

# Lateral registration of the pelvis based on consistent anatomical relationships – a CT study

HAIMERL M, WEGNER M, SCHUBERT M, KLING S, WEIDER M, JENDREWSKI C

*Brainlab AG, Feldkirchen, Germany*

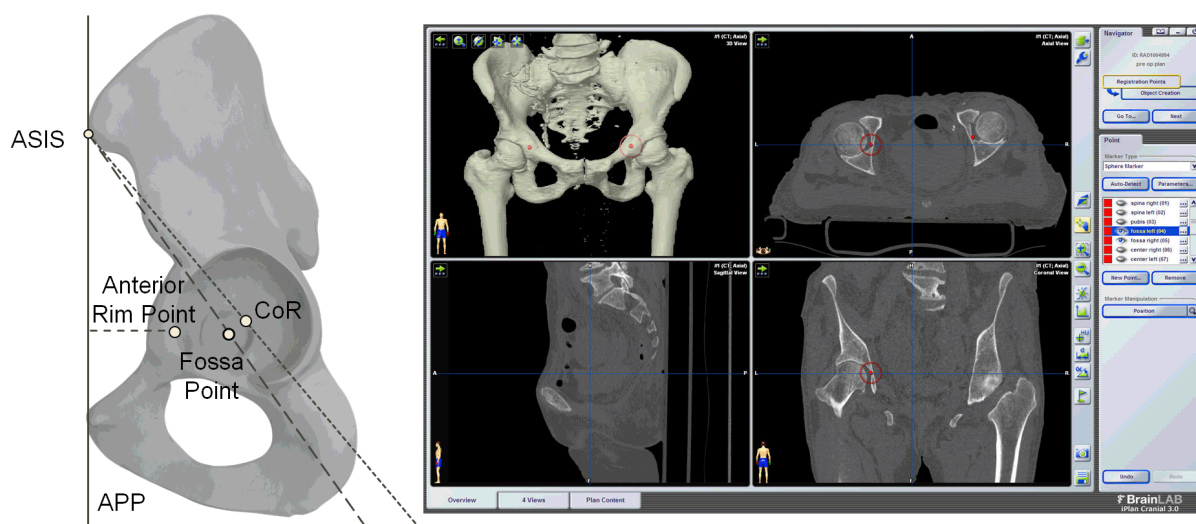
Martin.Haimerl@brainlab.com

**Introduction:** Optimal component orientation is important to avoid dislocation and excessive wear in hip arthroplasty. It has been shown, that computer navigation is able to improve accuracy in component placement [1]. However, most navigation systems rely on the direct registration of the anterior pelvic plane (APP) as a reference. This requires the digitization of landmarks on the contra-lateral side of the pelvic bone, which cannot be achieved without repositioning the patient when using a lateral approach.

Within this study, consistent anatomical relationships were used to develop a registration technique for the pelvis which only requires the digitization of landmarks that can be accessed from the ipsi-lateral side in a standard lateral clinical workflow. We determined the statistics of these relationships and analyzed the accuracy of the resulting registration technique. In particular, we determined how many cup positions would be in the Lewinnek safe zone [2] when utilizing the new registration technique.

**Methods:** We used a retrospective series of 420 CT data sets (174 male, 246 female) from different geographical regions to determine the statistics of anatomical relationships which can be used for a lateral registration of the pelvis. The series contained 223 pre- and 137 post-operative data sets from THR surgeries and 60 data sets from cadaveric specimens. The inter-teardrop (ITD) and inter-fossa (IFD) distances as well as deviations between the APP and alternative reference planes were analyzed. These alternative reference planes only differ from the APP in a sagittal projection. They still refer to the anterior superior iliac spine (ASIS) points as a basic reference; but the points at the pubic symphysis are replaced by other information around the acetabulum, i.e. center of the acetabulum, deepest point at the fossa acetabuli, and distance between an anterior rim point and the APP (see Fig. 1 left). It was calculated how accurate the APP could be reconstructed by using these reference planes when the connecting line between the ASIS points was used as a fixed medial-lateral orientation. For ITD and IFD, separate statistics were calculated for the male and female group. All landmarks were planned by using the iPlan 3.0 software (Brainlab AG, Feldkirchen, Germany, see Fig. 1 right).

We applied a new registration technique which reconstructs the APP based on the determined statistics. Males and females were treated separately using the corresponding statistics. For the registration, only landmarks were used which are accessible from the ipsi-lateral side in a sterile environment, including the ipsi-lateral ASIS, the spinous process of the L5 vertebra (point on the midsagittal plane) as well as points at the acetabular fossa, cavity, and anterior rim. For the evaluation of the registration technique, we used the landmarks as planned in the CT. A cup was virtually placed in a standardized orientation (40° inclination/ 15° anteversion) according to the new registration. The resulting cup orientation in relation to the APP was compared with the originally intended orientation. Descriptive statistics (mean±standard deviation) were calculated and statistically significant differences between subgroups in the population were checked according to a student's t-test ( $\alpha=0.05$ ). Additionally, it was determined how many of the cups would have been inside the Lewinnek safe zone (40°±10° inclination, 15°±10° anteversion) according to a statistical representation of the results based on a normal distribution. All cup orientation angles were analyzed based on the radiographic definition by Murray [3] and in relation to the APP.



left: alternative reference planes define the orientation of the pelvis in a sagittal projection  
right: planning of fossa points for the measurement of the interfossa distance (IFD).

**Results:** The ITD, IFD as well as the deviations between the APP and the alternative reference planes were found to be consistent between pelvises from different geographical regions. ITD and IFD showed statistically significant differences between genders, whereby being strongly correlated. The results for IFD were  $121.3 \pm 9.0$  mm (overall),  $124.9 \pm 8.5$  mm (female), and  $116.2 \pm 7.0$  mm (male). The case-by-case differences between IFD and ITD were  $3.6 \pm 3.7$  mm (female) group and  $4.5 \pm 3.1$  mm (male). The APP could be reconstructed by the alternative reference planes with an error of  $0.4^\circ \pm 3.8^\circ$ , when using the ASIS points as a fixed medial-lateral orientation. No statistically significant differences were found between genders for APP reconstruction.

When comparing the new registration methodology to the gold standard APP, the error in acetabular component inclination was  $0.1^\circ \pm 2.8^\circ$  and in anteversion  $0.4^\circ \pm 3.3^\circ$ . Statistically, 99.96% of the cases were inside the Lewinnek safe zone for inclination and 99.74% for anteversion. In the entire set of 420 cases, only one case (0.24%) was outside the safe zone.

**Discussion:** Within this extensive CT data analysis, a set of consistent anatomical relationships was found, which enables a true lateral registration of the pelvis. In particular, the IFD and deviations between the APP and alternative reference planes were found to be consistent within the gender groups. A distinction between male and female patients had to be taken into account. Based on these relationships, the APP could be reconstructed with high robustness across the entire test population. More than 99% of the virtual cup positions were found to be in the Lewinnek safe zone.

During the registration, only landmarks need to be acquired which are accessible in a lateral decubitus position during hip arthroplasty. In comparison to a standard APP registration, one point at the midsagittal plane has to be acquired at the L5 vertebra instead of the contra-lateral ASIS. The pubis points are replaced by points around the acetabulum. No changes in the basic clinical workflow, e.g. repositioning of the patient, are required within this approach. As a next step, the accuracy of this new lateral registration technique has to be demonstrated in a clinical setup. The study suggests that the proposed method is able to provide accurate positioning of the cup and an efficient clinical workflow.

## References

- [1] Ryan JA, Jamali AA, Bargar WL. Accuracy of computer navigation for acetabular component placement in THA. *Clin Orthop Relat Res.* 2010 Jan;468(1):169-77.
- [2] Lewinnek GE, Lewis JL, Tarr R, Compere CL, Zimmerman JR. Dislocations after total hip-replacement arthroplasties. *J Bone Joint Surg. Am A* 1978;60(2):217-220.
- [3] Murray DW. The definition and measurement of acetabular orientation. *J Bone Joint Surg Br.* 1993 Mar;75(2):228-32.