Pelvic Tilt and Rotation in Hip Radiographs Can Be Estimated Using Anatomical Landmarks to Avoid Incorrect Clinical Measurements

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Introduction: Although anterior-posterior pelvic radiographs are typically standardized, it can be difficult to position patients with cerebral palsy (CP) due to contractures of the hip. Thus, neutral hip radiographs are particularly difficult to achieve in the CP population. Radiographic measurements are routinely used for clinical decision-making and to evaluate progression of hip dysplasia in CP. Previous studies have not looked at the effects of improper positioning on clinical measurements used to treat the CP population. The purpose of this study was to use anatomical features within a non-pathological pelvis to predict the level of rotation and tilt in a hip radiograph and to establish the effect of incorrect positioning on clinical hip measurements used in treating CP hip dysplasia. We hypothesized that pelvic landmarks could be used to determine the degrees of tilt and rotation in a radiograph of a symmetric pelvis and that commonly used clinical hip measurements related to CP would be affected by deviations from neutral positioning.

Methods: A three-dimensional computed tomography (CT) scan was performed for a female cadaver pelvis. The pelvis donor was an 85-year-old woman who passed away from chronic obstructive pulmonary disease and congestive heart failure. Based on her medical history, the donor had mild scoliosis but no other musculoskeletal or hip pathologies. Digitally reconstructed radiographs (DRR) were generated from the CT scan using TeraRecon software. The pelvic CT was rotated 360°, in 1° increments from neutral, in both the sagittal (tilt) and transverse (rotation) planes independently.

Parameters assessing pelvic rotation included (a) the ratio of the obturator foramen widths (OF) and (b) the horizontal distance between the sacrococcygeal joint (SCJ) and the center of the superior edge of the pubic symphysis (PS); see Figure 1. Parameters assessing pelvic tilt included the vertical distances between (1) the SCJ and the center of the PS and (2) the inferior portion of the sacroiliac joints (SIJ) and center of the PS. Normalized parameters assessing pelvic tilt were the ratios of (3) measures 1 and 2, (4) measure 1 to pelvic width, and (5) measure 2 to pelvic width. Linear regression was applied to each parameter to determine correlation and goodness of fit with the degree of rotation or tilt. Nonlinear regression was used when the curve fit from linear regression was not ideal.

To validate each regression equation for radiographs that are both tilted and rotated, five DRRs were generated in random orientations. The predicted values for degrees of tilt and rotation were compared to the actual level of positioning.

Clinical radiographic measurements commonly used to assess the hip in CP were obtained from the DRRs at angles of -30°, -15°, 0°, 15°, and 30° for tilt and rotation. These measurements included femoral neck shaft angle (NSA) and acetabular depth ratio (ADR). Migration index was nearly zero in all views and could not be properly assessed, as expected from a subject without hip pathology.
Results: Rotation had a strong, linear correlation with the horizontal SCJ-PS distance (parameter b); see Figure 2. A similar strong linear correlation was found for tilt using the vertical SCJ-PS distance (parameter 1) and all three ratios (parameters 3, 4, and 5) (p<0.001). An exponential regression was applied to the OF ratio and rotation (parameter a) (p<0.001), and a polynomial regression was fit to the vertical SIJ-PS distance and tilt (parameter 2) (p<0.001). For predicting rotation, the SCJ-PS horizontal distance ($R^2=0.998$) and the OF ratio ($R^2=0.925$) both demonstrated strong correlations. The distance and ratio with the highest correlations for tilt were the SIJ-PS vertical distance ($R^2=0.999$) and the ratio of SCJ-PS vertical distance to pelvic width ($R^2=0.997$).

The absolute difference between the predicted and actual degrees of rotation or tilt was calculated for each parameter for all five validation x-rays. The rotation parameters SCJ-PS horizontal distance and OF ratio demonstrated an average difference of 0.94° and 2.2°, respectively. The distance and ratio with the smallest absolute difference for tilt were the SIJ-PS vertical distance (0.83°) and the SCJ-PS vertical distance to pelvic width ratio (1.0°).

The ADR and NSA measurements were affected by both rotation and tilt at all DRR positions sampled. ADR had the greatest percent change from the neutral value at 30° protracted rotation and 15° anterior tilt, while NSA had the largest percent change from neutral at 30° retracted rotation and 30° anterior tilt; see Figure 3.
Discussion: The results of this study provide evidence that the amount of pelvic tilt and rotation from the neutral position can be estimated in a hip radiograph utilizing anatomical features within a non-pathological pelvis. Both SCJ-PS horizontal distance and the OF ratio are good predictors for rotation, while tilt is best estimated using the SIJ-PS vertical distance and the ratio of SCJ-PS vertical distance to pelvic width. Both the ADR and NSA measurements were clearly affected by changes in radiograph positioning, with the greatest errors seen in ADR with rotation toward the observer of 30° (34.0% and 26.3% error for right and left sides, respectively). The strong correlation and excellent goodness-of-fit of these data to the regression models supports using the normalized (ratio) regression equations for rotation prediction in clinical radiographs despite using a single non-pathologic sample.

Significance: Since commonly used clinical measurements are affected by incorrect positioning in a pelvic radiograph, clinicians should take caution when making medical decisions for the treatment of children with CP based on measurements from rotated and/or tilted images. Measurements using pelvic landmarks to estimate the degree of rotation and/or tilt from neutral are accurate and can be used to determine when a radiograph is excessively displaced; thus, they should be repeated prior to making clinical measurements.

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References: