Article title

Surgeons changing the approach for Total Hip Arthroplasty from Posterior to Direct anterior with fluoroscopy should consider potential excessive cup anteversion and flexion implantation of the stem in their early experience.

Hideo Kobayashi, MD [1],
Yasuhiro Homma, MD, Ph.D [1]
Tomonori Baba, MD, Ph.D [1]
Hironori Ochi, MD [1],
Mikio Matsumoto, MD [1],
Takahito Yuasa, MD, Ph.D [1]
Kazuo Kaneko, MD, Ph.D [1]

Department affiliations

1) Department of Orthopaedic Surgery, Juntendo University, Tokyo, Japan, 113-0033

Corresponding author

Yasuhiro Homma
Department of Orthopaedic Surgery, Juntendo University
Address: 2-1-1 Hongo, Bunkyo-ku, Tokyo, Japan, 113-0033
Tel: +81-3-3813-3111, Fax: +81-3-3813-3428
yhomma@juntendo.ac.jp

Abstract

Purpose: Many reports outline the benefits derived from using the direct anterior approach (DAA) in primary total hip arthroplasty (THA); however, the learning curve for the DAA has not been well documented, and the complications associated with the DAA during this learning curve seem relatively high. The aim of this study was to investigate implant positioning in primary THA, when the surgeon was a novice at the DAA, and had previously used the standard posterior approach (PA).

Patients and methods: We investigated implant positioning in the first 80 consecutive THA cases performed by two senior surgeons using the DAA (with fluoroscopic assistance), and compared them to the same two surgeons' previous 80 respective THA cases performed using their previous standard posterior approach.

Results: Cup positioning accuracy was higher for the DAA ($p < 0.001$) but greater cup anteversion (19.3° ± 11.0 using the PA vs 27.6° ± 6.3 using DAA, $p < 0.0001$) was also demonstrated. 69.3 % of cups in the DAA group were positioned with an anteversion angle greater than their target angle. In the DAA group the stem was more frequently positioned in flexion and less frequently in neutral than for the PA group.

Conclusions: Although fluoroscopic assistance seemed to decrease complications such as femoral fracture, surgeons changing from PA to DAA for THA should consider potential excessive cup anteversion and flexion implantation of the stem in their early experience with DAA.

Keywords

direct anterior approach; implant position; fluoroscopy; total hip arthroplasty.

Text

Introduction

Total hip arthroplasty (THA) has been widely performed with significant success worldwide. Functional recovery and pain relief from hip pathologies such as arthritic hips and femoral neck fracture improve patient quality of life. The direct anterior approach (DAA) for hip surgery was first described in 1883 [1]. The DAA was then applied and developed for implantation of a hip prosthesis using a small acryl stem with a traction table [2]. The posterior approach (PA) then became the main approach used for primary THA for several reasons including a tendency to use long and big stems. The PA permits the surgeon a wide operative view to expose the acetabulum and femur, and allows easy manipulation of the leg owing to the lateral decubitus position; it can be used in a range of cases, from standard primary cases to challenging cases such as revision surgeries with massive bone loss. Recent nationwide data show that the PA was the approach used most frequently for THA [3]. However, the DAA-THA has recently regained popularity owing to smaller stem sizes, modified instruments and its perception as a minimally-invasive procedure [4, 5].

The DAA is hailed as a muscle preserving approach, using an intermuscular and internervous approach, to reach the hip joint. Benefits cited for the DAA include less soft tissue trauma, earlier postoperative recovery, lower dislocation rate, and better short-term outcomes compared with other approaches [6]. However, a high complication rate has been reported for THA performed by surgeons who are first beginning to use the DAA [7, 8]. Generally, it is assumed that the DAA is associated with a longer learning curve compared with other approaches [7, 8]. Woolson et al. reported that 9 % of major complications in their early experiences using the DAA were noted following primary THAs performed by senior surgeons who had mainly performed standard PA-THAs in their residency [8]. Besides, several papers showed no systematic advantage or very modest functional advantages in the DAA compared

PA [9, 10].

At our university hospital, we changed the main approach for primary THA from the PA to the DAA in 2011. The main reason for this was the arrival of a new senior surgeon who had performed more than 200 cases using with the DAA. Two other senior surgeons- who had previously used the standard PA – changed their main approach to the DAA. A tendency was noted for implant positioning to differ between the two approaches even when the target angle was the same. We hypothesized that there was a difference in implant positioning between the PA and the DAA, even when performed by the same surgeons using the same modern non-cemented implants with the same target angle. The aim of this study was to investigate the implant positioning in primary THA operated by a beginner of the DAA who had previously used the standard PA.

Materials and method

Subjects

Institutional review board approval was obtained before review of any medical records. A total of 160 THAs were retrospectively reviewed. A consecutive series of 80 THAs by two senior surgeons (40 cases each) using the DAA between 2011 and April 2015 were included in this study, and these were compared with the last 80 consecutive THAs using the PA performed by the same two surgeons. These two surgeons had each performed over 200 THAs by the PA, and changed their respective approaches around the same time. Exclusion criteria were: 1) previous osteotomy surgery; 2) Crowe type 4 hip dysplasia; 3) failure of osteosynthesis; and 4) inability to measure owing to cup character (ADM Acetabular system: (Stryker Orthopaedics, Mahwah, NJ, USA). A final total of 152 THAs were included in this study: 75 DAA-THAs and 77 PA-THAs (Fig. 1). No significant differences were found in age, gender, body mass index, and initial diagnosis between the PA and DAA group, or between the patients operated on by each surgeon (Table 1).

Implants

Modern uncemented cups and proximal coatied stems were used: the Trident–Accolade system (Stryker Orthopaedics, Mahwah, NJ, USA) and the Synergy-Reflection cupsystem (Smith and Nephew Orthopaedics, Memphis, TN, USA). The Trident-Accolade system was implanted in all cases in the DAA group, and in 70.1 % of the cases in the PA group.

Operative technique

For the PA-THA a standard approach was used, using the transverse acetabular ligament as a guide for version. The cup setup was adjusted with a trial handle, aiming for an inclination angle of 40° and an anteversion angle of 25°. After inserting the stem, leg length difference was

checked and optimal stem positioning checked intraoperatively using an X-ray and any necessary adjustments made. After confirming that they were not impinging, the articular capsule and piriformis muscle were suturedback together.

In the DAA-THA, the operation was performed using the distal part of the Smith-Petersen approach with the patient in the supine position on a standard surgical table, and only the affected leg was sterilized (Fig. 2). Osteotomy was performed after cutting the articular capsule in the supine position by intermuscular penetration of the tensor fasciae latae and sartorius muscle. The round ligament contact point was confirmed and the acetabular roof reamed under fluoroscopic guidance. The cup was set up , aiming for an inclination angle of 40° and an anteversion angle of 25°; this positioning is confirmed by fluoroscopy. After placing the patient in the extended supine position, the femur was raised with a retractor and the stem inserted. If the stem appeared undersized compared to the pre-operative plan, an appropriately sized stem was inserted and positioning checked with fluoroscopy.

Radiological evaluation

We evaluated Lauenstein and AP imaging in a recumbent position in both the PA group and the DAA group 8 weeks after surgery. Both the Trident and the Reflection acetabular cup were evaluated for each approach. Only the Accolade stem was compared for both approaches (55 stems in the PA group, 75 stems in the DAA group). For the radiographic assessments, a straight line was drawn to both tear drops using the Lewinneck method andthe cup inclination angle measured [11]. The anteversion angle was measured using the Widmer method [12]. Successful cup positioning was defined as an inclination of 40° ± 10 and an anteversion of 25° ± 10. Stem alignment was evaluated via the angle formed between the long axis of the prosthesis and the long axis of the femur [13]. As previously described by Abe et al. [14], the alignment of the stem in the coronal plane was defined as neutral, valgus (≥ 3° medial deviation), or varus (≥ 3° lateral deviation). Using an X-ray profile view, the stem alignment in the sagittal plane was defined as neutral, extension (≥ 3° anterior deviation), or flexion (≥ 3°

posterior deviation). The measurement was performed in a blinded fashion by an investigator (YH), who was not involved in the treatment.

Perioperative complications

Major complications during the operation such as femoral shaft fracture, stem penetration, and early postoperative complications -including deep infection and dislocation- were investigated.

Statistical analysis

Baseline characteristics were expressed as mean (standard deviation). The Student's *t*-test or the Welch test were used for continuous variables. Pearson's chi-squared test and Fisher's exact test were used for dichotomous variables. A value of $p < 0.05$ was considered statistically significant, and all tests were two-sided. Data were statistically analyzed using IBM SPSS Statistics for Macintosh (Version 22.0; IBM, Armonk, NY, USA).

Results

The cup inclination angle was 44.4° ± 7.0 in the PA group and 42.2° ± 6.9 in the DAA group ($p = 0.042$). The anteversion angle was 8.3° higher in the DAA group than the PA group (19.3° ± 11.0 in the PA vs 27.6° ± 6.3 in the DAA, $p < 0.0001$, Table 2). There was no difference between the angles of the cups placed by one surgeon compared with the other in both approaches. There was no difference in stem position on AP view between the PA and the DAA group, except for those stems implantated in valgus. On the lateral view, the stem was more frequently positioned in flexion and less frequently in neutral in the DAA group than the PA group. Scatterplot depicting the number of total hip arthroplasty of posterior and anterior approach is showing in Figure 3.

There was no difference of success rate in cup inclination angle using the PA versus the DAA ($p = 0.412$, Fig. 4A). There was a higher success rate in the DAA group compared with the PA group in anteversion and both inclination and anteversion angle ($p < 0.01$, Fig. 4A).

In the PA group, 61.0 % of cups were positioned at an angle less than the target anteversion angle, while 69.3 % of cups in the DAA group were positioned at an angle greater than the target anteversion angle (Fig. 4B).

There was one case of posterior dislocation in the PA group, and one case of anterior dislocation in the DAA group. Neither femoral shaft fracture nor stem penetration were observed.

Discussion

We investigated the difference in implant positioning between the PA-THA or the DAA-THA by two surgeons who had changed from using the PA to the DAA with fluoroscopy assistance.

There was a higher degree of accuracy regarding the acetabular side defined as being positioned within the target angle ± 10 in both inclination and anterversion using the DAA. There was also a significantly smaller acetabular cup inclination and significantly higher anteversion angle in the DAA-THA compared with the PA-THA. Higher accuracy of cup positioning using the DAA might be due to two reasons; fluoroscopic assistance and the supine position. Firstly, fluoroscopic assistance permits the surgeon to monitor the angle continuously and easily compared with a one-shot X-ray. Previous studies have also reported the advantages of fluoroscopy use [15, 16]. Secondly, the supine position may be superior for positional changes during surgery. In the PA, patients are in the lateral decubitus position; assuring the patient's positional shift during PA-THA is a major issue, as the patient can shift in the coronal and axial planes [17, 18]. Under those conditions, the surgeon must consider the changeable acetabular orientation during implant insertion. In contrast, the DAA-THA requires patients to be in a supine position, where the pelvis can be stabilized on the operation table. This permits easier manipulation to the acetabulum, leading to higher accuracy of cup positioning.

However, although higher accuracy of cup positioning was achieved in the DAA-THA, there was also a higher degree of cup anteversion. This is explained by the following reasons; interference with the femur, excessive target angle as pre-operative planning, and misinterpretation of the fluoroscopic images. Firstly, we used a straight cup impactor in both the DAA and the PA group, which we felt was easier to handle to achieve press fit fixation. In the PA-THA, this straight cup impactor interferes with the femur at the anterior rim, resulting in a smaller anteversion angle of the cup. In contrast, the straight cup impactor interferes with the thigh and femoral neck in the DAA-THA (Fig. 5), resulting in inadequate hand-down, which

means the cup is placed in anteversion. This could also be the reason that the majority of cup anteversion angles in the PA-THA were less than the target angle of 25°, while those in the DAA-THA were greater than the target angle (Fig. 4B). Sufficient soft tissue release, proper level of neck osteotomy, and use of a curved offset cup impactor might be needed to avoid higher anteversion (Fig. 5). Indeed, the greater anterversion angle in our series was unexpected event. Our target anteversion angle for the DAA-THA was also probably too high. Although several studies have reported an ideal cup anteversion of between 5 to 40° [19–22], we believe that the target anteversion angle in the DAA-THA should not exceed 25°. Most of the actual cup positions in our study were at an anteversion angle greater than the target angle in the DAA-THA, and one patient had an anteversion angle of 31° that resulted in an anterior dislocation. Thus, we have decreased our target anteversion angle for DAA-THA since completing this study. Secondly, although the DAA gives more stable positioning compared with the PA, positional shift uniquely in the sagittal plane could not be avoided, especially during press fit fixation. When we fixed the acetabular component with the press fit technique, we tried to lower the hands with the impactor in order to avoid excessive anteversion. During this procedure, the pelvis can flex in coordinating through the cup and impactor; so although the fluoroscopy shows no anteversion, this can then become excessive after release of the impactor keeping the pelvis in flexion. This may be why there was higher cup anteversion in the DAA-THA despite fluoroscopy assistance. At the time of the operations, we did not recognize these potential misinterpretations of the fluoroscopic image. As excessive cup anteversion can result in anterior dislocation due to posterior impingement and edge loading, DAA-THA novices should pay attention to these considerations in order to achieve a suitable anteversion angle. Although greater cup anteversion such as our series in the DAA-THA compared to the mini-PA-THA was also reported [9], Rodriguez et al. reported intentional lower cup anteversion due to concerns about anterior instability [10].

Woolson et al. reported that intraoperative femoral fracture is the most common

major complication in the DAA-THA, with 16 femoral shaft or trochanteric fractures occurring in 247 hips (6.5 %) [8]. Our data also showed a significantly higher incidence of stem in flexion in the DAA group. This is probably because of inadequate soft tissue release for femur elevation by beginner users of the DAA. Thus, the stem was inserted from anterior to posterior, where high risks of stem penetration and shaft fracture exist. In our series, however, there was no intraoperative femoral shaft fracture, probably mostly due to the assistance of fluoroscopy in the DAA-THAs; we were able to adjust the stem angle before femoral fracture occurred. We believe that adequate soft tissue release and femur elevation for stem insertion is the key to proper positioning. We recommend using fluoroscopy to confirm the stem alignment in the lateral view. Difficulty in stem insertion in the sagittal plane is consistent with several previous studies [14, 24]. Vaughan et al. reported that it was difficult to implant the femoral component using the anterolateral approach in the neutral position in the lateral view [23]. Abe et al. also confirmed the same tendency in the DAA-THA using computed tomography images with 3D template software [14]. Long-term survivorship of a malpositioned stem is still controversial. Vresilovic et al. reported that varus component alignment was correlated with stem loosening [25]; while some other authors reported no adverse effects [13, 25].

We believe that the use of fluoroscopy in the DAA-THA allows accuracy of cup positioning and avoidance of femoral fracture. However, cumulative exposure of the medical practitioner to radiation must be considered. Although the exposure is considered very minimal [26], the greatest precautions should be taken in every setting.

Our study had several limitations. First, it was a retrospective non-randomized study. The cumulative experiences of THA might have an effect on better radiographic outcomes using the DAA. However, we consider our data to be important, as we demonstrated the tendency of the implant position to differ between the PA and the DAA when the same two surgeons used the same implants. As the DAA-THA increases in popularity, our data will help surgeons who change their main approach from the PA to the DAA. Second, during the PA, intra-operative

X-ray was obtained to check prosthesis position. In the DAA series, intra-operative fluoroscopy was used to adjust both acetabular and femoral component position. Thus, the intra-operative radiologic technique is not comparable, and may potentially induce bias into the results. Third, the "target" anteversion for acetabular position was set at 25°± 10 for both groups. The consensus, however, among practitioners of the DAA is that anteversion should be reduced for the DAA, as compared with the posterior approach. Therefore, this misconfiguration would be expected to bias the results of the DAA. Fourth, conventional measurement using standard radiography was also performed, which does not permit calculation of the degree of stem rotation [27]. As the concept of combined anteversion gains consensus, further investigation should be conducted. Last, importantly, our result did not show any clinical superiority in the DAA-THA over the PA-THA. As many papers reported, obvious advantage in the DAA-THA is not yet clear [9, 10, 28], moreover, the complication in the DAA-THA is thought to be higher [29], especially in the early experience so called the learning curve [7, 8]. But we believe that our result might help for a surgeon who considers changing the main approach from the PA to the DAA.

Conclusion

We investigated implant positioning in primary THA operated by two novice users of the DAA who had previously used the standard PA. Higher accuracy of cup positioning was demonstrated using the DAA-THA, but also greater cup anteversion. Surgeons changing from the PA to the DAA should pay attention to excessive cup anteversion in their early experiences with the DAA-THA, and note that fluoroscopic assistance seems to decrease complications such as femoral fracture.

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Legend to figures and tables

Fig 1. Flow chart of this retrospective study.

Fig 2. The patient is positioned in the supine position on a standard surgical table, and only the affected leg was sterilized.

Fig 3. Scatterplot depicting the number of total hip arthroplasty of posterior and anterior approach.

Fig 4. Cup position assessment.

A. Rate of successful cup positioning defined as inclination 40°±10, anteversion 25±10. Higher achievement rate in AA group was observed in the anteversion and both inclination and anteversion ($p<0.01$)
B. Distribution of cup anteversion angle. The majority of cup anteversion angle in PA was less than the target angle (25°), while those in AA was more than the target angle (25°)

Fig 5. The straight cup impactor interferes with the thigh and femoral neck in the DAA-THA. Use of a curved offset cup impactor might be needed to avoid higher anteversion

Table 1. Patient characteristic.

Table 2. Implant positioning for posterior and anterior approach.