

# IMPROVING DIAGNOSTIC ACCURACY OF HIP DYSPLASIA MEASURES IN 2D ULTRASOUND SCANS OF INFANTS TO GUIDE DECISIONS REGARDING NEED FOR SURGERY

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## INTRODUCTION

Ultrasound (US) imaging is recommended for early detection of Developmental Dysplasia of the Hip (DDH) to guide decisions about possible surgical treatment [1]. However, a number of studies have raised concerns over the efficacy of US in early diagnosis [2, 3, 4, 5]. For example, Imrie et. al [3] found that around 29% of breech babies with a normal US at six weeks developed mild dysplasia by 4-6 months of age. A more reliable diagnostic test could reduce the incidence of missed early-diagnosis, and potentially avoid expensive surgical treatments often required after late diagnosis [6]. The main limitation of US-based diagnosis is sub-standard reliability of the primary dysplasia metric measurements: namely, the alpha and beta angles. Hakan et. al [4] reported poor intra-image repeatability - 4°-13° variability in the alpha angles and a 6°-19° variability in the beta angles. Another source of error is in the relative transducer-hip orientation during image acquisition; Jaremko et. al [5] determined that this can cause variability in the range of 19°-28° for the alpha angle measured on the same patient. In this paper, we present an automatic method for angle measurement from 2D US images, which we hope will improve the overall reliability of US-based DDH measurements by removing error due to subjective measurements. We hypothesize that improvements in reliability of dysplasia metric measurements will reduce the chances of missed early-diagnosis, and therefore reduce the need for later complex surgical treatments.

## METHODS

In this pilot study, we collected US scans (obtained as part of routine clinical care under appropriate institutional review board approval) from 16 hip examinations (5 patients) admitted to Children's & Women's Health Centre of British Columbia. Each of the patients underwent 1-3 sessions of US scans separated by ~1 month between each sessions of scans. Trained clinicians in the health centre measured the commonly used dysplasia metrics: the alpha and the beta angles; the alpha angle is formed by the acetabular roof and the vertical cortex of the ilium, whereas the beta angle is formed by the vertical cortex of the ilium and the triangular labral fibrocartilage. To determine these angles, we first extract the bone boundaries from the US image using an isotropic bone feature extraction technique recently reported by our group [7]. From the extracted bone boundaries, we determine the outline of the ilium in the US image. We perform Radon transform of three regions of interest (ROI) around the inferior edge of the ilium: a 30x30 pixel ROI towards the acetabular roof, a 30x30

pixel ROI towards the vertical cortex of the ilium, and a 30x30 pixel ROI towards the triangular labral fibrocartilage [8]. Peak responses of these Radon transforms correspond to the angles associated with the dominant structures ( $R_a$ ,  $R_i$ ,  $R_t$ ) in these regions, i.e., the acetabular roof, vertical cortex of the ilium, and triangular labral fibrocartilage. Finally, we find the alpha angle ( $R_i-R_a$ ) and the beta angle ( $R_t-R_i$ ).

## RESULTS

Figure 1 (a) shows an example of beta angle measurement from an US image collected in the coronal plane of an infant's femoral head. Figure 1 (b) shows angle measurements from a different US scan collected from the same patient on the same day. Although the two scans seem to portray similar beta angle values, manual measurements (measured by the same trained clinician, shown in white) differ by a total of  $22^\circ$ . This subjective error seems to be reduced with automatic measurements (shown in blue), where the beta angle values differ by only  $1^\circ$ .

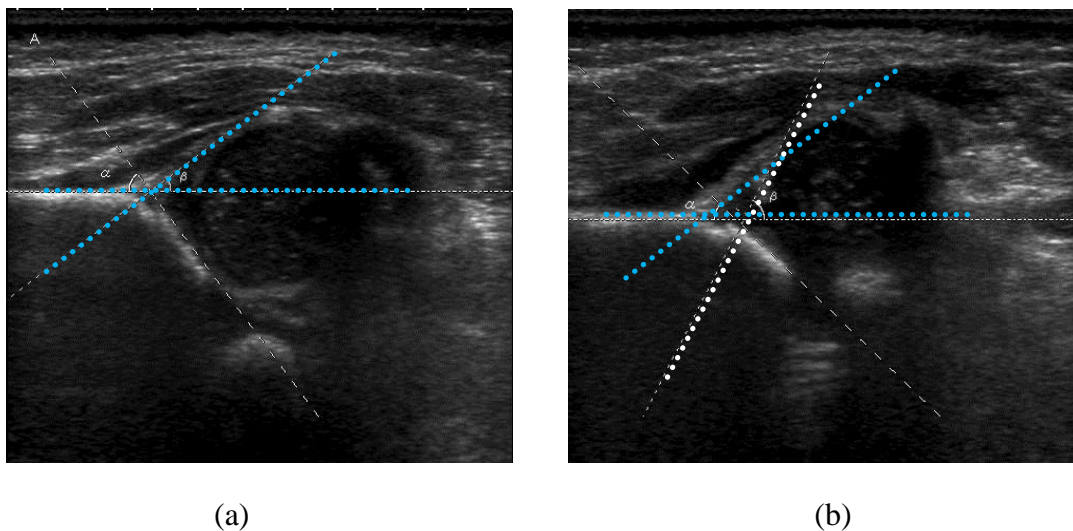


Fig.1. (a) and (b) are scans from the same patient in the same setting. In (a), both automatic and manual measurements of beta angles coincide where the line through the labrum goes through the superior side of the labrum; however, in (b), the manually-drawn line through the labrum goes through the inferior side of the labrum (marked in white). Our proposed automatic measurements of beta angles ( $36^\circ$  and  $37^\circ$ ) are much more consistent than manual measurements of beta angles ( $59^\circ$  and  $37^\circ$ ).

To evaluate the performance of our method, we compare our extracted angles with manually-extracted angles. We further evaluated our results in terms of Graf-classifications, i.e., type-1 ( $\alpha > 60^\circ$ , mature hip), type-2 ( $43^\circ < \alpha < 60^\circ$ , physiological immature hip) and type-3 ( $\alpha < 43^\circ$ , eccentric hip). We used maximum values of alpha for each of the Graf-classifications; the rationale for this is that a mature (normal) hip will have at least some relative hip-transducer orientations that show a high value of alpha, but eccentric hips do not have orientations that will show a high value of alpha. Figure 2 shows alpha and beta angle measurements together with the Graf-classification types. The mean discrepancies for alpha angle measurements and beta angle measurements were  $4.2^\circ$  (standard deviation of  $3.9^\circ$ ) and  $4.8^\circ$  (standard deviation of  $4.9^\circ$ ), respectively. In terms of the Graf-classification, our proposed method agrees with the manual measurement method in all cases except for only one patient (two US sessions of both hips- #13 to #16 in figure 2). Specifically, our proposed

method suggested that the patient had severe dysplasia whereas the manual measurement suggested only mild dysplasia. Later, the patient was confirmed to have severe dysplasia and was booked for surgery. This suggests the possibility that our proposed system may reduce the incidence of missed early detection of DDH.

Finally, for a B-mode US image of size 200x172, the extraction of alpha and beta angles took an average of 0.6s. All tests were run using MATLAB on a Xeon(R) 3.40 GHz CPU computer with 8GB RAM.

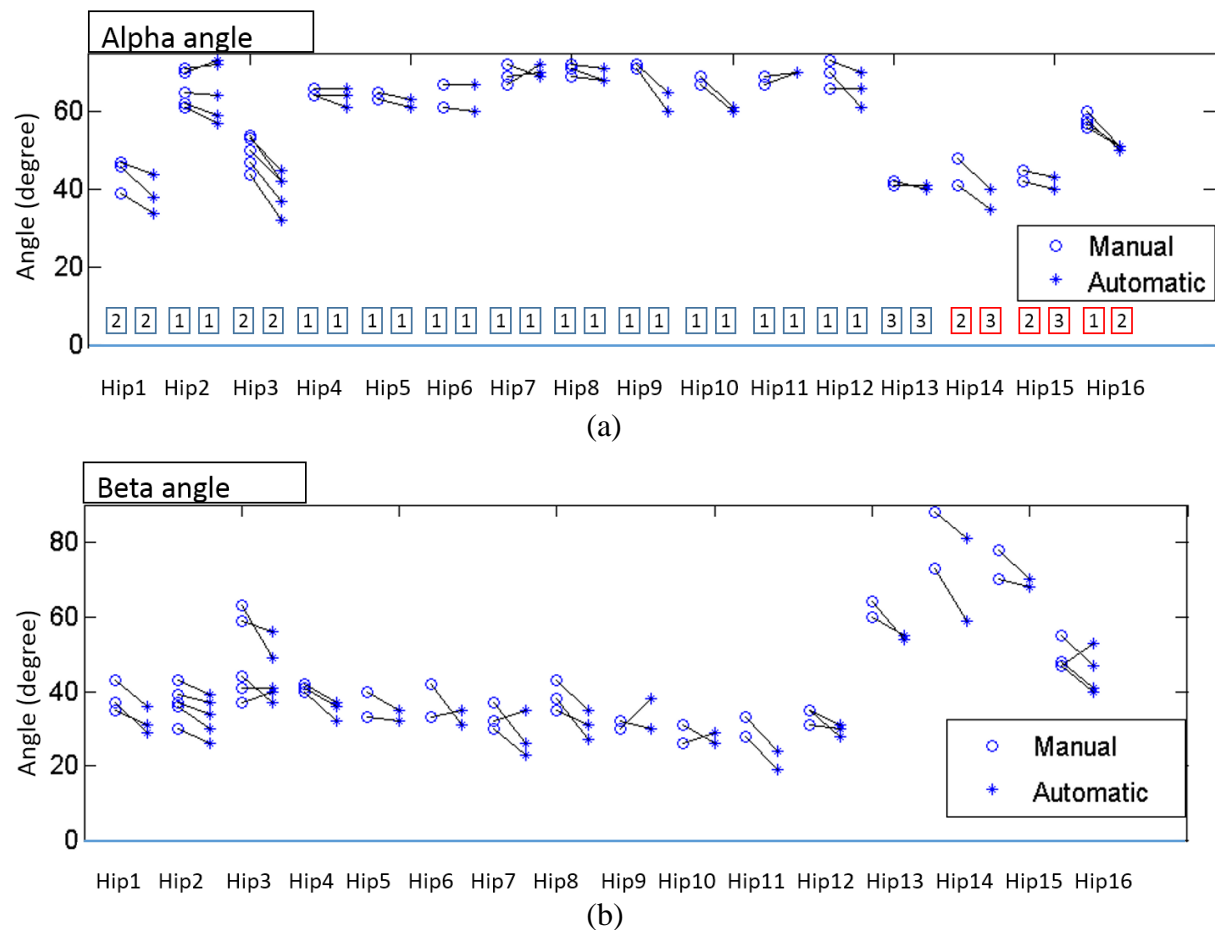


Fig.2. Manual and automatic measurements of alpha angles (a) and beta angles (b) for the diagnosis of the 16 hips (5 patients, 1 to 3 US sessions, both right and left hips). The boxes in (a) are the corresponding Graf-classification types.

## DISCUSSION

In this study, we have evaluated a novel and automatic method to extract dysplasia metrics from US images for the purpose of improving diagnostic accuracy for making surgical treatment decisions. The typical runtime of our algorithm is less than 1 second. We evaluated performance of the algorithm on 5 infants diagnosed with US scans for DDH. We found a  $5^\circ$  bias between manual and automatic measurements, with automatic measurements tending to be lower in value; the standard deviation in the discrepancy values was also relatively high at  $5^\circ$ . This suggests that there is considerable variability in the angle estimation process, which is typically done manually, which supports our contention that further work needs to be done to establish an accurate and repeatable measurement technique. Further, we found agreements

in the Graf-classification types in four out of the five patients. For the one patient where there were discrepancies in classification, later US sessions suggest the manual technique possibly missed the opportunity for early detection, in contrast to the automatic method which classified the patient as having evidence of severe dysplasia. Thus, such an automatic method may improve the reliability of current US-based DDH diagnosis techniques [2,3,4,5]. The primary limitation of this study is that we have done strictly an intra-image discrepancy analysis and have not compared the results with what could be considered a 'gold standard' reference. In future work, we plan to assess these indices on 3D images of the hip and assess the accuracy of proposed 2D and 3D-based automatic index calculation techniques against a 3D reference model.

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## DISCLOSURES

No relevant disclosures.

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