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 to 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).

**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.

**References:**

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**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.

**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.

**Diagnosis**

<table>
<thead>
<tr>
<th>Method (5th percentile)</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Accuracy</th>
<th>Specificity</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classic 2D CI ($&gt;/=0.68$)</td>
<td>0.75 TP</td>
<td>0.61 FN</td>
<td>90%</td>
<td>50%</td>
<td>92%</td>
</tr>
<tr>
<td>New 3DCI ($&gt;/=3.2$)</td>
<td>3.3 TP</td>
<td>3.4 TP</td>
<td>98%</td>
<td>100%</td>
<td>98%</td>
</tr>
</tbody>
</table>

**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**

**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).