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ORIGINAL RESEARCH ARTICLE

A novel fluoroscopic approach to assessing patient positioning in total hip arthroplasty: accuracy and the influence of body mass index

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ABSTRACT

Introduction: Accurate prosthetic cup placement is important in total hip arthroplasty (THA) and can be influenced by patient positioning. This study aims to assess the accuracy of patient positioning prior to THA, describe a new technique of assessment, and evaluate the influence of body mass index (BMI) on positioning error.

Methods: A consecutive series of 37 patients undergoing unilateral THA were investigated. After patient positioning in lateral decubitus, a lateral fluoroscopic image through the table was taken. The C-arm of the image intensifier was manipulated in 2 planes (coronal, transverse) until a perfect lateral view of the pelvis was obtained, defined as when the native acetabulae were superimposed. Degrees of positioning error in the 2 planes were recorded, along with patient BMI.

Results: There were 6 patients (16%) positioned within 2° of true lateral in both planes. A further 21 patients (57%) had an error of 5° or more in at least 1 plane. Mean absolute positioning error was 3.0° (SD 2.2°; range 0°-9°) and 3.0° (SD 3.2°; range 0°-13°) in the transverse and coronal planes respectively. Pelvic adduction in the coronal plane was 4.5 fold more likely than abduction (49% vs. 11%). Correlation was shown between patient BMI and the combined error in the 2 planes (R = 0.48, p = 0.001).

Discussion: Fluoroscopic positioning assessment prior to THA demonstrates that significant malpositioning is common and more likely with increasing BMI. This technique may be particularly useful for patients with a BMI of >30 kg m-2.

Keywords: Arthroplasty, Body mass index, Fluoroscopy, Hip, Patient positioning, Replacement

Introduction

Errors in acetabular component placement during total hip arthroplasty (THA) can lead to dislocation, impingement and higher wear rates amongst other complications (1-5). Nishikubo et al (6) describe 3 potential sources of error; manual implant placement, intraoperative changes to patient position and preoperative pelvic positioning. Patient alignment on the operating table during set-up is thus vital, and is often inaccurate (6-8). Whilst several mechanical tools assist with positioning, assessment of the true orientation of the bony pelvis relative to the operating table can be difficult. This may contribute to malpositioning of the prosthetic cup.

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We sought to assess the accuracy of patient positioning in a series of patients presenting for THA using a novel and simple technique of assessment. No prior studies have evaluated the influence of patient size on malpositioning, nor has this technique been previously described. We hypothesised that bony orientation would be different to gross visual alignment, and that given the difficulty of obtaining bony landmarks in obese patients, there would be a correlation between body mass index (BMI) and the severity of malalignment.

Methods

A consecutive series of 37 patients presenting to the Royal Melbourne Hospital for unilateral THA performed by the lead surgeon (AB) and/or his fellow (RJ) were included. The only exclusion criterion was significant asymmetrical pelvic deformity, which was not observed in this series. Study size was determined by temporal limitations. Patients presented between September 2010 and April 2011 and had a mean age of 61.7 years (SD 14.6 years; range 23-83 years). The cohort was 56% male, 44% female, with a mean BMI of 32.0 kg m^2 (SD 5.2 kg m^2, range 20-44 kg m^2).

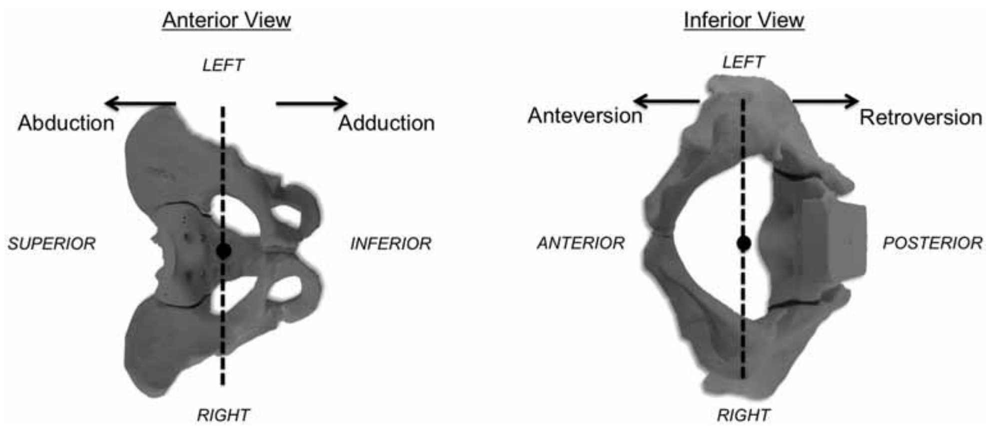

Fig. 1 - Yaw-type movement (left) and roll-type movement (right).

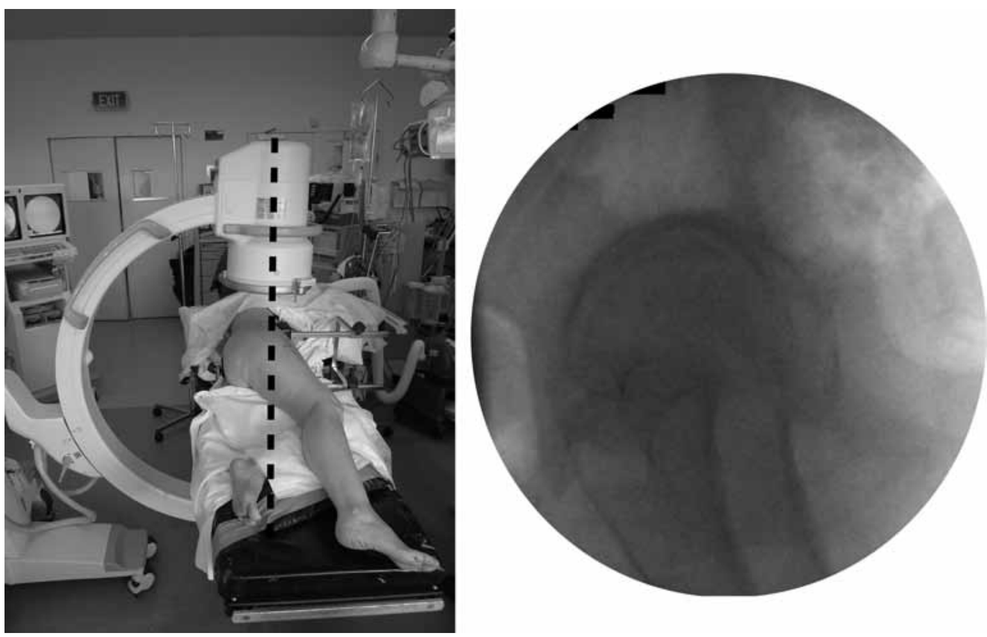

Fig. 2 - Initial set up in lateral decubitus and initial radiograph.

Rotation of the pelvis was annotated according to the terms used by DiGioia et al (9). Yaw is rotation in the coronal plane, where adduction describes superior acetabulum tilt toward the foot of the table (positive direction), and abduction where it is tilted towards the head of the table (negative direction). Roll is rotation in the transverse plane, where anteversion describes rolling towards prone (positive direction) and retroversion rolling towards supine (negative direction) (Fig. 1).

All patients were positioned in lateral decubitus using a double support anteriorly over the anterior superior iliac spines, and a support over the sacrum posteriorly (Maquet). Once the surgeon was satisfied that appropriate lateral positioning relative to the table had been achieved, an image intensifier was positioned to capture a direct lateral fluoroscopic image through the table (Fig. 2).

The C-arm of the image intensifier was manipulated in 2 planes that corresponded to coronal and transverse rotation of the pelvis until a true lateral image was observed, defined as when the 2 native acetabulae were superimposed (Fig. 3). The number of degrees of rotation in the coronal and transverse planes was noted from the gradation markings on the C-arm. Patient BMI was recorded from the preoperative anaesthetic assessment notes. All patients had their position corrected prior to commencing surgery.

For the continuous quantitative data (degrees of error) calculations were performed using an excel spreadsheet (Microsoft Excel 2008 for mac, Microsoft Corporation). Correlation between BMI and absolute degrees of error was analysed using the Pearson product-moment correlation coefficient and a 1-tailed p-value.

Results

The accuracy of patient positioning was assessed in both the coronal and transverse planes. Only 6 patients (16%) were positioned within 2° of true lateral in both planes. A further 21 patients (57%) had an error of 5° or more in at least 1 plane. The additional time required for fluoroscopic assessment was approximately 5-10 minutes, however this was not formally recorded.

In the transverse plane there was a mean error of 0.2° of retroversion (SD 3.7°; range -9°-7°) and the mean absolute

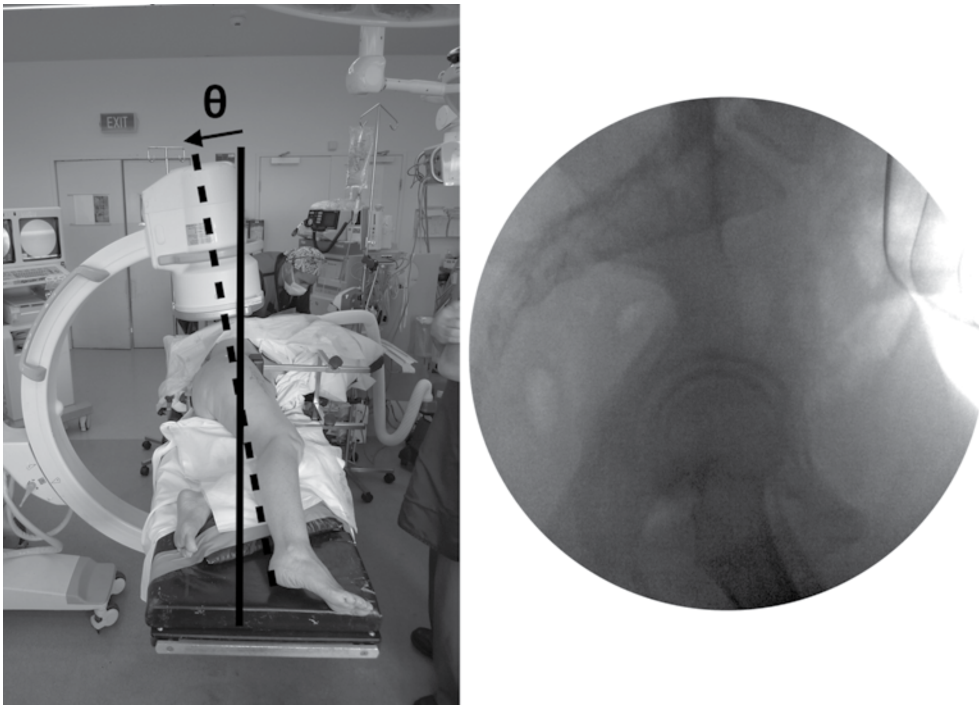

Fig. 3 - Subsequent C-arm adjustment and lateral pelvic image.

Fig. 4 - Scatterplot of transverse plane (roll) errors with direction.

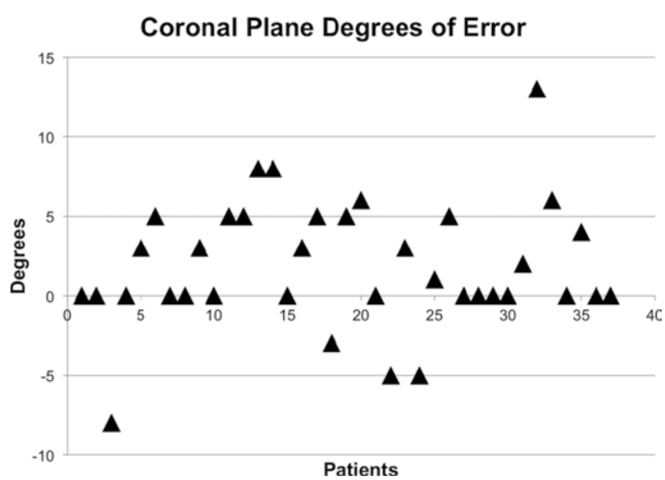

Fig. 5 - Scatterplot of coronal plane (yaw) errors with direction.

error was 3.0° (SD 2.2°; range 0°-9°) (Fig. 4). On initial positioning 5 patients (14%) appeared correctly positioned in the transverse plane. The remaining patients displayed pelvic anteversion (17 patients, 46%) or retroversion (15 patients, 40%). A total of 9 patients (24%) were positioned within 2° of lateral and 8 patients (22%) were tilted by 5° or more. 1 patient's pelvis was retroverted as far as 9° prior to adjustment.

In the coronal plane the mean error was 1.9° of adduction (SD, 4.0°; range, -8-13°) and the mean absolute error was 3.0° (SD, 3.2°; range, 0-13°) (Fig. 5). Initially 15 patients (40%) were positioned correctly with the remainder more likely to be positioned with pelvic adduction (18 patients, 49%) than abduction (4 patients, 11%). There were 16 patients (43%) positioned within 2° of lateral and 14 patients (38%) malpositioned by 5° or more. 1 patient's pelvis was adducted as far as 13° prior to adjustment.

The size and direction of positioning error was then compared with patient BMI. There was a moderate strength correlation demonstrated between patient BMI and combined (total) absolute error of the 2 planes ($R = 0.48$, $p<0.01$) (Fig. 6). There was no correlation between BMI and the direction of tilt in either plane, and only a weak correlation between BMI and absolute error in either plane individually ($R = 0.34$, $p = 0.02$ for both planes).

Discussion

This study aimed to evaluate the accuracy of patient positioning in the set-up for THA using a novel technique, and to

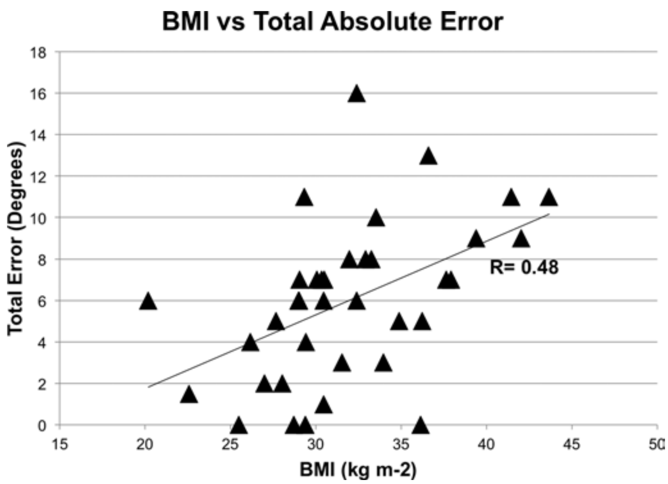

Fig. 6 - BMI compared to combined absolute error in 2 planes.

explore the influence of patient BMI on positioning error. The stimulus for the study was a concern that plain visual positioning may not accurately reflect the underlying bony positioning of the pelvis, and that patient weight is a contributing factor. These errors may contribute to cup malpositioning, particularly for surgeons referencing between the cup impactor and the operating table to guide alignment, as opposed to anatomic (such as the trans-acetabular ligament) or navigational guidance.

The findings of this study align well with those of previous studies. Nishikubo et al (6) described a mean absolute error of 2.9° in the coronal plane and 2.5° in the transverse plane, compared with 3.0° for both in our study. It is possible that the results underestimate error size due to the Hawthorne observer effect, which may encourage surgeons to more closely examine positioning prior to the known upcoming radiographic assessment. The 4.5-fold tendency toward pelvic adduction rather than abduction also likens to McCollum and Gray's description of a consistent 10°-15° tilt towards the foot of the bed, and similar observations by Nishikubo et al (6, 7). We concur with the hypothesis provided in the 2 aforementioned papers that perhaps the operative limb has a pulling effect on the pelvis causing it to sag. Interestingly, a tendency towards prone was not observed despite the significant abdominal weight in the obese patients.

We have described a simple method for a quick bi-planar preoperative position check prior to THA. The benefits of this technique, when compared to that of Nishikubo et al (6), are that there is no need for comparison to preoperative standing radiographs, and C-arm placement and patient adjustment is simple and swift.

There are several study limitations. As a descriptive cross-sectional study, there is no assessment of long-term clinical outcomes. An avenue for further research would be a comparison of final cup positioning and complication rates with and without the use of this technique. In addition, this study did not examine flexion and extension of the pelvis in the sagittal plane, primarily because assessment is time consuming and fine-tuned adjustment of flexion/extension with the positioning apparatus is not possible. As a result, the alignment will not account for the variation in flexion/extension between lying and standing that may be achieved by re-producing the standing orientation of the pelvis. An elegant technique for flexion/extension assessment has since been described (6). Also, despite attentive preoperative positioning, intraoperative movement occurs and cannot be prevented with this preoperative screen (10). Another consideration is the introduction of radiation with the fluoroscopic screening, however the radiation dose was minimal. Finally, in patients with preoperative asymmetry and anatomical abnormalities of the acetabulae, such as in developmental hip dysplasia, the technique of aligning the native acetabular rims may be misleading.

It is difficult to propose recommendations for the routine use of fluoroscopy preoperatively without the support of clinical outcome data. However, from figure 6 it must be noted that up to a BMI of 30 kg m^{-2}, the maximum combined error in the 2 planes was 7°, and in any 1 plane was 6°. This compared poorly to a combined error of up to 16° in 2 planes, and in any 1 plane up to 13° in the cohort with a BMI of 30 kg m^{-2} and above. If not a definitive indication for routine fluoroscopic positioning in obese patients, at the very least it should be a reminder to pay careful attention to their positioning.

This study utilises a novel technique for bi-planar pelvic position assessment prior to THA to demonstrate that significant errors may occur and are both more common and more severe with increasing BMI. Preoperative fluoroscopy to assist with accurate patient positioning may be useful, particularly for patients with a BMI of >30 kg m^{-2}.

Disclosures

Financial support: None.
Conflict of interest: None.

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