Effect of Pelvic Tilt and Rotation on Common Qualitative Acetabular Radiographic Markers: A 3-Dimensional Digitally Reconstructed Radiograph Analysis

Ameen Z Khalil, Daniel C Lewis, Devin Louis Froerer, Benjamin Theodore Johnson, Joseph Featherall, Stephen K Aoki INTRODUCTION:

Radiographic markers including the cross-over sign (COS), ischial spine sign (ISS), and the posterior wall sign (PWS), are frequently used to qualitatively assess acetabular morphology and help guide clinical decision-making. The purpose of this study was to analyze the extent of induced vertical tilt and horizontal rotation needed to elicit a change in findings from positive-to-negative, and vice versa, of acetabular signs using digitally-reconstructed anteroposterior (AP) radiographs (DRRs).

METHODS:

Computed tomography scans of the pelvis were retrospectively collected, and imported into 3-dimensional imaging software, producing transformed AP DRRs of the pelvis. Once rendered, pelvises were standardized to 0° of tilt and rotation, defined as a distance of 2 centimeters from the superior margin of the pubic symphysis to the tip of the coccyx. Once rendered, each DRR was homogenously manipulated at one-degree intervals (from 0-15° in each direction), progressively inducing pelvic tilt along the vertical axis, both anteriorly (pelvic inlet view) and posteriorly (pelvic outlet view). This was repeated along the horizontal axis, inducing rotation of each pelvis towards either hip. Each collection of DRRs was labeled and saved.

Two trained reviewers independently analyzed each collection of renderings. Pelvises were initially assessed for positive or negative findings of COS, ISS, and PWS at 0°. At one-degree intervals, pelvises were progressively tilted until a change in each finding was appreciated. This was then repeated for rotation, starting again at zero. The amount of tilt and rotation needed to change the findings in each hip was recorded, and standard descriptive statistics were calculated. RESULTS:

Twenty hips (ten pelvic DRRs) were assessed. On normalized AP pelvis, 45% had a positive COS (55% were negative), 25% had a positive ISS (75% negative), and 75% had a positive PWS (25% negative). In those with an initially positive COS, an average of $5.1 \pm 2.6^{\circ}$ of tilt towards an outlet view, and $5.8 \pm 2.4^{\circ}$ of rotation towards the contralateral hip changed the findings to negative. Amongst the negative hips, an average of $7.4 \pm 3.6^{\circ}$ of tilt towards the inlet view, and $7.2 \pm 4.9^{\circ}$ of rotation towards the ipsilateral hip, turned the COS sign positive. For patients with an initially positive ISS at 0° , $5.9\pm1.9^{\circ}$ of tilt towards the outlet view, and $4.1\pm1.4^{\circ}$ towards the contralateral hip, negated the findings. For those initially negative, a mean of $7.4\pm3.6^{\circ}$ inlet tilt and a mean of $4.9\pm2.7^{\circ}$ ipsilateral rotation to turn positive. For PWS, those initially positive required a mean of $7.5 \pm 4.6^{\circ}$ of tilt towards the outlet view, and $6.1 \pm 3.7^{\circ}$ of rotation contralaterally to negate. Those with negative PWS required $5.7 \pm 2.9^{\circ}$ of inlet tilt and $7.8 \pm 5.3^{\circ}$ of rotation ipsilaterally to turn positive. DISCUSSION AND CONCLUSION:

Findings for COS, ISS, and PWS were all noted to change in findings with small degrees of tilt and rotation, averaging 5.5 to 7.2°. Close consideration should be given to pelvic position when assessing for positive findings of COS, ISS, and PWS, as differences in body positioning and weight-bearing status may play a significant role in clinical findings and treatment.



	Reviewer 1	Reviewer 2	Combined Mean (± SD)	Combined Range	% of total measurements unmeasurable within 15°
COS (+) at 0°	-4.8 = 2.5°	-5.4 ± 2.8°	-5.1 ± 2.6°	-11 to -1°	
COS (-) at 0°	6.7 ± 3.6*	8.0 ± 3.8*	7.4 = 3.6°	1 to 15°	
COS total	5.6±3.1°	6.6±3.4°	6.1 ± 3.2°	-11 to 15°	n=10/40 or 25%
ISS (+) at 0°	-6.2 ± 2.3°	$-5.6 = 1.5^{\circ}$	-5.9 ± 1.9°	-10 to -4°	
ISS (-) at 0°	6.6 ± 3.3°	8.1 ± 3.8°	7.4 ± 3.6°	2 to 15°	
ISS total	6.6±3.2°	6.9±3.3°	7.2 ± 3.4°	-10 to 15°	n=5/40 or 12.5%
PWS (+) at 0°	-7.4 ± 4.4°	-7.7 ± 5.0°	-7.5 ± 4.6°	-15 to 0	
PWS (-) at 0º	5.7 ± 1.2°	5.7 ± 1.2°	5.7 ± 2.9°	1 to 15°	
PWS total	7.0 ± 3.9°	7.3±4.8°	7.1±4.3°	-15 to 15°	n=6/40 or 15%

	Reviewer 1	Reviewer 2	Combined Mean (* SD)	Combined Range	% of total measurements unmeasurable within 15°
COS (+) at 0°	-6.1 ± 3.0°	-5.4 ± 1.9°	-5.8 ± 2.4°	-11 to -1°	
COS (-) at 0º	6.8±4.7*	7.6 ±5.5*	7.2 ± 4.9°	1 to 15°	
COS total	6.4 ± 3.6°	7.3 ± 4.6°	6.9 ± 4.2°	-11 to 15°	n=8/40 or 209
ISS (+) at 0°	-4.6 ± 1.3°	-3.6 ±1.3°	-4.1 ± 1.4°	-7 to -3°	
ISS (-) at 0°	6.0 ± 2.9°	5.9 ± 3.5°	5.9 ± 2.7°	1 to 10°	
ISS total	5.7 ± 2.6°	5.3 ± 2.6°	5.5 ± 2.6°	-7 to 10°	n=0 or 0%
PWS (+) at 09	-6.7 ± 3.8°	-5.5 ± 3.7°	-6.1 ± 3.7*	-15 to -1°	
PWS (-) at 0°	4.7 ± 2.5°	9.6±5.9°	7.8 ± 5.3°	1 to 15°	
PWS total	6.3±3.6*	6.6±4.5*	6.4 ± 4.1°	-15 to 15°	n=2/40 or 5%

Figure 1.4.E: Variations in tilt of standard AP Pelvis DRRs: (A) Neutral view of AP Pelvis (B) 15 degrees of tilt towards the inlet view of the pelvis (C) 15 degrees of tilt towards the left hip (D) 15 degrees of tilt towards the outlet view of the pelvis (E) 15 degrees of tilt towards the right bin