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COMMUNICATION

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Assessment of the acetabular version in relation to sagittal sacropelvic parameters

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Abstract

The relationship between acetabular orientation and the sacropelvic parameters is of interest to both hip and spine surgeons as it is increasingly clear disease in one area can affect the other, including the outcome of surgical procedures. The aim of this study was to further clarify the relationship between measures of acetabular orientation and sacropelvic parameters. This study utilized a trauma CT database. A total of 100 scans on adult patients without overt hip or spinal disease were included. Measures of acetabular orientation included the acetabular sagittal angle (ASA) which uses the anterior pelvic plane as a reference and sacroacetabular angle which uses the sacral endplate as a reference (SA); spinopelvic parameters include the pelvic incidence (PI), sacral anatomic orientation (SAO) and pelvic thickness (PTH). Mean age 48.2 years (SD 18.0), 62% male. Mean values were: PI 50.5, SAO 50.7, PTH 106.4 mm, ASA-right 62.1, ASA-left 64.0, SA-right 67.2, and SA-left 65.4. There was substantial correlation between PI and SA ($r = 0.628$–0.630) and also between SAO and SA (-0.657 to -0.692). Liner regression determined SA was best predicted by the model: SA $= 81 \times$ SAO $+ 0.36 \times$ PI. When using the anterior pelvic plane as a reference to define acetabular orientation, there does not appear to be any significant relationship between the sagittal orientation of the acetabulum and sacropelvic parameters. Using the sacrum as a common point of reference allows some further understanding of the interplay between pelvic parameters and the orientation of the acetabulum.

KEYWORDS
acetabulum, computed tomography, pelvic, sacrum, spine

1 | INTRODUCTION

The relationship between the hip and lumbar spine continues to garner interest from clinicians as the interplay between hip function and spinal alignment can influence the outcome of surgery in either region (Ike et al., 2018; Vigdorchik et al., 2019; Wiznia et al., 2021). Understanding determinants of the relationship between the acetabulum and spine are essential as hip surgeons aim to antevert the acetabular component appropriate to the individual patient to minimize the risk of dislocation and avoid problems such as impingement (Lazennec et al., 2007; Lewinnek et al., 1978). Assessment of the anterior plane of the pelvis (APP) or position of the transverse acetabular ligament (TAL) have been used as guides for correct placement of the acetabular component in relation to the sagittal plane, yet no technique is perfect (Pearce et al., 2008). The orientation of the acetabulum changes significantly between positions—when sitting the pelvis rotates dorsally in relation to the lumbar spine, or retroverts, resulting a more vertically oriented acetabulum (Lazennec et al., 2011). If there is an abnormality in hip or spinal motion, likely a result of degenerative disease or previous surgery such as spinal fusion, then this normal change in orientation can be disturbed (Esposito et al., 2018).

Pelvic incidence (PI), widely used as a predictor of ideal lumbar lordosis in an individual and thereby in surgical planning when restoration of lumbar spine lordosis is required, reflects the link between the sacrum (considered the 'pelvic vertebra') as the base of the spine and the hip joints (Legaye et al., 1998). As a result of this interplay between the spine, pelvis and hip, attention has been given to analysis of the PI, and determining whether PI is associated with the normal orientation of the acetabulum—results have been variable. In part this is due to different techniques being utilized including analysis of 2-dimensional and 3-dimensional computed tomography (CT) imaging, magnetic resonance imaging with arthrography and plain radiographs (Hatem et al., 2020; Kim et al., 2021; Lee et al., 2019; Radcliff et al., 2014). Measures to define the sagittal orientation of the acetabulum have also varied meaning comparison of studies has been challenging if not impossible.

The aim of this study therefore was to help clarify the relationship of acetabular version, as defined by its relationship to the anterior pelvic plane and the sacral endplate, with known sagittal sacropelvic parameters including the PI.

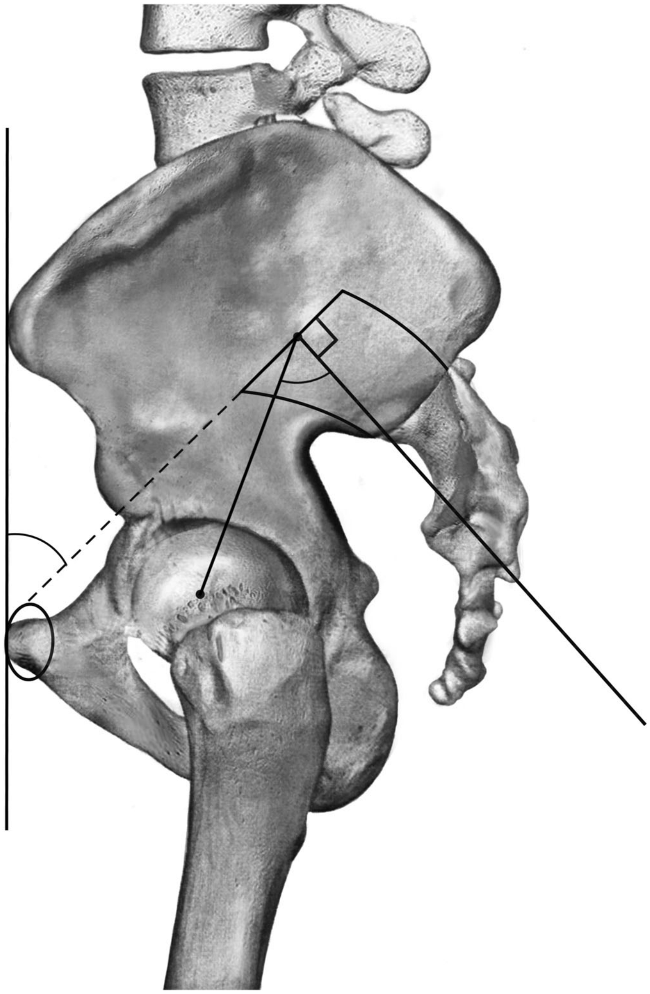

FIGURE 1 PI is measured as the angle subtended by a line from the bicoxofemoral axis to the center of the sacral endplate and a line drawn perpendicular through the center of the sacral endplate. PTH is measured (in millimeters) as the distance from the bicoxofemoral axis to the midpoint of the sacral endplate. SAO is the angle subtended by a line along the anterior plane of the pelvis and a line drawn along the sacral endplate. PI, pelvic incidence; PTH, pelvic thickness; SAO, sacral anatomic orientation

2 | MATERIALS AND METHODS

Ethical body approval was obtained for this study (HDEC: 18/CEN/8). Given the retrospective nature of the work patient consent was not required.

A total of 100 consecutive CT scans of the spinal column were identified from a previously used dataset. Scans obtained for the purposes of major trauma assessment were identified that clearly showed the base of skull to proximal femori allowing determination of normal counts of vertebral bodies and presence or absence of transitional anatomy. Scans were excluded if there was an abnormal vertebral body count (that is any deviation from 7 cervical, 12 thoracic, and 5 lumbar vertebrae), transitional anatomy, evidence of previous surgery to the spine, pelvis of hip(s), tumor, infection, fracture or deformity such as spondylolisthesis that could preclude measurements of sacropelvic parameters. All imaging was viewed and analyzed using IntelliSpace PACS (v4.4, Koninklijke Philips N.V., Amsterdam, Netherlands) using the built-in measurements tools (linear measurements in millimeters).

Demographic data including age (years) and sex were recorded. Measures recorded included: PI, pelvic thickness in millimeters (PTH), sacral anatomic orientation (SAO), acetabular sagittal angle (ASA), and sacroacetabular angle (SA) (Baker et al., 2020; Legaye et al., 1998; Peleg et al., 2007; Radcliff et al., 2014; Vrtovec et al., 2012).

The techniques for measuring PI, PTH, and SAO have previously been well-described and excellent reliability demonstrated (Figure 1) (Baker et al., 2020). Identifying the anterior pelvic plane (APP), that is the plane defined by points at the anterior superior iliac spines and most ventral prominence of the symphysis pubis, is key to defining the SAO.

Both PI and SAO were assessed—while they both use the sacral endplate as a reference plane the PI used the bicoxofemoral axis and the SAO the anterior pelvic plane therefore allowing consideration of how the reference points may influence the association of pelvic parameters with acetabular orientation (Legaye et al., 1998; Peleg et al., 2007; Vrtovec et al., 2012).

As has been done in previous studies, measurements of acetabular orientation were taken in the sagittal plane corresponding with the center of the femoral heads as defined on the coronal plane

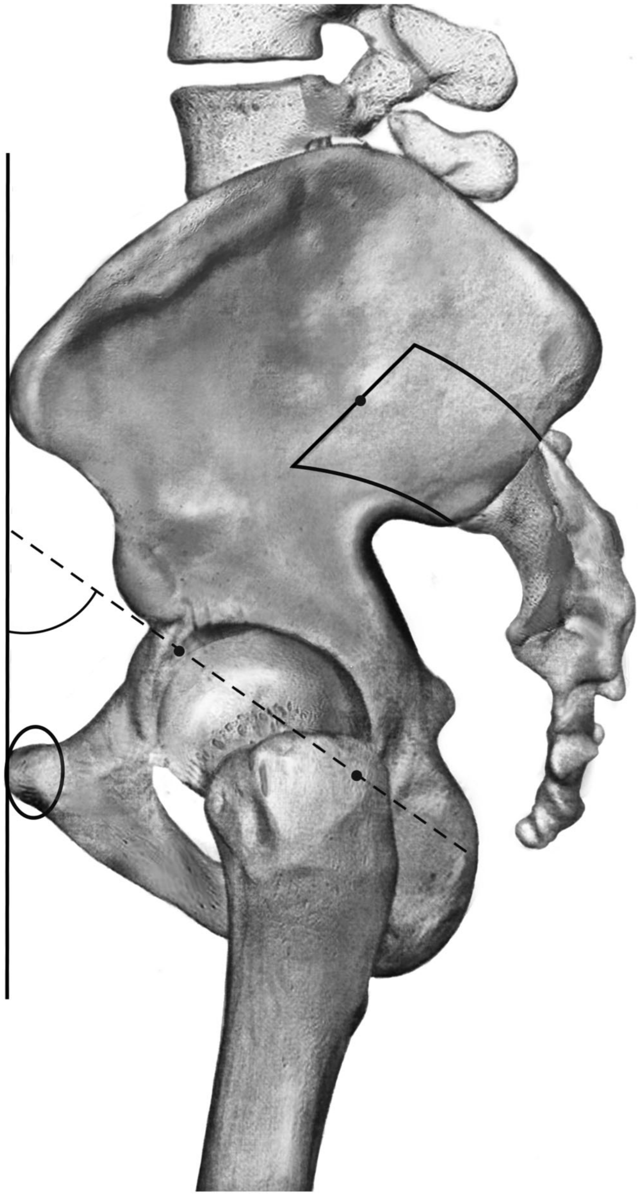

FIGURE 2 Technique for measuring the ASA. The APP is first determined by identifying the maximal protuberance of the anterior superior iliac spine on the relative sagittal sequences and the APP defined by line connecting the midpoint of these loci on the midsagittal sequence to the anterior margin of the pubic symphysis. The ASA is then measured as the angle subtended by the APP and a line connecting the anterior and posterior margins of the acetabulum at the center of the femoral head as defined on both sagittal and coronal (not shown) images. APP, anterior pelvic plane; ASA, acetabular sagittal angle

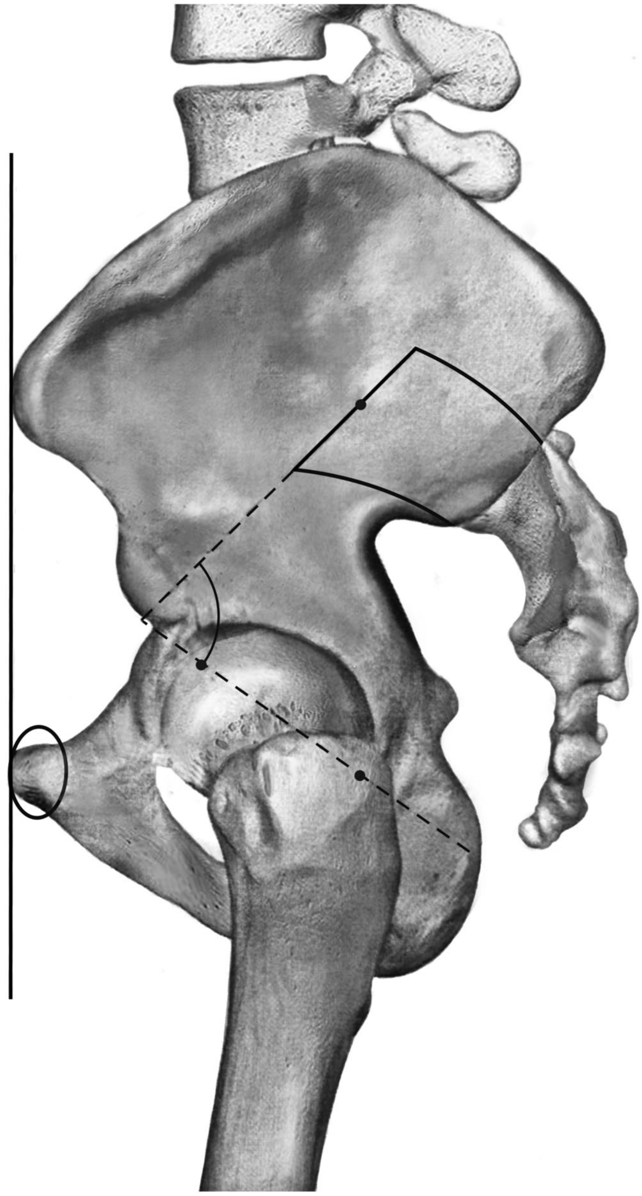

FIGURE 3 Technique for measuring the SA. The SA is measured at the angle subtended by a line along the sacral endplate taken in the midsagittal and a line connecting the anterior and posterior margins of the acetabulum at the center of the femoral head as defined on both sagittal and coronal (not shown) images. SA, sacroacetabular angle

assisted by using the region-of-interest (ROI) function to define the center femoral head (Radcliff et al., 2014). The midpoints of the femoral heads were identified using the ROI circle on the coronal images before then identifying the anterior and posterior horns of the acetabulum on the relevant sagittal image on which acetabular measures were recorded. To assess the sagittal orientation of the acetabulum as indicated by the ASA, the angle was measured between a line connecting the anterior and posterior horns and a line drawn along the anterior pelvic plane (Figure 2). SA was measured as previously described by Radcliff et al. (2014) (Figure 3). In each instance the sagittal measures were obtained in the plane through the center of the femoral head as seen on the coronal images.

Reliability analyses have been previously performed measuring PI, SAO, PTH and SA on CT images with excellent reliability noted (Baker et al., 2020; Radcliff et al., 2014). Intraobserver reliability was performed for the ASA using Cronbach's α with excellent and good reliability seen for right (0.918) and left (0.866), respectively.

2.1 | Statistics

Statistical analysis was performed using ExcelSTAT (Microsoft). Data was tested for normality using the Shapiro-Wilks test. Results are represented as mean (±standard deviation) and subgroups compared using Student's *t*-test where appropriate. Correlation analysis was performed to identify significant associations between variables. Stepwise linear regression analysis was performed to determine the contribution of significant predictors. Statistical significance was accepted as $p < 0.05$.

3 | RESULTS

A total of 100 consecutive scans were analyzed (62% male), mean age 48.2 years (SD 18.0). Mean, standard deviation and range for each of the collected variables are shown in Table 1. Variables were compared between sexes: only ASA, on both right and left, was significantly different between male and female (right: male 64.8°, female 57.7°, $p < 0.001$; left: male 66.2°, female, 60.3°, $p = 0.001$).

The mean ASA was different between right and left (62.1° vs. 64.0°; $p = 0.036$). The mean SA was different between right and left (67.2° vs. 65.4°; $p = 0.036$).

TABLE 1 Minimum, maximum, mean and standard deviation (SD) for collected variables

	Minimum	Maximum	Mean	SD
Age (years)	19	88	48.2	18.0
PI	30	80	50.5	10.1
SAO	26	72	50.7	8.4
PTH (mm)	91	132	106.4	6.9
ASA-R	41	90	62.1	9.1
ASA-L	48	88	64.0	8.4
SA-R	25	99	67.2	12.0
SA-L	33	92	65.4	11.6

Abbreviations: ASA, acetabular sagittal angle; L-, left; PI, pelvic incidence; PTH, pelvic thickness; R-, right; SA, sacroacetabular angle; SAO, sacral anatomic orientation.

Correlation analysis results, shown in Table 2, demonstrated a substantial association between PI and SA and also between SAO and SA. A fair association was demonstrated between PTH and SA. There was no significant association between ASA and any of the pelvic measures.

Stepwise linear regression analysis was performed to assess contributions from PTH, SAO and PI in determining the SA. PI (coefficient 0.332, $p < 0.001$) and SAO (coefficient − 0.494, $p < 0.001$) remained predictive variables, $R^2 = 0.58$. SA was best predicted by the model: $SA = 81 \times SAO + 0.36 \times PI$.

4 | DISCUSSION

This study aimed to determine the relationship between known sagittal sacropelvic parameters including the PI, and the sagittal orientation of the acetabulum as defined by its relationships to the APP and sacral endplate. A strength of this study is the assessment of multiple pelvic parameters and measures of acetabular orientation simultaneously.

The APP is well defined and used a reference for surgeons in planning surgery and orientating the position of the acetabular components. We failed to show a relationship between ASA, which relates the acetabular orientation to the APP, and PI nor the other pelvic parameters SAO and PTH. This is consistent with findings by others using different techniques. Hatem et al. studied 94 hips using magnetic resonance arthrography (Hatem et al., 2020). They used the plane of the TAL to define the sagittal plane of the acetabulum. They then determined sagittal acetabular orientation as the angle subtended from the plane of the acetabulum and the axial plane. They failed to find any relationship between either PI or sacral slope and the sagittal orientation of the acetabulum indicating significant variation between individuals. Kim et al. developed a 3-dimensional model based on 100 male and 50 female pelves to study the relationship between PI and both acetabular anteversion and inclination (Kim et al., 2021). The APP was defined, and the axial plane of the pelvis defined as perpendicular to the APP. The acetabular plane was defined using a best fit technique. They found no correlation between

TABLE 2 Results from Pearson correlation analysis

	Age	PI	SAO	PTH	ASA-R	ASA-L	SA-R	SA-L
Age	1							
PI	0.114	1						
SAO	−0.153	**−0.696**	1					
PTH	0.174	**−0.388**	**0.211**	1				
ASA-R	−0.175	−0.190	−0.052	0.119	1			
ASA-L	−0.126	−0.175	−0.042	0.259	**0.510**	1		
SA-R	**0.239**	**0.628**	−0.657	−0.237	−0.719	−0.355	1	
SA-L	**0.202**	**0.630**	−0.692	−0.339	−0.330	−0.691	**0.732**	1

Note: Statistically significant *R*-values ($p < 0.05$) appear in bold.
Abbreviations: ASA, acetabular sagittal angle; L-, left; PI, pelvic incidence; PTH, pelvic thickness; R-, right; SA, sacroacetabular angle; SAO, sacral anatomic orientation.

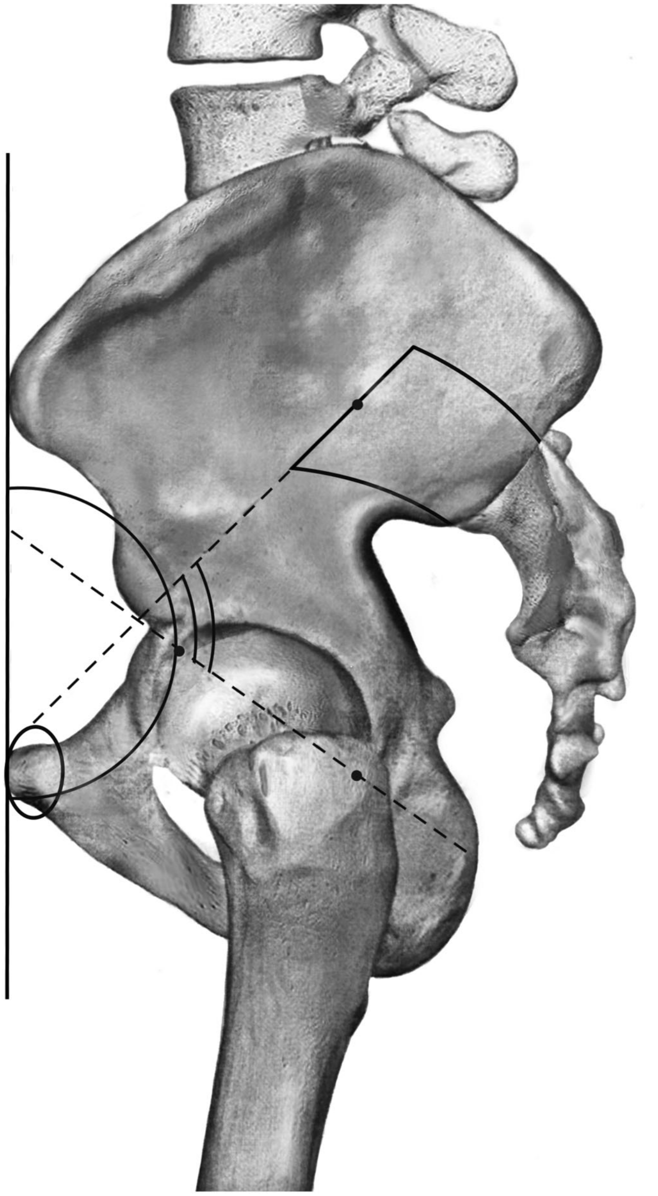

FIGURE 4 This demonstrates how the SAO, SA and ASA, when summed, add to 180°. ASA, acetabular sagittal angle; SA, sacroacetabular angle; SAO, sacral anatomic orientation

PI and either the sagittal nor coronal orientation of the acetabulum ($r = 0.160$ and $r = -0.059$, respectively).

In contrast to the ASA, the SA correlated substantially with the PI and the SAO. This is consistent with previous work by Radcliff et al. although they did not consider the relationship between acetabular orientation and SAO (Radcliff et al., 2014). In a CT-based study of 164 hips they found a significant correlation ($r = 0.641$) between PI and the SA. The authors found no correlation greater than weak between any of the parameters describing acetabular orientation and measures of body composition including height, weight and body mass index. They indicated that an increasing PI is associated with increasing acetabular anteversion—the reference point for defining acetabular version is the sacral endplate. Indeed, measurement PI, SAO, and SA all include the sacral endplate and so some degree of association could be anticipated (Vrtovec et al., 2012).

The significant association between the SAO and SA does focus on the relationship between the APP and the relative position of the sacral endplate—a more advanced analysis of the relationship may be desirable. The APP is static and is used to determine the SAO (Peleg et al., 2007). When upright the APP has been thought to be vertical however studies have not necessarily supported that notion and instead the plane may be either considered either positive or negative depending on the version of the pelvis (Legaye, 2009). The relationship between SAO and SA further underlines the importance of the location and position of the sacrum within the pelvis as a determinant of the relationship between, essentially the primary link between, the hips and spine. It is also evident that considering the three measures, SAO, SA, and ASA, the sum of the three is 180° (Figure 4), as they represent three contiguous measures posterior to the APP and this may be incorporated into further studies on this topic (Peleg et al., 2007; Radcliff et al., 2014).

We must acknowledge weaknesses in this study. CT scans were utilized in 2-dimensions and arguably advanced 3-dimension analysis may be more accurate (Lee et al., 2019). However, despite using 2-dimensional analysis, we were able to validate findings from others that have utilized more advanced assessments (Kim et al., 2021). The scans assessed were also taken supine which arguably limits their clinical application—however, the measurement of fixed parameters in our experience and that of others remains more accurate on CT than plain radiographs. The major challenge to advance these findings, is to determine whether the orientation of the sacrum within the pelvis may be utilized as a more reliable reference for orientation of acetabular components during hip surgery.

In summary, when using the anterior pelvic plane as a reference to define acetabular orientation, there does not appear to be any significant relationship between the sagittal orientation of the acetabulum and sacropelvic parameters. From a clinical perspective, using the sacrum as a common point of reference allows some further understanding of the interplay between pelvic parameters and the orientation of the acetabulum. Improved understanding of these variations will facilitate surgical planning in both hip and spine reconstruction.

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