EPiC Series in Health Sciences
Volume 3, 2019, Pages 157–160
CAOS 2019. The 19th Annual Meeting of the International Society for Computer Assisted Orthopaedic Surgery

Reliability of pelvic parameters measurement with sterEOS: preliminary results

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Abstract

SterEOS is a software developed by EOS Imaging® allowing the measurement of 3D orthopaedic parameters on two bi-planar radiographs. The goal of this preliminary study was to assess the reliability of the pelvic measurements. Two observers, a novice and an intermediate user, measured three times these parameters on pre and postoperative EOS images coming from ten patients. Intra- and inter-observer precision have been evaluated with intra-class coefficient (ICC) and Bland-Altman graphs. On preoperative EOS images, a high intra- and inter-observer precision (ICC>0.8) was obtained for the measurement of the femoral head diameter, the femur length, the pelvic version and the pelvic obliquity. The offset, the femoral neck length, the pelvic incidence and the sacral slope measurement had a high intra-observer precision but a lower inter-observer precision. The measurement of the acetabulum inclination and anteversion, the CCD angle, the femur torsion, the pelvic rotation and the anterior pelvic plane inclination had a low intra- and inter-observer precision. Similar results were found on postoperative EOS images. Our results are partially consistent with the literature since authors found high intra- and inter-observer precision for all pelvic parameters. Further studies are therefore needed to evaluate the impact of the observer experience on the reliability of those measurements.

1 Introduction

The orientation of the acetabular cup remains a major challenge in total hip arthroplasty (THA) (Lewinnek, et al. 1978). New tools are continuously developed to allow orthopaedic surgeons to measure clinical parameters and assist them in their task (Dardenne, et al. 2009) (Rivière, et al. 2018). The sterEOS planning software developed by EOS Imaging® allows, from EOS images, the three dimensional measurement of several pelvic parameters useful in total hip arthroplasty (THA): the acetabulum inclination and anteversion, the femoral head diameter, the offset, the femoral neck length, the CCD angle, the femur torsion, the pelvic incidence, the sacral slope, the pelvic version, the pelvic obliquity, the pelvis axial rotation and the anterior pelvic plane (APP) inclination. The goal of this study was to assess the reliability of these measurements by assessing (1) the learning effect and (2) the precision of the measurements.

2 Materials

Two observers, a novice and an intermediate user, respectively an engineer and an orthopaedic surgeon, carried out measurements on pre and postoperative EOS images coming from ten patients. There were 5 males and 5 females and the mean age was 67.5±5.0 years old. Both observers made three times the measurements on the 20 images.

Learning effect has been assessed by recording the time required for the analysis of one radiograph in each session. Times in the first and last sessions were compared using the Wilcoxon and t tests for paired values (Rietveld et van Hout 2017).

Intraclass coefficient (ICC) and their confidence interval (CI) have been calculated for each observer and each parameter to assess the intra-observer precision. Inter-observer precision has been assessed with Bland-Altman plots.

All statistical tests and visualisations have been processed in R, using ICC, irr, MethComp and plotrix libraries.

3 Results

A learning effect has been observed for both observers. The intermediate and novice users reduced their measurement time between the first and the last sessions, from 14.2±8.3min to 5.1±1.8min and from 14.5±4.0min to 10.0±2.0min respectively, on preoperative EOS images. For both observers, this time reduction was statistically significant in terms of mean (t test p-value<0.02) and median (Wilcoxon test p-value<0.02).

Regarding the intra observer precision on preoperative images, ICC greater than 0.8 with a small confidence interval was obtained for the femoral head diameter, the offset, the femoral neck length, the CCD angle, the femur length, the pelvic incidence, the sacral slope, the pelvic version and the pelvic obliquity (Table 1). Lower ICC or with a large confidence interval was obtained for the acetabulum inclination, the acetabulum anteversion, the femur torsion, the pelvis axial rotation and the APP inclination.

Regarding the inter-observer precision on preoperative images, we obtained a good agreement (limits of agreement <5° or <5cm) for the femoral head diameter, the femur length, the pelvic version and the pelvic obliquity. The agreement was poorer for the acetabulum inclination and anteversion, the offset, the femoral neck length, the CCD angle, the femur torsion, the pelvic incidence, the sacral slope, the pelvis axial rotation and the APP inclination.

Similar results were found on postoperative EOS images. Intra-observer agreement was high (ICC>0.75) with small CI for the offset, the CCD angle, the stem torsion, the femur length, the pelvic incidence, the sacral slope, the pelvic version and the pelvic obliquity (Table 2). Intra-observer agreement was lower (ICC<0.75) or with larger CI for the cup inclination, the cup anteversion, the pelvic axial rotation and the APP inclination. Inter-observer agreement was good (limits of agreement <5° or <5cm) for the offset, the femur length, the pelvic version, the pelvic obliquity and the pelvis axial rotation, and poor for the cup inclination and anteversion, the CCD angle, the stem torsion, the pelvic incidence, the sacral slope, and the APP inclination.

Preoperative pelvic parameters	Engineer			Surgeon		
	ICC	CI	P-value	ICC	CI	P-value
Acetabulum inclination	0.84	0.54-0.96	< 0.01	0.39	-1.1-0.84	0.20
Acetabulum anteversion	0.78	0.36-0.94	< 0.01	0.67	0.05-0.91	0.02
Femoral head diameter	0.98	0.93-0.99	< 0.01	0.97	0.92-0.99	< 0.01
Offset	0.99	0.96-1.00	< 0.01	0.92	0.79-0.98	< 0.01
Femoral neck length	0.99	0.98-1.00	< 0.01	0.95	0.86-0.99	< 0.01
CCD angle	0.91	0.75-0.98	< 0.01	0.81	0.45-0.95	< 0.01
Femur torsion	0.75	0.27-0.93	< 0.01	0.87	0.62-0.96	< 0.01
Femur length	0.99	0.99-1.00	< 0.01	1.00	1.00-1.00	< 0.01
Pelvic incidence	0.98	0.95-1.00	< 0.01	0.99	0.96-1.00	< 0.01
Sacral slope	0.97	0.92-0.99	< 0.01	0.98	0.93-0.99	< 0.01
Pelvic version	0.99	0.97-1.00	< 0.01	0.99	0.98-1.00	< 0.01
Pelvic obliquity	1.00	0.99-1.00	< 0.01	0.99	0.95-1.00	< 0.01
Pelvic axial rotation	-0.43	-5.3-0.66	0.68	0.45	-0.66-0.85	0.14
PPA inclination	0.87	0.63-0.97	< 0.01	0.77	0.32-0.94	< 0.01

Table 1. Intraclass coefficient (ICC), confidence interval (CI) and ICC p-value for every parameter measurement by each observer on preoperative EOS images

Preoperative pelvic parameters	Engineer			Surgeon		
	ICC	CI	P-value	ICC	CI	P-value
Cup inclination	0.76	0.3-0.94	< 0.01	0.66	-0.03-0.91	0.03
Cup anteversion	0.61	-0.03-0.89	0.03	0.82	0.49-0.95	< 0.01
Offset	1.00	0.99-1.00	< 0.01	0.99	0.97-1.00	< 0.01
CCD angle	0.92	0.75-0.98	< 0.01	0.91	0.75-0.98	< 0.01
Stem torsion	0.93	0.79-0.98	< 0.01	0.77	0.35-0.94	< 0.01
Femur length	1.00	1.00-1.00	< 0.01	1.00	0.99-1.00	< 0.01
Pelvic incidence	0.96	0.88-0.99	< 0.01	0.99	0.93-1.00	< 0.01
Sacral slope	0.95	0.85-0.99	< 0.01	0.99	0.96-1.00	< 0.01
Pelvic version	0.94	0.84-0.98	< 0.01	0.89	0.54-0.97	< 0.01
Pelvic obliquity	0.98	0.94-0.99	< 0.01	0.99	0.96-1.00	< 0.01
Pelvic axial rotation	0.13	-0.47-0.68	0.32	0.09	-0.54-0.66	0.37
PPA inclination	0.01	-1.4-0.71	0.47	0.00	-0.36 - 0.26	1.00

Table 2. Intraclass coefficient (ICC), confidence interval (CI) and ICC p-value for every parameter measurement by each observer on postoperative EOS images

4 Discussion

We first observed a learning effect regarding the sterEOS software since the measurements time significantly decreased between the first and the last session. We also obtained a high intra and inter-observer precision regarding the femoral head diameter, the femur length, the pelvic version and pelvic obliquity. However, the agreement between and among observers was lower for the acetabulum inclination and anteversion, the femur torsion, the pelvis axial rotation and the APP inclination.

These results are partially consistent with the literature. Demzik et al. performed measurements on 25 postoperative images of patients (Demzik, et al. 2016). The three involved physicians followed a training session before performing measurements. They obtained good inter- and intra-observer agreement with an ICC higher than 0.75 for all measurements. Thelen et al. analyzed the acetabular anteversion and inclination only, on 30 good quality EOS images from asymptotic volunteers (Thelen, et al. 2017). Measurements were performed by two physicians and they obtained a good inter- and intra-agreement (ICC>0.8).

Those differences may be partly explained by the users' expertise level (novice and intermediate) and by the quality of images from our dataset. Further studies are therefore needed to evaluate the impact of the observer experience on the reliability of those measurements.

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