Relationship Between the Accuracy of Acetabular Cup Angle and Body Mass Index in Posterolateral Total Hip Arthroplasty With CT-Based Navigation: A Retrospective Case-Control Study

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Abstract

Background: Precise acetabular cup placement is essential for successful total hip arthroplasty (THA). In obese patients, its accuracy is often difficult to achieve because of the thickness of the soft tissues. This study aimed to determine the relationship between the accuracy of acetabular cup angle and body mass index (BMI) in posterolateral THA using the computed tomography-based navigation (CT-navi) system.

Methods: We retrospectively reviewed 145 consecutive primary THAs using the CT-navi system between January 2015 and January 2018. All surgeries were performed using cementless cups employing the posterolateral approach with the patient in the decubitus position. We compared the radiographic inclination and anteversion obtained from the angle displayed on the CT-navi screen with those measured by the postoperative CT using the three-dimensional templating software. We evaluated the relationship between the extent of errors and correlation with BMI. Statistical analyses were performed using the Student's t-test and Spearman's rank coefficient test.

Results*:* In non-overweight patients (BMI < 25, 88 hips), the mean navigation errors for inclination were 2.8 ± 2.2° and for anteversion were 2.6 ± 2.3°. Meanwhile, in overweight patients (BMI ≥ 25, 57 hips), the mean navigation errors were 2.6 ± 2.4° for inclination and 2.4 ± 2.4° for anteversion. We found no significant difference between overweight and non-overweight patients in both inclination and anteversion. The Spearman's rank correlation coefficients were -0.04 for inclination and -0.11 for anteversion, showing no correlation between the extent of errors and BMI.

Conclusions: In posterolateral THA, CT-navi can aid the precise placement of the acetabular cup irrespective of a patient's BMI.

Trial registration: This trial was retrospectively registered and approved by the institutional ethics committee of Teikyo University. The registration number is 17-190, and the date of approval was March 1, 2018. URL of trial registry is: https://www.teikyo-u.ac.jp/application/files/7015/8432/1341/2016_all_syounin_1.pdf

Background

Total hip arthroplasty (THA) has been around for over 50 years, is widely performed in patients with hip diseases, and has become one of the most common and successful surgeries. To guarantee a successful surgical outcome, the accurate positioning of the implant is vital. Acetabular component malposition is associated with instability, impingement, and accelerated wear, and may sometimes necessitate early revision [1–4]. Lewinnek suggested that the radiographic cup inclination should ideally be 40° ± 10° and anteversion should be 15° ± 10°, based on the rate of postoperative dislocation [1]. However, several reports have questioned the reliability of those results because dislocation occurs very often, even in the region of the Lewinnek's safe zone [5].

Widmer et al. proposed combined anteversion (CA) to achieve a sufficient range of motion without impingement [6]. They proposed that the ideal CA, when the radiographic inclination (RI) of the cup lies between 40° and 45°, may be determined as follows: cup radiographic anteversion + 0.7 × stem antetorsion (SA) = 37.3°. Yoshimine et al. developed a model adding the cup inclination, which was given as the cup anatomic anteversion + cup RI + 0.8 × SA = 90.8° [7].

Past studies demonstrated that the accuracy of cup placement in THA without navigation is reduced in obese patients [8]. Moreover, the accuracy of cup placement also decreased in imageless navigation [9]. On the other hand, for the anterolateral THA, the accuracy of the acetabular cup angle using the computed tomography-based navigation system (CT-navi) was reported to be maintained irrespective of patients' BMI [10]. However, to the best of our knowledge, there are no reports on the relationship between the accuracy of cup angle and obesity in posterolateral THA using CT-navi. The accuracy of cup placement decreases in the absence of CT-navi when the procedure is performed in the lateral position compared to the supine position in THA because it is more difficult to maintain its orientation in the lateral position [11]. In addition to posture, it is apparent that in posterolateral THA for an obese patient, the surgical view is deeper and narrower because of the thicker fat and gluteus maximus muscle.

Our study aimed to ascertain the relationship between the precision of the acetabular cup angle and the patients' body mass index (BMI) in posterolateral THA with CT-navi.

Methods

Participants

We retrospectively reviewed 153 consecutive hips in which primary THA was performed using CT-navi from January 2015 to January 2018. We excluded patients (8 hips) who experienced intraoperative issues such as apex pin loosening, mechanical seizure, and incongruity of verification. As a result, 145 hips were reviewed in this study. A senior hip surgeon (M.N.) was responsible for all the surgeries. CT-navi (Stryker CT-based Hip Navigation System, Stryker-Leibinger, Freiberg, Germany) was used in all surgeries. Patients with a BMI of ≥ 25 were classified as overweight and those with a BMI < 25 were considered non-overweight, according to the criteria of the World Health Organization. The retrieved patient data were anonymized and de-identified before the analyses.

Preoperative planning

CT examinations were performed on three 64-detector row scanners (Light Speed VCT; GE Healthcare, Milwaukee, USA/ Aquilion; Toshiba Medical Systems, Tochigi, Japan / SOMATOM Definition Flash; Siemens AG, Forchheim, Germany) with a slice thickness of 0.5 mm. CT images in DICOM format were transferred to both the three-dimensional planning software (Zed Hip, Lexi Co., Ltd., Tokyo, Japan) and the navigation planning station. Initially, using the three-dimensional planning software, the SA was determined to match the shape of the femoral medullary canal and to restore the hip centre. If the native SA was too large (> 40°) or too small (< 10°), the modular stem was used to revise the SA. The cup RI was planned at 43° for all hips. Cup anteversion was obtained from those values and by calculation using the formula of Yoshimine [7]. Finally, we fine-adjusted the implant position, the length of the neck, and offset to strike a bilateral balance.

Furthermore, in the navigation planning station, we set several bony landmarks including the bilateral anterior superior iliac spine (ASIS), pubic tubercles and ischia, the pubic symphysis, and the sacral midplane to coordinate the pelvic position. Cup size and position were determined according to the plan using the three-dimensional planning software.

Surgical procedure with CT-navi

The posterolateral approach was used in all surgeries, with patients in the lateral decubitus position. In all the procedures, we used CT-navi without intraoperative fluoroscopy. Two apex pins were inserted in the ipsilateral ilium through small stab incisions. A pelvic tracker was affixed to the apex pins with an external fixation device (Hoffman II, Stryker-Leibinger) to enable detection by the infrared sensor camera. After exposing the acetabulum, initial paired-point matching registration was performed by digitizing the seven or eight landmarks including ASIS and greater sciatic notch. Surface matching of the pelvis was then performed by digitizing more than 30 points around the acetabulum and the ilium. The reliability was verified by touching the bone surfaces, including both the inside and outside of the acetabulum, ASIS, and apex pin insertion site. During all the surgeries, we adhered to the preoperative plan as closely as possible. The cup angles on the display were recorded after achieving press-fit fixation of the cup. The femoral stem was positioned without the navigation system.

Postoperative evaluation

Postoperative CTs were obtained a week following the surgeries using a minimal radiation dose protocol [12]. The CT data were imported into the Zed Hip software for three-dimensional analyses. After matching the postoperative pelvis position with the preoperative one, the cup angles were measured. In this study, “navigation error” was defined as the difference between the calculated value, value shown on the navigation display during the surgeries, and the one measured by the Zed Hip software.

Data analysis

Statistical analysis was performed using IBM SPSS Statistics for Windows, version 24.0 (IBM Corp., Armonk, New York, USA). The student’s t-test was used to compare the mean navigation errors between obese and non-obese patients. The Spearman’s rank correlation coefficient was used to ascertain the correlation between the extent of navigation errors and BMI. The strength of the correlations, indicated by Spearman’s rank correlation coefficient, were as follows: <0.3, negligible; 0.3–0.5, low positive; 0.5–0.7: moderate positive; 0.7–0.9: high positive; 0.9–1.0: very high positive [13, 14].

Results

Thirty-six patients were male, and 109 were female (145 hips). The mean age was 64.0 ± 10.1. The demographics of the two groups are shown in Table 1. The patients in the overweight group were significantly younger than those in the non-overweight group. Overall, the mean navigation errors in patients were 2.7 ± 2.3 for inclination and 2.5 ± 2.3 for anteversion.

Table 1
Patients' demographic characteristics

	Non-overweight	**Overweight**	***P-value***
Number of hips	88	57	
Age (years)	66.3 ± 11.3	60.5 ± 10.5	0.002*
Female sex	70 (80%)	39 (68%)	0.13**
Diagnosis			
OA	68 (77%)	45 (79%)	0.81**
ON	17 (19%)	10 (18%)	0.91**
FNF	2	1	
RA	1	1	

OA: osteoarthritis; ON: osteonecrosis; FNF: femoral neck fracture; RA: rheumatoid arthritis

* Student’s t-test

** Chi-square test

In non-overweight patients (BMI < 25, 88 hips), the mean navigation errors were 2.8 ± 2.2° for inclination and 2.6 ± 2.3° for anteversion. Meanwhile, in overweight patients (BMI ≥ 25, 57 hips), the mean navigation errors were 2.6 ± 2.4° for inclination and 2.4 ± 2.4° for anteversion (Table 2). There were no significant differences between overweight and non-overweight patients in both inclination and anteversion. The Spearman’s rank correlation coefficients were − 0.04 for inclination and − 0.11 for anteversion, indicating that there was no correlation between the extent of navigation errors and BMI (Fig. 1, 2).

Table 2
Navigation errors of the acetabular cup angle

	Non-overweight	**Overweight**	***P-value***
RI (°)	2.8 ± 2.2	2.6 ± 2.4	0.67*
RA (°)	2.6 ± 2.3	2.4 ± 2.4	0.58*

RI: radiographic inclination; RA: radiographic anteversion

* Student’s t-test

Discussion

This study indicated that a remarkable accuracy in cup placement could be achieved in THA using CT-navi (2.7° for inclination and 2.5° for anteversion). Also, CT-navi could aid in precise placement of the acetabular cup irrespective of a patient's BMI.

Many previous studies described the effectiveness of CT-navi. A retrospective study demonstrated that fewer cups were placed outside of the safe zone and fewer postoperative dislocations occurred in the CT-navi group compared to the control group [15]. According to previous studies, the mean error of the cup angle with CT-navi was 1.5–3.0° for inclination and 1.2–3.3° for anteversion [16–18]. The result of our study is in agreement with those results.

Obesity makes the THA procedure more challenging. Previous studies revealed that obesity was associated with increased complication rates and poor outcomes following primary THA, including infection, dislocation, and early aseptic loosening [19, 20]. Previous studies compared the incidence of these complications among several approaches. In THA in obese patients, there was no difference in the incidence of wound complications and deep infections when direct anterior and posterior approaches were compared [21]. Another study suggested that the increase in complication rates with THA for obese patients in comparison to non-obese patients was similar among several approaches [22]. Therefore, in THA for obese patients, approach strategy is often based on the condition of each patient or the surgeon's preference.

In THA without navigation, the accuracy of acetabular cup angle can decrease in obese patients because of the depth of the surgical field and the narrow surgical view [8]. In THA with imageless navigation, the thick subcutaneous tissue makes the registration inaccurate, leading to the increased error of the cup angle [9]. On the contrary, in THA with CT-navi, the registration was performed by touching the bony surface directly. This procedure could help minimize the effect of being overweight in the posterior approach. The result of this study confirmed the usefulness of CT-navi, particularly in overweight or obese patients.

Several limitations must be considered when interpreting the findings of this study. First, the BMI of Japanese persons tends to be lower than those of persons from other countries [23]. Therefore, the number of obese patients (BMI $\geq$ 30) was relatively small (n = 14). Moreover, there were no morbidly obese patients (BMI $\geq$ 40) were included in this study. Further studies to investigate the relationship between morbid obesity and accuracy of implant positioning are required. Second, the pelvic coordinate system constructed on the navigation system used for surgery and the one constructed on the Zed Hip software used for postoperative measurement may not completely match. However, because both coordinate systems were constructed based on the pelvic bony surface and we uniformly used the radiographic angle for the measurements, the discrepancies should be minimized.

With these limitations considered, the result of this study could be beneficial because the acetabular component accuracy in posterolateral THA with CT-navi is retained regardless of a patient's BMI.

In conclusion, posterolateral THA with CT-navi could offer precise placement of the acetabular cup irrespective of a patient’s BMI

Declarations

Ethics approval and consent to participate

The study was approved by the institutional ethics committee of Teikyo University (no. 17-190) and all the procedures were conducted in accordance with the Declaration of Helsinki and its later amendments. All participants enrolled in this study gave their written informed consent.

Consent for publication

Consent for publication was obtained from all the patients.

Availability of data and materials

The datasets generated during the current study are not publicly available due to patients’ privacy but are available from the corresponding author upon reasonable request.

Competing Interests

The authors declare that they have no competing interests.

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The authors did not receive any funding for this study.

Authors’ contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Hisatoshi Ishikura, Masaki Nakamura, Hanae Nishino, and Shigeru Nakamura. The first draft of the manuscript was written by Hisatoshi Ishikura and all authors reviewed and edited on previous versions of the manuscript. All authors read and approved the final version of the manuscript.

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Figures

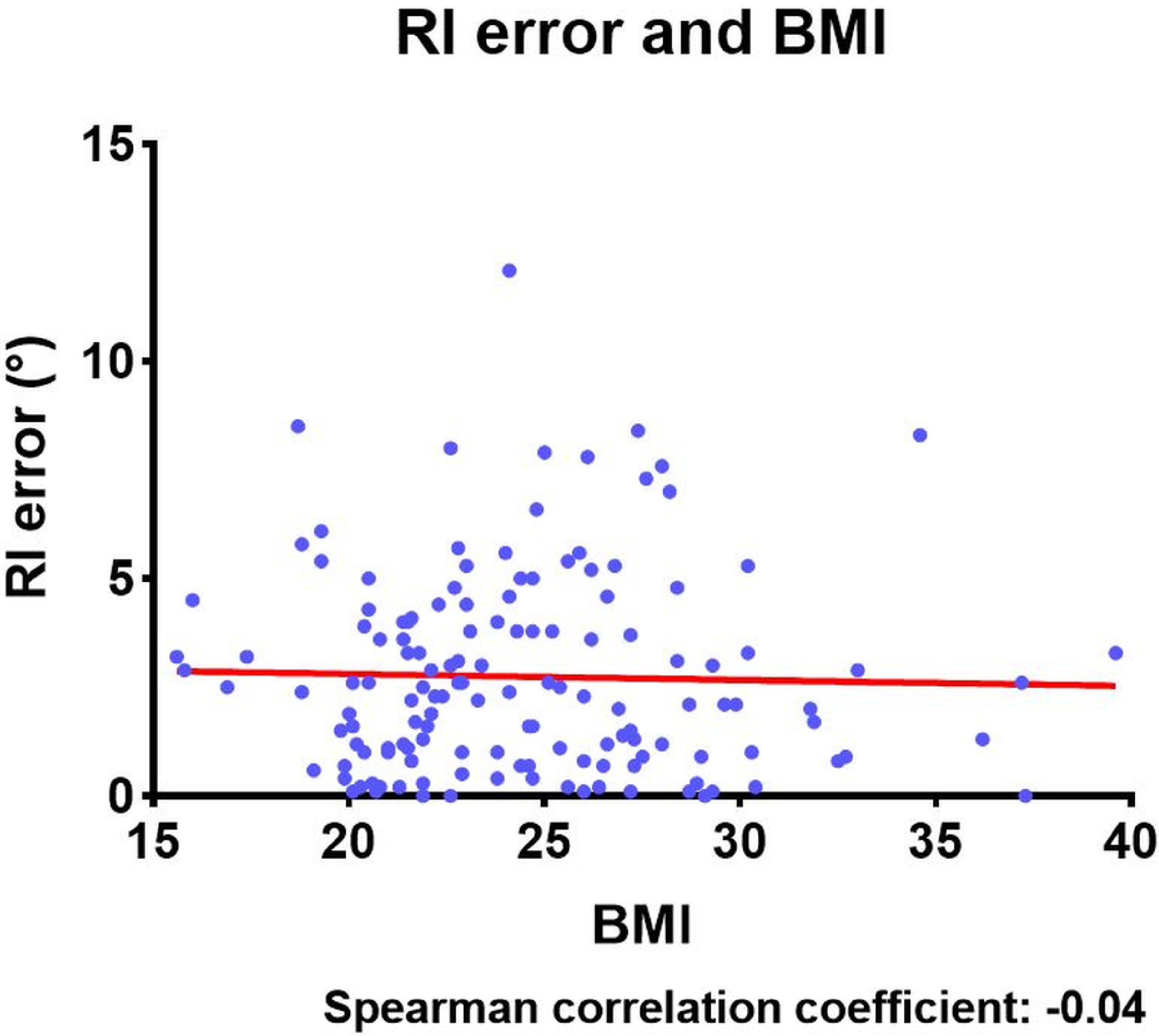

Figure 1

Relationship between RI error and the patient's BMI. RI: radiographic inclination; BMI: body mass index

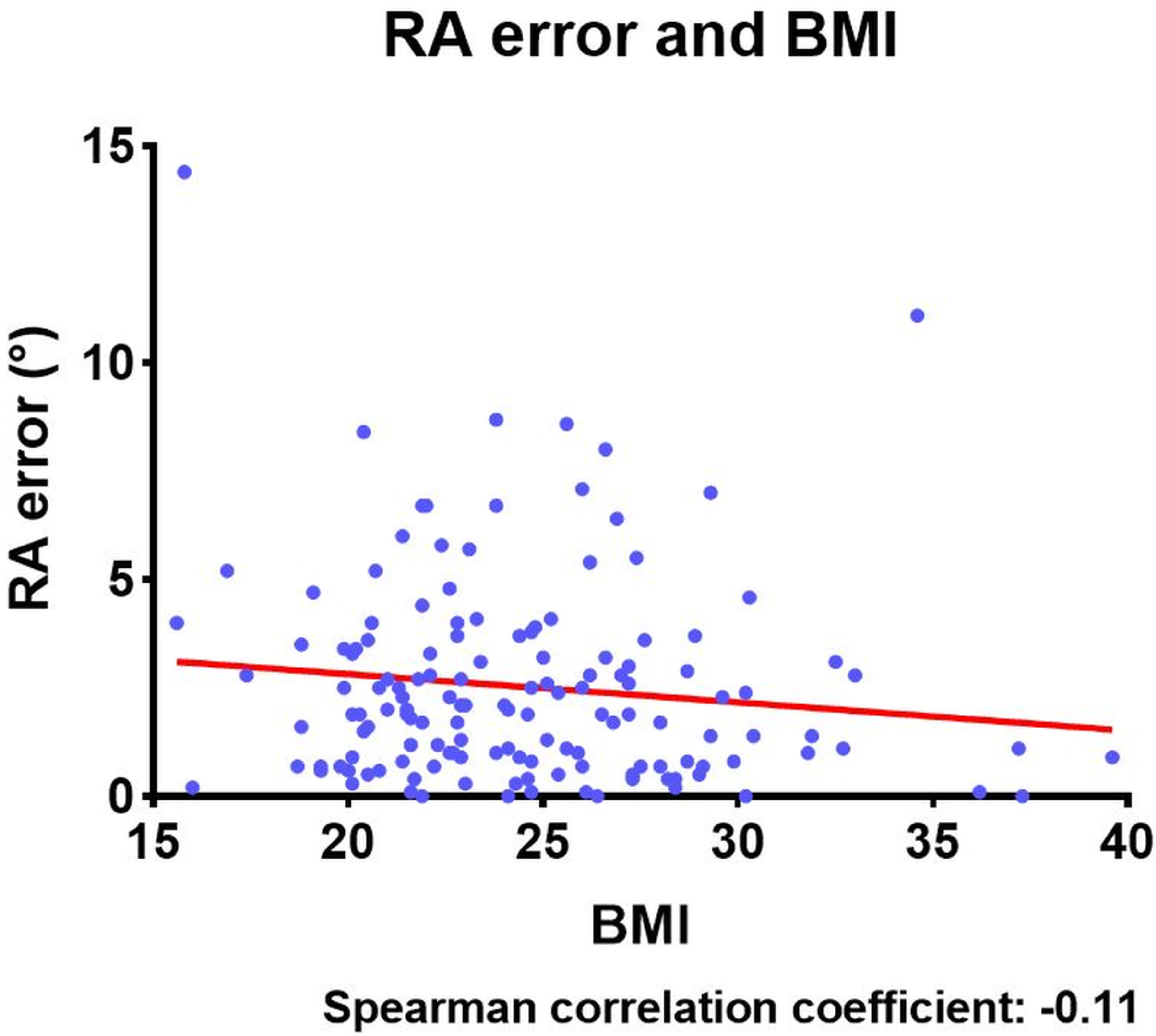

Figure 2

Relationship between RA error and the patient’s BMI. RA: radiographic anteversion; BMI: body mass index