Precision of Limb Length Measurement in Imageless Navigation THA with Modified Registration Technique in Semilateral Decubitus Position

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Background: *Limb length discrepancy (LLD) following total hip arthroplasty (THA) can be a significant problem and leading to patient dissatisfaction. Several researchers have reported that imageless navigation is a reliable technique and results in more precise cup placement compared to conventional freehand techniques, however, few studies have been reported about the accuracy of the femoral stem placement.*

Objective: *(1) To evaluate the precision of an imageless navigation system in measuring the limb length change and (2) to evaluate LLD following imageless navigation THA with modified registration technique in semilateral decubitus position.*

Material and Method: *The authors reviewed 66 cases receiving cementless THA with imageless navigation from September 2013 to December 2014. The radiographic limb length change measured from pre-operative and post-operative digital x-ray was compared with the intraoperative calculation by the navigation system. Postoperative LLD in unilateral cases and second operation of staged bilateral cases were also recorded.*

Results: *The mean radiographic limb length change measured on digital x-ray was 17.4 mm (5 to 29.3, SD 5.7). The mean limb length change calculated by navigation system was 16.8 mm (3 to 28,SD 5.9). The mean paired difference was 2.27 mm (-6 to 8, SD 0.9). This difference was significant ($p = 0.01$). There was significant correlation between LL change measured on digital x-ray and which were calculated by navigation system ($r = 0.95$, $p<0.001$). The navigation system had an accuracy of within 1 mm of the radiographic measurement in 7.6% of cases, within 2 mm in 39.4% of cases and within 5 mm in 93.9% of cases. The mean postoperative LLD was 2 mm (0 to 7, SD 1.9), 92% were within 5 mm.*

Conclusion: *The present study showed that the imageless navigation THA with modified registration technique in semilateral decubitus position offered a precise limb length measurement and the results encouraged us for clinical use to minimize LLD in THA.*

Keywords: *Hip arthroplasty, Imageless navigation, Limb length discrepancy*

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Total hip arthroplasty (THA) is one of the most successful orthopedics procedures. However, limb length discrepancy (LLD) following THA can be a significant problem and leading to patient dissatisfaction. LLD following THA may contribute to abnormal gait, knee and back pain, abnormal force transmission across the joint, instability and early failure of the prosthesis. Even for experienced surgeons it is challenging to obtain equal limb length during the surgery.

To minimize this problem, many techniques have been proposed to assess the limb length intraoperatively with varying results[1-5]. Nowadays, the use of computer navigation in THA is increasing. Several researchers[6-12] have reported that imageless navigation is a reliable technique and results in more precise cup placement compared to conventional freehand techniques.

Few studies have been reported about the accuracy of the femoral stem placement using imageless navigation.Manzotti A. et al[13] compared imageless

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navigation and freehand technique in the benefit of leg length restoration and found that in thenavigation group, the mean postoperative discrepancy was reduced to 5.06 mm (range, 0-12) as compared to 7.64 mm (range, 0-20) in the freehand group. They concluded that restoration of leg length was significantly better in the navigation group.

The purposes of the present study were (1) to evaluate the precision of an imageless navigation system in measuring the limb length change by comparing the limb length change measured from pre-operative and post-operative digital x-ray with the intraoperative values recorded by navigation system and (2) to evaluate LLD following imageless navigation THA with modified registration technique in semilateral decubitus position.

Material and Method

The present study was approved by the Ethics Committee of the Maharat Nakorn Ratchasima Hospital. From September 2013 to December 2014, patients receiving cementless total hip arthroplasty with imageless navigation were included in the present single-center study. The exclusion criteria were patients who were not suitable for cementless prosthesis (Dorr type)[14].

All cases underwent cementless THA (Metha or Excia stems and Plasmafit cup; B. Braun Aesculap, Tuttlinggen, Germany) with imageless navigation in semilateral decubitus position with OrthoPilot THA Pro software (Aesculap AG). Two small pins were inserted into the ipsilateral ASIS through a stab incision.The authors modified the technique by inserting another two pins into the medial side of the distal femur instead of using the proximal femoral clamp to measure limb length change (Fig. 1). The navigation trackers were attached to both pin adaptors. Bony landmarks (Anterior Superior Iliac Spinein both sides and Pubic Symphysis) were determined and digitalized with a metal pointer to define anterior pelvic plane (APP) and the native limb length was measured.

All patients were performed with the modified Hardinge's approach. After removal the femoral head, the deepest point of the acetabular fossa was registered as an additional reference point. Then, by using the trial cup, the native abduction and anteversion angles of the acetabulum were determined. During reaming, the position of the reamer was acquired by the navigation system and the operating surgeon was provided with real-time information about the resulting position of the reamer (medialization, cranialization and anteroposterior direction) and its orientation (abduction and anteversion) in relation to APP as well as the native acetabulum. After reaching the design reaming position, the final cup was implanted and the operating surgeon was provided with real-time information about the cup position and orientation. Cup orientation was aimed at 40°±5° of abduction and 15°±5° of anteversion in all cases. The final cup position was saved by the navigation system. After finishing the cup, the operating table was tilted forward until the patient was in the lateral decubitus position, then the patient's leg was dropped anteriorly to perform the femoral stem (Fig. 2). After final stem sizing, the operating surgeon was provided with real-time information about the stem position and the amount of the limb length change. After finishing the stem, the stem position and the limb length change were recorded by the navigation system.

Preoperative and minimum three months postoperative digital x-rays were used to measure the limb length discrepancyusing the method described by Ranawat et al[2] (Fig. 3). On an AP radiograph of both hips, the authors drew a horizontal reference line through the inferior aspect of the teardrop. The perpendicular distance between the reference line and the lessor trochanter was measured in each side to calibrate the limb length discrepancy. Using the non-operated side as the reference,the limb length change was calculated by the difference between preoperative and postoperative LLD. All measurements were performed 2 times in 2 weeks interval and averaged. Postoperative LLD in unilateral cases and second operation of staged bilateral cases were also recorded. Patients' age, gender, BMI and diagnosis were recorded as demographic data.

Statistical analysis

The radiographic limb length change measured from pre-operative and post-operative digital x-ray were compared with the intraoperative calculation by the navigation system by a paired t-test and a Pearson correlation test with Stata version 10.0. A *p*-value less than 0.05 was considered statistically significant.

Table 1. Demographic data of navigated-THA patients

Characteristic	Total n = 66
Unilateral procedures	25
Staged bilateral procedures	41
First operation	16/41
Second operation	25/41
Gender, n (%)	
Male	56 (84.8%)
Female	10 (15.2%)
Age (years), Mean (range, SD)	48.9 (21 to 70, 13.3)
BMI (kg/m^2), Mean (range, SD)	22.58(16.5 to 32.5, 3.5)
Diagnosis, n (%)	
Osteonecrosis (ONFH)	51 (77.3%)
Developmental dysplasia of the hip (DDH)	13 (19.7%)
Post-traumatic arthritis	2 (3%)

Table 2. Limb lengthchange measured on x-ray and navigation

	X-ray value Mean(range, SD)	Navigation value Mean (range, SD)	Paired difference Mean (range, SD)	*p*-value
Limb length change	17.4 mm. (5 to 29.3, 5.7)	16.8 mm. (3 to 28, 5.9)	2.27 mm. (-6 to 8, 0.9)	= 0.01

Fig. 1 (A) The patient was performed in semilateral decubitus position. (B) Two pins were inserted into the medial side of the distal femur to measure the limb length change.

Fig. 2 The patient's leg was dropped anteriorly to perform the femoral stem.

Fig. 3 These x-ray pictures showed preoperative (A) and postoperative (B) measurements of the limb length discrepancy. A horizontal reference line was draw through the inferior aspect of the teardrop. The per pendicular distance between the reference line and the lessor trochanter was measured in each side to calibrate the LLD.

Results

There were 66 cases in the present study. Twenty-five cases (37.9%) were unilateral procedures, 16 cases (24.2%) were first operation and 25 cases (37.9%) were second operation of staged bilateral procedures. The mean patient age was 48.9 years (21 to 70, SD 13.3) and 84.8% of cases were men. There were 51 cases of osteonecrosis of the femoral head (ONFH) (77.3%), 13 cases of developmental dysplasia of the hip (DDH) (19.7%) and 2 cases of post-traumatic arthritis (3%). The mean BMI was 22.58 km/m^2 (16.5 to 32.5, SD 3.5) (Table 1).

The mean radiographic limb length change measured on digital x-ray was 17.4 mm (5 to 29.3, SD 5.7). The mean limb length change calculated by navigation system was 16.8 mm (3 to 28, SD 5.9). The mean paired difference was 2.27 mm (-6 to 8, SD 0.9). This difference was significant (p = 0.01) (Table 2). There was significant correlation between LL change measured on digital x-ray and which calculated by navigation system (r = 0.95, p<0.001). The navigation system had an accuracy of within 1 mm of the radiographic measurement in 7.6% of cases, within 2 mm in 39.4% of cases and within 5 mm in 93.9% of cases. The mean LLD in unilateral and second operation of staged bilateral cases was 2 mm (0 to 7, SD 1.9), 92% of cases (46/50) LLD was within 5 mm.

Discussion

Limb length discrepancy after THA is a common problem. White TO and Dogall TW[15] demonstrated that 41 in 272 hips in their series were lengthened more than 10 mm. Whitehouse MR et al[16] reported a series of 191 patients underwent THA and found that 8.9% of cases had shortening, 0.5% no LLD and 90.6% had lengthening. In 21.5% the LLD was more than 10 mm.

There were many intraoperative methods to minimize LLD. Bose[1] used a measuring caliberand found that the average postoperative limb length inequality was 3.4 mm and 84% of cases had limb length within 6 mm of the contralateral side.Ranawat et al[2] used a vertical Steinmann pin at the infracotyloid groove of the acetabulum in 100 consecutive primary THA and demonstrated that the mean postoperative limb length inequality was 1.9 mm (-7 to 8) and none of the patients had to use shoe lifts for equalization

of the limb lengths. Shiramizu K et al[3] used the L-shaped caliper in 50 cases and demonstrated that the mean post-operative limb length inequality was 2.1±1.5 mm. Ogawa K et al[4] made a comparison between computer navigation and a simple manual measurement device (PCA limb lengthening gauge) and found that the post-operative LLD was 3 mm (0-8) in the computer-assisted group and 2.9 mm (0-10) in the manual group, there was no statistical difference between two groups. Lim YW et al[5] studied a simple method using a PACS to minimize LLD by measuring head to lessor trochanter length and reproducing it in the operative field with a modular neck system. They demonstrated that the mean post-operative LLD of the 42 hips was 1.9±2.4 mm (0-7).

Kitada M. et al[17] studied the accuracy of CT-based navigation for femoral stem orientation and LLD, they demonstrated that the differences in postoperative measurements from intraoperative records were -0.6±4.8 (-11 to 10) for stem anteversion, -0.2±1.8 (-4 to 3) for valgus angle of stem and 1.3±4.1 mm (-6 to 10) for leg length.

In imageless navigation system, Lamber A. et al[18] studied the accuracy of leg length measurement in 24 patients and found that the mean difference between the radiographic and navigational measurement was 0.4±2.8 mm, the navigation system was accurate to within 1 mm of the radiographic measurement in 50% of cases, within 2 mm in 67% of cases and within 5 mm in 96% of cases.Renkawitz T. et al[19] studied the accuracy of leg length measurement in the pinless femoral reference system in 50 patients, they demonstrated that the mean difference between navigation and radiographic measurements was 0.4 mm(±3.6).

Consistent with the present study, the authors found that the mean paired difference between the radiographic and navigational measurement was 2.27 mm (-6 to 8, SD 0.9) and the navigation system had an accuracy of within 1 mm of the radiographic measurement in 7.6% of cases, within 2 mm in 39.4% of cases and within 5 mm in 93.9% of cases. The difference of the results when compared with other previous studies might be due to the difference in navigation workflow of any systems and thedifference in surgical technique. Despite these differences, all of the results were encouraging for clinical use, showing by the mean LLD in the present study was only 2 mm (-6 to 7, SD 1.9).

In the present study, the authors modified the technique to insert two pins into the medial side of the distal femur instead of using the proximal femoral clamp to measure limb length change as recommended by the company. The authors found that in usingthis technique the femoral tracker was more stable and not disturbed during the process of femoral stem preparation. The drawback of this technique was that the patient had two additional small stab wounds in the medial side of the distal femur.

In conclusion, the present study showed that the imageless navigation THA with modified registration technique in semilateral decubitus position offered a precise limb length measurement and the results encouraged us for clinical use to minimize LLD during the operation.

What is already known on this topic?

The imageless navigation is a reliable technique and results in more precise cup placement compared to conventional freehand techniques. However, few studies have been reported about the accuracy of the femoral stem placement using imageless navigation.

What is this study adds?

The imageless navigation offered a precise limb length measurement and its resultsen couraged us for clinical use to minimize LLD in THA.

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Potential conflicts of interest

None.

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ความแม่นยำของการวัดความยาวขาในการผ่าตัดเปลี่ยนข้อสะโพกเทียมโดยใช้คอมพิวเตอร์นำร่องช่วยผ่าตัดในท่ากึ่งนอนตะแคง

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ภูมิหลัง: *ความยาวขาไม่เท่ากันหลังผ่าตัดเปลี่ยนข้อสะโพกเทียมเป็นปัญหาที่สำคัญ ผลทางคลินิกพบว่าคอมพิวเตอร์นำร่องช่วยผ่าตัดได้ผลดีในเรื่องมุมของเบ้าสะโพกเทียม แต่ยังมีการศึกษาน้อยในเรื่องความแม่นยำของการวัดความยาวขา*

วัตถุประสงค์: *เพื่อศึกษาความแม่นยำของการวัดความยาวขาในการผ่าตัดเปลี่ยนข้อสะโพกเทียมโดยใช้คอมพิวเตอร์นำร่องช่วยผ่าตัด*

วัสดุและวิธีการ: *ศึกษาในผู้ป่วย 66 ราย โดยเปรียบเทียบความยาวขาที่เปลี่ยนแปลงก่อนและหลังผ่าตัดระหว่างค่าที่อ่านจากเอกซเรย์และค่าที่อ่านจากคอมพิวเตอร์นำร่อง*

ผลการศึกษา: *ค่ามัธยฐานความยาวขาที่เปลี่ยนแปลงของค่าที่อ่านจากเอกซเรย์เท่ากับ 17.4 มม. ค่ามัธยฐานความยาวขาที่เปลี่ยนแปลงของค่าที่อ่านจากคอมพิวเตอร์นำร่องเท่ากับ 16.8 มม. ค่าความแตกต่างเฉลี่ยเท่ากับ 2.27 มม.*

สรุป: *การผ่าตัดข้อสะโพกเทียมโดยใช้คอมพิวเตอร์นำร่องในท่ากึ่งนอนตะแคงมีความแม่นยำสูงในการวัดความยาวขา เพื่อลดปัญหาของความยาวขาไม่เท่ากันหลังผ่าตัด*