Fetal Imaging

National Center for Fetal Medicine
Dept Ob & Gyn

Trondheim - Norway
Outline of presentation

• Basic imaging technique
• Normal sonoembryological and fetal development in 2D and 3D imaging
• The routine fetal examination at 18 weeks
• Fetal medicine
• Teaching and training
Those were the days ..
Traditional obstetric communication with the fetus has changed
Sound

- Infrasound (0 - 20 Hz)
- Audible sound (20 - 20kHz)
- Ultrasound > 20kHz
- Diagnostic ultrasound (1 - 20 MHz)
Bats need ultrasound ..... 

Sound produced by bats is reflected from the walls of their cave.

The echo patterns are picked up by the bat’s ears enabling them to avoid obstacles in the dark
Sending

Voltage impulse

Voltage Burst

Ultrasound pulse

Receiving

Ultrasound pulse
Linear array
Technical development
Ultrasound imaging of the fetal head
The technical development will go on - Smaller objects will be imaged better end earlier
What makes the embryo special?

Small size

Constantly changing appearance

5 weeks to 10 weeks

2

6

10

13

20

30 mm

10 weeks
Embryology of Norwegians

At 9 weeks The Norwegian usually has mono-skis
A Norwegian at the routine 18 week scan

Fully developed Norwegian
The implantation
# 6 weeks

**Sonoembryology**

<table>
<thead>
<tr>
<th>Day</th>
<th>Description</th>
<th>Carnegie stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Embryonic pole, beating heart</td>
<td>13</td>
</tr>
<tr>
<td>1</td>
<td>Upper limb buds, 4 pairs branchial arches</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Lower limb buds</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td><strong>Heart rate 120</strong>, upper limbs paddle-shaped</td>
<td>14</td>
</tr>
<tr>
<td>4</td>
<td>Primordia of cerebral hemispheres</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Rhombencephalon on top, mesencephalon anterior</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower limbs paddle-shaped, hand plates</td>
<td>15</td>
</tr>
<tr>
<td>6</td>
<td>Amniotic membrane</td>
<td></td>
</tr>
</tbody>
</table>
6 weeks, CRL 4 mm
The sagittal folding
<table>
<thead>
<tr>
<th>Day</th>
<th>Description</th>
<th>Carnegie stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Heart rate 130, di- &amp; mes encephalon</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Spine, limbs</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Telencephalon divided into hemispheres</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>Physiological herniation, major calyces</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Blood flow in vitelline vessels</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Cerebral vesicles prominent, digital rays</td>
<td>17</td>
</tr>
<tr>
<td>6</td>
<td>Fourth ventricle largest brain cavity</td>
<td></td>
</tr>
</tbody>
</table>
7 weeks, CRL 12 mm
CRL 17 mm
# 9 weeks

**Sonoembryology**

<table>
<thead>
<tr>
<th>Day</th>
<th>CRL 23 mm–31 mm</th>
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<tbody>
<tr>
<td>0</td>
<td>Heart rate 175, cerebellar hemispheres</td>
</tr>
<tr>
<td>1</td>
<td><strong>Stomach</strong>, choroid plexuses divide 4th ventricle</td>
</tr>
<tr>
<td>2</td>
<td>Hands &amp; feet approach at the midline, toes</td>
</tr>
<tr>
<td>3</td>
<td><strong>Ossification of clavicle, maxille, mandible</strong></td>
</tr>
<tr>
<td>4</td>
<td>Width of mesencephalon &gt; diencephalon</td>
</tr>
<tr>
<td>5</td>
<td><strong>All fingers distinguishable</strong></td>
</tr>
<tr>
<td>6</td>
<td>Large midgut herniation</td>
</tr>
</tbody>
</table>

**Carnegie stage**

20

21

22

23
9 weeks, CRL 22 mm
The three sacs

- Chorionic cavity
- Amniotic cavity
- Yolk sac

CRL 26 mm
The heart is relatively large compared to the body of the young embryo.
Size of embryonic/fetal heart

at 9 weeks
Mean diameter (mm) 2.6–4.8 mm

Blaas et al. 1995
Heart

Trondheim, 2001

6 1/2 weeks, CRL 6 mm
9 weeks; CRL 23 mm
Early diagnosis
10 weeks

• Acrania, anencephaly, encephalocele
• Myelomeningocele
• Large facial defects
• Limb defects; poly-, oligodactyly
• Gross body wall defects (LBWC, gastroschisis, epigastric omphalocele)
• Major heart defects (AV-commune)
Cerebro-oculo-muscular syndrome
Lissencephaly type II

10 weeks
Cerebro-oculo-muscular syndrome with encephalocele (lissencephaly type II)
Fetus 13 weeks (CRL 65 mm)
3D scan-conversion

US data

Regular volume
For the **evaluation of the small embryo by 3D** certain demands have to be made to the ultrasound equipment

**CRL 17 mm**

**Ultrasound tomograms**
Embryonic development from 7 - 10 weeks
(Blaas et al. The Lancet 1999)
Volumes of embryos & brain cavities

Crown-rump length (mm) vs. volumes (mm$^3$):
- Mean weight (Streeter, N = 28)
- Mean weight (Jirásek, N = 18)
- Mean volume (Trondheim, N = 34)

Graphs showing the relationship between crown-rump length and volumes for different brain cavities (Rhombencephalon, Mesencephalon, Diencephalon, Hemispheres).
The shape
The evolution of a Norwegian -
3D visualization modes

- Contours
- Surface
- Volume
- Geometry visualization

Original scan

CRL 29 mm
9 weeks 6 days

Anyplane slicing

Segmentation

Volume Segmentation
3D - Still limited resolution
"Make embryology come alive!"

- An embryology text book
- An artist - Heather Spears
- A sonoembryologist - Blaas
- Computer power - Visual Knowledge ©
The development of the embryonic face
The Routine use of Ultrasound:
The fetal examination
Officially introduced ultrasound monitoring programs

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Scans</th>
<th>Weeks</th>
<th>New German program (1995)</th>
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<tbody>
<tr>
<td>Germany</td>
<td>1980</td>
<td>2</td>
<td>18 - 32</td>
<td>10 - 20 - 30</td>
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<tr>
<td>Norway</td>
<td>1986</td>
<td>1</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Iceland</td>
<td>1987</td>
<td>1</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Austria</td>
<td>1988</td>
<td>2</td>
<td>18 - 32</td>
<td></td>
</tr>
<tr>
<td>Switzerland</td>
<td>1996</td>
<td>2</td>
<td>10 - 18</td>
<td></td>
</tr>
<tr>
<td>Country</td>
<td>% of pop. scanned</td>
<td>GA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------</td>
<td>-------------------</td>
<td>----------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>95</td>
<td>18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belgium</td>
<td>95</td>
<td>10-20-32</td>
<td></td>
<td></td>
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<tr>
<td>Canada</td>
<td>90</td>
<td>18</td>
<td></td>
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<td>Croatia</td>
<td>90</td>
<td>18-32</td>
<td></td>
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<tr>
<td>Czech Republic</td>
<td>96</td>
<td>18-32</td>
<td></td>
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<tr>
<td>Denmark</td>
<td>51</td>
<td>17</td>
<td></td>
<td></td>
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<tr>
<td>Finland</td>
<td>87</td>
<td>18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>90</td>
<td>12-22-33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hungary</td>
<td>95</td>
<td>10-18-28-37</td>
<td></td>
<td></td>
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<tr>
<td>Italy</td>
<td>?</td>
<td>12-20-36</td>
<td></td>
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</table>

Marsal, 1997
<table>
<thead>
<tr>
<th>Country</th>
<th>% of pop. scanned</th>
<th>GA</th>
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</thead>
<tbody>
<tr>
<td>Poland</td>
<td>40</td>
<td>10-24</td>
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<tr>
<td>Portugal</td>
<td>?</td>
<td>12-20-30-36</td>
</tr>
<tr>
<td>Romania</td>
<td>25</td>
<td>8-20-35</td>
</tr>
<tr>
<td>Slovakia</td>
<td>70</td>
<td>10-20-32-38</td>
</tr>
<tr>
<td>Spain</td>
<td>95</td>
<td>10-18-35</td>
</tr>
<tr>
<td>Sweden</td>
<td>97</td>
<td>18</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>70</td>
<td>18</td>
</tr>
<tr>
<td>Turkey</td>
<td>?</td>
<td>12-17-32</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>96</td>
<td>18</td>
</tr>
<tr>
<td>USA</td>
<td>60</td>
<td>20</td>
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</table>

Marsal, 1997
The second trimester fetal examination

- Assess the gestational age
- Detect multiple pregnancies
- Locate the placenta
- Detect developmental disorders
Fetus at 18 weeks
Fetal sections

- Frontal section
- Sagittal section
- Horizontal section
In this world of evidence based medicine
Improved quality of care
- definition

• Decrease mortality rate
• Decrease morbidity rate
• Reduce unnecessary intervention
• Provide lifesaving information
• Provide important, but not lifesaving information
• Make obstetrical management more secure
• “Be prepared”
The fetal examination
Malformations at NCFM
1985 – 2000

N = 1960
- some conditions where antenatal diagnosis may decide between life and death

• Sacrococcygeal teratoma
• Cystic hygroma of the neck
• Diaphragmatic hernia
• Ductus dependent CHD
• Abdominal wall defects
• Cystic adenomatoid malformation of the lung
Sacro coccygeal teratoma
Gastroschisis
Gastroschisis
Cystic hygroma
"EXIT"-procedure

EX  utero  Intrapartum

Treatment procedure
EXIT-procedure

Originally developed to secure open respiratory system during delivery following fetal tracheal occlusion treatment ("PLUG") for diaphragmatic hernia.

"PLUG": Plug the Lung Until it Grows

Harrison, Adzick et al, 1997
EXIT-procedure

Caesarian section
Head, arm, upper trunk extracted
Umbilical cord intact
Secure airways by endotracheal intubation or tracheostomy
Cut umbilical cord and deliver child
Procedure may last 1 hour
EXIT-team

Anesthetist
Pediatric surgeon
Midwife
Neonatologist
Obstetrician
The difficult heart
### Transposition of great arteries

#### Effect of prenatal detection

<table>
<thead>
<tr>
<th></th>
<th>Neonatal group</th>
<th>Prenatal group</th>
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</thead>
<tbody>
<tr>
<td>Patients (N)</td>
<td>250</td>
<td>68</td>
</tr>
<tr>
<td>Mean delay birth -</td>
<td>73</td>
<td>2 *</td>
</tr>
<tr>
<td>admission (h)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative mortality</td>
<td>15</td>
<td>6 (3-9)</td>
</tr>
<tr>
<td>Postoperative mortality</td>
<td>20</td>
<td>8</td>
</tr>
</tbody>
</table>

** * p < 0.01

** Known risk factors for operative mortality identical in groups

Bonnet, Circulation, 1999
Transposition of the Great Arteries

- Prevalence 1: 3000
- To get 68 you need 204 000 pregnancies
- We only find 50% of TGA
  --> So: 408 000
- Large numbers are needed!
Non-selected population
Trondheim area, Pop. 200 000, 2 700 births
Non-selected population
Trondheim area, Pop. 200 000, 2 700 births

- One non-selected population
- One scanning unit
- One delivery dept.
- One pediatrician – neonatal exams
- One NICU
- One pediatric cardiology dept.
## Routine fetal examination

### A prospective study

<table>
<thead>
<tr>
<th>Phase</th>
<th>Registration</th>
<th>Period</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Rough</td>
<td>Aug. 86 - May 88</td>
<td>4,435</td>
</tr>
<tr>
<td>II</td>
<td>4-chamber view</td>
<td>June 88 - Jan. 91</td>
<td>7,459</td>
</tr>
<tr>
<td>III</td>
<td>4-ch. view + outlets</td>
<td>Febr. 91 - Dec. 00</td>
<td>25,899</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>37,793</td>
</tr>
</tbody>
</table>
Prenatal detection of critical heart defects

N = 41 793

Phase I: 1986-88
Phase II: 1988-90
Phase III: 1991-00

- Not detected
- Late
- Routine
- Early
Future obstetrics
Maternal transport of a fetus rather than a sick neonate
Invasive procedures

• Blood sampling
• Blood transfusion
• Acute drainage of fluid
• Chronic drainage of fluid
• Laser surgery
Fetal blood transfusions

- Direct intravascular
- Umbilical vein, placental insertion
- Infusion of packed cells, Hct ≥ 80%
- Computer calculation of volume to be transfused
- Infused volume up to 50% of fetoplacental volume
- Tranfusion velocity approx. 5 ml/min
Fetal blood transfusion
Conclusion

- Fetal blood transfusion for fetal Rh-disease has over 30 years been developed to perfection using ultrasound
Drainage of fluid in fetal / amniotic cavities

- Single or repeated aspirations
- Application of pig-tail catheter

Hydrothorax
Pericardial fluid
Thoracic tumors (CCALM)
Ovarian / mesenteric cyst
(Urinary tract obstruction)
CCALM type I
Intrauterine drainage of pleural effusion or chylothorax
Chylothorax

2 catheters inserted. 22 weeks
CCALM
Type I
Chylothorax

35 weeks
Polyhydramnion
Slight upper body edema
Drainage of fetal chylothorax at 35 weeks

Needle tip

Aspiration of 115 ml completed
2000 challenge

Twin - twin transfusion
Laser ablation
Ultrasound made the evaluation of fetal hemodynamics possible
Fetal vessels

- A. cerebri media
- Aorta
- A. umbilicalis
- Umbilical vein
- Ductus venosus
The perinatal team

- Obstetrician
- Pediatric cardiologist
- Pathologist
- Pediatrician
- Neonatologist
- Geneticist
- Midwife
- Neurosurgeon
- Pediatric surgeon
- Social worker

Pregnant couple
Fetal medicine
Aim

• Diagnose fetal disease and abnormal conditions
  – Cure or improve disease or abnormal conditions
  – Prepare parents
  – Prepare postnatal staff

  – Make prognosis better than it would have been without $D_x$
Fetal medicine

• Will remain controversial
• Balance between obviously "good" and "bad"
The teaching challenge

- The diagnostic potential of ultrasound technology is great
- Diagnosis be made during the examination
- Requires high level of skill
18 weeks scan - Performed by midwives/sonographers

**Definition of level of experience**

- **Experienced**
  - Basic ultrasound training
  - Performed more than 2000 routine ultrasound scans

- **Inexperienced**
  - Basic ultrasound training
  - Performed between 500 – 1500 ultrasound scans
18 weeks scan

4-chamber view and great arteries obtained over time

Year

1991 1993 1995
18 weeks scan

Level of experience and detection rate among midwives

<table>
<thead>
<tr>
<th>Isolated critical CHD’s</th>
<th>N</th>
<th>Detected</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td>Experienced</td>
<td>20</td>
<td>9</td>
<td>45</td>
</tr>
<tr>
<td>Inexperienced</td>
<td>21</td>
<td>6</td>
<td>29</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Critical CHD’s with associated malformations</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
</tr>
<tr>
<td>----</td>
</tr>
<tr>
<td>Experienced</td>
</tr>
<tr>
<td>Inexperienced</td>
</tr>
</tbody>
</table>
The solution

• Focus on dedicated personnel (sonographers, midwives) to do the fetal examination

• But - introduce formal training and certification
Teaching across the latitudes
NCFM
International relations

WHO Collaborating Center for Diagnostic Ultrasound in Obstetrics and Gynaecology
NCFM/ISUOG Outreach Program

• Reaching out to countries where systematic teaching is less developed and/or need for international cooperation
N CFM/ISUOG Outreach Program

• Manila 96 - 98
• Bangkok 96 - 98
• Hong Kong 98
• Murmansk 97 - 99
• Anthalya 99
• Cape Town 02
Drakensberg - 2001
Priorities in perinatal medicine

• Ed Coetzee
• Sturla H. Eik-Nes
• Gerald Mantel
• Jack Moodley
• Bob Pattison
• Eva Tegnander
Drakensberg - 2001
Priorities in perinatal medicine

• Is it possible to make a condensed education for African midwives working in rural Health care centers?
Drakensberg - 2001
Priorities in perinatal medicine

• If possible - is it worth doing?
• If yes - what would the objective be?
Modified teaching plan for midwives in rural Health Care Centers

- Objective
  - Dating
    » Growth, prematurity
  - Multiple pregnancies
  - Placenta
  - (Anomalies)
  - Delivery management
Teaching across the latitudes

"Drakensberg Project"

Project funded by

- **Norwegian Government**
  (NORAD - Norwegian Agency for Development Cooperation)

- **National Center for Fetal Medicine**
  University of Trondheim
Thank you!

Åbødalen - my favorite mountains
So far - so good