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Original article

Supine versus lateral position for accurate positioning of acetabular cup in total hip arthroplasty using the modified Watson-Jones approach: A randomized single-blind controlled trial

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ABSTRACT

Background: The orientation of the acetabular cup is a critical factor for prevention of various postoperative complications in total hip arthroplasty (THA). Although most patients are treated in either supine or lateral position during surgery, it is still unclear which position is superior to achieve more accurate cup positioning. Our study was conducted in order to answer the following questions: (1) does the supine position provide a higher accuracy of cup positioning than the lateral position in THA using modified Watson-Jones approach? (2) is there any difference in the distribution of cup position between the two positions?

Hypothesis Our hypothesis was that the supine position would provide a higher accuracy of cup positioning than the lateral position in THA using modified Watson-Jones approach.

Patients and methods: A single-center prospective randomized study (registration number: UMIN000021627) was conducted between May 2016 and December 2017. We recruited a total of 60 participants undergoing unilateral primary cementless THA using modified Watson-Jones anterolateral approach based on the result of the sample size calculation. They were randomly assigned to either supine position ($n = 29$) or lateral position ($n = 31$). The cup alignment was targeted using a goniometer during surgery. The radiographic cup inclination was targeted to 40° and the radiographic cup anteversion was targeted considering the femoral stem anteversion during surgery. Postoperative cup alignment was measured by plain radiography and computed tomography. We defined the difference between postoperative and target cup angle as *target error* and our primary outcome was the absolute value of the target angle. As secondary outcome, the distribution of the target error was evaluated. The target errors of each inclination and anteversion were divided into 3 groups; neutral ($-3° \leq$ the target error $\leq 3°$), positive error ($3° <$ the target error), and negative error (the target error $< -3°$).

Results: The assessment of primary outcome for all recruited patients showed that supine group was significantly more accurate than lateral group in terms of radiographic inclination (2.4° vs. 4.5°, respectively, mean difference 2.1°; 95% confidence interval, 0.7 to 3.5; $p < 0.01$). There was no significant difference in terms of radiographic cup anteversion (5.6° vs. 5.2°, mean difference 0.4°; 95% confidence interval, −1.8 to 2.6; $p = 0.69$). The rate of positive error of anteversion in supine and lateral group was larger than that of negative value of anteversion (51.7% vs. 10.3% and 48.4% vs. 12.9%, respectively). Any acute complication (dislocation, fracture, and infection) was not found in both groups during postoperative 3 months.

Discussion: In this randomized-controlled trial, higher accuracy of acetabular cup inclination was provided by supine position than by lateral position in THA. On the other hand, there was no significant difference between both groups in terms of cup anteversion. In both groups, most cups were placed with larger anteversion than we targeted. Modified Watson-Jones approach in both positions should be performed considering these results.

Study registration number: UMIN000021627.

Level of evidence II, randomised controlled study (population-limited).

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1. Introduction

The orientation of the acetabular cup in total hip arthroplasty (THA) is a critical factor for prevention of postoperative dislocation, accelerated wear and loosening, reduced range of motion, and patient dissatisfaction [1–6]. There have been several studies regarding the proper orientation of the acetabular cup in THA. Lewinnek et al. [7] recommended an inclination angle of $40^\circ \pm 10^\circ$ and an anteversion angle of $15^\circ \pm 10^\circ$ as the safe zone for cup orientation in THA. Although this theory had been used as the standard theory, some authors have argued that those angles must be arranged individually considering the femoral anteversion angle and/or other factors, recently [1,6,8–10]. Whereas the orientation of the acetabular cup can be varied by surgeon's discretion within the anatomical limits, it is still difficult to achieve the ideally planned cup positioning because of the difficulty in recognizing the position and tilt of the pelvis during surgery correctly even if various assisting devices such as goniometers, mechanical alignment guides, and computer-assisted systems are used [11–16].

Intraoperative positioning of the patient is critical to help achieve anatomical accuracy of the acetabular component positioning [17–23]. Patient positioning is crucial in providing stability of the pelvis and in determining bony landmark availability and usability. In the supine position, the anterior superior iliac spines and the pelvic tubercles are more readily palpable and usable as bony landmarks for references to allow accurate positioning of the acetabular component [17–20]. The lateral position is the more traditionally utilized position for surgery but with less obvious intraoperative bony landmarks. Positioning in the lateral position needs to take care to avoid movement of the pelvis when moving the leg intraoperatively [17–20]. Although it is expected that there is a difference in the accuracy of cup positioning between both positions, there has been no randomized-controlled study that compared the accuracy of cup positioning between both positions, specially for the Watson-Jones anterolateral approach.

Therefore, we performed a randomized study to compare the accuracy of acetabular cup positioning between supine and lateral position in cementless THA using the same modified Watson-Jones anterolateral approach in randomized-controlled trial. Our study was conducted in order to answer the following questions: (1) does the supine position provide a higher accuracy of cup positioning than the lateral position in THA using modified Watson-Jones approach? (2) is there any difference in the distribution of cup position between the two positions? Our hypothesis was that the supine position would provide a higher accuracy of cup positioning than the lateral position; the absolute value of mean difference between postoperative inclination and the inclination we target during surgery in supine position is at least 2 degrees smaller than that in lateral position.

2. Patients and methods

2.1. Patients

This prospective, two-arm, parallel-group, randomized-controlled trial was performed in a single university hospital. The trial protocol was approved by the institutional ethics committee (Registration number: R2016-003) and registered on the University Hospital Medical Information Network Clinical Trials Registry (Registration number: UMIN000021627) before enrolment of the first participant.

Sample size calculation that had been performed before this trial showed that 29 patients per each group would be needed to detect 2.0° difference in the absolute target error between two positions with a power of 80% at a type I error rate of 5%. For power analysis, we used a standard deviation of 3.0° in the absolute target error based on the results of former studies [16–18]. Based on this result of power analysis, we recruited 60 participants from patients undergoing primary unilateral cementless THA between May 2016 and December 2017. These patients were recruited individually by three surgeons (RT, MH, KM) who had had enough experience of modified Watson-Jones approach in both positions. They had performed at least 50 cases each prior to the study. The patients by the surgeons who had not had enough experience of either approaches were not included. Participants were informed that we were comparing supine and lateral position in THA and they would be randomly assigned to either position.

The inclusion criteria were as follows: patients who were indicated for unilateral THA, were older than 18 years old, of any gender or race, had an underlying diagnosis of osteoarthritis, and agreed to provide informed consent to participate in this study. The exclusion criteria were as follows: patients with dementia, severe dysplasia graded as Crowe III or IV [24], and a previous history of the hip surgery.

2.2. Randomization and blinding

Using web-based randomization, participants were assigned in a 1:1 ratio to receive surgery in supine position or in lateral position. Randomization was performed by one surgeon (RT). Randomized numbers from 0 to 99 were generated using List Randomizer software (Randomness and Integrity Services, Dublin, Ireland). Patients with even numbers were allocated to the anterolateral approach in supine position (ALS) group and those with odd numbers were allocated to the anterolateral approach in lateral position (ALL) group. The surgeons, nursing staff, and patients were not blinded to the allocation through follow-up. Only radiographic assessments were performed in blinded fashion.

3. Methods

Cementless THA was performed under spinal anesthesia with intravenous sedation. The patients who were assigned to supine position were placed on the standard operating table without leg traction device, which was positioned in the horizontal axis to the floor. The patients who were assigned to lateral position were positioned along the longitudinal axis of the operation table. The fixation devices were positioned on the sacral bone and the anterior superior iliac spines of the patient to immobilize their pelvis. The pubic tubercles were not immobilized.

All surgeries were performed using the minimally invasive anterolateral approach with the only difference being the intraoperative positioning of the patient in either the supine or the lateral position. The anterolateral approach modifying the Watson-Jones approach, which is called Röttinger [25] approach when performed in lateral position, is an approach separating the inter-muscular plane between the tensor fascia lata and the gluteus medius muscles. It has been widely used as one of the minimally invasive approaches [25–30]. Although this minimally invasive approach was basically used in lateral position, in recent years, some studies have reported early functional recovery and excellent clinical results with this approach performed in supine position [27–30]. All three surgeons (RT, MH, KM) who participated in this study had had an experience of using each approach in more than 50 cases before this study began. Initial incision was made on the anterolateral aspect of the hip (10–12 cm) and the interval between the tensor fascia lata and gluteus medius was bluntly developed without muscle cutting or detachment, and the exposed plane was not developed too proximally to minimize the risk of superior gluteal nerve injury [30].

After capsulotomy, all patients underwent cementless implantation with ceramic-on-highly cross-linked polyethylene bearings. Femoral preparation was prior to acetabular preparation. Accolade II (Stryker Orthopaedics, Mahwah, NJ) and Trident PSL shell (Stryker Orthopaedics) were used as femoral and acetabular component. The acetabular cups were inserted in press-fit fashion. No additional screws for fixation were used. X3 (Stryker Orthopaedics) and 32 or 36 mm delta ceramic head were used as bearing surface.

The radiographic angle values were used based on the definitions by Murray [9]. The radiographic inclination was defined as the angle between the longitudinal axis of the body and the acetabular axis when this was projected on to the coronal plane. The radiographic anteversion was defined as the angle between the acetabular axis and the coronal plane. Intraoperative radiographic inclination and anteversion were targeted with a conventional manual goniometer [16]. The radiographic inclination was targeted to 40°. The radiographic anteversion was targeted considering intraoperative femoral stem anteversion which was measured using a goniometer in reference to the tibial axis during femoral preparation and calculated based on the theory by Widmer and Zurfluh [8]. The target anteversion was finally decided by arranging this calculated angle considering patients' range of motion of the hip, age, the shape and angle of acetabular bone, spine deformity, and so on. Intraoperative X-rays, fluoroscopy, and other computer-assisted devices were not used. The patients were mobilized on the first postoperative day with full weight bearing as tolerated. The patients were discharged when they were well enough to walk with aid.

3.1. Methods of assessment

Patients' background data (age, sex, side of surgery, body mass index, and diagnosis), preoperative and 3-month postoperative Japanese Orthopaedic Association score (0 to 100, worst to best) [31], surgical data (operating time, intraoperative blood loss, stem anteversion measured during operation, and target radiographic anteversion), and early complications by postoperative 3 months (e.g. dislocation, infection, intraoperative fracture) were recorded.

Postoperative radiographic inclination was assessed from anteroposterior pelvic radiographs which were obtained within 3 months of surgery. Postoperative radiographic anteversion was converted from anatomical anteversion in computed tomography which were performed at the same time as the radiography in reference to the study using the formula of Murray et al. [9]. All radiographic assessment was performed by one surgeon (XX) in blinded fashion. We defined the difference between postoperative and target angle as *target error* (positive value of the target error means that postoperative angle is larger than target angle) and the absolute value of the target error as *absolute target error*.

Primary outcome was the absolute target error of inclination and anteversion in each group. The number of the outliers of the absolute target error (the absolute target error $\geq 10^{\circ}$) in each group was also estimated. As secondary outcome, the distribution of the target error was evaluated. The target errors of each inclination and anteversion were divided into 3 groups; neutral ($-3^{\circ} \leq$ the target error $\leq 3^{\circ}$), positive error ($3^{\circ} <$ the target error), and negative error (the target error $< -3^{\circ}$). Each number of neutral, positive error, and negative error was estimated.

In order to evaluate the inter-observer reliability of radiographic assessment, the radiographic inclination and anteversion in 20 cases selected randomly were measured by a second observer (YY).

3.2. Statistical analysis

To compare the primary outcome between supine and lateral group, the differences in the absolute target error and 95% confidence intervals were calculated with unpaired *t*-test. Other comparisons between the study groups were performed with the Chi-squared test for categorical variables and unpaired *t*-test for continuous variables. All tests were two sided, and $p < 0.05$ was considered statistically significant. Inter-observer reliability for the measurement of each inclination and anteversion was analyzed using Spearman's rank correlation coefficient. The

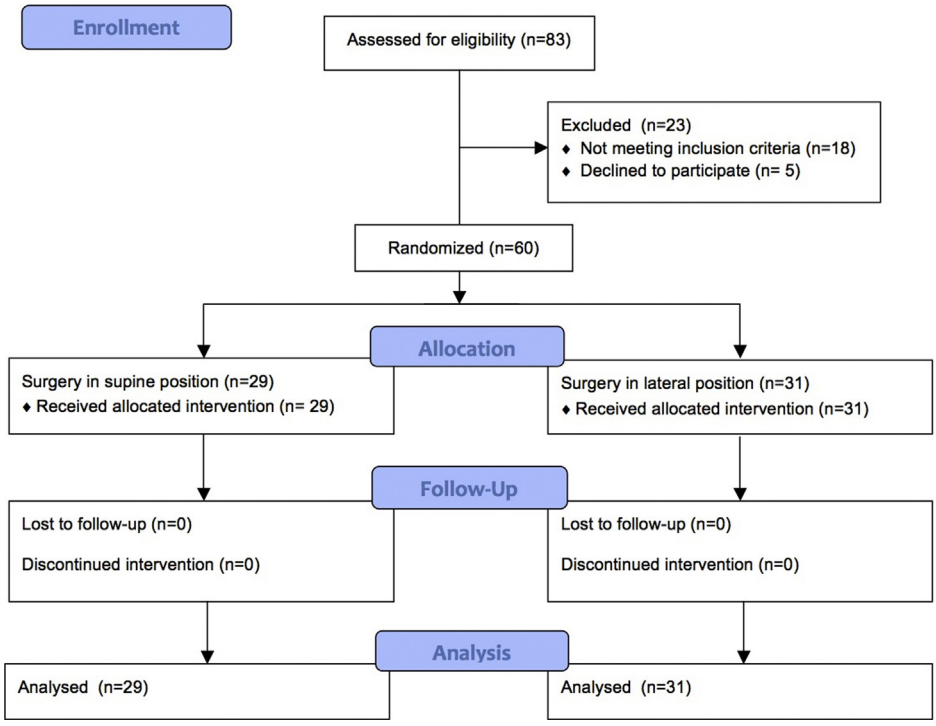

Fig. 1. Detail of the enrollment and randomization of patients undergoing unilateral total hip arthroplasty.

Table 1
Patients' background, Japanese Orthopaedic Association score, and surgical data.

Variable	ALS ($n=29$)	ALL ($n=31$)	p value
Age (years)	64.5 ± 12.1 (25–89)	66.5 ± 12.3 (21–87)	0.48
Sex (female/male)	25/4	24/7	0.38
Side (right/left)	21/8	21/10	0.69
Body mass index (kg/m^2)	23.4 ± 4.1 (16.6–33.2)	24.8 ± 4.9 (18.4–35.9)	0.25
Diagnosis			0.93
Osteoarthritis	26	28	
Osteonecrosis	3	3	
JOA score [31]			
Before surgery	52.1 ± 12.3 (30–82)	49.4 ± 11.8 (23–74)	0.38
Postoperative 3 months	92.5 ± 7.9 (60–98)	89.9 ± 8.8 (64–99)	0.24
Operative time (min)	82.0 ± 33.8 (52–216)	79.9 ± 24.1 (50–140)	0.78
Intraoperative blood loss (ml)	265.7 ± 131.2 (71–780)	208.6 ± 90.0 (48–400)	0.064

Values are given as mean ± standard deviation (range); ALS: anterolateral approach in supine position; ALL: anterolateral approach in lateral position; JOA: Japanese Orthopaedic Association.

Table 2
The absolute target error.

The absolute target error	ALS ($n=29$)	ALL ($n=31$)	Difference (95% confidence interval)	p value
Radiographic inclination (°)	2.4 ± 2.0 (0–9.0)	4.5 ± 3.2 (0–13.0)	2.1 (0.7–3.5)	< 0.01
Radiographic anteversion (°)	5.6 ± 4.7 (0.4–20.2)	5.2 ± 3.7 (0–13.1)	0.4 (−1.8–2.6)	0.69

Values are given as mean ± SD (range); ALS: anterolateral approach in supine position; ALL: anterolateral approach in lateral position.

correlation coefficients were judged: 0.3–0.5: fair; 0.6–0.8: moderately strong; > 0.8: very strong [32]. All statistical analyses were performed with G*Power Version 3.1.9.2 (Düsseldorf University, Düsseldorf, Germany) and Statcel 3rd edition (OMS Publishing Inc. Saitama, Japan).

4. Results

Spearman's correlation coefficients for the inclination and the anteversion showed "very strong" inter-observer reliability ($r=0.95$, $p<0.001$ and $r=0.94$, $p<0.001$). Flow chart of participants through the study is shown in Fig. 1. A total of 60 patients were allocated and not excluded after randomization because we collected all data and there was no lost follow-up or drop-out during the study period. There was no significant difference between both groups in the patients' background, pre- and postoperative Japanese Orthopaedic Association scores, and surgical data (Table 1).

The absolute target error of radiographic angle in ALS and ALL group is shown in Table 2. The absolute target error of cup inclination in ALS group was significantly lower than ALL group ($p<0.01$). There was no statistically significant difference of the absolute target error between both groups in the radiographic anteversion ($p=0.69$). The numbers of outliers of the absolute target error in ALS and ALL group were 3 cases (9.7%) (0 case for inclination and 3 cases for anteversion) and 6 cases (19.4%) (2 cases for inclination and 4 cases for anteversion), respectively ($p=0.33$). The scatter diagram of the target error is shown in Fig. 2.

Each number of neutral, positive error, and negative error in both groups is shown in Table 3. There was significant difference between both groups in the distribution of cup inclination ($p=0.002$). The rate of positive error of anteversion in ALS and ALL group was larger than that of negative value of anteversion (51.7% vs. 10.3% and 48.4% vs. 12.9%).

The stem anteversion during surgery in ALS and ALL group was 33.9° ± 12.8° (mean ± SD; range −1.0°–45.0°) and 27.4° ± 12.4° (mean ± SD; range 4.0°–50.0°), respectively ($p=0.052$). Target radiographic cup anteversion in ALS and ALL group was 16.4° ± 3.1° (mean ± SD; range 10.0°–25.0°) and 17.5° ± 4.0° (mean ± SD; range 10.0°–25.0°), respectively ($p=0.27$). Postoperative radiographic inclination in ALS and ALL group was 39.0° ± 3.0° (mean ± SD; range 34.0°–49.0°) and 41.9° ± 5.3° (mean ± SD; range 30.0°–53.0°), respectively ($p=0.014$). Postoperative radiographic anteversion in ALS and ALL group was 19.3° ± 5.6° (mean ± SD; range 4.8°–31.8°) and 21.0° ± 6.8° (mean ± SD; range 5.8°–38.1°), respectively ($p=0.30$). A scatter diagram of cup orientation in both groups is shown in Fig. 3.

The number of surgeries by each surgeon is shown in Table 4. Each surgeon performed approximately the same number of surgeries in supine position as those in lateral position. Any early complication during postoperative 3 months was not observed in both groups.

5. Discussion

This study showed that higher accuracy of acetabular cup inclination was provided by supine position than lateral position in THA using modified Watson-Jones approach. On the other hand, there was no significant difference between both groups in terms of cup anteversion. Positioning of the patient in the supine position also reduced the risk of the acetabular cup being placed in an outlier position (i.e. in the incorrect inclination or anteversion). Although we did not clarify how a mean of 2.1° difference of the absolute target error of radiographic inclination between two positions would influence their clinical results, this difference is comparable or even larger to those between with and without some computer-assisted technique in other studies [12–19]. This difference in our study should be valuable to be considered to improve the accuracy of cup positioning.

Some authors explain that the supine position allows better pelvic stability and landmark availability during surgery which can help achieve accurate cup positioning [18–20,28]. Nakata et al. [18] reported that 99% of acetabular cups in supine direct anterior approach had been within the safe zone of Lewinnek et al. [7], but that only 91% of acetabular cups in the posterior approach in lateral position were positioned within the safe zone. They hypothesized that the pelvis could be tightly stabilized in supine position on an operating table. This resulted in less change in the pelvic tilt

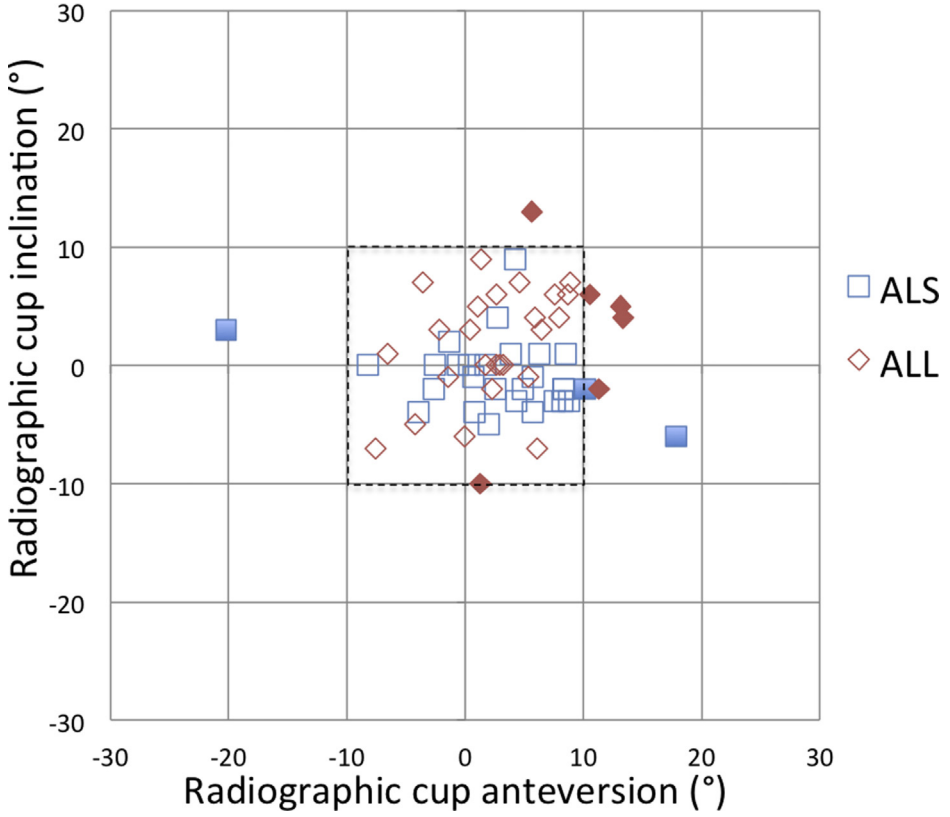

Fig. 2. A scatter diagram of the target error. The case with positive value of target error indicates that the postoperative angle is larger than the target angle. Square box with dotted lines reflects outlier line we defined (the absolute target error ≥ 10°). The outlier is represented by a filled marker. This diagram shows positive value of the target error of anteversion in the anterolateral approach in supine position (ALS) group and the anterolateral approach in lateral position (ALL) group were more likely found than negative value. This also shows that the two largest outliers (≤ 15°, or > 15°) of anteversion were ALS group.

Table 3
The number of neutral, positive error, and negative error in the target error (neutral ± 3° from the target error, positive error (> 3° from the target and negative error < −3° from the target error).

The target error	ALS (n = 29)	ALL (n = 31)	p value
Radiographic inclination			0.002
neutral	22 (75.9)	12 (38.7)	
positive error	2 (6.9)	14 (45.2)	
negative error	5 (17.2)	5 (16.1)	
Radiographic anteversion			0.94
neutral	11 (37.9)	12 (38.7)	
positive error	15 (51.7)	15 (48.4)	
negative error	3 (10.3)	4 (12.9)	

Values are given as number(%); ALS: anterolateral approach in supine position; ALL: anterolateral approach in lateral position.

angle during cup positioning in supine position compared to the lateral position. Moreover, some authors have indicated that in the lateral position there is a risk of intraoperative tilt and rotation change of the pelvis during the operation [18–20]. On the other hand, in the supine position, there is less intraoperative movement of the pelvis along with bony landmarks such as the anterior superior iliac spines and pelvic tubercles which can easily recognize pelvic tilt [18–20,28,30]. Grammatopoulos et al. [20] clarified that the positions of the pelvis during surgery differ less when the patient is in the supine position compared with the lateral position. These findings help explain the improved accuracy of positioning of the acetabular component, in terms of inclination, in the supine position compared to the lateral position.

Kishimura et al. [23] reported the opposite results to our findings, recently. In their retrospective pilot study comparing modified Watson-Jones approach in both supine and lateral position, supine position did not provide higher accuracy of cup positioning compared with lateral position. We suppose this opposite results of our findings were caused by the difference of the assisting device; they used a mechanical guide in their study. As we mentioned above, one of the advantages of supine position is bony landmark availability and usability during surgery. Although we used the anterior superior iliac spines determining the horizontal baseline of pelvis in order to assess intraoperative cup inclination using a goniometer, the mechanical guide is commonly used without considering the pelvic tilt and position directly. From the above, bony landmark availability and usability may be more critical advantage in supine position than pelvic stability.

Whereas we did not find the significant difference of the absolute target error between both groups in anteversion, positive error of anteversion in both groups were found more than negative error (Table 3, Fig. 2). These results mean most of cups were implanted with the larger anteversion than that we targeted. Maeda et al. [17] reported that their radiographic cup anteversion in direct anterior approach using a mechanical guide in supine and lateral position became 6.9° and 4.3° larger than their target angle, respectively.

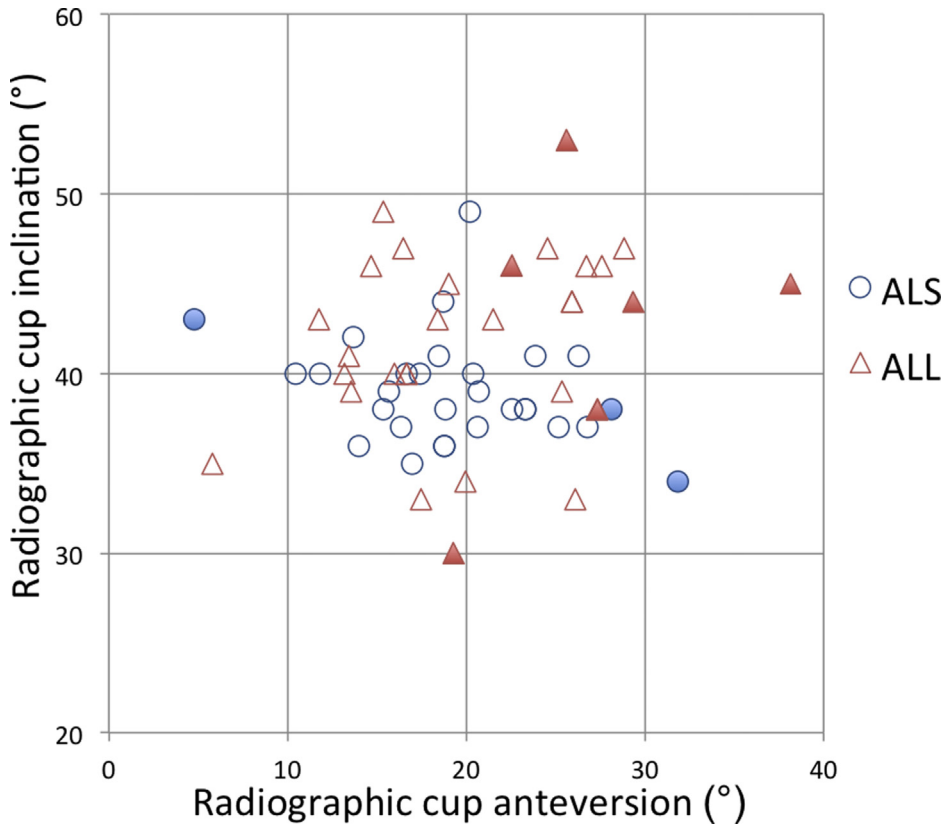

Fig. 3. Scatter diagram of cup orientation for the anterolateral approach in supine position (ALS) and the anterolateral approach in lateral position (ALL) group. This diagram indicates the higher accuracy of cup inclination in ALS group than that in ALL group. Each outlier (the absolute target error ≥ 10°) is represented by a filled marker.

Table 4
The number of surgeries performed by each surgeon.

Surgeon	ALS (n = 29)	ALL (n = 31)	p value
RT	12	13	0.94
MH	14	14	
KM	3	4	

ALS: anterolateral approach in supine position; ALL: anterolateral approach in lateral position.

They hypothesized that the reason for the larger anteversion in both positions could be explained by the pelvic rotation caused by the retractor placed at the posterior acetabular wall, which retract the femoral bone and rotate the ipsilateral pelvis posteriorly during cup preparation. Kawarai et al. [28] also indicated that this can also occur in the anterolateral approach as well as the direct anterior approach. This rotational instability of the pelvis during surgery could explain the large numbers of positive values of target error of anteversion found in both groups. We also found two largest outliers of anteversion in ALS group (Fig. 2). It is expected that the pelvis was extremely rotated during surgery in such cases. In our study, the operation prop located on both anterior superior iliac spines and stabilizing the pelvis in the lateral position might have been effective to prevent the excessive pelvis rotation. From the above, it can be suggested that cup preparation in both ALS and ALL should be done with high attention to the ipsilateral posterior rotation of the pelvis.

To our knowledge, although some authors have compared the accuracy of cup positioning between different approaches [17,18,20–22] and Kishimura et al. [23] have compared two positions using the same anterolateral approach in their retrospective study, this study is the first randomized-controlled trial to compare supine and lateral position in THA using the same approach. Our study design using the same approach must have contributed to decrease confounding factors to find the significant difference between both positions. Callanan et al. [2] clarified that the difference of approach influenced the accuracy of cup positioning. Although other assisting devices, especially computer-assisted navigation system, must be valuable to achieve high accuracy of cup positioning [11–15], they are currently available in not all institutions. The study of one of the registration data in the United States published by Aoude et al. [33] showed that approximately 97% of THAs were performed without any computer-assisted system at the time they reported. Therefore, we believe our study is informative to other surgeons to improve their ability to achieve improved accuracy of cup positioning. Our results also can be a valuable reference for the understanding the accuracy of cup positioning in ALS which has been reported by few studies so far [23,28]. At the same time, we demonstrated that there was no significant difference between ALS and ALL in terms of the surgical factors and early outcome.

There are several limitations in our study. First, the accuracy of cup positioning must have depended on surgeons' experience and skill. This is the inevitable limitation for such researches regarding the surgical technique for accuracy of implantation [11–19]. Only the surgeons who had had adequate experience of the anterolateral approach in both positions were allowed to perform surgeries in this study in order to minimalize this limitation. Second, we did not use other assisting device such as mechanical guide, fluoroscopy, and computer-assisted navigation system [11–23]. Maeda et al. [17], in their retrospective study using mechanical guide for

THA, reported that there was no significant difference of the mean inclination and anteversion in direct anterior approach between supine and lateral position. As we mentioned above, Kishimura et al. [23] reported even lower accuracy of cup positioning in supine position than in lateral position in their retrospective study using a mechanical guide. Using other assisting device might affect the inferiority of lateral position. The difference of other instruments such as operation table, pelvic fixation device, and other surgical instrument also might affect our results. Third, patients with severe deformity of the hip were not included in this study. The influence of positioning of such patients during surgery to accuracy of cup positioning should be investigated in the future. Fourth, our study compared only the accuracy of cup positioning of both positions. Also, it is unclear whether the difference of 2 degrees in inclination will influence the difference of clinical results between both positions. Long term follow-up and comparison of clinical results should be done in the future. Fifth, we did not investigate the actual pelvic movement during surgery. Although Grammatopoulos et al. [20] reported the details of pelvic movement during surgery using intra- and postoperative radiography and they found better pelvic stability in supine position than in lateral position, further investigation (e.g. a study using computed tomography) for this issue should be performed in the future.

6. Conclusion

In conclusion, higher accuracy of acetabular cup inclination was provided by supine position than lateral position in cementless primary THA. On the other hand, there was no significant difference between both positions in cup anteversion. In both groups, most cups were placed with larger anteversion than we targeted. Modified Watson-Jones approach in both positions should be performed considering these results.

Disclosure of interest

The authors declare that they have no competing interest. Apart from this work, T.J. reports grants and personal fees from Stryker, personal fees from Zimmer Biomet, personal fees from Depuy Synthes.

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Contributions

Ryohei Takada performed study design and data collection, analysis and interpretation, and wrote the article. Tetsuya Jinno contributed to study design and helped to write the article. Kazumasa Miyatake contributed to data collection and interpretation. Masanobu Hirao contributed to data collection and the analysis of inter-observer reliability. Kazuyoshi Yagishita contributed to study design and data interpretation. Toshitaka Yoshii contributed to restructuring and revision of article. Atsushi Okawa contributed to study design and data interpretation.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.otsr.2019.05.004.

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