Validation of a novel, automated 2D/3D registration software for acetabular component alignment from fluoroscopy imaging

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INTRODUCTION:

Total Hip Arthroplasty (THA) is a highly successful surgical procedure. Malposition of the components contributes to increased complications and early revisions. Supine positioning during direct anterior THA facilitates the easy use of intraoperative fluoroscopy. Fluoroscopic image limitations include parallax errors and an inability to assess patient-specific pelvic tilt, leading to inaccuracies when compared to preoperative imaging. Image intensifier (II) fluoroscopy images suffer distortional effects at the edge of images, further adding to assessment errors. Preoperative CT scans are often used for preoperative assessment and planning. This study evaluates the accuracy of an automated 2D/3D registration software, matching pre-operative 3D information to 2D intraoperative fluoroscopy images.

METHODS:

We developed a novel automated 2D/3D registration software leveraging routinely taken fluoroscopy imaging and matching 3D patient data (from pre-operative CT planning). The system iteratively aligns the 3D models of pelvis and cup while maximizing the similarity between 2D projections of the model and the 2D intraoperative projections. After registration, the system measures in 3D the intraoperative inclination and anteversion relative to the Anterior Pelvic Plane as well as the cup depth and height based on the 3D-aligned models.

65 unique datasets containing pre-operative CT, 3D functional planning, an intra-operative image, and post-operative CT (ground truth data) were identified. Intra-operative images were taken as part of the surgeon's standard workflow, with some containing the cup impactor (n=23). Clinical images were taken from both flat panel (digital) and image intensifier (analogue/II) fluoroscopy machines. Of the 65 datasets, the software returned results for 60.

Cup orientation was determined from post-operative CT using a 3D/3D registration of the cup geometry to the post-op CT. Radiographic inclination and anteversion were calculated compared to the APP.

Accuracy was assessed by comparing the radiographic cup inclination and anteversion (in degrees) and height and depth results (in mm) from the 2D/3D software to the ground truth data (3D/3D registered data).

RESULTS:

The mean absolute difference between ground truth and the intraoperative 2D/3D software was 1.8° [SD 1.2°, max 4.4°] for inclination, 2.1° [SD 1.6°, max 7.3°] for anteversion, 1.8mm [SD 1.1, max 4.9 mm] for cup height (superior-inferior) and 1.1mm [SD 1.5mm, max 10.1 mm] for depth (medial-lateral). 100% of inclination and 95% of anteversion results were within 5° whilst 88% of cup height and 97% of cup depth results were within 3mm of the ground truth, Figure 1 and 2.

DISCUSSION AND CONCLUSION:

We validated the accuracy of a novel automated 2D/3D registration software for use in THA. Whilst our method requires pre-operative data from CT, the results are comparable to similar systems, and present a promising, non-invasive, fully-automated image-based measurement technology that can be easily integrated into an operating room to provide real-time feedback on THA component position. Future work shall apply similar technology to measure leg length and offset.