EVALUATION OF AN ULTRASOUND APPROACH TO OVERCOME SOFT-TISSUE INTERFERENCE ON DIGITIZING BONY LANDMARKS IN NAVIGATION ASSISTED TOTAL HIP ARTHROPLASTY (THA)

INTRODUCTION: An imageless Computer-Assisted Navigation System (NAV) in THA has been shown to help increase the accuracy of cup placement [1-2]. NAV relies on the location of the Anterior Superior Iliac Spines (ASISs) and the Pubic Symphysis (PS) to establish the pelvic coordinate system for operation. However, in obese individuals, who account for more than half of the patient population, palpated location of these landmarks can deviate from the real bony location due to the substantial amount of the soft tissue. This error introduces the inaccuracy in establishing the pelvic coordinate system and may increase the possibility of misalignment of the hip prostheses [3], resulting in the failure of THA [4]. The objective of this study was to initially evaluate an alternative solution in palpating the bony landmarks using an ultrasound probe.

MATERIALS AND METHODS
Participants: After obtaining informed consent approved by the Institutional Review Board, THA and data collection was performed on a total of 19 patients (8 female and 11 male; 63.6±9.9yrs, 172.6±11.7cm, 83.0±15.7kg, and with BMI 28.0±5.3) with the aid of an NAV (Stryker® Navigation System, Stryker Corporation, Kalamazoo, MI). CT scans for all individuals were obtained postoperatively in the supine position.

Intraoperative Measurement of Anatomical Landmarks on Pelvis: Active navigation trackers, with infrared LEDs, were attached to the iliac crest and distal femur with percutaneous pins. Bony landmarks on pelvis were measured using 2 methods, manual palpating probe of the NAV, and a B-mode ultrasound probe (3000, Terson Ultrasound, Burlington, MA). Both probes were attached to the NAV system with attached multiple infrared LEDs. The location of the registration points were then determined by the navigation system, which consisted of a camera and computer. For manual palpation, the tip of the probe was placed on the skin surface of each palpated bony landmark to collect the underlying the soft tissue in real time. With the help of the real-time image, a customized software program assisted the surgeon in selecting the landmarks. For the ultrasound method, bilateral ASISs and the bilateral Pubic Tubercles (PTs) were measured using 2 different modes, point mode (USP) and surface mode (USS). In point mode, a point from the displayed B-mode image for each landmark was selected, while in surface mode, the ultrasound probe was glided over the skin surface overlying each bony landmark to obtain a 3 dimensional (3D) scan of the bony surface.

Intraoperative Acetabular Cup Position: When the acetabular cup was implanted, the rim of the cup component was measured by gliding the tip of the probe over it while multiple points were collected.

Acetabular Cup Orientation by CT Model: A 3-D model of the pelvis together with the prosthesis was created for each hip from the CT scans (CT3D model) and the inclination and anteversion were calculated from this model using our validated method [5]. Cup orientation obtained here was used as the true value for comparison.

Data Analyses:
Bony landmarks: For each method, an Anterior Frontal Pelvic Plane (AFPP) was created for every subject. Surface data collected using USS method was first processed using Avizo software (Mercury Computer Systems, Inc., Chelmsford, MA) by creating the AFPP to best fit the most anterior tip of the 4 surfaces. For data from USP, the midpoint of the bilateral PTs was first calculated to represent the PS. Then the AFPP was created using the 3 points of bilateral ASISs and the PS. The AFPP for NAV manual palpation was similarly obtained.
Coordinate system: For each method, a pelvic coordinate system was established based on its AFPP to take the origin at the midpoint between the bilateral ASISs, with the X-axis pointing to the right ASIS, the Y-axis to anterior, and the Z-axis to the superior.
Intraoperatively measured acetabular cup orientation: A plane was fit to the points of the rim of the acetabular cup then the orientation of the implanted cup was obtained as the orientation of this plane in the pelvic coordinate system.

Statistical analysis: The difference on the cup orientation obtained using USS, USP and NAV from the true value (CT3D) was computed. A paired t-test was performed to determine whether the difference was significant. For each method, the percentage that the calculated cup orientation fell within 5° of the true value was also obtained. A cross-table analysis was used to detect any difference on these percentages among the 3 methods. All significance was assessed for alpha as 0.05.

RESULTS
Fig. 1 plots the average cup orientations (mean±SD) obtained from US, USS, and NAV in comparison with the true values from CT3D. There was significant difference for the anteversion obtained using USP and NAV from that of the true value (P<0.01). Both the inclination and the anteversion obtained using USS are close to the true values without any significant difference. The variation of the difference from the true values for all 3 methods was beyond 5°.

Fig. 2 shows the percentage of the cup orientation values fell within 5° range of the corresponding true value of CT3D. Two ultrasound methods (USS and USP) had 94.7% of the data in the 5° range of the true value for cup inclination, however, had only 47.4% and 57.9% for cup anteversion, respectively. NAV method had fewer data within this range for cup inclination but higher percentage for cup anteversion, but none of the differences was significant.

DISCUSSIONS AND CONCLUSIONS:
Both ultrasound methods resulted in accurate measurement of the cup inclination, but only the surface mode (USS) improved the measurement of the cup anteversion. However the tested ultrasound digitization methods were biased by the subjectivity with which the different landmarks are identified leading in some cases to significant differences from the true values. With improvements in the digitization protocol and the ultrasound technique towards a less subjective and more stable digitization technique which could exploit a priori anatomical information of the digitized surfaces, this method has the potential for more accurate bone registration in navigated THA.


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