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A New Method of Registration in Navigated Hip Arthroplasty Without the Need to Register the Anterior Pelvic Plane

Edward T. Davis, FRCS [a,b], Mario Schubert, MS [c], Melanie Wegner, MS [c], Martin Haimerl, PhD [c]

[a] The Royal Orthopaedic Hospital NHS Foundation Trust, Northfield, Birmingham, UK
[b] The Dudley Group NHS Foundation Trust, Dudley, West Midlands, UK
[c] Brainlab AG, R&D Surgery, Feldkirchen, Germany

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ABSTRACT

A prospective clinical study of 50 patients was conducted to validate a new method of imageless computer navigated hip arthroplasty. The new method enables the surgeon to acquire all registration points with the patient positioned and draped in lateral decubitus position. The final component orientation was measured from post-operative CT scans. The mean error in component position was −1.1° (SD 3.1°) for inclination and 0.9° (SD 4.3°) for anteversion. This compared favourably with the error of −1.8° (SD 1.8°) for inclination and −4.8° (SD 2.7°) for anteversion when using the traditional APP registration. Results show that one can expect the acetabular component to be within a safe zone of ±10° in 99.8% for inclination and 97.7% for anteversion when using the new lateral registration method. Level of Evidence Level II, Prognostic study.

Correct acetabular component orientation in hip arthroplasty is critical. The association between incorrect acetabular component orientation and dislocation is well documented in the literature [1–4]. Incorrect orientation has been associated with increased wear rates of metal on polyethylene bearings and associated with early osteolysis [5–7]. It has also been associated with increased cobalt and chromium blood levels, increased wear rates and the formation of pseudo-tumours in patients with metal on metal bearings [8–10]. Further on, ceramic on ceramic bearings are affected with increased wear rates and an association with 'squeaking' [11–13].

Obtaining an acceptable acetabular orientation is challenging. A recent study of 1952 patients with hip arthroplasty showed that only 49% were found to be in an acceptable position, which only increased to 51% among the high volume surgeons [14]. These results are not inconsistent with other published series [15,16] with some studies [17] showing that only 26% of acetabular components were within the most recognised safe zone of 40° ± 10° of inclination and 15° ± 10° of anteversion [4]. Computer navigation has been shown to be a tool to improve accuracy in placing the acetabular component in hip arthroplasty with excellent precision and accuracy [16,18]. Unfortunately, this technology has not been widely accepted due to practical issues in the registration of bony landmarks. Current computer navigation techniques necessitate the acquisition of the anterior pelvic plane (APP), which requires registration through soft tissue. Access to the contralateral anterior superior iliac spine (ASIS) is difficult when operating within the lateral position and usually requires repositioning after pelvic registration. This gives rise to increased operative time and possible concerns over sterility. For surgeons operating in the supine position, the disproportionate amount of adipose tissue over the pubic tubercles has also been shown to lead to possible errors in component anteversion [19,20].

Recently, it was shown that there are specific anatomical relationships/constants which can be used for reconstructing the APP based on a point acquired on the ipsilateral ASIS, a mid sagittal point (obtained through the drapes), and points acquired during the normal surgical exposure [21]. This reconstruction can be utilised as a registration method for hip navigation systems [21–23]. It may encourage more surgeons to adopt this technology with improved component positioning as it avoids workflow and sterility issues which are caused by the repositioning of the patients as required by currently established navigation systems.

Within this paper, we analyse the accuracy of this new approach in a clinical setting. We conducted a prospective cohort study to compare these new methods of pelvic registration with that of the traditional epicutaneous APP and analysed the accuracy using post-operative CT measurements of acetabular component orientation. We aim to demonstrate that cup orientation can be reliably determined according to a ±10° safe zone in particular with at least 95% of the cases lying within the safe zone.

Materials and Methods

A prospective cohort study design was used with full ethical approval obtained. All patients listed for total hip arthroplasty were screened for

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Reprint requests: Edward T. Davis, FRCS, Department of Orthopedic Surgery, Dudley, West Midlands, DY1 2HQ, UK.

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the following inclusion and exclusion criteria. Patients under the age of 55 years were excluded due to concerns over the radiation exposure from the post-operative CT scan. Patients with previous ipsilateral hip surgery affecting the pelvic or acetabular anatomy, pelvic fracture, ipsilateral acetabular fracture, and women with childbearing potential were excluded. Eligible patients were approached and provided with information on the study. Patients were then fully consented for entry into the study.

All patients included underwent a computer navigated total hip arthroplasty performed by the senior author (***) using an image-free Hip 5.1 navigation system (Brainlab AG, Feldkirchen, Germany). Within the Hip 5.1 system, the intra-operative navigation and final verification of the cup implant are based on a standard epicutaneous acquisition of the APP. All landmarks required for the new registration procedures were acquired in a separate step as described further below. This enabled to virtually adapt the recorded cup orientation to the new registration technique within a post-operative analysis. The radiographic definition according to Murray [24] was used for all cup orientation measurements within this study.

As a first step in the clinical procedure, the distance between the ASIS points on the treated and non-treated side was determined using a specific measurement tool, i.e. Hip Caliper (Brainlab AG, Feldkirchen, Germany), while the patient was still awake in the anaesthetic room. At the start of the surgery, the patient was first positioned in a semi-lateral position for performing the epicutaneous acquisition of the APP according to the protocol specified for most currently established navigation systems. This means, that a reference array was fixated into the iliac spine on the treated side using two 4 mm Schanz screws. The treated ASIS and non-treated ASIS as well as points on the pubic tubercles were acquired on the tissue according to this pelvic reference in a semi-sterile environment, i.e. the area around the pelvic reference array was draped whereas the other areas remained unsterile. These landmarks defined the epicutaneous APP which is subsequently named P2 (see Fig. 1). The ideal reference would be an acquisition of the APP directly on bone named P1 (see Fig. 1).

After the acquisition of these landmarks, the pointer was discarded and the patient was finally prepared according to the standard surgical procedure in a lateral decubitus position. The patient positioner was placed at a location which ensured free access to the spinous process of the L5 vertebra (L5 landmark), which was used as a reference point on the mid sagittal plane. After the preparation of the patient, the L5 landmark was digitised through the drapes. The ASIS on the treated side was re-acquired to exactly reproduce the point acquisition process for a clinical setup performed in the lateral decubitus position.

As a next step, the surgical approach was performed including the resection of the femoral head. The acetabular fossa and the acetabular cavity were digitised. Additionally, a point directly located at the anterior side of the acetabular rim (anterior rim point) was acquired. The coordinates of all acquired landmarks were recorded and logged by the navigation system.

The surgery was performed using a femur first approach. The desired orientation of the cup implant was adapted according to the individual anatomy of the patient and the antetorsion of the trial stem as measured by the navigation system. Thus, the cup orientation was not always planned to be 40° inclination and 15° anteversion as described by Lewinnek et al [4] but took individual variations of stem antetorsion into account as described in the literature about femur first/combined anteversion approaches [25,26]. The femur first approach was not a basic objective of this study.

After inserting the cup, the final cup orientation was verified by the navigation system, i.e. the cup inserter was held in place and the navigation system recorded the final cup orientation. All values shown during cup planning and insertion steps were referencing to the epicutaneous APP (P2). As a next step, the acetabular liner as well as the head and neck design was adjusted regarding an optimisation of leg length, offset, and range-of-motion. The final stem and head were then inserted and the surgical approach completed.

Post-operatively, a CT of the hip, including the ASIS region and proximal femur was performed using a Siemens Sensation 64 CT scanner (Siemens AG, Erlangen, Germany). In each CT scan, the bony APP and the post-operative cup orientation were determined using the iPlan 3.0 software (Brainlab AG, Feldkirchen, Germany). The bony APP (i.e. P1, see Fig. 1) was specified by defining the ASIS and pubic landmarks directly on bone. The final orientation of the cup implant was determined in the CT data by defining four points equally distributed around the rim of the implant's opening plane and calculating the orientation of this plane in reference to the gold standard APP. This analysis was performed independently by four observers for each data set. The measured cup orientation was averaged to overcome inter-individual variation. This final orientation, which is subsequently called gold-standard orientation, was compared to the intra-operatively verified cup orientation angles. The differences in inclination and anteversion were calculated.

To assess the accuracy of the new registration techniques, the intra-operatively digitised landmarks were used to simulate the new registration according to the anatomical constants analysed by Haimerl et al [21]. On the one hand, a new lateral registration was performed by reconstructing the APP based on the L5 and treated ASIS landmarks as well as the points at the acetabular fossa, acetabular cavity, and anterior

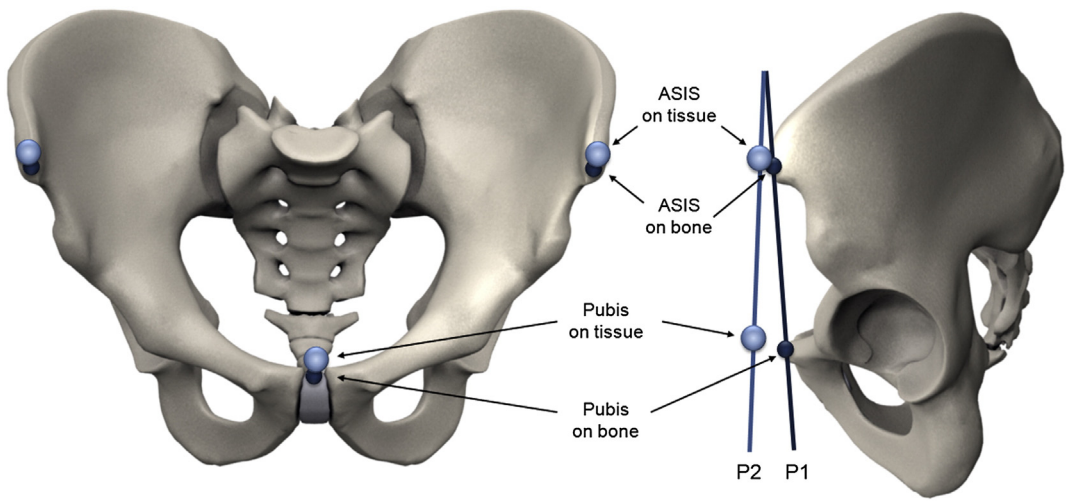

Fig. 1. Landmarks used for defining the epicutaneous APP (P2) according to established registration techniques. The large light blue circles represent the landmarks which were used to define P2. Additionally, the APP on bone (P1) is shown as an ideal reference. The defining landmarks are shown as small, dark blue circles.