Acta Orthopaedica et Traumatologica Turcica 51 (2017) 470–473

Contents lists available at ScienceDirect

Acta Orthopaedica et Traumatologica Turcica

journal homepage: https://www.elsevier.com/locate/aott

Determination of the hip rotation centre from landmarks in pelvic radiograph

Hasan Bombaci*, Bestami Simsek, Mehmet Soyarslan, Mustafa Murat Yildirim

Haydarpasa Numune Education and Research Hospital, Orthopaedics and Traumatology Department, Tibbiye Cad. Uskudar, Istanbul, Turkey

ARTICLE INFO

Article history:
Received 9 January 2017
Received in revised form
8 May 2017
Accepted 19 September 2017
Available online 10 October 2017

Keywords:
Hip rotation centre
Total hip arthroplasty

ABSTRACT

Objective: The hip rotation centre (HRC) is an important reference point in cases of total hip arthroplasty (THA). The aim of this study is to investigate the reference points in the Turkish population that enable the identification of the HRC in standard pelvic radiographs.

Methods: The pelvic radiographs of 50 women and 50 men were examined. The mean age was 46.2 (range; 18–91). Patients with deformity of the hip joint and non-standard pelvic radiograph due to hip flexion contracture were excluded from the study. The pelvic height (PH), the distance between the HRC and teardrop (HRC-Td), and the HRC and the line tangent tuber ischiadicums (HRC-TI) were measured. The ratio of HRC-Td and HRC-TI to PH were calculated. The first is called "the horizontal-HRC ratio" and the second, "the vertical-HRC ratio".

Results: Mean PH was 239 (±13.58) mm in males and 225 (±12.52) in females ($p < 0.0001$). The distances of HRC-TI were 71 (±6.35) and 65 (±6.72) mm ($p < 0.0001$) and the distance of HRC-Td were 34 (±3.73) and 30 (±4.05) mm ($p = 0.0007$), respectively. The vertical-HRC ratios were 30.01% (±2.05) for males, 29.10% (±2.35) for females, the horizontal-HRC ratio, 14.25% (±1.42) and 13.69% (±1.38), respectively ($p > 0.05$).

Conclusion: Although the quantitative values obtained in the present study differ between the genders, the ratios ("vertical-HRC" and "horizontal-HRC") are comparable in both sexes. The results show that these proposed ratios can be used in THA planning, regardless of gender in the Turkish population

Level of evidence: Level IV, diagnostic study.

Introduction

The use of high hip centre might result in inadequate soft tissue balancing, dependent upon decreased lever arm of the abductor muscles and increased abductor muscle forces and joint reaction force.[1] Subsequently, premature implant aseptic loosening might develop relating to high rate of linear wear, particularly in the hips placed in a lateralized position.[2–4] Furthermore, the leg length discrepancy is another factor which causes additional abnormal force on the hip and patient dissatisfaction.[5]

Therefore, the placement of the acetabular component on the anatomical hip centre is quite an important consideration for total hip arthroplasty (THA) survival.[1] There are several methods to achieve the optimal position for the acetabular component in both medial-lateral and superior-inferior direction.[6–8] One reference point to achieve this goal is the teardrop and the other, the medial wall of the acetabulum. O'Sullivan et al show that even though the shape of teardrop might be altered some depending on the angle of beam, the teardrop image is an important landmark in pelvis.[9] However, these reference points can be deformed (i.e. developmental dislocation of the hip) or destroyed (i.e. revision arthroplasty) in some cases. In these conditions, the normal opposite hip can be used successfully.[10] But in the cases with unavailable reference points on the opposite hip, as in the bilaterally affected hips, we need more solid references points. For this intent various references points and methods have been described in the literature.[7,8,11,12] Some of them were described in the scale of millimetres. However, it is known that measurements are quite variable between races or even communities, so these measurements might not be applicable universally.[13–16]

* Corresponding author. Haydarpasa Numune Education and Research Hospital, Orthopaedics and Traumatology Department, Tibbiye C. 34671, Uskudar, Istanbul, Turkey. Fax: +90 216 346 0582.
E-mail address: bombacih@hotmail.com (H. Bombaci).

Peer review under responsibility of Turkish Association of Orthopaedics and Traumatology.

https://doi.org/10.1016/j.aott.2017.09.004

In the present study we aimed to determine the reference points of anatomical hip centre in the scale of ratio rather than in millimetres. We hypothesized that; the pelvic height (PH) and the vertical line which tangent to teardrop figure, can be used to determine the anatomical hip centre as a more solid reference point in the bilaterally affected hip with developmental abnormality or previous surgical procedures.

Patient and methods

In the present study a 100 anteroposterior (AP) pelvic radiographs, taken for reasons unrelated to the pelvic bone abnormality, were randomly chosen. The mean age of fifty men and fifty women was 46.2 (range; 18–91). AP radiographic views of the pelvis were obtained with the same protocol when patients were placed in a supine position with the lower limbs parallel with each other. The film focus distance was 100 cm and the X-ray beam was directed to the midpoint of the symphysis pubis. Although, taking the pelvic X-ray was intended as described above, the position of the pelvis cannot be exactly controlled in routine radiographic examination. Therefore, the radiographs in which the coccyx was in the same line as the symphysis pubis, and the image of obturator foramen were symmetrical were chosen for evaluation to exclude the radiographs with abnormal pelvic tilt and rotation.[17] All measurements were independently performed by the three authors (BS, MS, MY).

The hip rotation centre (HRC) was determined by using concentric circles. Three references lines were drawn on the AP pelvic radiograph; the first line was the inter-ischial line (TI) which was drawn through at the lowest end of the pelvis, second line which was tangent to the upper end of iliums (UP) and the third was the vertical line which was perpendicular to the two lines described above and tangent to the most medial point of teardrop, which was shown as a reliable anatomical landmark in pelvic radiographs by O'Sullevian et al (Fig. 1).[9,18] Pelvic height (PH-the distance of the lowest (TI) and highest (UP) point of pelvis), the distance between the HRC and the most inner part of teardrop (HRC-Td) and the distance between the HRC and the line which is tangent to the both tuber ischiadicum (HRC-TI) were measured (Fig. 1). The values were automatically calculated by the software (Extreme Pacs Client XDS web viewer, Dicom 3.0, Teknokent, Ankara) in millimetres. The rate of HRC-Td to PH and HRC-TI to PH was calculated. The former value was designated as "the horizontal–HRC ratio", latter as "the vertical-HRC ratio". The results in each gender were compared with the student t-test, except the HRC-Td results in which the Mann–Whitney U test was used (GraphPad InStat, GraphPad Software Inc., USA). $P < 0.05$ was considered as significant. Power analysis was performed with the Post-Hoc power calculator.

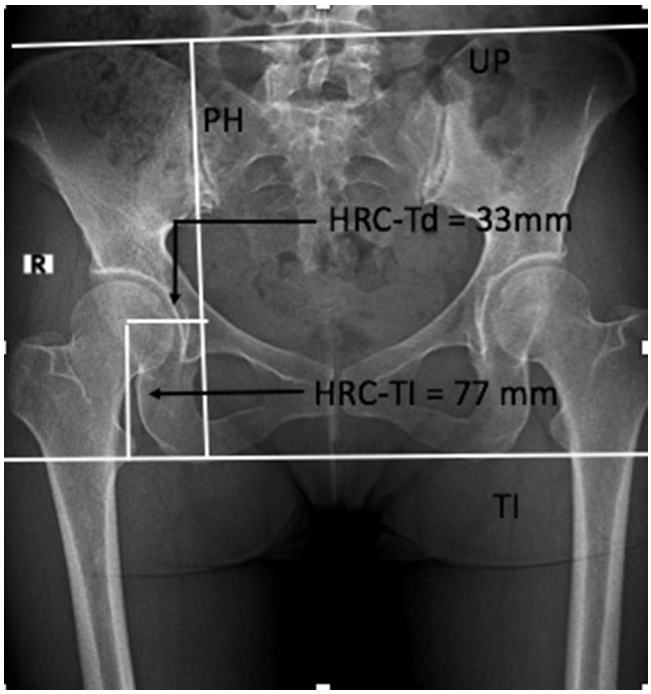

Fig. 1. Determination of the HRC on the standard AP pelvic radiograph. Pelvic morphometric parameters; PH: pelvic height, TI: inter-ischial line, UP: upper pelvic line, HRC: hip rotation centre, HRC-Td: the distance between HRC and teardrop, HRC-TI: the distance between HRC and inter-ischial line.

Results

The mean PH was 239 (±13.58) mm in men, 225 (±12.52) mm in women ($p < 0.0001$). The HRC-Td distances were 34.14 (±3.73) mm and 30.97 (±4.05) mm ($p < 0.0001$), the HRC-TI distances were 71.9 (±6.35) mm and 65.7 (±6.72) mm ($p < 0.001$), respectively. The differences were statistically significant between the two sexes ($p < 0.05$). "The mean horizontal–HRC ratio" was 14.25% (±1.42) in men and 13.69% (±1.38) in women; "the mean vertical-HRC ratio" was 30.01% (±2.05) and 29.10% (±2.35), ($p = 0.049$) respectively. The differences were not statistically significant ($p > 0.05$).

The power of study was found as 100% in the PH, 98.3% in the HRC-Td, 99.7% in the HRC-TI values, 51.5% in "the horizontal-HRC" and 54.1% in "the vertical-HRC" ratios.

Discussion

One of the reasons for polyethylene wear, and the consequent premature loosening of THA, is the position of HRC related to the anatomical hip centre, apart from the other variables such as quality of the polyethylene, size of the femoral head, surface of the prosthesis, age or activity of the patient. If the circumstances prevent placing the components in the normal anatomic location, medialization of the acetabular component and lateralization of the femoral stem is preferred from the biomechanical point of view.[11,14,19] However, the most desirable objective in THA is to reconstruct the HRC in the normal anatomic location if applicable. This is because medialization might impair the medial support of the acetabulum, and lateralization might lead to increased stress on the femoral component.[14] Nie et al reported that superior displacement of the HRC more than 5 mm above the anatomical hip centre, changes load distribution on the acetabulum. This is followed by cortical bone loss above the acetabular dome, which precipitates implant loosening.[16]

Several methods to restore anatomical HRC have been defined by different authors.[8,19,20] The acetabular teardrop is one of the frequently used reference points for acetabular component placement in THA.[9,11,16,19–21] The exact point of the HRC is usually determined as vertical and horizontal distance from the teardrop.[7,8,11] Usually, the distances in millimetres are used to describe the normal anatomic location.[5,14,16] Schofer et al compared previously described six methods to determine HRC.[18] They found that, normalization of the measurements by the inter-teardrop line distance or PH in varying X-ray magnification, facilitates to interpret the results.[18] They also stated that, while Ranawat's method had significant variability in vertical direction, Fessy's method was most reliable method to predict the true anatomical centre of the femoral head.[9,18,22] It is generally accepted that HRC should be reconstructed within 5 mm from the anatomical point.[5] Komiyama et al stated that acceptable vertical displacement should not exceed

above the point of 20 mm from the anatomical hip centre in terms of hip ROM.[23] However, this distance might be quite variable in terms of gender, race, community and even dependent upon the technique in which the radiograph was taken.[10,12,18,24] The difference between genders is already clearly shown in the present study too ($p < 0.05$). There are also some other studies, which reported the pelvic dimensions to be quite variable in the Japanese, African and Western populations.[13,15,25] Therefore, the ratio can be more consistent to define HRC in a given population.

Pierchon's method, which uses the ratios between HRC-"U-landmark" and HRC-sacroiliac joint in the both male and female genders, can be more convenient from this point of view.[7] However, the lower point of sacroiliac joint, which was used as a reference point by Fessy et al and Pierchon et al, may also be affected by developmental abnormality of pelvis as in case of DDH, in addition to abnormal pelvic positioning during radiographic examination.[8,22,26] The method, which is presented in this study and takes the upper end of the iliac bone as a reference point, is more reliable from this point of view (Fig. 2).

Previously, John and Fisher were used PH to normalize the distance between HRC and lower end of the teardrop figure.[27] They reported in the cadaver study that, HRC is at the point from 13% of PH laterally, 0.7% of PH superiorly according to the teardrop in both genders.[27] In the present study the horizontal location of HRC according to the teardrop (14.25% of PH ±1.42 in men, 13.69% of PH ±1.38 in women) is comparable with John and Fisher's study (13% of PH).[27] However, the only reference point in John and Fisher's study was the most inferior lateral part of the teardrop figure.[27] Although the teardrop figure is considered to be a reliable reference point, the lower point of teardrop might be indeterminable in some cases depended upon the incidence angle of beam.[9,18,24] Boudrait et al used the superior rims of the two foramina obturatoria as landmark, which can also be deformed depended upon rotational malposition of the pelvis.[28] On the other hand, Samani and Weinstein stated that minor degree of rotation in pelvis causes little change in the inferior one third of the teardrop figure.[24] In the present study, apart from the John and Fisher's, we have taken the most inner part of the teardrop as a reference point, which corresponds to the inferior one third of teardrop figure and the lateral border of the obturator canal that is easier to define and latest disturbed part of the acetabular structure even after revision of THA (Fig. 3). For the same reasons above, we have taken the inter-ischial line for the vertical location. This method provides the landmarks that are not easily affected by the pelvic malposition. Since, an unintentional malpositioning of pelvis during X-ray examination is very likely in DDH cases depended upon glutaeal muscle asymmetry. Therefore, the present technique is more useful to define HRC by using the PH measurement in the long term, in the cases with advancing bone loss. Furthermore, If the ratios (i.e. "the horizontal–HRC ratio" and "the vertical-HRC ratio") could be taken into consideration, the difference between genders were not statistically significant, which is again comparable with John's study ($p > 0.05$).[27]

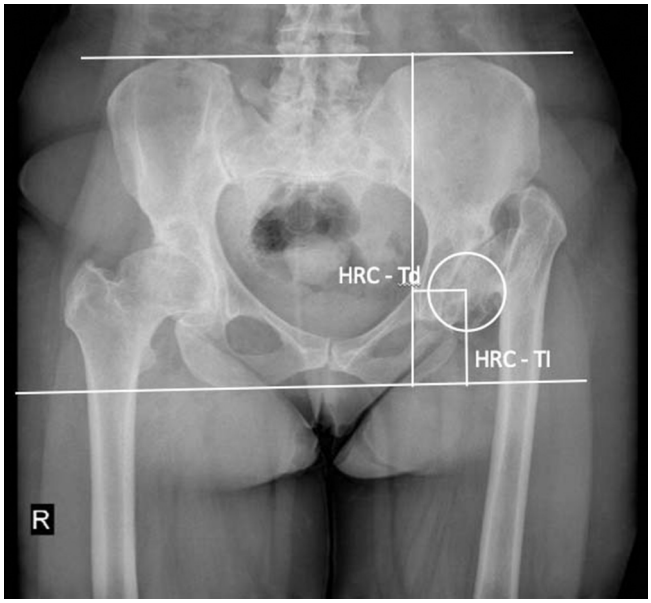

Fig. 2. Determination of HRC in the left hip of patient with bilateral DDH. Foramina obturatorius and pelvic inlet are deformed. UP and TI lines and medial side of the teardrop figure are identifiable. HRC was determined by applying "the mean horizontal–HRC ratio" (13.69%) and "the mean vertical-HRC ratio" (29.10%) in the left hip for this female patient.

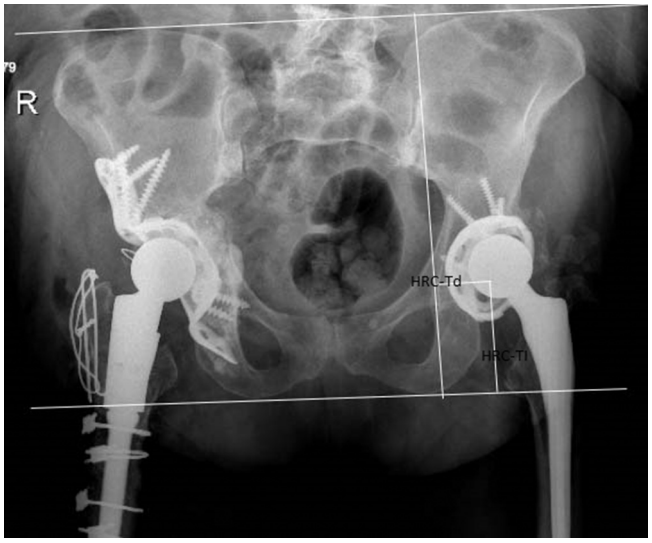

Fig. 3. Determination of HRC in the left hip of patient with aseptic loosening. Abnormal position of the acetabular component can be seen in the preoperative X-ray of the patient bilaterally affected. The medial side of teardrop figure is identifiable. HRC was determined by applying "the mean horizontal–HRC ratio" (13.69%) and "the mean vertical-HRC ratio" (29.10%) in the left hip for this female patient.

There are several limitations in this study; first, it is a retrospective study, although the radiographs analysed were chosen punctiliously. Second, this proposed method requires standard AP radiographs. In the cases with hip flexion contracture or increased lumbar lordosis, it might need some positional modification to obtain a pelvic radiograph to apply this method. Thirdly, in the cases with advanced acetabular defect, the most inner part of the teardrop, quite rarely, might be deformed which precludes using this technique.

In conclusion, HRC calculating method, which is described in the present study, is simple, safe and reliable, even in the bilaterally affected cases. Relying on the comparable data of the present study and John and Fisher's data, we can speculate that the measurements of the cases analysed in this study are similar to those of Western countries'.

References

1. Bicanic G, Delimar D, Delimar M, Peciina M. Influence of the acetabular cup position on hip load during arthroplasty in hip dysplasia. *Int Orthop*. 2009;33:397–402.
2. Kelley SS. High hip center in revision arthroplasty. *J Arthroplasty*. 1994;9:503–510.

3. Lecerf G, Fessy MH, Philippot R, et al. Femoral offset: anatomical concept, definition, assessment, implications for preoperative templating and hip arthroplasty. *Orthop Traumatol Surg Res*. 2009;95:210–219. https://doi.org/10.1016/j.otsr.2009.03.010.
4. Nawabi DH, Meftah M, Nam D, Ranawat AS, Ranawat CS. Durable fixation achieved with medialized, high hip center cementless THAs for crowe II and III dysplasia. *Clin Orthop Relat Res*. 2013. https://doi.org/10.1007/s11999-013-3187-0.
5. Cassidy KA, Noticewala MS, Macaulay W, Lee JH, Geller JA. Effect of femoral offset on pain and function after total hip arthroplasty. *J Arthroplasty*. 2012;27:1863–1869. https://doi.org/10.1016/j.arth.2012.05.001.
6. Bell AL, Pedersen D, Brand RA. A comparison of the accuracy of several hip center location prediction methods. *J Biomech*. 1990;23:617–621.
7. Pierchon F, Migaud H, Duquennoy A, Fontaine C. Evaluation radiologique du centre de rotation de la hanche. *Rev Chir Orthop*. 1993;79:281–287.
8. Ranawat CS, Dorr LD, Inglis AE. Total hip arthroplasty in protrusion acetabuli of rheumatoid arthritis. *J Bone Joint Surg Am*. 1980;62:1059–1065.
9. O'Sullivan GS, Goodman SB, Jones HH. Computerized tomographic evaluation of acetabular anatomy. *Clin Orthop Relat Res*. 1992;277:175–181.
10. Durand-Hill M, Henckel J, Satchithananda K, et al. Calculating the hip center of rotation using contralateral pelvic anatomy. *J Orthop Res*. 2016;J34:1077–1083. https://doi.org/10.1002/jor.23118.
11. Hirakawa K, Mitsugi N, Koshino T, Saito T, Hirasawa Y. Effect of acetabular cup position and orientation in cemented total hip arthroplasty. *Clin Orthop Rel Res*. 2001;388:135–142.
12. Olmedo-Garcia N, Loez-Prats F, Agullo A, Ortuno A, Palazon A. A comparative study of the accuracy of Ranawat's and Pierccon's methods to determine the centre of rotation in bilateral coxopathy. *Skelet Radiol*. 2000;29:652–655.
13. Patriquin ML, Steyn M, Loth SR. Metric analysis of sex differences in South African black and white pelves. *Forensic Sci Int*. 2005;147:119–127. https://doi.org/10.1016/j.forsciint.2004.09.074.
14. Sakalkale DP, Sharkey PF, Eng K, Hozack WJ, Rothman RH. Effect of femoral component offset on polyethylene wear in total hip arthroplasty. *Clin Orthop Relat Res*. 2001;388:125–134.
15. Lavy CBD, Msamati BC, Igbigni PS. Racial and gender variations in adult hip morphology. *Int Orthop*. 2003;27:331–333. https://doi.org/10.1007/s00264-003-0507-0.
16. Nie Y, Pei F, Li Z. Effect of high hip center on stress for dysplastic hip. *Orthopaedics*. 2014;37:e637–e643. https://doi.org/10.3928/01477447-20140626-55.
17. Tannast M, Fritsch S, Zheng G, Siebenrock KA, Steppacher SD. Which radiographic hip parameters do not have to be corrected for pelvic rotation and tilt. *Clin Orthop Relat Res*. 2015:1255–1266. https://doi.org/10.1007/s11999-014-3936-8.
18. Schofer MD, Pressel T, Heyse TJ, Schmitt J, Boudriot U. Radiological determination of the anatomic hip centre from pelvic landmarks. *Acta Orthop Belg*. 2010;76:479–485.
19. Nawabi DH, Maftah M, Nam D, Ranawat AS, Ranawat CS. Durable fixation achieved with medialized, high hip center cementless THAs for Crowe II and III dysplasia. *Clin Orthop Relat Res*. 2014;472:630–636. https://doi.org/10.1007/s11999-013-3187-0.
20. Yufeng L, Liming C, Wanshou G, et al. Ability of lower teardrop edge to restore anatomical hip center height in total hip arthroplasty. *Chin Med J*. 2014;127:3915–3920.
21. Robb JE, Rymaszewski LA, Bentley HB, Donnan PT. Reliability of the acetabular teardrop as a landmark. *Surg Radiol Anat*. 1991;13:181–185.
22. Fessy MH, N'Diaye A, Carret JP, Fischer LP. Locating the center of rotation of the hip. *Surg Radiol Anat*. 1999;21:247–250.
23. Komiyama K, Nakashima Y, Hirata M, Hara D, Kohno Y, Iwamoto Y. Does high hip center decrease range of motion in total hip arthroplasty? A computer simulation study. *J Arthroplasty*. 2016. https://doi.org/10.1016/j.arth.2016.03.014.
24. Samani DJ, Weinstein SL. The pelvic tear-figure: a three-dimensional analysis of the anatomy and effects of rotation. *J Pediatr Orthop*. 1994;14:650–659.
25. Takamatsu T, Shishido T, Takahashi Y, et al. Radiographic determination of hip rotation center and femoral offset in Japanese adults: a preliminary investigation toward the preoperative implications in total hip arthroplasty. BioMed Res Int https://doi.org/10.1155/2015/610763.
26. Mellano CR, Spitzer AI. How does pelvic rotation or tilt affect radiographic measurement of acetabular component inclination angle during THA? *J Orthop*. 2015;12:222–227.
27. John FC, Ficher PE. Radiographic determination of the anatomic hip joint center. A cadaveric study. *Acta Orthop Scand*. 1994;65:509–510.
28. Boudriot U, Hilgert J, Hinrichs F. Determination of the rotational center of the hip. *Arch Orthop Trauma Surg*. 2006;126:417–420. https://doi.org/10.1007/s00402-006-0157-y.