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● *Original Contribution*

ULTRASOUND QUANTIFICATION OF ACETABULAR ROUNDING IN HIP DYSPLASIA: RELIABILITY AND CORRELATION TO TREATMENT DECISIONS IN A RETROSPECTIVE STUDY

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Abstract—Currently, acetabular rounding is only subjectively assessed on ultrasound for developmental dysplasia of the hip. We tested whether acetabular rounding can be quantified reliably and can distinguish between hips requiring and not requiring treatment. Consecutive infants (n = 90) suspected of having dysplasia of the hip, seen at a pediatric orthopedic clinic, were separated into four diagnostic categories (normal, borderline but resolved, treated by brace, treated surgically). Acetabular rounding was assessed by semi-quantitative grade (0 = nil, 1 = mild, 2 = moderate, 3 = severe) by three observers and by direct measurement of acetabular radius of curvature (AROC) by two observers. Inter-observer reliability of rounding grade was poor (κ = 0.30–0.37). AROC had an inter-observer intra-class correlation coefficient of 0.84 and coefficient of variation of 29%–34%. Mean AROC was significantly higher for hips requiring treatment than for those not requiring treatment (3.3 mm vs. 1.6 mm, p = 0.007). AROC reliably quantifies an observation currently being made subjectively by radiologists and surgeons, and may be useful as a supplementary ultrasound index of dysplasia of the hip in future prospective studies. (E-mail: jjaremko@ualberta.ca) © 2015 World Federation for Ultrasound in Medicine & Biology.

Key Words: **Developmental dysplasia of the hip, α angle, Acetabular rounding, Reliability, Ultrasound.**

INTRODUCTION

Consistent detection of developmental dysplasia of the hip (DDH) is difficult. Barlow and Ortolani physical exam maneuvers in neonates miss up to 50% of cases of DDH (Clarke et al. 1989; Hansson and Jacobsen 1997) and are positive only when the hip is unstable (Bache et al. 2002). Two-dimensional ultrasound (2-D US) visualizes cartilaginous components of the newborn hip before ossification occurs near 6 mo of age (Harcke 1994, 2005) by static and dynamic techniques (American Institute of Ultrasound in Medicine (AIUM) 2009). A key component of DDH ultrasound is the coronal image in the Graf standard plane, containing a flat baseline (iliac wing), labrum, os ilium and os ischium (Graf 1984). The acetabular morphology is assessed on this image (American Institute of Ultrasound in Medicine (AIUM) 2009), combining the slope of the acetabular roof (termed *α angle*) and acetabular rounding, which is assessed visually, with greater rounding suggesting dysplasia. Interscan and inter-observer variation strongly influences the α angle (Bar-On et al. 1998).

Currently, late diagnoses of DDH occur with or without addition of ultrasound to clinical examination (Holen et al. 2002; Paton et al. 1999; Schwend et al. 2007) and can be associated with damage to the developing acetabulum if treatment is delayed even for just 3 mo (Azzopardi et al. 2011) or with premature osteoarthritis (OA). Meanwhile, more than 90% of "abnormalities" seen on initial ultrasound resolve spontaneously at follow-up, often including initially prominent acetabular rounding (Gwynne Jones et al. 2006).

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Clearly, there is room to improve current 2-D US assessment to better predict clinical outcomes.

One potentially helpful step would be to quantify acetabular rounding. Rounding is a visually obvious aspect of acetabular deformity that is currently only informally assessed by radiologists and pediatric orthopedic surgeons, with no numeric index of rounding available. Therefore, we developed semi-quantitative and quantitative indices of acetabular rounding and assessed their reliability. Because rounding is visually obvious and already subjectively assessed in treatment decisions, it is not possible to blind observers to its presence and it is difficult to isolate its clinical impact. We focused on creating novel indices to measure rounding and noted whether they were correlated to the decision to treat for hip dysplasia.

METHODS

Patients

This retrospective image and chart review was approved by our institutional ethics committee, with requirement for consent waived. Consecutive infants referred to a tertiary pediatric orthopedic clinic by primary care physicians or neonatologists for possible hip dysplasia with available ultrasound imaging and clinical follow-up averaging 32.2 mo (range: 11.0–86.6 mo) were included. We used the initial ultrasound of the hip of clinical concern in each patient (selecting one side randomly if concern was bilateral), saving the image most closely matching the Graf standard plane and removing patient identifying information. Age at ultrasound averaged 6.8 wk (range: 2 d to 8.1 mo). Hips were categorized from clinical records as: 0 = normal and patient discharged (n = 22); 1 = initially indeterminate, but hip normalized at follow-up without treatment (n = 5); 2 = dysplastic hip treated with Pavlik harness or similar external brace (n = 30); 3 = dysplastic hip treated by surgical reduction and Spica casting and/or osteotomy (n = 33).

Index measurement

We performed several reading exercises. Although acetabular morphology was unavoidably visually obvious in each image, for each reading exercise, the observers were blinded to each other's results, the clinical treatment group and calculated index values.

A semi-quantitative "rounding grade" in which the rounding of the acetabular margin was characterized as "minimal" (0), "mild" (1), "moderate" (2) or "severe" (3) was recorded for each hip by three observers: a board-certified pediatric radiologist with pediatric and musculoskeletal imaging fellowships (J.J.), an engineering graduate student preparing a thesis on hip dysplasia ultrasound (M.M.) and a medical student with 6 mo of dedicated hip ultrasound imaging experience (E.C.). Each observer repeated the exercise after a week's time to assess intra-observer variability.

Quantitative indices were also measured. Using custom software (MATLAB 2012, The MathWorks, Natick, MA, USA) on each image, users drew standard lines along the iliac wing (baseline), acetabular roof and femoral head diameter and five points tracing the acetabular curve. The acetabular curve was defined as the distance between the point where the bony margin began to curve away from iliac wing baseline (*A* in Fig. 1) and the point where its slope became equal to the acetabular roof line (*B* in Fig. 1). After B-spline smoothing, the arc length between *A* and *B* was calculated. Lines perpendicular to endpoints *A* and *B* and their intersection point (*O*) were generated. Acetabular radius of curvature (AROC) was the average distance between endpoints and intersection point (lines *OA* and *OB*, Fig. 1). Traditional coverage and α angle indices were also measured. Acetabular coverage was defined as the percentage of femoral head diameter located medial to the inferior projection of the baseline ($c1/c2$, Fig. 1) and α angle the angle between the iliac wing and acetabular roof (α, Fig. 1). Two observers, J.J. and M.M., each made all measurements on all 90 hips in random order. Each reader also repeated

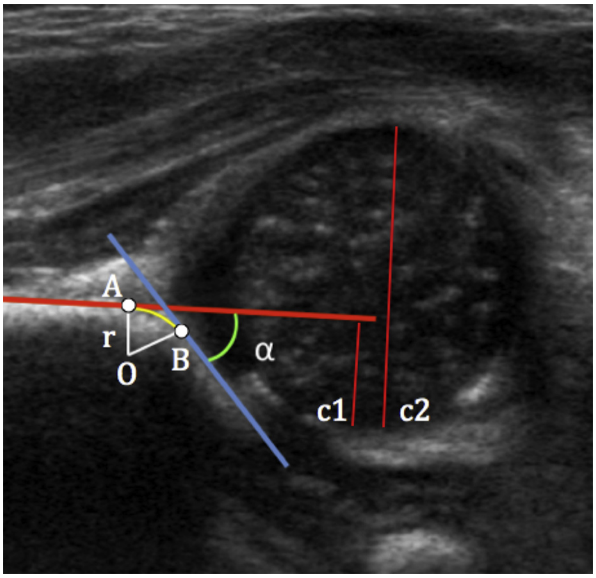

Fig. 1. Ultrasound tracings conducted by observers on custom MATLAB software (The MathWorks, Natick, MA, USA). The *red line* represents the iliac wing (baseline), and the *blue line*, the acetabular roof. Acetabular arc length was defined as the distance from *A* to *B*, and acetabular radius of curvature as the average distance between *O*–*A* and *O*–*B*. The ratio of lengths $c1/c2$ was used to calculate acetabular coverage, and the α angle is noted.