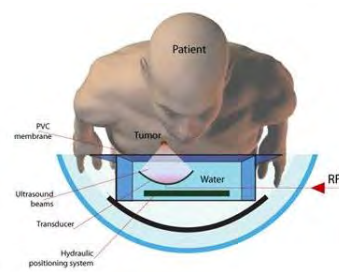
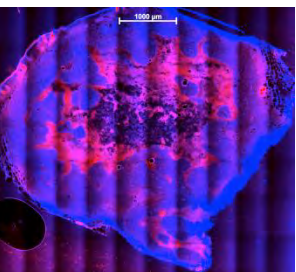




# Ultrasound Image Analysis Of Fetal Heads and Brains

Professor Alison Noble

Institute of Biomedical Engineering, University of Oxford, UK  
March 8, 2016



My research has been shaped by the engineering challenges posed by healthcare need.....



Collaborators define the protocols (input) and diagnostic criteria (output) for analytics we develop



# INTERGROWTH-21<sup>st</sup> Study

## The likeness of fetal growth and newborn size across non-isolated populations in the INTERGROWTH-21<sup>st</sup> Project: The Fetal Growth Longitudinal Study and Newborn Cross-Sectional Study

Jean-Marie Le Douarin, Ana Pappargolis, Ryan Peng, Eric O Olorun, Leticia Chahin Lima, Fernando C Barros, Ann Lomner, Maria Carolina Yamani A Valle, Leticia Barros, Michael G Gravens, David Callaway, Marina Maria Pereira, Harvey de Toledo, Judith Melillo, Cassia Vitorino, Zulfiqar A Bhutta, Stephen Kennedy, for the International Fetal and Newborn Growth Consortium for the 21<sup>st</sup> Century (INTERGROWTH-21<sup>st</sup>)

### Summary

**Background** Large differences exist in size at birth and in rates of maturation, disease, the environment, and genetics on these differences are often used to assess fetal growth and newborn international standards for assessing growth in infants and child. Despite, our aim was to assess fetal growth and newborn size in which the health and nutrition needs of mothers were met and:

**Methods** For this study, fetal growth and newborn size were studied using prospectively measured markers and the same methods, on Longitudinal Study (FGLS), we studied educated, affluent, healthy at low risk of intrauterine growth restriction. The primary mark fetal crown-rump length at less than 14 weeks and 9 days to 14 weeks and 9 days to 42 weeks and 9 days of gestation, one population-based Newborn Cross-Sectional Study (NCS5), we study geographically defined urban populations with the same or large NCS5 cohort, we selected an FGLS-like subpopulation to:

**Findings** Between May 14, 2009, and Aug 2, 2013, we enrolled 461 NCS5, 20 486 (34–6%) women met the FGLS eligibility criteria. Various component analysis, only between 1–9% and 3–5% of circumference, and newborn length could be attributed to 1) analysis to 10 gestational age windows (from 9 weeks and 0 (24 compartments), only size was marginally higher than 9–5.5% analysis, including individual population in sum from the pool no noticeable effect on the 3rd, 5th, 8th, and 9th centile derived of centiles at birth with those in the WHO Multicenter Growth study newborn babies in this study was 49–5 cm (SD 1–9), which (1–9) and the NCS5 derived FGLS-like subpopulation (49–5 cm).

**Interpretation** Fetal growth and newborn length are similar; maternal and health needs are met, and environmental context are in strong agreement with those of the WHO MGRS. The international standards for growth from conception to new childhood WHO MGRS standards.

### Funding Bill & Melinda Gates Foundation.

**Introduction** Many populations are exposed to adverse environmental conditions and inadequate nutritional intakes that affect fetal growth. Therefore, findings of an increased number of newborn babies small for gestational age in these geographical areas and in immigrants in less centrally disadvantaged populations in developed

[www.thelancet.com/gate/openaccess](http://www.thelancet.com/gate/openaccess) Published online July 19, 2014

### Articles

## International standards for newborn weight, length, and head circumference by gestational age and sex: the Newborn Cross-Sectional Study of the INTERGROWTH-21<sup>st</sup> Project

Jean-Marie Le Douarin, Cassia Vitorino, Eric O Olorun, Leticia Chahin Lima, Fernando C Barros, Ann Lomner, Ana Pappargolis, Maria Carolina Yamani A Valle, Leticia Barros, Michael G Gravens, Ryan Peng, Harvey de Toledo, David Callaway, Zulfiqar A Bhutta, Stephen Kennedy, for the International Fetal and Newborn Growth Consortium for the 21<sup>st</sup> Century (INTERGROWTH-21<sup>st</sup>)

### Summary

**Background** In 2006, WHO published international growth standards for infants and children up to age 5 years on the basis of recommendations from a WHO expert committee. Using the same standards and conceptual approach, the Fetal Growth Longitudinal Study (FGLS), part of the INTERGROWTH-21<sup>st</sup> Project, aimed to develop international growth and size standards for fetuses, newborn infants, and:

**Methods** INTERGROWTH-21<sup>st</sup> is a population-based study geographically defined urban populations. These groups of mothers were met, adequate prenatal care was given to growth. As part of the Newborn Cross-Sectional Study measured weight, length, and head circumference in all for pregnancy and the perinatal period. To construct the standard in addition to the underlying population characteristics at low risk of impaired fetal growth (labelled the NCS5) per centiles of gestational age using crown-rump length had care scanned between 14 weeks and 24 weeks or less of gestation within 12 h of birth by identically trained anthropometric technicians assuming a skewed distribution were used.

**Findings** We identified 20 486 (35%) eligible women from May 14, 2009, and Aug 2, 2013. We calculated sex-specific head circumference for gestational age at birth. The 4<sup>th</sup> percentiles of the 3rd, 5th, 8th, 9th, and 9th centile curves:

**Interpretation** We have developed, for routine clinical newborn size that are intended to complement the WHO multichannel populations.

### Funding Bill & Melinda Gates Foundation.

**Introduction** In 1994, the main WHO expert committee on the use and interpretation of anthropometry recommended the use of international standards in assess anthropometric measures. To implement these recommendations for infants and children, WHO initiated the Multicenter Growth Reference Study (MGRS). In 2006, this study generated WHO Child Growth Standards for children younger than 5 years, which are now accepted worldwide. Two characteristics made the WHO MGRS unique and unprecedented: the study included populations from Brazil, Ghana, India, Norway, Oman, and the USA, and it used a prospective approach to select the study population (population of only urban and infants from mothers who did not smoke and who had minimal environmental constraints on growth). Aiming to complement the WHO MGRS, in 2006 the International Fetal and Newborn Growth Consortium for

[www.thelancet.com/gate](http://www.thelancet.com/gate) Published online July 19, 2014

### Articles

## International standards for fetal growth based on serial ultrasound measurements: the Fetal Growth Longitudinal Study of the INTERGROWTH-21<sup>st</sup> Project

Ana Pappargolis, Eric O Olorun, Douglas G Akman, Tulin Tubulu, Leticia Chahin Lima, Anel Arabi, Yousang Ju, Leticia Barros, Zulfiqar A Bhutta, Stephen Kennedy, Jean-Marie Le Douarin, for the International Fetal and Newborn Growth Consortium for the 21<sup>st</sup> Century (INTERGROWTH-21<sup>st</sup>)

### Summary

**Background** In 2006, WHO produced international growth standards for infants and children up to age 5 years on the basis of recommendations from a WHO expert committee. Using the same standards and conceptual approach, the Fetal Growth Longitudinal Study (FGLS), part of the INTERGROWTH-21<sup>st</sup> Project, aimed to develop international growth and size standards for fetuses.

**Methods** The multicentre, population-based FGLS assessed fetal growth in geographically defined urban populations in eight countries, in which most of the health and nutritional needs of mothers were met and adequate prenatal care was provided. We used ultrasonography to take fetal anthropometric measurements prospectively from 14 weeks and 0 days of gestation until birth to a cohort of women with adequate health and nutritional status who were at low risk of intrauterine growth restriction. All women had a reliable estimate of gestational age confirmed by ultrasonographic measurements of fetal crown-rump length in the first trimester. The two primary ultrasonographic measures of fetal growth—head circumference, biparietal diameter, abdominal circumference, and femur length—were obtained every 5 weeks (within 1 week either side) from 14 weeks to 42 weeks of gestation. The bias owing to error for the five measures were selected using second-degree fractional polynomials and further modelled in a multilevel framework to account for the longitudinal design of the study.

**Findings** We screened 13 108 women commencing antenatal care at less than 14 weeks and 0 days of gestation, of whom 4617 (35%) were eligible. 4321 (93%) eligible women had pregnancies without major complications and delivered live singletons without congenital malformations (the analytic population). We documented very low maternal and perinatal mortality and morbidity, confirming that the participants were at low risk of adverse outcomes. For each of the five fetal growth measures, the mean differences between the observed and smoothed centiles for the 3rd, 5th, and 9th centiles, respectively, were small: 2.25 mm (SD 1.9), 0.40 mm (1.9), and -2.69 mm (1.2) for head circumference; 0.43 mm (0.9), -0.45 mm (0.8), and -0.84 mm (1.6) for biparietal diameter; 0.43 mm (1.2), 0.64 mm (1.1), and -1.46 mm (1.3) for occipitofrontal diameter; 2.99 mm (1.1), 0.25 mm (2.2), and -4.22 mm (1.7) for abdominal circumference; 0.42 mm (0.8), 0.43 mm (0.8), and -0.45 mm (0.8) for femur length. We calculated the 3rd, 5th, 8th, 9th, and 9th centile curves according to gestational age for these five ultrasonographic measures, representing the international standards for fetal growth.

**Interpretation** We recommend these international fetal growth standards for the clinical interpretation of routinely taken ultrasonographic measurements and for comparisons across populations.

### Funding Bill & Melinda Gates Foundation.

**Introduction** Screening for deviations in fetal growth is one of the main purposes of antenatal care. Some of the biomarkers assessed to do so can accurately predict fetal growth restriction; however, screening relies on routine measurements of maternal fundal height, complemented by ultrasonographic measures of fetal size to women with pregnancy complications or with a relevant history of clinical evidence of fetal growth restriction. Despite the widespread use of ultrasonographic worldwide, concerns have been expressed about the low detection rates of abnormal fetal growth in routine practice. A

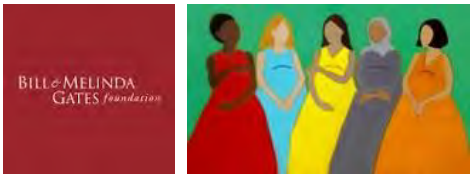
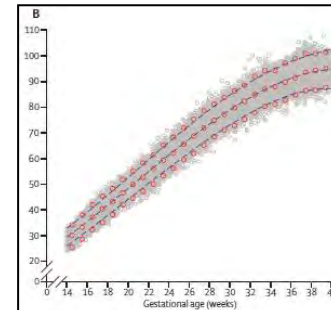
when used mostly in high risk subpopulations. However, these observations should be interpreted with caution in view of the large number of locally derived reference standards similar to the standards used for monitoring intra-growth. Additionally, large variation is seen in the cutoff points (eg, 3rd, 5th, or 10th centile) used to establish whether fetal growth is abnormal, even within the same population or region. The use of such a range of cutoff points in clinical decision making about fetal growth patterns inevitably leads to diagnostic confusion, difficulties comparing outcomes across

[www.thelancet.com/gate](http://www.thelancet.com/gate) Published online July 19, 2014

# International biometry charts for optimal fetal growth to improve pregnancy care worldwide – a reference of care; Lancet 2014a-c

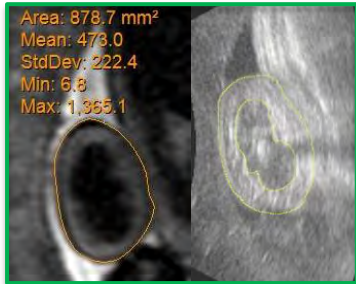
### Articles

### Articles

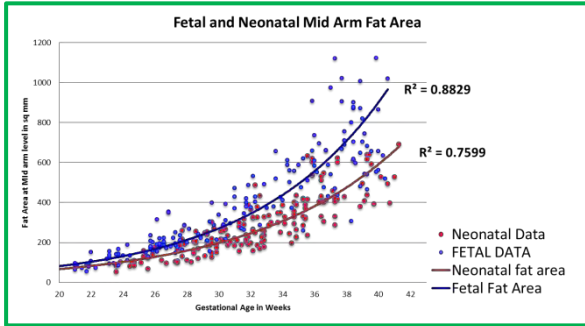


# Perinatal Monitoring – Womb-to-Cot Imaging

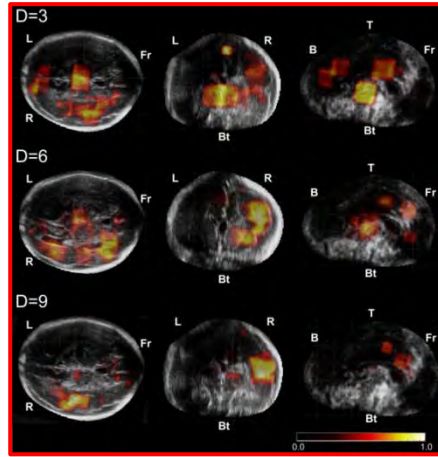
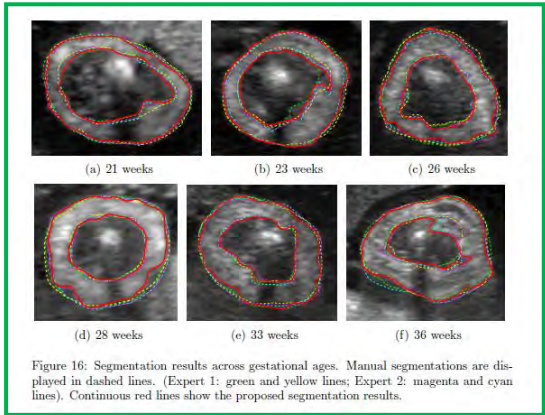
MR-US fetal limb fat correlated



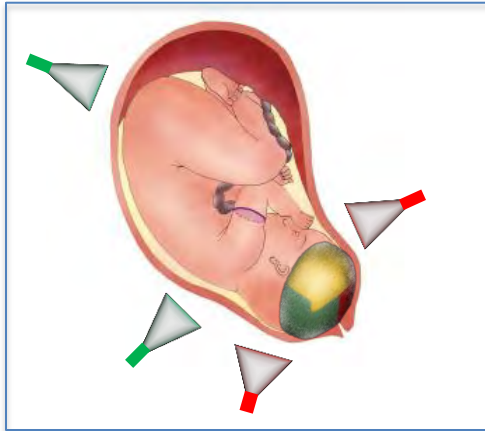
Womb-to-cot nutritional assessment: US fetal-neonatal limb fat correlated



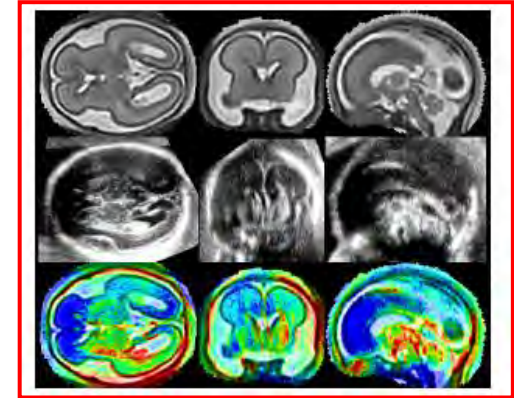
Automatic fetal limb measurement reliable across GA



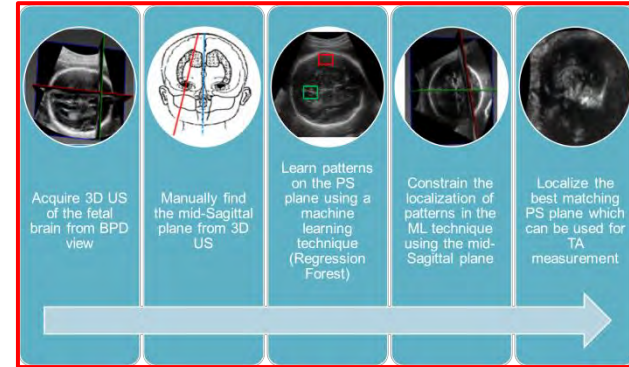
3D sonographic patterns predict GA better than biometry



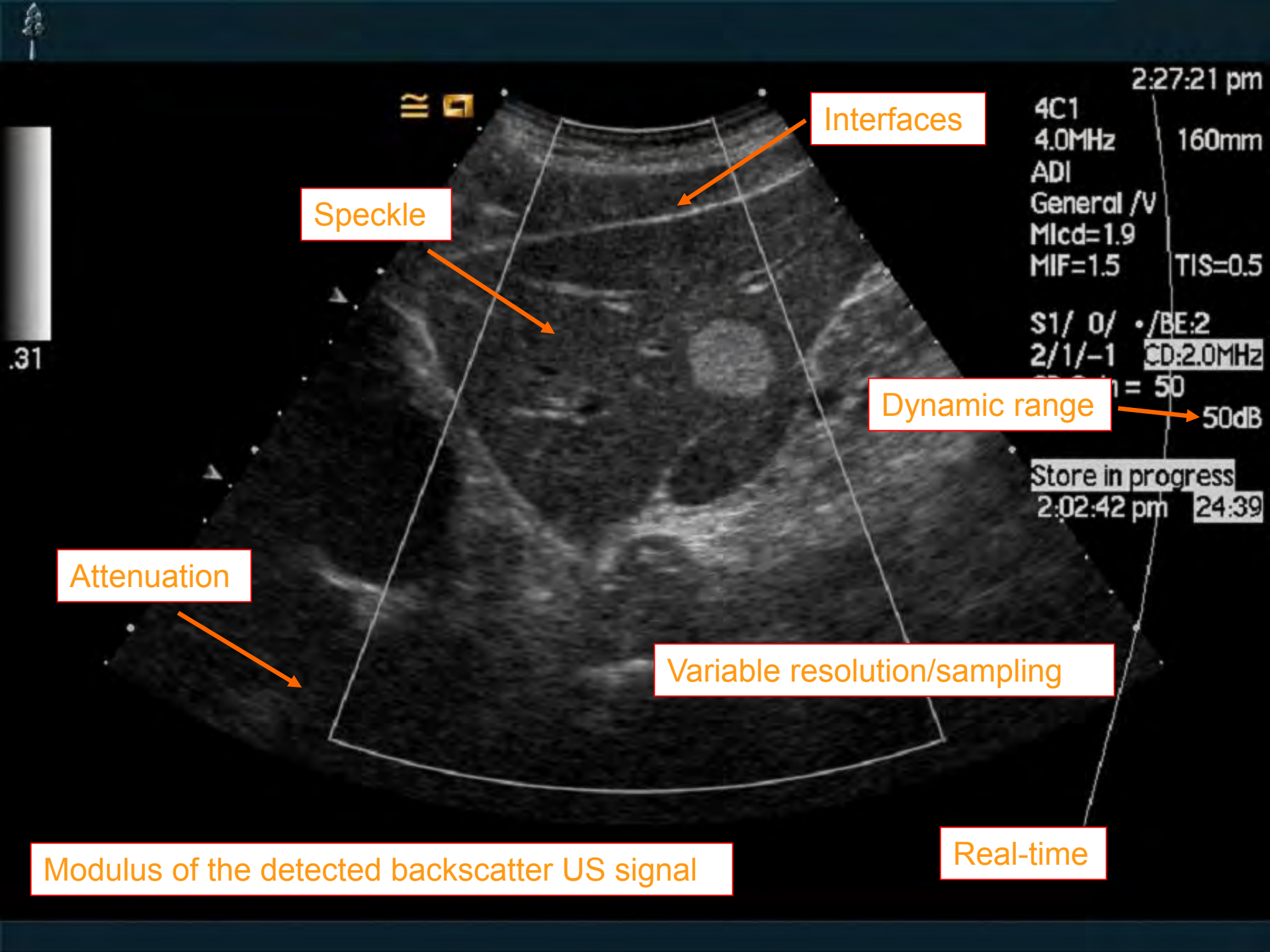
MR-US fetal neuroimage alignment



Womb-to-cot neurosonography: Automatically finding 2D fetal planes in 3D volumes for correlation with 2D neonatal brain scans



3D fetal shape analysis for womb-to-cot assessment of syndromes



2:27:21 pm

Interfaces

Speckle

Dynamic range

Attenuation

Variable resolution/sampling

Modulus of the detected backscatter US signal

Real-time

4C1  
4.0MHz  
160mm  
ADI  
General /V  
Mlcd=1.9  
MIF=1.5  
TIS=0.5  
S1/ 0/ •/BE:2  
2/1/-1  
CD: 2.0MHz  
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50dB  
Store in progress  
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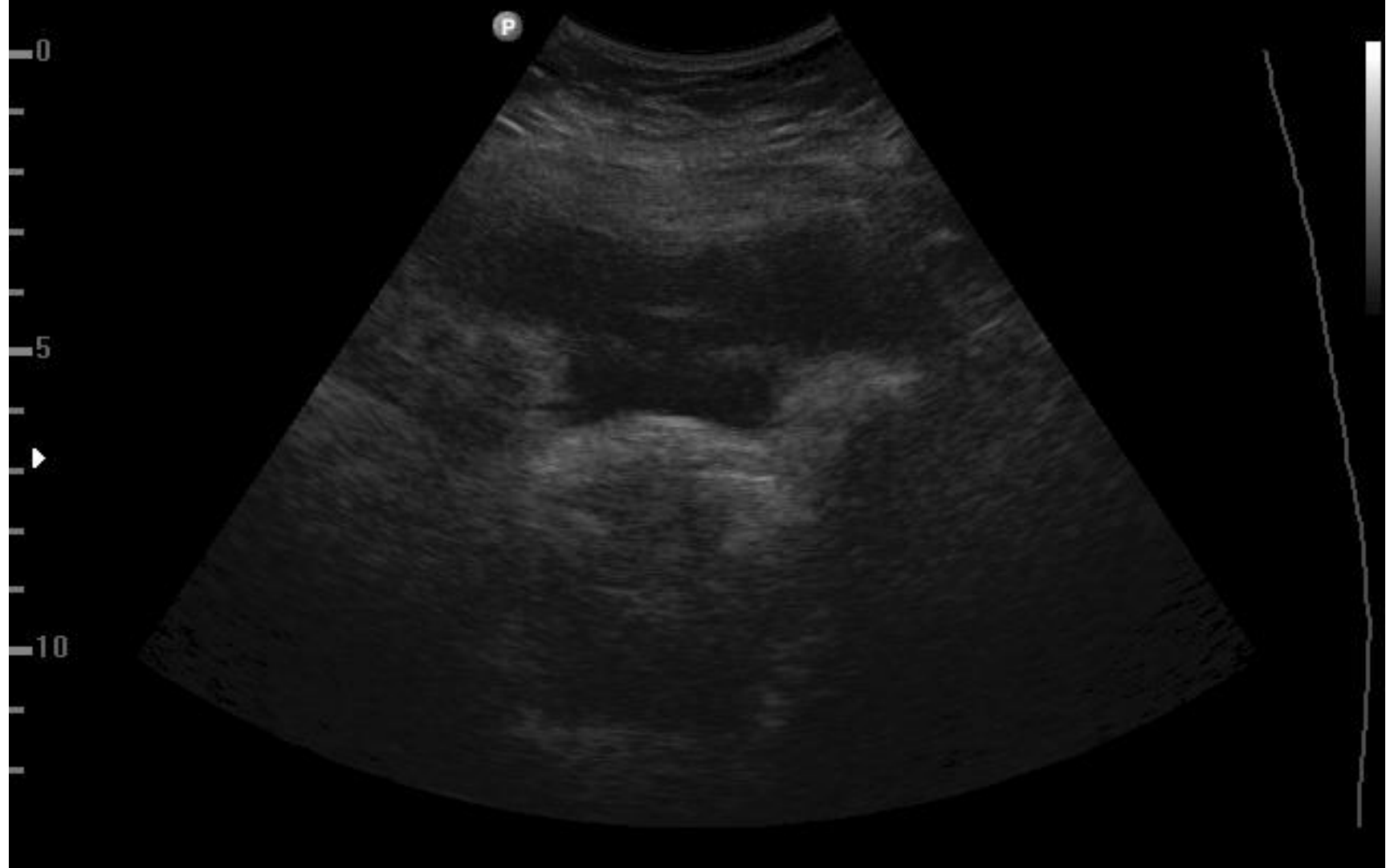
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M11131 /

V7-3/OB Gen/FPS32D/13.0cm/HGen./MI0.95/TIb0.2/15-02-2013 15:18:23

[2D] G34/110dB/PER8/P90/HAR/FSI 3

SNR



# INTERGROWTH-21<sup>st</sup> Study

## The likeness of fetal growth and newborn size across non-isolated populations in the INTERGROWTH-21<sup>st</sup> Project: the Fetal Growth Longitudinal Study and Newborn Cross-Sectional Study

Joshi V, Leão Chibrikova, Cesar G Vizcaro, Eric O Olorun, Doris Bertra, Dag G Aremas, Anu Lerner, Arif Pappagopal, Mona Gharib, Yannis Agita, Michael G Gravens, Doug Callames, Marina Ana Peres, Harpreet Singh, Judith Mills, Cass G Vinton, Zulfiqar A Durrani, Stephen K Ennsley, for the International Fetal and Newborn Growth Consortium for the 21<sup>st</sup> Century (INTERGROWTH-21<sup>st</sup>)

**Summary**  
Background Large differences exist in size at birth and in rates of maturation, disease, the environment, and genetics on these differences are often used to assess fetal growth and newborn international standards for assessing growth in infants and child. Practice, our aim was to assess fetal growth and newborn size in which the health and nutrition needs of mothers were met and:

**Methods** For this study, fetal growth and newborn size were assessed using prospectively measured and the same methods, on longitudinal study (FGLS), we studied educated, affluent, healthy at low risk of intrauterine growth restriction. The primary mark fetal crown-rump length at less than 14 weeks and 9 days, 14 weeks and 9 days to 40 weeks and 9 days of gestation, one population-based Newborn Cross-Sectional Study (NCS5), we studied geographically defined urban populations with the same or large NCS5 cohort, we selected an FGLS-like subpopulation to:

**Findings** Between May 14, 2009, and Aug 2, 2013, we enrolled 461 NCS5, 20 486 (34–6%) women met the FGLS eligibility criteria. Various component analysis, only between 1–9% and 3–5% of circumference, and newborn length could be attributed to 1) analysis to 10 gestational age windows (from 9 weeks and 0 (I24 compartments), only one was marginally higher than 9–5.5% analysis, including individual population in sum from the pool no noticeable effect on the 3rd, 5th, 9th, and 9th centile derived of centiles at birth with those in the WHO Multicenter Growth standards newborn babies in this study was 49–5 cm (SD 1–9), which (I–9) and the NCS5 derived FGLS-like subpopulation (9–1 cm):

**Interpretation** Fetal growth and newborn length are similar: nutritional and health needs are met, and environmental context are in strong agreement with those of the WHO MGRS. The international standards for growth from conception to new childhood WHO MGRS standards.

**Funding** Bill & Melinda Gates Foundation.

**Introduction**  
Many populations are exposed to adverse environmental conditions and inadequate nutritional intakes that affect fetal growth. Consistent findings of an increased number of newborn babies per gestational age in these geographical areas and in immigrants in less centrally homogeneous populations in developed countries

[www.thelancet.com/journal/2014/09/04](http://www.thelancet.com/journal/2014/09/04)

## International standards for newborn weight, length, and head circumference by gestational age and sex: the Newborn Cross-Sectional Study of the INTERGROWTH-21<sup>st</sup> Project

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**Summary**  
Background In 2006, WHO published international growth standards for infants, newborn infants, and:

**Methods** INTERGROWTH-21<sup>st</sup> is a population-based 1) eight geographically defined urban populations. These groups of mothers were met, adequate maternal care was provided. As part of the Newborn Cross-Sectional Study measured weight, length, and head circumference in all 1) for pregnancy and the perinatal period. To construct the meeting (in addition to the underlying population characteristics at low risk of impaired fetal growth (labelled the NCS5) per centiles of gestational age using crown-rump length (we scanned between 14 weeks and 24 weeks or less of gestation within 12 h of birth by identical trained anthropometric personnel assuming a skewed 1) distribution were used:

**Findings** We identified 20 486 (35%) eligible women from May 14, 2009, and Aug 2, 2013. We calculated sex-specific head circumference for gestational age at birth. The 1) present the 3rd, 5th, 50th, 90th, and 97th centile curves:

**Interpretation** We have developed, for routine clinical 1) newborn size that are intended to complement the WHO multichannel populations.

**Funding** Bill & Melinda Gates Foundation.

**Introduction**  
In 1994, the main WHO expert committee on the use and interpretation of anthropometry recommended the use of international standards to assess anthropometric measures.<sup>1</sup> To implement these recommendations for infants and children, WHO initiated the Multicenter Growth Reference Study (MGRS).<sup>2</sup> In 2006, this study generated WHO Child Growth Standards for children younger than 5 years, which are now accepted worldwide.<sup>3</sup> Two characteristics made the WHO MGRS unique and unprecedented: the study included populations from Brazil, Ghana, India, Norway, Oman, and the USA, and it used a prospective approach to select the study populations (population of only urban, sedentary mothers who did not smoke and who had minimum environmental constraints on growth).<sup>4</sup>

[www.thelancet.com/journal/2014/09/04](http://www.thelancet.com/journal/2014/09/04)

## International standards for fetal growth based on serial ultrasound measurements: the Fetal Growth Longitudinal Study of the INTERGROWTH-21<sup>st</sup> Project

Joshi V, Leão Chibrikova, Cesar G Vizcaro, Eric O Olorun, Doris Bertra, Dag G Aremas, Anu Lerner, Arif Pappagopal, Mona Gharib, Yannis Agita, Michael G Gravens, Doug Callames, Marina Ana Peres, Harpreet Singh, Judith Mills, Cass G Vinton, Zulfiqar A Durrani, Stephen K Ennsley, for the International Fetal and Newborn Growth Consortium for the 21<sup>st</sup> Century (INTERGROWTH-21<sup>st</sup>)

**Summary**  
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**Methods** The multicentre, population-based FGLS assessed fetal growth in geographically defined urban populations in eight countries, in which most of the health and nutritional needs of mothers were met and adequate maternal care was provided. We used ultrasonography to take fetal anthropometric measurements prospectively from 14 weeks and 0 days of gestation until birth to a cohort of women with adequate health and nutritional status who were at low risk of intrauterine growth restriction. All women had a reliable estimate of gestational age confirmed by ultrasound measurements of fetal crown-rump length in the first trimester. The two primary ultrasound measures of fetal growth—head circumference, biparietal diameter, occipitofrontal diameter, abdominal circumference, and femur length—were obtained every 5 weeks (within 1 week either side) from 14 weeks to 42 weeks of gestation. The bias being cast on for the five measures were selected using second-degree fractional polynomials and further modelled in a multilevel framework to account for the longitudinal design of the study.

**Findings** We screened 13 108 women commencing antenatal care at less than 14 weeks and 0 days of gestation, of whom 4617 (35%) were eligible. 4321 (94%) eligible women had pregnancies without major complications and delivered live singletons without congenital malformations (the analytic population). We documented very low maternal and perinatal mortality and morbidity, confirming that the participants were at low risk of adverse outcomes. For each of the five fetal growth measures, the mean differences between the 50th and 90th centiles for the 3rd, 5th, and 97th centiles, respectively, were small: 2.25 mm (SD 0.9), 0.40 mm (1.0), and -2.49 mm (1.2) for head circumference; 0.43 mm (0.9), -0.45 mm (0.8), and -0.84 mm (1.0) for biparietal diameter; 0.43 mm (1.2), 0.64 mm (1.1), and -1.45 mm (1.3) for occipitofrontal diameter; 2.99 mm (1.1), 0.25 mm (1.2), and -4.22 mm (1.7) for abdominal circumference; 0.42 mm (0.8), 0.43 mm (0.8), and -0.45 mm (0.8) for femur length. We calculated the 3rd, 5th, 50th, 90th, 95th and 97th centile curves according to gestational age for these ultrasound measures, representing the international standards for fetal growth.

**Interpretation** We recommend these international fetal growth standards for the clinical interpretation of routinely taken ultrasound measurements and for comparisons across populations.

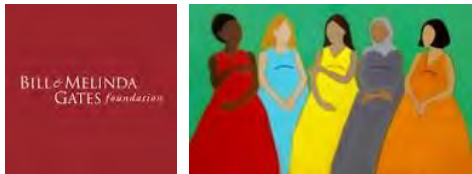
**Funding** Bill & Melinda Gates Foundation.

**Introduction**  
Screening for deviations in fetal growth is one of the main purposes of antenatal care. Some of the biomarkers assessed to do so can accurately predict fetal growth restriction: abdominal circumference, biparietal diameter, and femur length. Additionally, large variation in size to the centile points (eg, 3rd, 5th, or 90th centile) used to establish whether fetal growth is abnormal, even within the same population or region.<sup>1</sup> The use of such a range of centile and centile points<sup>2</sup> in clinical decision making about fetal growth patterns inevitably leads to diagnostic confusion, difficulties comparing outcomes across

[www.thelancet.com/journal/2014/09/04](http://www.thelancet.com/journal/2014/09/04)

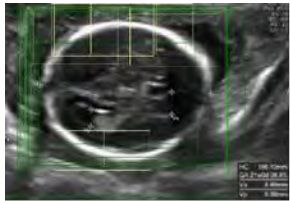
International biometry charts for optimal fetal growth to improve pregnancy care worldwide – a reference of care; Lancet 2014a-c

8TB carefully quality assured longitudinal data on 5000 healthy pregnancies from 8 sites (incl. 3D/2D ultrasound)



# Guided Random Forests for Identification of Key Fetal Anatomy and Image Categorization in Ultrasound

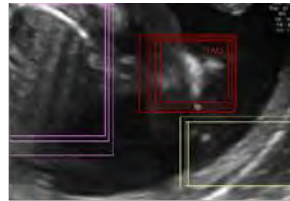
Designing fetal structure detection algorithms for real world data



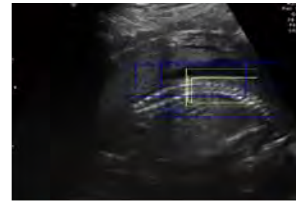
Head: Green box



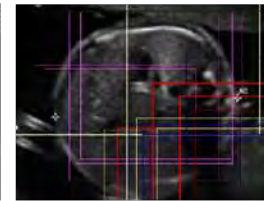
Femur: Yellow box



Face: Red box



Spine: blue box

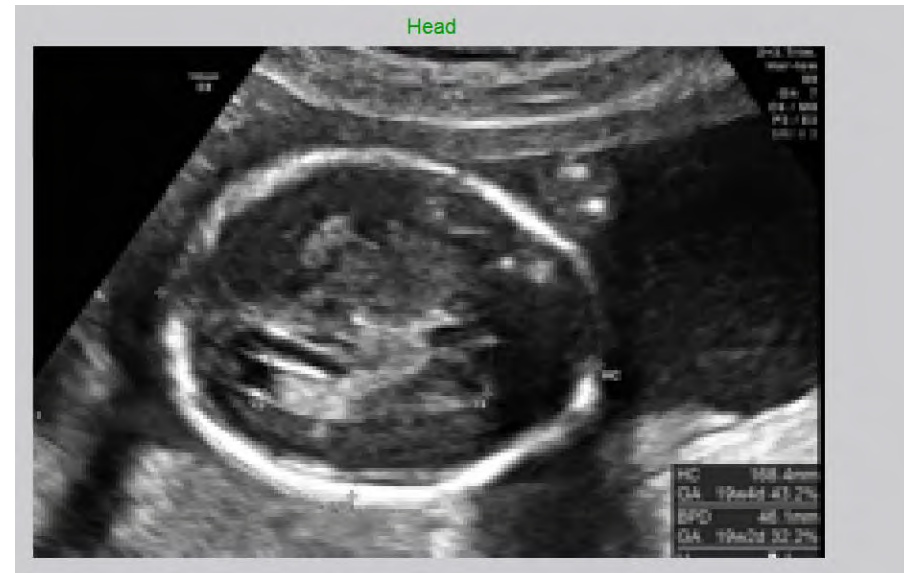


Magenta: blue box



Heart: light blue box

7





# Detecting key events in ultrasound videos



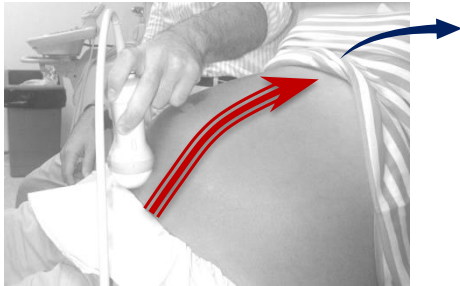
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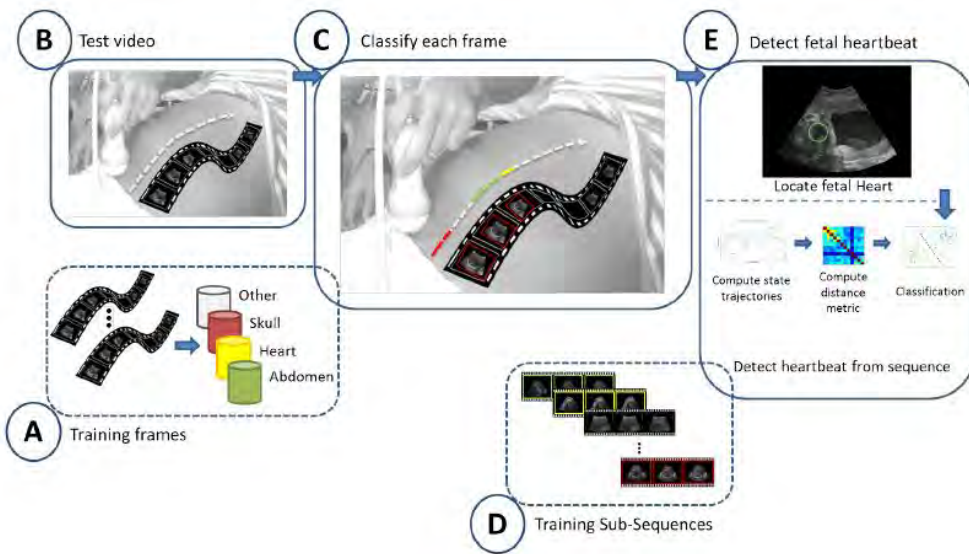
Normal Position



Breech Presentation

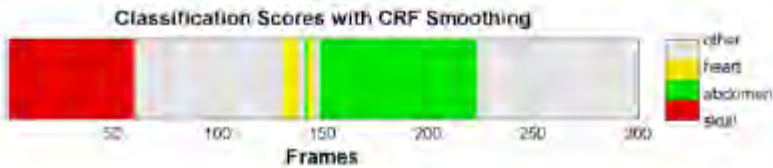


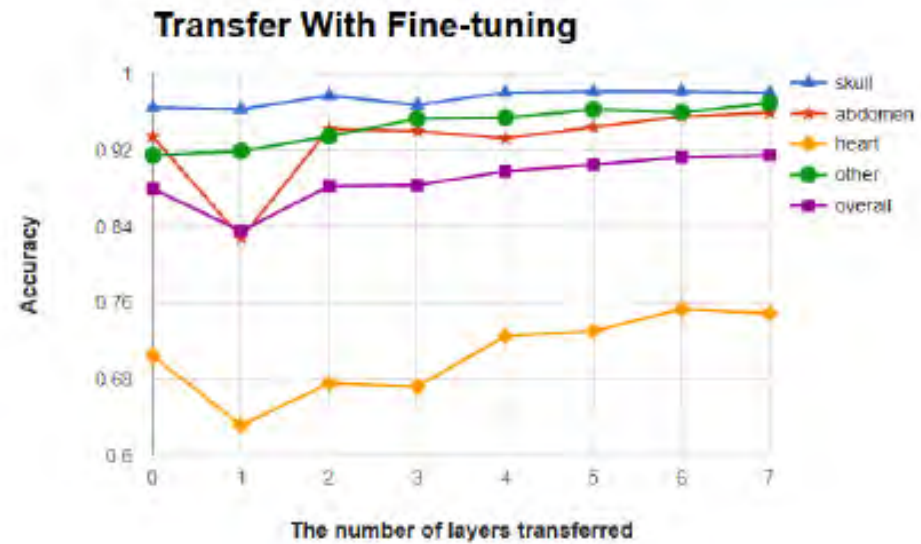
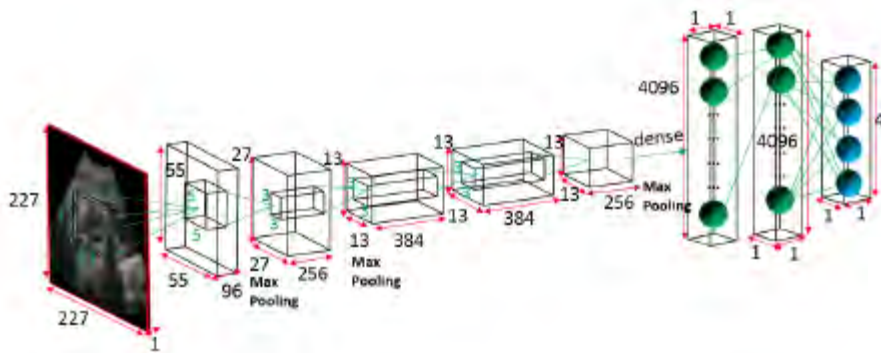
(Maraci, Napolitano, Papageorgiou and Noble, ISUOG 2013, MLMI 2014)



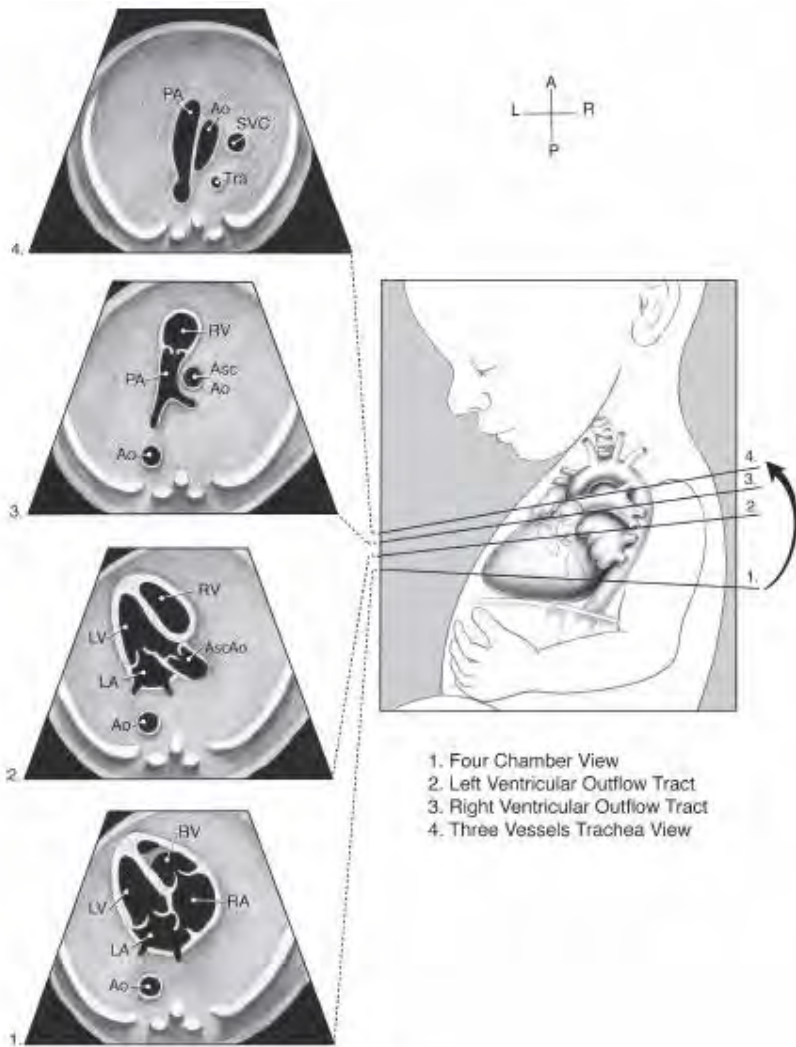
# Detecting Key Structures in Ultrasound Videos

Current detection of skull, heart, abdomen and "other" frames is 92% accurate

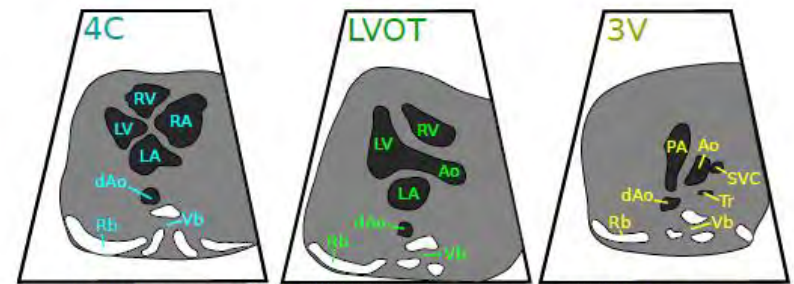




(Gao et al IEEE ISBI 2016 (to appear))



1. Four Chamber View
2. Left Ventricular Outflow Tract
3. Right Ventricular Outflow Tract
4. Three Vessels Trachea View



**LV/RV** left/right ventricle, **LA/RA** left/right atrium, **(d)Ao** (descending) aorta, **PA** pulmonary artery, **SVC** superior vena cava, **Tr** trachea, **Vb** vertebra, **Rb** ribs

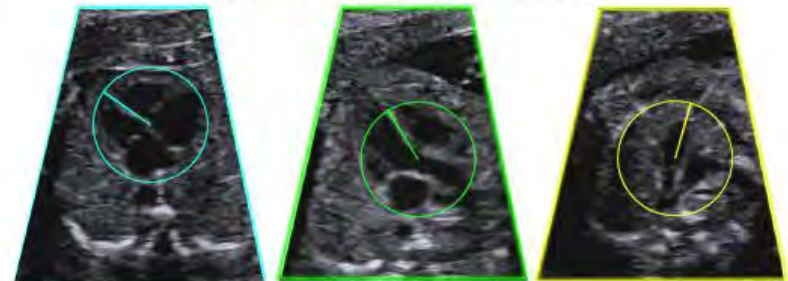
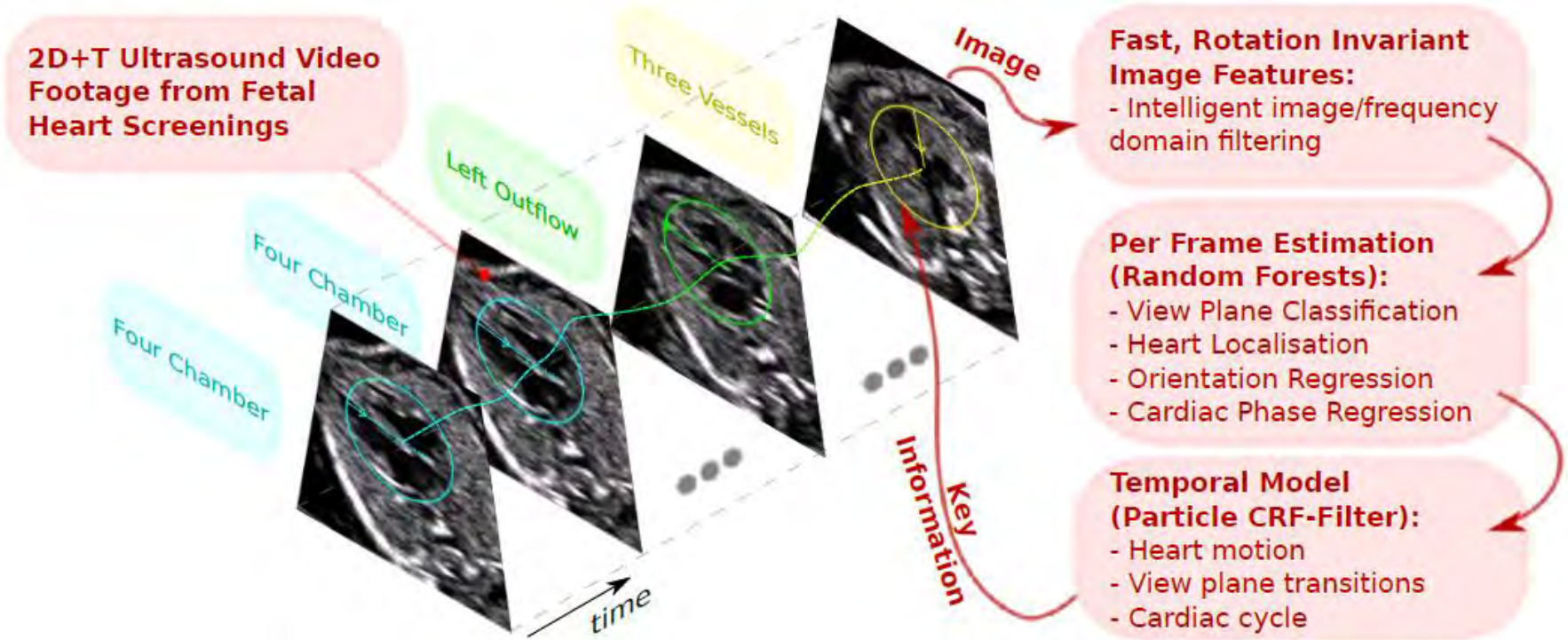
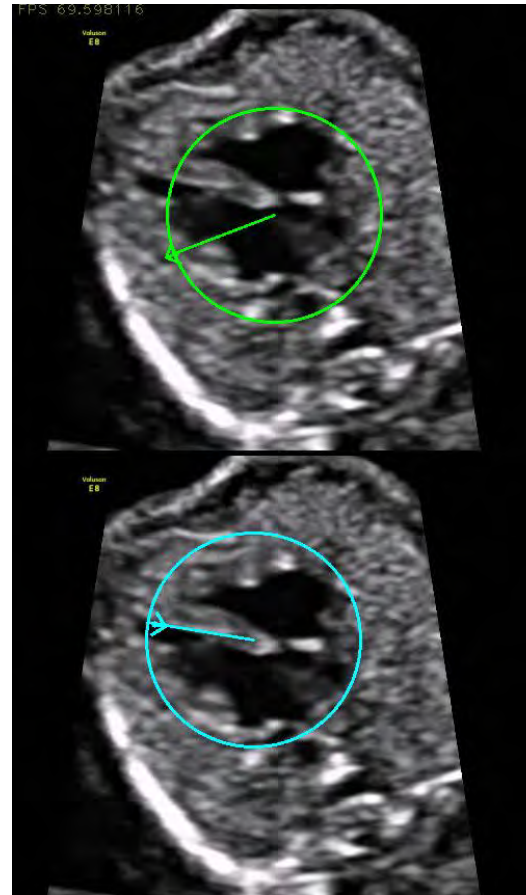
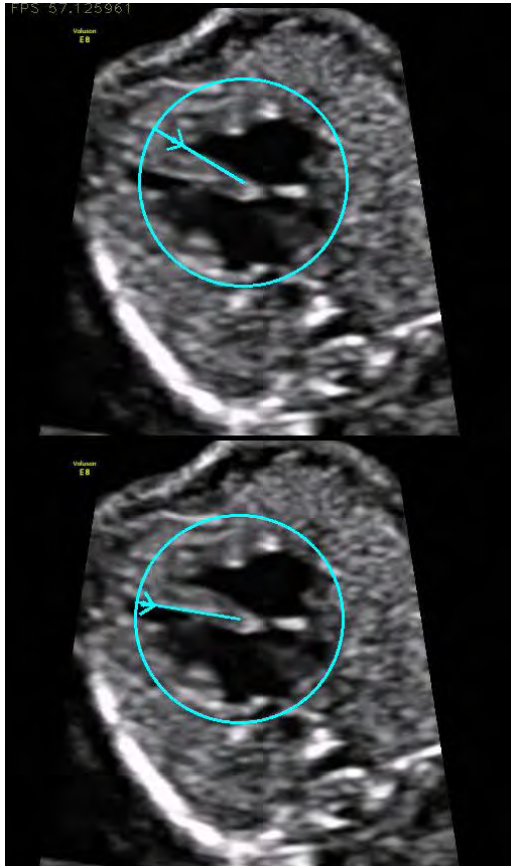


Figure 1: Definition of the three viewing planes and their annotations. *Top row* schematics showing the anatomic structures visible within the fetal abdomen in each view. *Bottom row* example image and annotation.

# Describing fetal heart videos

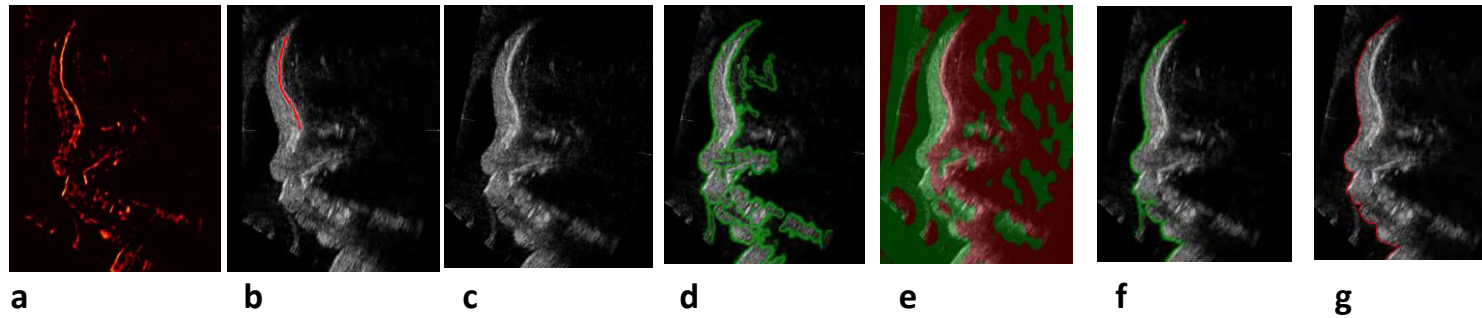




“state” description –  
heart location, view  
label, heart orientation  
and current cardiac  
phase.

Translate into a state  
estimation problem

Current solution uses a  
conditional random  
field (CRF) filter for  
state estimation.



**Figure 1 Segmentation of the mid-line fetal profile from a single slice of a 3D ultrasound volume**

- a) Feature Symmetry (FS) identifies high intensity ridges.
- b) A combination of Local Energy and the delineated ridges enables skull segmentation (red curve).
- c) Orientation of the skull determines a rotation to bring the mid-sagittal profile into a common pose.
- d) Feature Asymmetry (FA) identifies edges in rotated image and enables selection of largest connected region with  $FA > 0$ .
- e) Local Orientation (LO) of edges in (d) codes regions as  $LO > 0$  (green) and  $LO < 0$  (red).
- f) Regions with  $FA > 0$  (indicating an edge) and  $LO > 0$  (upward facing edge) are preserved (green).
- g) The profile is segmented (red).

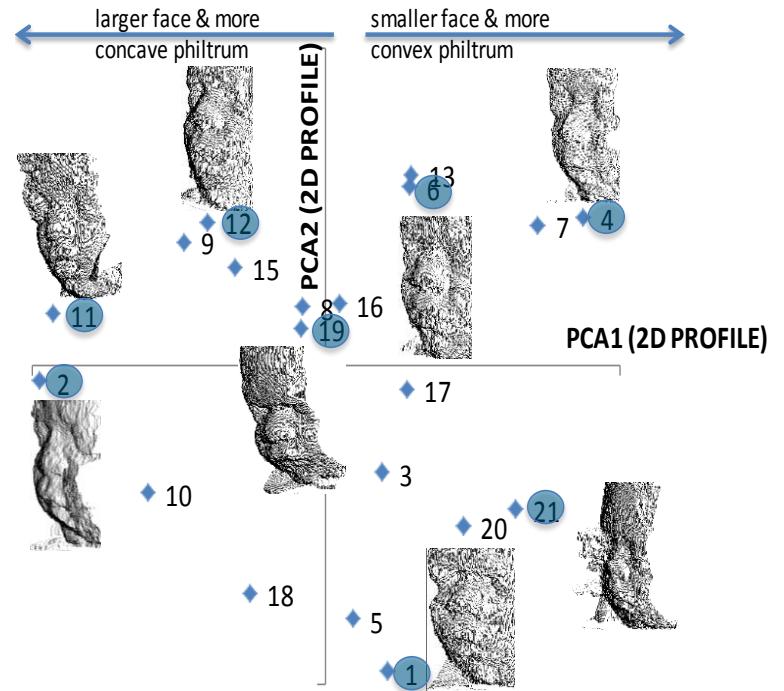
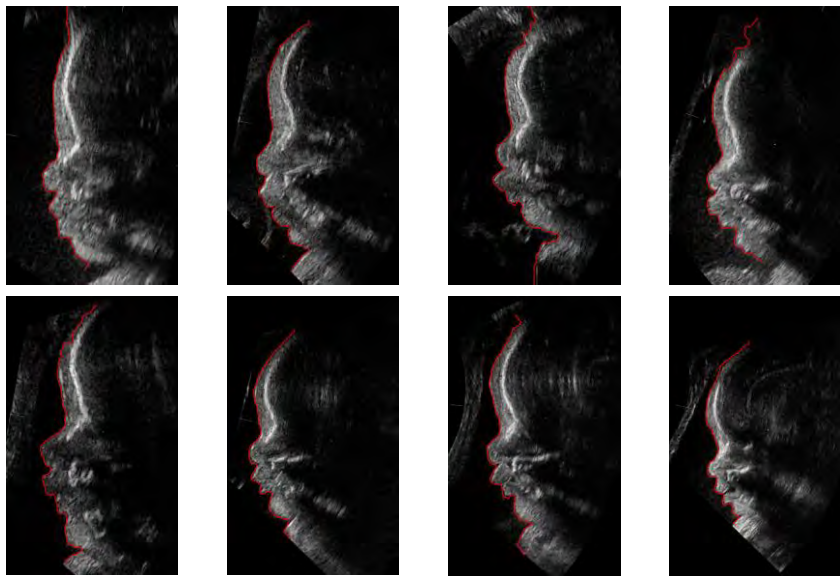
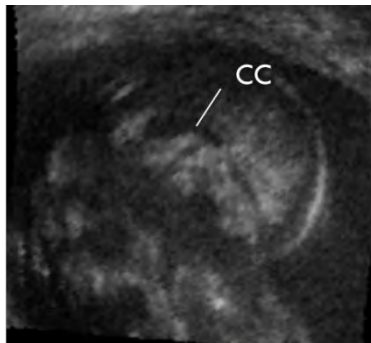


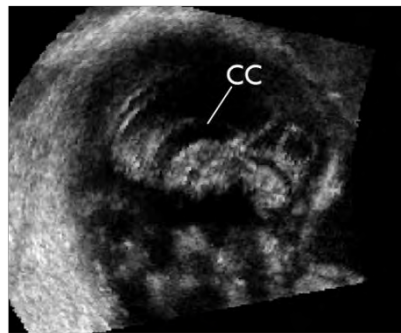
Figure 5 Scatter plot of PCA1 and PCA2 for 2D mid-line facial profile annotated with 3D point clouds



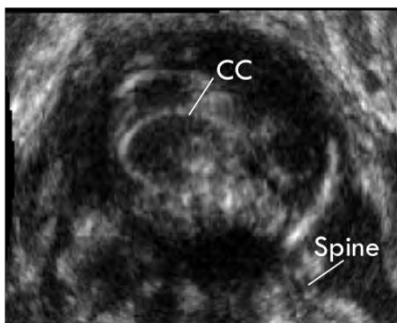
# Detecting and Characterizing the Corpus Callosum in Ultrasound Images



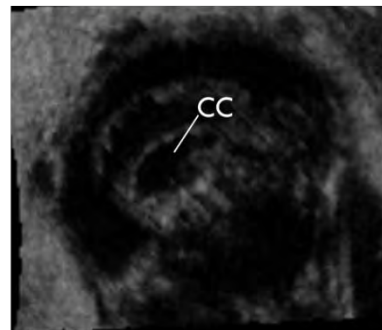
Different configurations



Acoustic shadows



Vague Boundary



Poor contrast

The Corpus Callosum (CC) is a blob-like structure but difficult to model due to imaging artefacts and acquisition-related variations in appearance.

We weakly model the structure as a maximal stable extremal region (MSER) augmented with intensity and geometric descriptors.

The resulting regional descriptor is used in a RUSboost (machine learning) object detection framework to detect the structure of interest.

## Detecting and Characterizing the Corpus Callosum in Ultrasound Images

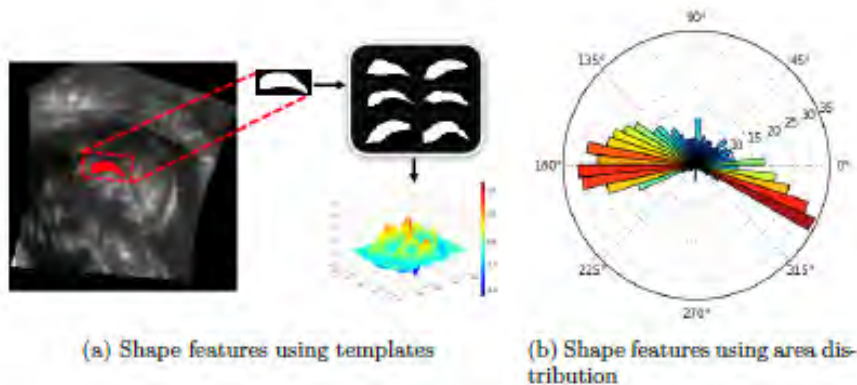
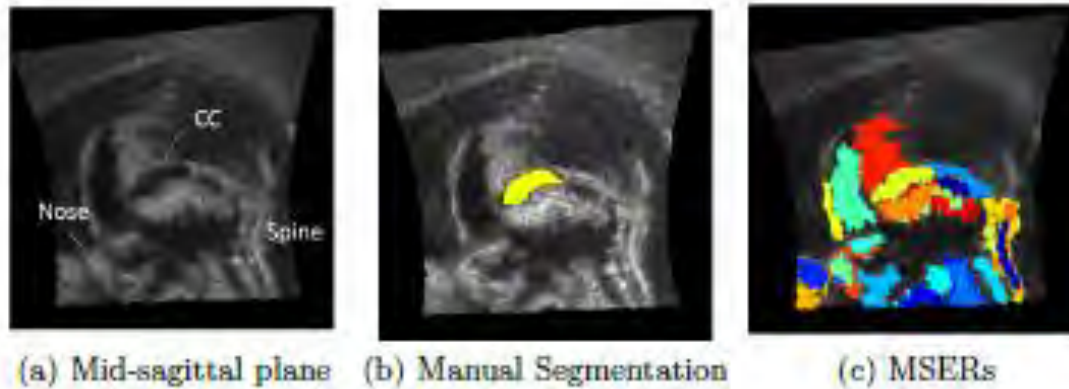
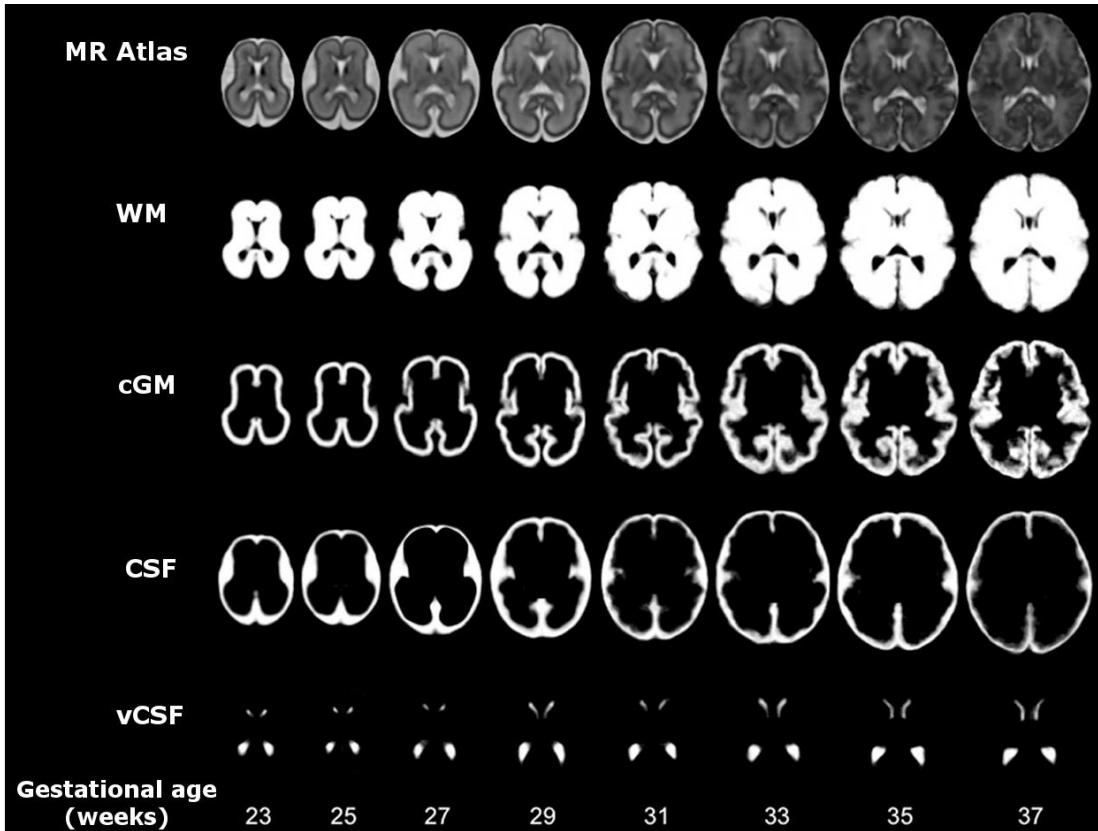


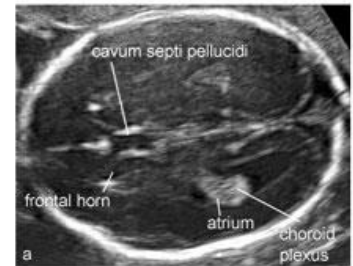
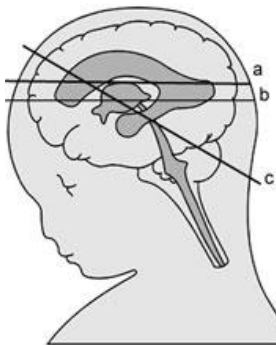
Fig. 2: Shape features. Candidate region is firstly binarized, rescaled and rotate to remove information unrelated to shape. (a) Features generated by calculating the maximum value of normalized cross correlation between the candidate region and a set of templates. (b) Features derived from the area distribution of the candidate region on a polar coordinate system. Colours represents the number of pixels lies within each fan section, while red represents the maximum and blue represents the minimum.

Table 1: Results of automatic brain structures segmentation

Brain Structure	Region classification		Quantitative Validation	
	Accuracy	Precision	$d_H(mm)$	$DC$
CP	97.4%	96.1%	$7.7 \pm 3.4$	$0.78 \pm 0.06$
CC	98.1%	96.4%	$2.8 \pm 0.9$	$0.76 \pm 0.08$



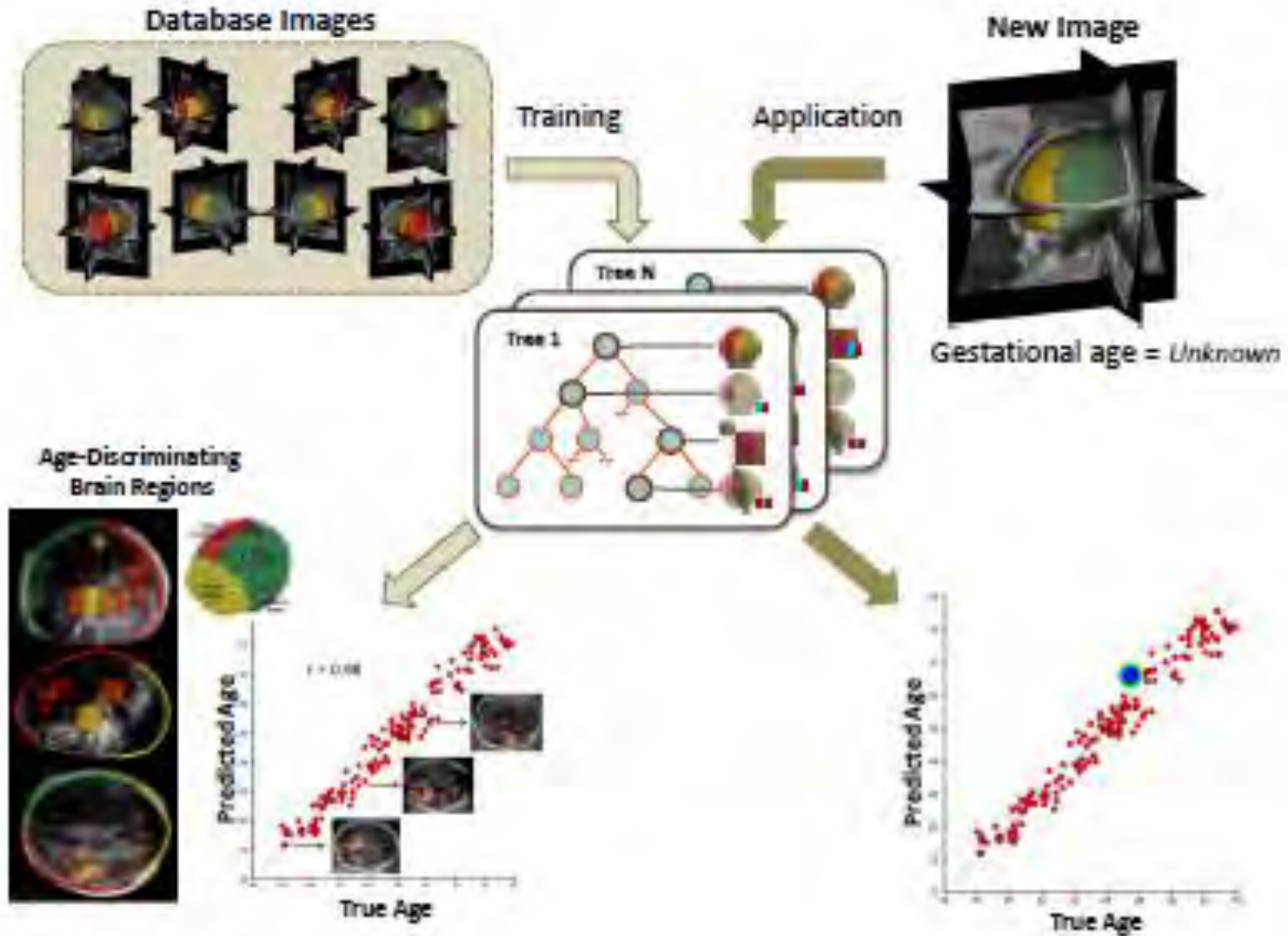
How can we characterise the developing brain using imaging?

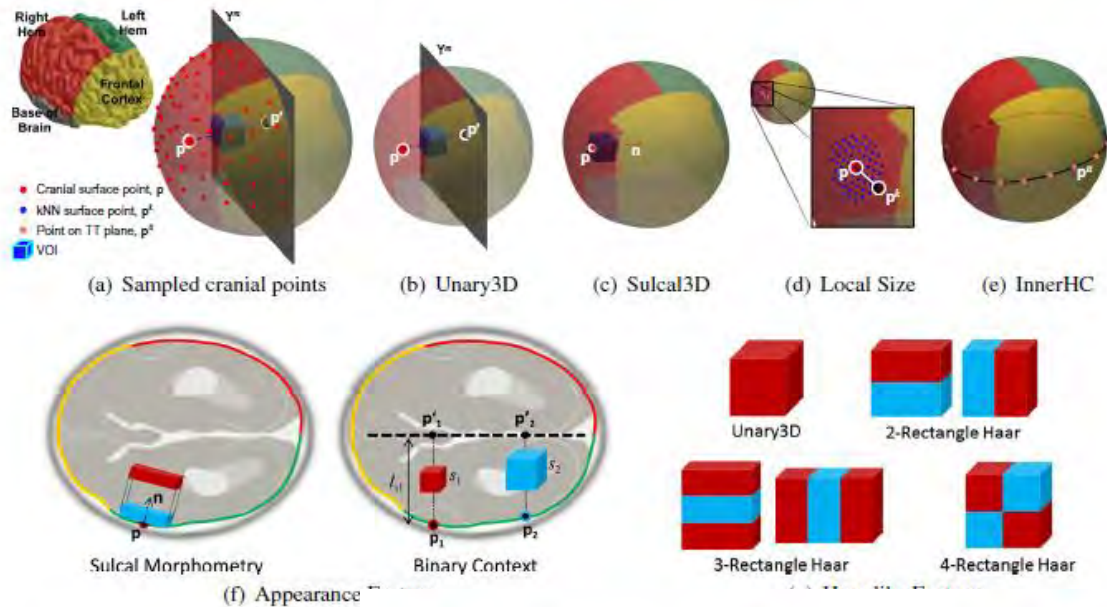


Are there unique sonographic signatures/patterns which tell us how well a given brain is developing?

# “Can you estimate the Gestational Age of a fetus for a mother presenting at the clinic for the first time late in pregnancy?”

(Doctoral research of Ana Namburete (IBME) and Bryn Kemp (NDOG))





The model features were chosen based on knowledge of longitudinal anatomical change, and needed to be computable from volumetric data of varied clinical quality (quality decreases with increased GA).

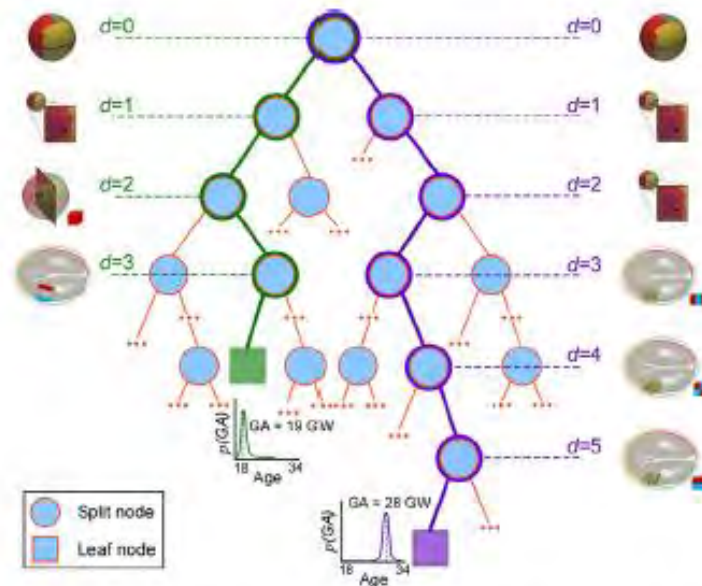
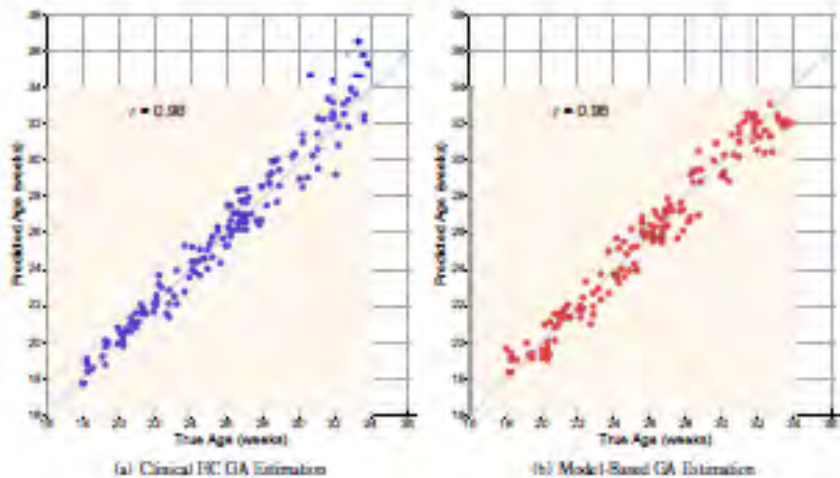


Fig. 6. Example feature selection, Illustration of feature selection paths for two different fetuses at 19 and 28 GW, demonstrating typical tree traversal.



The machine learning solution is more accurate than the current “golden standard” manual clinical measurement for late pregnancy.

The analysis uses a standard clinical scan.

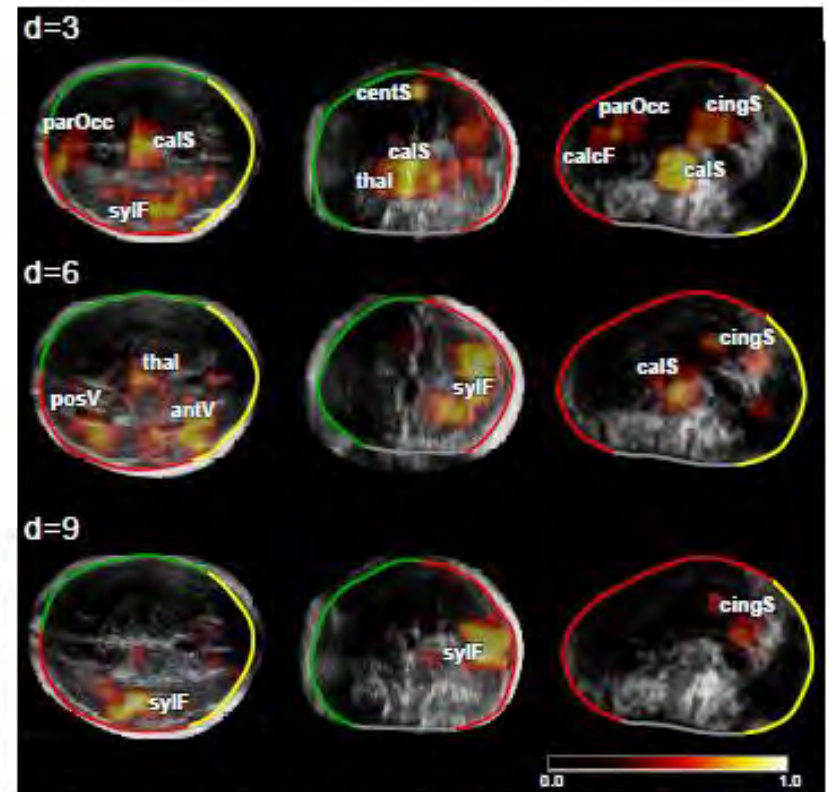


Figure 8: GA-discriminating brain regions. Visual example of the feature locations selected at three different levels of the forest ( $d = 3, 6, 9$ ) superimposed on axial (left column), coronal (centre column), and sagittal slices (right column). The heat map corresponds to the relative feature importance, such that bright regions correspond to frequently selected brain regions. *syIF*: Sylvian Fissure, *calS*: Callosal Sulcus, *centS*: Central Sulcus, *parOcc*: Parieto-occipital Fissure, *cingS*: Cingulate Sulcus, *calcF*: Calcarine Fissure, *posV*: Posterior Ventricle, *antV*: Anterior Ventricle, *thal*: Thalami

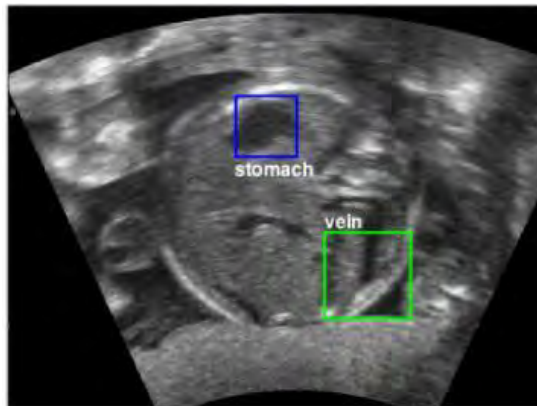
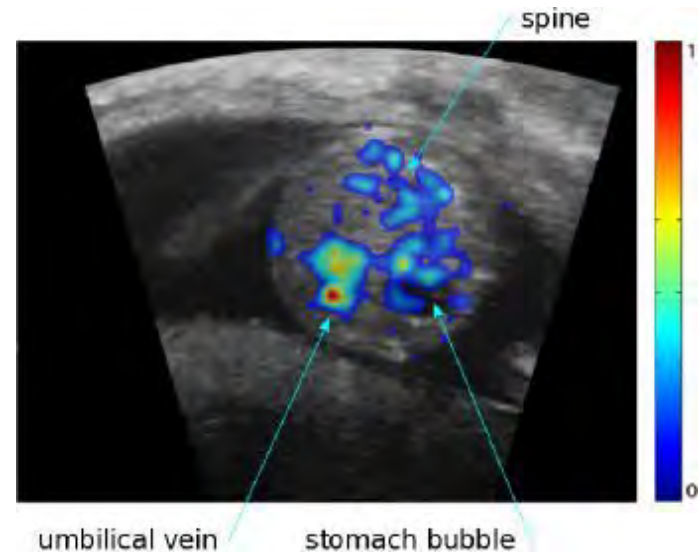
Key sonographic patterns driving machine-learning correspond to known anatomical structures that change in early brain development and go beyond the radiologists eye...

# Tracking Eye Movements to Boost Recognition of Anatomical Features in Fetal Ultrasound

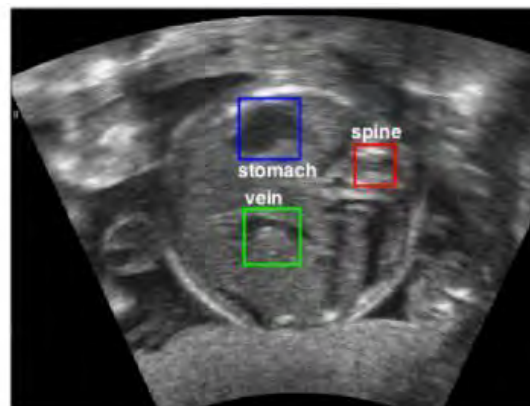


LCD monitor

IR LEDs and cameras



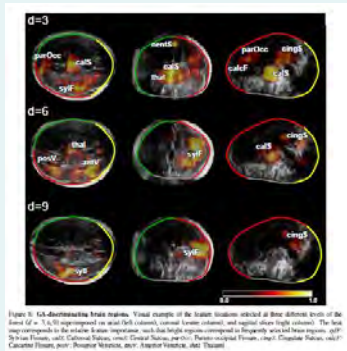
Detection without using spine as a reference



Detection with using spine as a reference

Detection increases to 87.2% (+4.5%) for stomach bubble and 83.2% (+9.6%) for umbilical vein.

# Summary



Biomarkers based on sonographic patterns that are not readily seen by eye



Eye-tracking during sonography to inform solution design



Simplify scanning. Intelligent interpretation.

The inter-play of (ultra) sound and vision (computer and human) to advance use of ultrasound in clinical practice is entering an exciting new era. One particular area of exciting possibilities is to support improved diagnosis of fetal conditions



