

Use of image-free navigation in determination of acetabular cup orientation: a comparison with a single X-ray image-based 2D/3D reconstruction method

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Introduction: Optimal acetabular cup orientation has been shown to be an important factor in determining the success of total hip arthroplasty (THA). In order to improve the intra-operative cup placement precision, navigation systems have been developed. Although both image-based as well as image-free navigation systems have been proposed before, in clinical routine the most-often used systems are image-free navigation systems, despite the fact that the registration method percutaneously touching bony landmarks may decrease the accuracy, especially in obese cases or in patient with acetabular dysplasia.

Materials & Methods: Placement accuracy in 9 joints in which THA was performed with the support of an image-free navigation system (OrthoPilot; Aesculap, Tuttlingen, Germany) was calculated by comparing the intra-operatively placement angle in the Anterior Pelvic Plane (APP) with the post-operative angle measured by a single X-ray image-based 2D/3D reconstruction method. With a statistical shape model, this single X-ray image-based 2D/3D reconstruction method allows reconstructing a patient-specific 3d-model of the pelvis from a standard post-operative anteroposterior (AP) X-ray radiograph (see Fig. 1). Cup orientation (inclination and anteversion) is then calculated with respect to the APP that is derived from the reconstructed model. Our recent study [1] conducted on 31 hips demonstrated high precision of this novel method. In this study, we defined the difference between the intra-operative placement angle that was displayed on the navigation screen and the angle measured from a post-operative X-ray radiograph by the single X-ray image based 2D/3D reconstruction method as the error.

Results: The mean anteversion angle readout from the navigation screen was found to be $17.2^{\circ} \pm 3.9^{\circ}$ (range: $10^{\circ} - 23^{\circ}$) and the mean inclination angle was $43.7^{\circ} \pm 3.0^{\circ}$ (range: $38^{\circ} - 48^{\circ}$). The mean anteversion angle measured from post-operative X-ray radiographs with the single X-ray image based 2D/3D reconstruction method was $21.4^{\circ} \pm 4.8^{\circ}$ (range: $12.8^{\circ} - 28.4^{\circ}$) and the mean inclination angle was $45.2^{\circ} \pm 4.3^{\circ}$ (range: $40.4^{\circ} - 54.5^{\circ}$). In both inclination and anteversion angles, good agreement was observed for 7 out of 9 joints. A discrepancy of more than 5° was observed in 1 case for inclination angle and 2 cases for anteversion angle, respectively. For the 7 joints with good agreement for both angles, a mean error of $2.3^{\circ} \pm 2.0^{\circ}$ (range: $-2^{\circ} - 4.3^{\circ}$) and a mean error of $0.6^{\circ} \pm 2.6^{\circ}$ (range: $-2.2^{\circ} - 3.2^{\circ}$) were found for the anteversion angle and the inclination angle, respectively. Using a pairwisd T-test and choosing the significant level as 0.01, it was found that the differences were not statistically significant for both anteversion angle ($p = 0.022$) and inclination angle ($p = 0.54$).

Discussions and Conclusions: Accuracy analysis of the image-free navigation system has been performed before by taking post-operative CT measurements or post-operative X-ray radiograph measurements as the ground truth. This is for the first time to conduct the accuracy analysis of the image-free navigation system using measurements from our newly developed, single X-ray image-based 2D/3D reconstruction method as the ground truth. Previous studies have shown that the potential factors leading to assessment error in the use of the image-free system is inaccurate localization of the bony landmarks. In particular, since we did not divided the involved patients in this study into sub-groups based on their obesity or on whether they had acetabular dysplasia or not, we cannot eliminate the influence of these factors on the assessment accuracy. This probably explained

why we found a discrepancy larger than 5° in 1 case for the inclination angle and in 2 cases for the anteversion angle. However, the exact reason for such a relatively large discrepancy may be found with a post-operative CT scan, which at this moment is not available for this study.



Fig.1. Screenshots of the single X-ray image-based 2D/3D reconstruction method for measuring cup orientation from a post-operative X-ray radiograph.

References

- [1] G. Zheng, et al. "Validation of a statistical shape model-based 2D/3D reconstruction method for determination of cup orientation after THA", Int. J. CARS, In press, 2012.