Applying Machine Learning in Obstetric Ultrasound

Novel 3D Ultrasound-based Metric to Assess the Fetal Skull: a pilot study

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Rationale

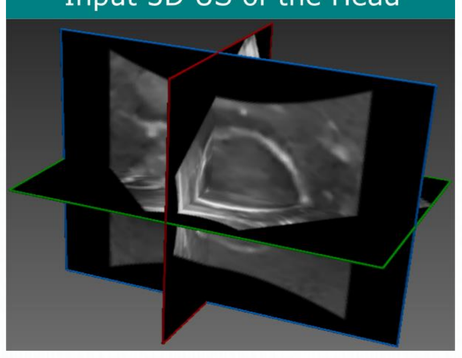
- Fetal 2D biometric measurements can be subject significant random error of up to +/- 11.1% for fetal biometry[1].
- Developments in deep learning and medical image analysis techniques can now provide more objective tools[2,3].
- This pilot evaluates the potential of a novel 3D cranial index (3DCI), derived automatically from 3D ultrasound (US) volumes.

Methods

- Retrospective study (NRES 14/LO/1806).
- 55 cases, mean GA 24.7 weeks (range 20-36).
- Philips Epiq 7G scanner with X6-1 xMatrix 3D probe.
- Novel 3DCI and map of volumetric shape analysis was compared with the 2D cephalic index (2DCI).
- 2DCI = BPD/OFD (biparietal/occipitofrontal diameters).

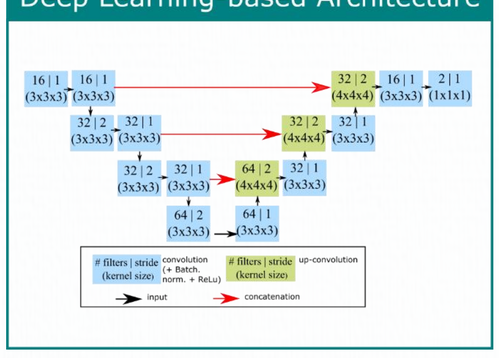
1 Automatic Skull Segmentation

Input 3D US of the Head



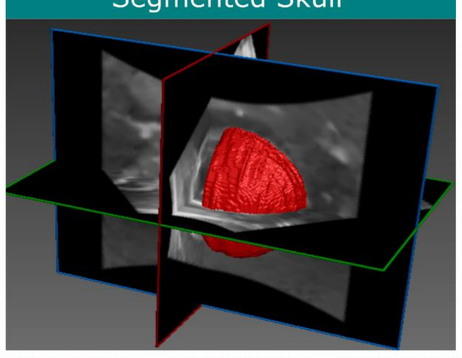
(i) 3D US volume manually acquired by sonographer.

Deep Learning-based Architecture



(ii) Unet 3D convolutional architecture.

Segmented Skull



(iii) Volumetric segmentation of the fetal skull.

Segmentation Workflow

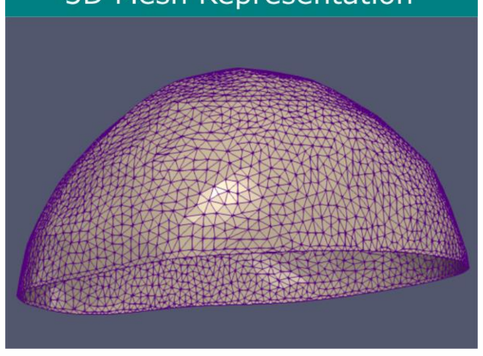
i The sonographer acquire a 3DUS volume of the head using a 3D volumetric probe (Philips X6-1 xMatrix).

ii Computer-based automatic segmentation of the skull using novel machine learning technology (computational time 2sec).

iii The system generates a 3D volume of the fetal skull.

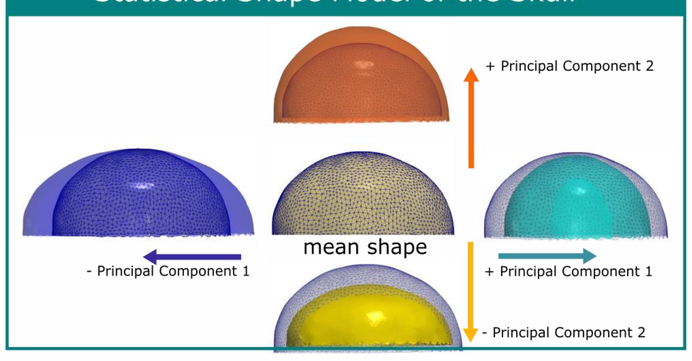
2 3D Shape Analysis

3D Mesh Representation



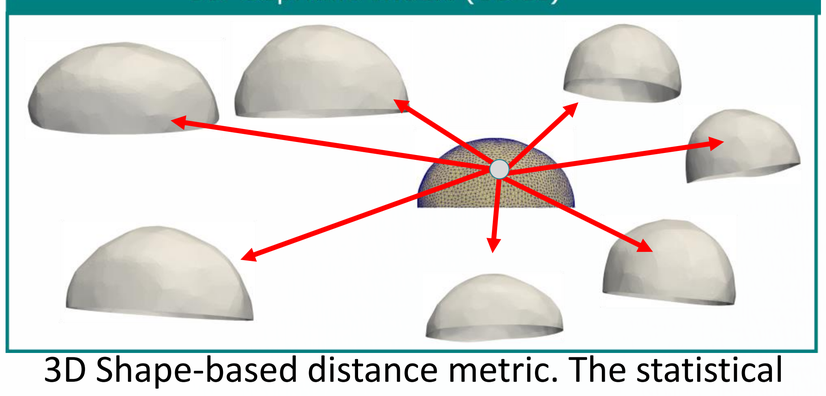
Each landmark represents the same specific anatomical skull location in all cases.

Statistical Shape Model of the Skull



Principal Component Analysis-based statistical model.

3D Cephalic Index (3DCI)



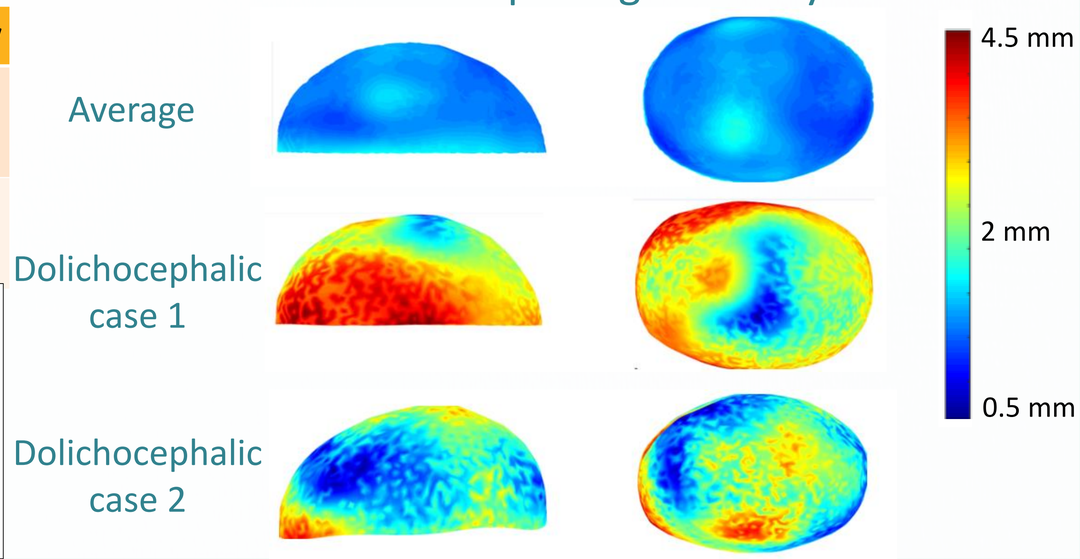
3D Shape-based distance metric. The statistical shape model allows definition of a 3D shape-based distance to the mean shape for each patient.

3 Diagnosis

Method (5th percentile)	Case 1	Case 2	Accuracy	Specificity	Sensitivity
Classic 2D CI (>/= 0.68)	0.75 TP	**0.61 FN**	90%	50%	92%
New 3D CI (>/= 3.2)	3.3 TP	3.4 TP	98%	100%	98%

Morphological maps (right):
Patient specific head deformation maps of the fetal skull showing the sagittal and axial view of the distance map to the expected mean head shape (mm). 2 abnormal cases were identified and verified by a fetal medicine specialist (the remainder were of normal shape).

Detailed Morphological Analysis



Key Findings & Clinical Applications:

- The new automatic and objective US-based 3D biometric has the potential to provide rapid assessment of the fetal head shape, reducing sonographer subjectivity.
- 2 cases of dolichocephaly were accurately identified from the 55 cases (and a false negative from the BPD-based 2DCI).
- The patient-specific morphological map of the fetal skull could be used as a visual and quantitative record of the progression and severity of skull shape anomalies.

Future work:

- Larger study of the new 3DCI tool, including a range of abnormal cases, to include: microcephaly, dolichocephaly, and suspected craniosynostosis.
- Development of automatic segmentation and objective quantification of soft tissue facial dysmorphic features, including: hypo/hypertelorism, low set ears, micrognathia, flattened profile (syndromic).

References:
1.Sarris I., et al, "Intra- and interobserver variability in fetal ultrasound measurements," Ultrasound Obstet. Gynecol., 39(3), 2012.
2.Namburete A. and Noble A., "Fetal cranial segmentation in 2D ultrasound images using shape properties of pixel clusters", ISBI, 2013.
3.Cerrolaza J.J., et al, "Fetal skull segmentation in 3D ultrasound via structured geodesic random forest", Int. Workshop on Fetal and Infant Image Analysis, 2017.

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