of bulk femoral head allografts in total hip acetabular reconstructions at 10 years. J Arthroplasty 1993;8:341-6.
10. Shinar AA, Harris WH. Bulk structural autogenous grafts and allografts for reconstruction of the acetabulum in total hip arthroplasty. Sixteen-year-average follow-up. J Bone Joint Surg Am 1997;79:159-68.
11. Christodoulou NA, Dialetis KP, Christodoulou AN. High hip center technique using a bicortical threaded Zweymüller cup in osteoarthritis secondary to congenital hip disease. Clin Orthop Relat Res 2010;468:1912-9.
12. Hendricks KJ, Harris WH. High placement of uncemented...
acetabular components in revision total hip arthroplasty. A concise follow-up, at a minimum of fifteen years, of a previous report. J Bone Joint Surg Am 2006;88:2231-6.

13. Murayama T, Ohnishi H, Okabe S, Tsukukami H, Mori T, Nakura N, et al. 15-year comparison of cementless total hip arthroplasty with anatomical or high cup placement for Crowe I to III hip dysplasia. Orthopedics 2012;35:e313-8.

14. Bozic KJ, Freiberg AA, Harris WH. The high hip center. Clin Orthop Relat Res 2004;420:101-5.

15. Nie Y, Pei F, Li Z. Effect of high hip center on stress for dysplastic hip. Orthopedics 2014;37:e637-43.

16. Bicanic G, Delimar D, Delimar M, Pecina M. Influence of the acetabular cup position on hip load during arthroplasty in hip dysplasia. Int Orthop 2009;33:397-402.

17. Antoniades J, Pellegrini VD Jr. Cross-sectional anatomy of the ilium: Implications for acetabular component placement in total hip arthroplasty. Clin Orthop Relat Res 2012;470:3537-41.

18. Pagnano W, Hanssen AD, Lewallen DG, Shaughnessy WJ. The effect of superior placement of the acetabular component on the rate of loosening after total hip arthroplasty. J Bone Joint Surg Am 1996;78:1004-14.

19. Yoder SA, Brand RA, Pedersen DR, O’Gorman TW. Total hip acetabular component position affects component loosening rates. Clin Orthop Relat Res 1988;228:79-87.

20. Cheng XW, Lan PW, Shen B, Liu Z, Zhang YL, Yang J, et al. Three-dimensional finite element analysis of acetabular prosthesis in an adult patient with total hip arthroplasty for high dislocation. J Sichuan Univ (Med Sci Ed) 2013;44:787-91.