

Correspondence

2D measurements of cup orientation are less reliable than 3D measurements

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Sir—I read with interest the paper by Davda et al. (2015) which described an assessment of the reliability of measurement of metal-on-metal (MoM) acetabular cup orientation using 3-D CT and EBRA. I would like to make the following comments.

1. It is generally appreciated that 3D-CT is inappropriate for routine cup orientation measurements because of the increased cost, radiation level and procedure/analysis time. Nevertheless, the authors of this paper would seem to encourage the belief that it is the “gold standard” for measuring cup orientation. They state: “A critical advantage of 3D-CT is that the pelvis is corrected to the APP (anterior pelvic plane), eliminating the variability in patient positioning at the time of scanning, thus allowing objective measurements of cup placement to be made between different subjects”. This view is not uncommon: but is it correct?

The APP provides the basis for a local 3D co-ordinate axis system and is a convenient reference plane which can be repeatedly identified. However, its relationship to other aspects of the pelvis may vary amongst different patients due to variations in pelvis size and morphology (Rousseau et al. 2009). As the latter authors state:

“In our opinion, the morphological variations of the iliac bones simply relate to inter-individual variations in the appearance, which has not much to do with pelvic orientation and function of the hip or spine. Some may have prominent iliac crests, while others may have small ones, without any relevant anatomical or physiological implications.”

There is no guarantee of a consistent relationship between the APP and the pelvis – which is the main requirement of a standard reference plane. In this sense, the APP is an arbitrary reference plane, particular to each individual patient. Cup orientations of different patients cannot therefore be compared if they are referenced to this plane. In addition, because the pelvis is a link in the kinematic chain supporting the body, the angle of the APP to the coronal plane (pelvic tilt) also varies between patients due to the many variables that can affect posture.

The range of inter-patient variations in pelvic tilt could be at least -25° to 20° (Nishihara et al. 2003, Babisch et al. 2008, Legaye 2009, Zhu 2010, Lazennec et al. 2011). It seems inappropriate, therefore, to measure cup orientation relative to the APP without a correction for pelvic tilt (Eilander et al. 2013, Malik et al. 2010). Measurements rel-

ative to the coronal plane (with the patient either supine or standing) would be automatically corrected for pelvic tilt. Such measurements would relate the pelvis to the global axis system and thereby provide a standard reference by which all patients could be compared. They would also enable the functional orientation (e.g. when standing) to be taken into account – which would seem to be appropriate if edge-loading effects were the objective.

An inevitable consequence of including pelvic tilt effects is that intra-patient measurements could vary due to random changes in pelvic tilt caused by variations in patient positioning or posture. It is worth emphasising that even 3D-CT measurements would be affected by these changes, whether measured directly from supine patients or with pelvic-tilt-corrected APP measurements.

The use of the APP also introduces a confusion of terminology. The widely accepted medical definitions of “version” and “inclination” (Murray 1993) describe angles relative to the cardinal planes (coronal, transverse, sagittal). If cup orientation is measured relative to the APP, this terminology cannot be used because the APP is not usually parallel to the coronal plane – unless it is contrived to be so (Lewinnek et al. 1978). If the pelvic tilt angle is known, APP referenced cup orientation measurements can be corrected to the coronal plane using the mathematical formulae of Lembeck et al. (2005) in order to correspond with the standard terminology.

2. The authors state that a study by Langton et al. (2010) was the “only study in the literature to validate EBRA in MoM hips using a controlled laboratory study”. They would seem to have overlooked our laboratory study – published online 1 year before their submission date – in which we measured the orientations of 2 types of MoM resurfacing cup (Birmingham Hip and ASR) and compared the EBRA technique with our new, 2D Wrightington Cup Orientation software (WCO) (Derbyshire et al. 2014).

3. Although measurement of MoM cup orientation using EBRA has been validated in laboratory studies, the same cannot be said for MoM cup measurement using their 3D CT technique – as the authors acknowledge. According to Hart et al. (2011), the 3D-CT cup orientation is determined from manually placed points around the rim of a computer-model image of the cup. The accuracy of this has not been tested. It was not strictly valid, therefore, for the authors to

assume that their 3D-CT technique had not contributed to the differences found between the 2 techniques. Controlled conditions are crucial for comparing the accuracies/agreement of 2 systems. Precision (inter/intra – observer repeatability) is not a measure of accuracy.

4. According to the authors, each retrospective pelvic radiograph had been taken so that both obturator foramina appeared symmetrical and the coccyx was in-line with the pubic symphysis. The X-ray beam had been focused at the pubic symphysis. Judging from Figure 1 (assuming it is a full image of the radiograph), it would seem that this was not always achieved: the X-ray focus point (centre of the radiograph) is several centimetres above the pubic symphysis, and the obturator foramina are not symmetrical. Pelvic alignment and X-ray focusing are usually quite variable on routine radiographs.

The WCO software can correct version and inclination for X-ray focus point offset from the hip (Derbyshire 2008, Derbyshire et al. 2014). I estimate that, for the cup in Figure 1, the anteversion measurement would have needed a correction of about +4° (+2° if focused at the middle of the pubic symphysis).

5. The authors were unable to distinguish retroverted cups using EBRA. However, it is possible to distinguish retroversion reliably using the WCO system – provided that a second antero-posterior X-ray examination is taken with the beam focused at a different location from the first (Derbyshire et al. 2014).

6. It is not clear what point the authors were trying to make with their version/inclination scatter graphs. More data points were inside the “safe zone” for the CT data than for the EBRA data. That “safe zone” was derived by Grammatopoulos et al. (2010) who used EBRA to measure pelvic radiographs (coronal plane). It could be inferred, therefore, that the authors’ EBRA data identified multiple cases of possible pseudo-tumours and that standard, 2D radiographic measurements were better than 3D-CT measurements for detecting the pseudo-tumours using that “safe zone”.

The 3D-CT APP graph is not comparable to the other 2 graphs due to the change in orientation definitions (see point 1). The “safe zone” in this graph is also incompatible with the coronal plane referenced zone of Grammatopoulos et al. (2010).

In conclusion, provided that the effect of X-ray beam offset is corrected for (as with the WCO) and provided that pelvic rotation about the longitudinal axis is limited (which should be easy to ensure), there would seem to be no obvious reason why 3D-CT should be better than an accurate, 2D radiographic technique such as the WCO.

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Sir—We thank Dr Derbyshire for his interest in our paper. We value the points raised and would respond as follows.

1. As discussed in our paper, we accept that 3D-CT is not routinely or commonly available, particular for the purpose of cup orientation measurement. It has been used as research tool within the setting of our implant retrieval centre. The radiation dosage used in our scanning protocol is low at approximately 1.7mSv. By comparison, the radiation doses from plain AP and lateral pelvic radiographs are approximately 0.7 mSv and 0.8 mSv respectively, and therefore equivalent to a single CT scan. Whilst time is required by an investigator in uploading the images into the software used in our study (Robins 3D, Robin Richards, London), it is now capable of finding the anterior pelvic plane (APP) automatically. The process of edge detection of the cup is indeed manual, but the whole process from image acquisition to cup orientation measurements takes no more than a few minutes. All commercially available image analysis software will require a level of user interaction and time. In addition, the 3D-CT software allows a surgeon to examine the femoral component orientation, available acetabular bone stock and plan for revision surgery. Thus the utility of the scan is more than that of examining cup orientation.

2. The APP does indeed ‘provide a local 3D co-ordinate axis system and is a convenient reference plane which can be repeatedly identified’. Although the relationship of the APP to the pelvis may change, the relationship to the cup is constant and can be reliably determined on repeated measurements with precision. And that, we believe, is the main requirement of a clinical study that investigates metal on metal hip (MoM) function. There is no 1 single reference plane that has been universally accepted or provides a reference standard, and continues to be a matter of debate. We advocate the APP as the best reference plane that is currently available. We define the APP by its anatomical parameters (the anterior superior iliac spines and pubic tubercles of the pubic symphysis) adjusted to the coronal plane as per the method of Lewinnek et al. (1978) As has been correctly pointed out, we agree with Dr Derbyshire that the function of a cup cannot be determined from a pelvis in a static position – whether supine or standing. The use of either planar radiography with the pelvis standing is no more or less applicable than a radiograph with the pelvis supine. Neither can be truly used to infer the functional position of the pelvis as it constantly moves. Pelvic tilt, rotation, pelvic incidence and sacral slope all play a role in the complex motion of the hip and the varying functional orientation of the acetabular component. We acknowledge this as a limitation of both 2D and 3D imaging. Adjustment for pelvic tilt should be a separate component of interpatient comparison.

3. Testing the 3D software used in our study in controlled laboratory conditions with a synthetic test pelvis or with the use of a jig used by Dr Derbyshire is an avenue of further

research. Setting cup orientation to known inclination and version values, as well to predetermined pelvic orientation and tilt would be of value. We acknowledge this as a limitation in our paper.

4. We congratulate the authors on their study ‘A New Technique for Radiographic Measurement of Acetabular Cup Orientation’ (Derbyshire et al. 2014). This important paper compares the accuracy of Wrightington Cup Orientation (WCO) software to 2 other measurement systems: Traumacad and EBRA. Varying orientations of 2 types of metal on metal hip resurfacing prostheses and a metal on polyethylene couple are used in a purpose built jig, with subsequent analysis of WCO software in 21 images of a common resurfacing hip. Their results demonstrate that WCO software is more accurate and precise than the other 2. The results show the EBRA technique, used in numerous papers in the analysis of over 4000 metal on metal hips, has a relatively large variability in the measurement of version. These findings are echoed in our study that demonstrates the EBRA measurements were comparatively less reliable than 3D-CT.

The authors state ‘in order to ensure a fair comparison of the 3 systems, only the “pubis”-centered radiographic measurements were compared, and all version measurements were deemed to be positive (i.e. anteversion).’ It is unclear why this is so; does it imply that Traumacad and EBRA cannot reliably detect retroversion. We note that WCO software is able to detect retroversion based on the method by Seradge et al. (1982). This requires an additional radiograph, the marking of a patient with a metallic cross, the film focus distance to be known as well as the magnification. Whilst these variables can be controlled for in the designer centre for the purposes of research, it is practically and logistically more difficult to ascertain such parameters when conducting a prospective analysis of retrospective data from other centres. As Dr Derbyshire correctly points out ‘pelvic alignment and X-ray focusing are usually quite variable on routine radiographs.’

We also note that a metal on polyethylene cup, as well as 2 MoM bearings were used in the analysis of reliability, accuracy and precision between the 3 types of software. The distinction between the cup and femoral head in a metal on polyethylene bearing is likely to be more clear than that of a MoM bearing where the edge of the cup has a similar radioopacity to that of the head; this would potentially bias the results of the study. We appreciate the statistical analysis performed in the paper would suggest this is not a confounder. The comparison between software programmes for the MoM bearing alone would have been interesting.

5. The purpose of our scatter graphs is merely to illustrate that the number of cups falling within a safe zone is dependent on the method used to evaluate the cup orientation. This point should be emphasized to any clinician or researcher

investigating metal on metal hip function and component orientation. The findings and conclusions of any such study could change dramatically depending on the imaging used. The general concept of a safe zone and whether it should be applied continues to be debated amongst hip surgeons.

We advocate any imaging, be it 2D or 3D that can reliably and precisely report cup orientation in the metal on metal bearings. We do not believe EBRA is fit for this purpose, and is supported by Dr Derbyshire’s work. We find the use of WCO software promising in this regard and look forward to further work that demonstrates its capability in the clinical setting when analysing hip prostheses from different manufacturers (both resurfacing and total hip arthroplasty) as well as in radiographs of varying quality from non designer centres.

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