Assessment of acetabulum anteversion aligned with the transverse acetabulum ligament: cadaveric study using image-free navigation system

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Abstract

The transverse acetabulum ligament (TAL) has been used as an intraoperative anatomical landmark to position the acetabulum cup in total hip arthroplasty (THA). However, the validity of the use of TAL has not been clarified. The purpose of this study was to examine the orientation of the cup component aligned with the TAL in *cadaveric study*. The 31 hips in 25 whole-body embalmed cadavers were examined. The donors were 12 men and 13 women. Simulated THA procedure using image-free navigation system was performed and a trial cup with a diameter of approximately 2 mm less than the size of the acetabulum were inserted and snugly fitted on the TAL through the posterior wall of acetabulum. The orientation of the cup component was measured using an image-free THA navigation system. The measured radiographic anteversion and inclination angles averaged 18.2±7.2° (range: 2.0-33.2°) and 43.5±4.2° (range: 33.1-51.0°) respectively. Based on the Lewinnek's *safe zone* criteria, 26 hips (80.6%) were judged to be within the. Moreover, in the analysis of the gender difference of TAL angles, the average anteversion angle was shown to be significant larger in female than male population. The TAL can be effectively used an intraoperative landmark to align the acetabulum component helping reduce the risk of dislocation after surgery. In the intraoperative judgment, a gender difference in the alignment of the TAL should be taken into consideration.

Introduction

In total hip arthroplasty (THA), achievement of optimal component alignment is a critical factor to avoid postoperative complications and obtain favorable outcome. Among the factors related to prosthetic alignment, inclination and anteversion of the acetabulum cup has been raised as one of the critical factors influencing the operative outcome.

In order to consistently achieve optimal alignment of the acetabulum cup, there have been a number of measures reported in the literature such as surgical navigation, use of intraoperative instruments and anatomical landmarks. Among the various anatomical characteristic structures, the transverse acetabulum ligament (TAL) has been proposed as a visible intraoperative landmark to control positioning of the acetabulum component.[1,2] Archbold *et al*. determined the acetabulum anteversion relying on this landmark during THA procedure, and showed excellent clinical results of 1000 consecutive THAs with a dislocation rate of 0.6%.[1] Based on the satisfactory results of this clinical follow-up, they concluded that the TAL could be reliably used to determine the orientation of the acetabulum cup. In their procedure, the cup anteversion angle was adjusted parallel with the TAL. However, the measured value of post-operative cup anteversion angle in their study population was not presented.

Thereafter, the orientation of the TAL in relation to the pelvic plane has been examined and reported in several studies.[2-4] However, the reported results are variable and orientations of the TAL in patients who undergo THA have not been clarified. One of the factors leading to the variability in the reported results is that the orientation has been evaluated using various methods such as plain radiographs, MRI arthrographs and optoelectronic (navigation) system in previous studies. More recently, Kalteis reported that the TAL could be used to prevent serious malpositioning of the component using image-free navigation system during THA procedure.[5] We reviewed for the those intra-observer reliability in the cadaveric study. The purpose of the present study was to evaluate the cup anteversion and inclination angles as aligned with the TAL and posterior wall of acetablum in our patient population without osteoarthritis. Embalmed cadaveric hips were used in the study, and the cup orientation was measured using an image-free THA navigation system. Previous anatomical studies have shown that the acetabulum anteversion is significantly greater in female than male population.[6,7] Therefore, we additionally examined whether there is a gender difference in the anatomy of acetabulum version.

Our hypotheses were that the TAL can be reliably utilized as a landmark to achieve the optimal acetabulum component alignment, and there is a gender difference in orientation of the TAL in relation to the pelvic plane.

Materials and Methods

This study design was approved by the Institutional Review Board, and thirty-one hips of the 25 embalmed whole-body cadavers were used in the study. These cadavers have been donated to our institute for education and research purposes, and informed consent for donation was obtained from each patient and the family prior to the time of decease. All races were the Japanese. The donors were 12 men and 13 women. Although the detailed history of hip function or symptom before death was not available, all hips were without osteoarthritic changes that had an osteophyte or an ossification of the enthesis of the TAL. The OrthoPilot™ image-free navigation system (B/BRAUN-Aesculap, Tuttlingen, Germany) was used to measure the radiographic anteversion and inclination of the acetabulum component. In our clinical investigation, the intraoperative inclination and anteversion angles presented by the navigation system and the corresponding postoperative values obtained by CT measurement were compared. Consequently, accuracy of the navigation system was proven with the mean differences between the intraoperative and postoperative values of 2.3° in anteversion angle and 1.2° in inclination angle.[8] In accordance with the standardized procedure of this system, a tracker pin was inserted and fixed to the iliac crest and the bilateral anteriosuperior iliac spines and the upper margin of the symphysis were located and registered. In this process, we applied the pointer directly onto the bone to represent a true pelvic plane. In this navigation system, the triangular plane made by these three anatomical landmarks is defined as

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the reference plane (anterior pelvic plane) in the analysis.

Subsequently, all hips were dissected free of the surrounding capsule completely and dislocated. We could expose the TAL and the rim of acetabulum completely. Thereafter, a trial cup with a diameter of approximately 2 mm less than the size of the acetabulum was inserted and snugly fitted. The cup was aligned to the TAL for anteversion and simultaneously fitted to the posterior wall of acetabulum for inclination as described by Archbold and Keltis.[1,5] Finally, the anteversion and inclination angles of the trial cup were measured using the navigation system (for three times in each case). This system shows the acetabulum component orientation by the radiographic anteversion (RA) and inclination angles in relation to the anterior pelvic plane. In order to compare our results with those in the previous reports, we converted the RA value into the anatomical anteversion (AA) angle using a formula proposed by Murray.[9]

$$[\mathrm{Tan}\,(A.A.)=\mathrm{Tan}\,(R.I.)\,/\,\mathrm{Sin}\,(R.A.)]$$

In the statistical analysis of the numerical results, comparison between gender differences was assessed using the unpaired-t test. A P-value of less than 0.05 was considered statistically significant.

Results

In all cases, the TAL could be distinctly identified as a bridge-like structure connecting the inferior acetabulum notch.

The measured RA angles ranged from 2.0° to 33.2° (average: 18.2±7.2°) and the radiographic inclination angle ranged from 33.1° to 51.0° (average: 43.5±4.2°) (Figure 1). Based on the Lewinnek *safe zone* criteria, 26 hips (80.6%) were judged to be within the *safe zone*.[10]

Regarding the gender difference, a significant difference in the RA angle was demonstrated between male and female groups (Figure 2).

The RA angle of the TAL in female (average: 20.8±8.1°, range: 2.0-33.2°) was significant higher than the value calculated for male subjects (average: 15.5±5.1°, range: 9.7-25.7°) (P<0.05).

By contrast, no significant gender difference was demonstrated in inclination.

When the angular value was converted from RA to AA, the mean AA angle calculated for the whole specimens increased from 18.2±7.2° to 25.3±9.5°. In the analysis of the gender difference, the average AA angle in the male and female groups were 22.4±6.4° and 28.2±10.9° respectively, again, indicating a significant gender difference (P<0.05).

Discussion

The TAL is composed of fibrocartilage bridging the anterior and posterior horns of the lunate surface.[11] Base on the anatomical observation, Löhe reported that the TAL consists of two densely packed fiber bundles that are slightly twisted around each other.[12] From a biomechanical point of view, it has been reported that the TAL stabilizes the femoral head within the acetabulum during hip joint loading.[12] Archbold *et al*. proposed the use of this ligament as an intraoperative landmark to position the acetabulum cup during THA procedure, and confirmed the validity of their proposal based on the clinical follow-up study of large patient population.[1] Moreover, these authors rely on this ligament to determine the vertical height of the cup, and showed satisfactory outcome in restoring limb length, adding to utility of this anatomical landmark.[13] Subsequent to this study, significance of the use of this landmark has been examined in several other clinical studies with additional confirmation of its usefulness.[2,3] As a result, currently, a large number of hip surgeons follow this guideline.

Reviewing the previous literature dealing with the significance of the TAL in THA, there are still remaining issues yet to be clarified. First, reported results of orientation (anteversion angle) of the TAL in relation to the pelvis are different among the studies. Archbold *et al*. showed that the AA of the TAL ranges from 5.3-36.1° (average: 23.0°) based on the image analysis using MRI arthrography.[2] Pearce *et al.* performed a radiographic (RA) measurement for cadaveric hips and reported the range of 11.3-24.0° (average: 15.4°).[3] Kelteis *et al.* used the image-free navigation system for the TAL with osteoarthritis and reported the RA of the TAL ranges from -1° to 36° (average: 18°).[5] The measured AA angles and RA angles in the present study are 25.3° and 18.2° respectively, that are comparable to the data reported by Archbold (AA), Pearce (RA) and Kelteis (RA). However, the limitation of our study was measured the TAL angle obtained normal cadaveric hips. For clinical situation, we should review these angles for the patients with dysplastic

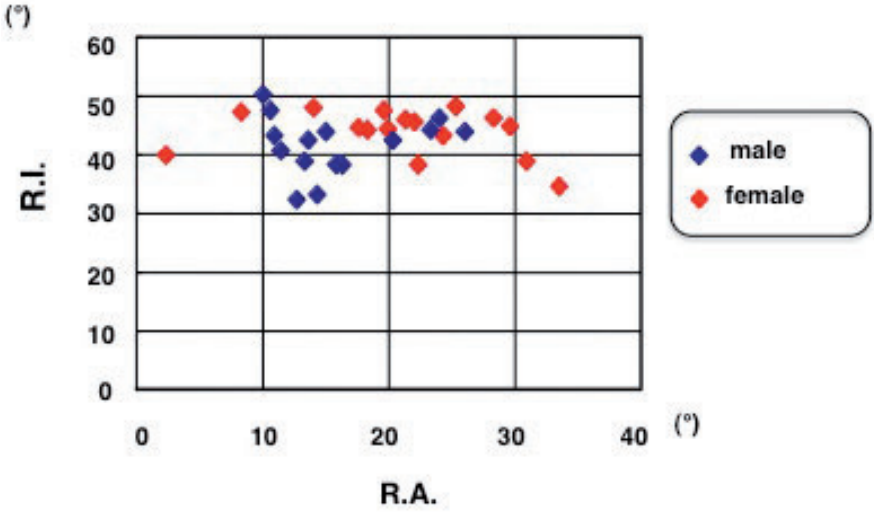

Figure 1. Scatter plots showing radiographic anteversion and inclination angles in each hip. The measured radiographic anteversion angles ranged from 2.0° to 33.2° and RI angle ranged from 33.1° to 51.0°.

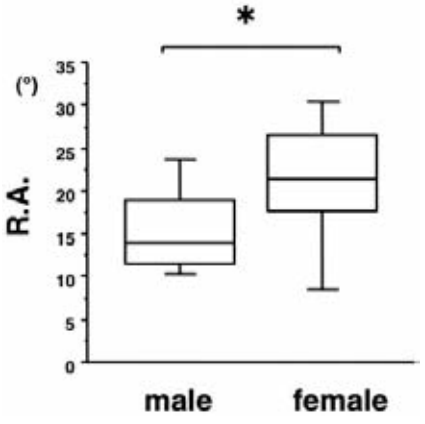

Figure 2. Anteversion and inclination angles in female and male populations. The radiographic anteversion angle of the transverse acetabulum ligament in female (average: 20.8±8.1°) was significant higher than the value calculated for male subjects (average: 15.5±5.1°) (P<0.05).

hip. Kelteis also could not point out the detail of their patient population whether including dysplastic hip or not. It might be possible that the end to end of the TAL could not figure out to obstruct the osteophyte or an osisfication of the enthesis of the TAL during the surgery. On the other hand, Viste *et al*. used an optoelectronic (navigation) system and reported that the measured AA values ranged from -8° to 13.3° (average: 1.9°).[4] These values are different from the results obtained in this study. In the present study, acetabulum alignment was assessed with the navigation system while the trial cup component was inserted (Figure 3). By contrast, Viste *et al.* defined orientation of the TAL by pointing five points along the course of the ligament. Moreover, the navigation system used in their measurement is different from the OrthoPilot system utilized in this study. Those differences may account for the discrepancy in the measurement results between the two studies.

Based on the Lewinnek *safe zone* criteria, 26 hips (80.6%) were judged to be within the *safe zone*, this results prove that the cup orientation aligned the TAL was a method more reliable than the cup orientation using the mechanical alignment guide reported by Digioia (22%).[14] Although the anteversion angle of the TAL mostly fits within the *safe zone*, the angle measured for each individual is substantially variable. Therefore, whether the anteversion of the acetabulum cup should be aimed at the middle of the *safe zone* or individualized relying on the anatomical variation is another issue of controversy. Based on the satisfactory outcome, Archbold *et al.* claim that the cup orientation should be aligned to the TAL and can be varied in each patient.[1] Judging from the wide variation of the anteversion angle of the TAL shown in this study, we agree with their statement of individualization. Moreover, in the clinical situation, we must take into consideration for the relation between the cup anteversion and stem antetortion to avoid the bone-to-bone impingement or implant impingement, in addition to use the TAL technique. Therefore, it may be advised to assess the acetabulum anteversion and femoral antetortion by CT or other evaluation for each patient as a part of preoperative planning.

Additionally, the present study showed a significant difference in the anteversion angle between the male and female populations. In the previous cadaveric study, Maruyama showed that the acetabulum anteversion angle for the acetabulum edge in female (average: 21.3°) was larger than that in male (average: 18.5°).[6] In the anatomical study performed for the hip joint in newborn, Mckibbin also described similar results with the average acetabulum anteversion for the acetabulum edge of 19° in female versus 14° in male.[7] Our results regarding the gender difference correspond to these previous results. This finding may present adjunctive information in clinical judgment of cup anteversion during the THA.

Limitations of this study include small sample size with limited adjunctive medical information for each cadaver. And so we could not evaluate the feature of each acetabulum that had a normal morphology or a dysplasia. Since power analysis was not performed in this study, it is not clear whether the quantity of the data in the study was robust enough to draw conclusive comments. Further accumulation of the morphologic data for larger sample size is warranted. Additionally, in this experiment, the TAL orientation was measured using the trial cup with a diameter of 2 mm less than the size of the acetabulum without reaming. Thus, the experimental setup adopted in the study does not exactly simulate the actual surgical procedure, which may be raised as a potential source of assessment error. Finally, validity of the use of the TAL as an intraoperative landmark has to be proved by long-term clinical follow-up study for large patient population.[15]

Figure 3. The trial cup component was inserted and snugly aligned with transverse acetabulum ligament. The anteversion and inclination angles of the trial cup were measured using the navigation system. The navigation monitor was showing the anteversion and inclination angles of the trial cup.

Conclusions

Orientation of the acetabulum component as aligned to the TAL was measured using an image-free navigation system in 31 cadaveric hips. The measured radiographic anteversions and inclination angles averaged 18.2±7.2° (range: 2.0-33.2°) and 43.5±4.2° (range: 33.1-51.0°) respectively. Based on the Lewinnek *safe zone* criteria, 26 hips (80.6%) were judged to be within the *safe zone*. In the analysis of the gender difference, the anteversion angle were shown to be significant larger in female than male population.

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