

Automated Analysis of 3D Hip Ultrasounds for Screening of Infantile Hip Dysplasia

Omar Shareef, Carter E Hall, Wudbhav N Sankar, Christopher J DeFrancesco

INTRODUCTION: While 2D ultrasound is commonly used for screening in developmental dysplasia of the hip (DDH), automatic segmentation of 3D ultrasound scans using artificial intelligence techniques could potentially be used to generate 3-dimensional models of the infantile hip. These could allow for comprehensive evaluation of anatomy and the identification of novel metrics associated with prognosis. But before this, any segmentation algorithm would have to be validated against historical metrics. Thus, the goal of this study was to introduce an automated segmentation algorithm for 3D ultrasound in DDH and show that it can reliably be used to re-create traditional ultrasound measurements.

METHODS: A retrospective sample of 151 infantile hip ultrasounds (performed for DDH screening or treatment monitoring) from a tertiary care children’s hospital were reviewed. Each ultrasound followed a local standard, including 2D cine files as well as 3D scans made using the Philips VL13-5 linear array transducer (3D transducer). For each scan, the historical standards for alpha angle and femoral head coverage (FHC) of the femoral head were calculated from a static central coronal slice with the hip in the flexed position, with the specific slice selected by the reader in the typical fashion. In a subsegment of the cases, the 3D scans (coronal orientation, hip flexed) were manually segmented to outline the femoral epiphysis and acetabulum. This was done by a fellowship-trained pediatric orthopaedic surgeon (37 scans, 1794 segmented slices). These segmentations were augmented using spatial and intensity transformations and used to train an nnUNet model—a deep learning-based segmentation framework—to perform accurate and reproducible 3D anatomical segmentation.

The nnUNet model was employed to infer segmentations of the femoral head and acetabulum across an additional 114 ultrasound volumes. Post-processing included 3D smoothing, hole filling, and morphological contour interpolation to refine anatomical structures. Automated curve-fitting algorithms employing contour smoothing and Random Sample Consensus (RANSAC) regression were then applied to calculate alpha angle and FHC from an identified slice in an automated fashion for each of the 114 volumes.

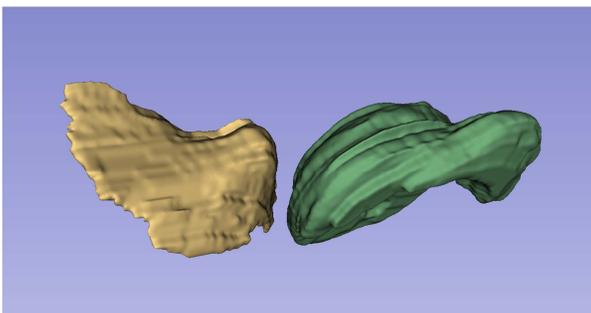
The automated values for alpha angle and FHC were then compared to the manual values to assess accuracy and agreement.

RESULTS:

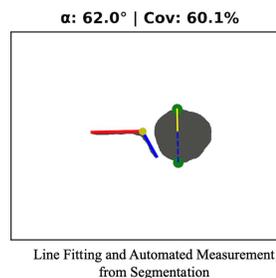
The mean absolute error between manually measured and automatically calculated alpha angles was 2.12° with a median error of 1.0° (paired t-test, $p = 0.338$). 92% of automated measurements were within 5° of the manual measurement. For FHC, the mean absolute error was 4.31% with a median error of 2.75% (paired t-test, $p = 0.199$). 90% of automated FHC measures were within 10% of the manual value.

DISCUSSION AND CONCLUSION:

These findings demonstrate that automated analysis of 3D ultrasound using a deep learning-based segmentation framework can produce alpha angle and femoral head coverage measurements in-line with manual measurements. This algorithm in itself has important implications for DDH screening and could be especially helpful given the clinical pressures facing pediatricians and orthopedists today. Additionally, the data presented support the validity of 3-dimensional models built upon the automated segmentations introduced here. Future analysis of such 3-dimensional models represents a new frontier for clinicians seeking to understand DDH and identify novel prognostic anatomical variables.



AI Generated Hip Model (Acetabulum = Yellow; Femoral Head = Green)



Line Fitting and Automated Measurement from Segmentation



Segmentation Overlay on 2D Ultrasound Slice