Fetal-Maternal Monitoring and Technology for Neonates
Key Points

Labor & Delivery Technology,
Fetal-Maternal Monitoring and Technology for Neonates:

- Know the two methods of measuring fetal heart rate **FHR:**
  - ultrasound transducer
  - direct ECG (DECG)

- Know the two methods of measuring uterine activity (contractions) **UA:**
  - toco (tocodynamometer)
  - IUPC (intrauterine pressure catheter)

- Know the four measurements for maintenance of an incubator

- Know the purpose and wavelength of a “bili light”
GLOSSARY:

**Amnioinfusion:** A procedure whereby a physiologic solution such as normal saline or lactated ringer's solution is infused through a lumen in an intrauterine pressure catheter into the uterus to alleviate cord compression and to help dilute meconium staining.

**Amniotic fluid:** The liquid in the amniotic sac that cushions the fetus and regulates temperature in the placental environment. Amniotic fluid also contains fetal cells.

**Amniotomy:** Rupturing or breaking the amniotic sac (bag of waters) to permit the release of fluid.

**Asphyxia:** Lack of oxygen.
Deceleration: A decrease in the fetal heart rate that can indicate inadequate blood flow through the placenta.

Hypoxia: A condition characterized by insufficient oxygen in the cells of the body.

Meconium: A greenish fecal material that forms the first bowel movement of an infant.

Perinatal: Referring to the period of time surrounding an infant's birth, from the last two months of pregnancy through the first 28 days of life.
Fetal Monitoring History

- With the invention of the stethoscope in 1810, physicians could hear the fetal heart beat.

- However, the instrument could not detect subtle changes or provide continuous surveillance.

- These deficiencies were overcome in 1968 with the development of electronic fetal monitoring.

- **EFM**, Electronic fetal monitoring, is performed late in pregnancy or continuously during labor to ensure delivery of a healthy baby.
**EFM** (Electronic fetal monitoring) includes both:
- the fetal heart rate (FHR), and
- mother’s uterine contractions or activity (UA)

EFM can be either **external** or **internal**.
In **external monitoring**, 
- the fetal heart rate (FHR) is detected by means of an ultrasound transducer, and
- uterine contractions (UA) are detected by a strain gauge, called a **tocodynamometer**.
Fetal heartbeat sensors  (Ultrasound sensors)
Ultrasound Transducer (M1356A)

Figure 15-1 Ultrasound Transducer

Description
The M1356A Ultrasound Transducer detects fetal heart movements by directing a low-energy pulsed Doppler ultrasound beam towards the fetal heart. The transducer contains seven crystals which transmit the ultrasound signal and receive the reflected signal from the fetal heart. The frequency shift caused by fetal heart movement is converted into an electrical signal from which the fetal heart rate is derived. Blue Ultrasound transducers are sealed units and are NOT repairable. The only repair allowed for the blue transducer is the exchange of the connector.

Specifications
- **System**: Pulsed Doppler
- **Oscillator Frequency**: 998.4 kHz
- **Ultrasound Intensity**: < 1.5mW/cm²
- **Dimensions**: 75mm diameter, 21.5mm depth
- **Transducer weight with Cable**: 185 grams
- **Cable Length**: 2.5m/8ft 2in
- **Watertight**: to a depth of 0.5m
- **Temperature Storage Range**: -40°C to +75°C
Uterine activity (UA), is recorded when the pressure of a contraction pushes on the external sensor, a tocodynamometer (“toco”), contacting the mother’s abdomen.

This external transducer is essentially a strain gauge pressure transducer.
- During contractions, the FHR normally slows somewhat, then speeds up again as the contraction episode ends.

- The average normal fetal heart rate is from 110 to 160 beats per minute (bpm).
The moment-by-moment FHR and UA are usually viewed on a display while simultaneously being printed on graph paper. *(FHR is measured by ultrasound, NOT ECG)*

**Fetal heart rate:**

**Uterine contractions:**

The default paper speed is 3cm / min. 1- or 2 cm / min often optional.
Uterine contractions are not displayed on the monitor as units of pressure, but as relative strength, 0 to 100.

Usually, the users wait for a period between contractions, and set that pressure as a value of 20 (not zero). When contractions occur, the value increases toward 100.
Tocodynamometer ("Toco") sensors -

toco - childbirth or labor
dynamo - force, torque, or power
meter - measuring device
Toco Transducer (M1355A)

Description
The M1355A Toco Transducer detects relative measurement of uterine activity. **Blue** Toco transducers are sealed units and are NOT repairable. The only repair allowed for the blue transducer is the exchange of the connector.

Specifications Toco Transducer

- **System:** Passive Strain Gauge
- **Sensitivity:** 0 to 12N/overload protected
- **Dimensions:** 75mm diameter, 25mm depth
- **Transducer Weight with Cable:** 180 gram
- **Cable Length:** 2.5m/8ft 2in
- **Watertight:** to a depth of 0.5m
Ultrasound Fetal heartbeat sensor

Tocodynamometer
Uterine Activity
Sensor ‘Toco’

Fetal Heart Rate Sensor
In **internal monitoring**, 
- the fetal heart rate is detected by means of an **ECG electrode**, and 
- the uterine contractions are detected by an **intra-uterine pressure catheter** and **transducer**.
The internal measurement of fetal heart rate is achieved by attaching a spiral ECG electrode directly to the fetus’ scalp.

This invasive procedure is associated with occasional complications.
Monitor interface for ECG scalp electrode -

**DECG Transducer (M1357A)**

**Description**

The M1357A Direct ECG Transducer has two spring loaded clamp type connectors for connection to the 15133D (EU) or 15133E (USA) spiral scalp electrodes.

**Specifications**

- **Input Impedance**: > 10MΩ
- **CMRR**: with patient cable, 51.5kΩ/0.047μF imbalance at line frequency > 110dB
- **Noise**: (referred to input with 25kΩ) < 4μVp
- **Contact Potential Difference**: ±500mV
- **Input Voltage Range**: 20μVp to 3mVp
- **Patient Leakage Current**: 120V at 60Hz, 10μA rms
- **Patient Auxiliary Current**: < 0.1μA (dc)
- **Dielectric strength**: 1500Vrms spark gap protected
- **Transducer Weight with Cable**: 185 grams
- **Cable Length**: 2.5m/8ft, 2in
The internal monitor for uterine contractions is by insertion of an intrauterine pressure catheter (IUPC) to measure the actual strength of the contractions.

Another use of an IUPC is for amnioinfusion. This is a procedure where normal saline is infused into the uterine cavity to replace the amniotic fluid. It relieves cord compression, reduces fetal distress, and acts as a supplement for decreased amniotic fluid (to help dilute meconium staining).
The pattern of the fetal heartbeat compared to the contractions is an indicator of the baby's condition.
Summary of Fetal-Maternal Monitoring:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Measured by</th>
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<tbody>
<tr>
<td>Uterine Activity</td>
<td>external strain gauge (tocodynamometer) <em>(most common)</em></td>
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<tr>
<td></td>
<td>or:</td>
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<tr>
<td></td>
<td>intrauterine pressure catheter (IUPC)</td>
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<tr>
<td>Fetal Heart Rate</td>
<td>external ultrasound transducer <em>(most common)</em></td>
</tr>
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<td></td>
<td>or:</td>
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<td></td>
<td>direct ECG (DECG scalp electrode)</td>
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</tbody>
</table>
Alternative modes of fetal-maternal monitoring:

Fetal ECG by surface electrodes -

Uterine contractions by surface strain gauges -
Monitors with chart recorders

Note NIBP and SpO2 for mother
Fetal-Maternal monitoring by telemetry:
And of course... there's an app or a device for that

"BabyScope"
Listen to your baby's heartbeat
Technology for neonates:

> Incubators:  
  Controlled environment for neonates

> Bilirubin phototherapy:  
  ‘Blue light’ to reduce bilirubin
Incubators:
Provide an environment for neonates in which four parameters are controlled:

- temperature,
- humidity,
- air flow, and
- sound level.

IEC 60601-2-19, Amendment I: Medical Electrical Equipment - Part 2: Particular Requirements for the Safety of Baby Incubators

Temperature is maintained by an IR or other lamp, with careful regulation.

Humidity is maintained by a water humidifier.

Air flow is provided by an internal fan.

Sound level depends on the design of the unit.
Test Standards for Incubators:

Temperature: 35º C, +/- 1%

Humidity: 40% - 85% relative humidity

Air flow: ≤ 0.35 m/S

Sound level: 55 dB (normal)
(≤ 80 dB with alarm)
(≥ 80 dB with alarm placed 3m away)

There are only two analyzers made for functional testing of incubators:

The Fluke “INCU” and the Datrend “IncuTest”.

Both systems use four or five sensors for temperature which are spaced evenly in the incubator, and sensors for humidity, air flow, and sound.

Both systems interconnect with software in a laptop for record-keeping.
dBa: Measured 1m away in a straight line

- Breathing: 10 dBa (SILENT)
- Whisper: 20 dBa (QUIET)
- Decent computer fan: 25 dBa
- Fridge when it kicks in: 40 dBa
- Small office: 50 dBa
- Large office: 55 dBa
- Laughter: 60 dBa
- Hairdryer: 70 dBa
- Side of motorway: 75 dBa
- Risk of tinnitus increases: 85 dBa
- Motorcycle: 90 dBa
- MP3 player max volume: 100 dBa
- Orchestra: 110 dBa
- Front row Metallica: 120 dBa
- Starts to hurt: 130 dBa
- Pain, Gunshot at close range: 140 dBa
- Instant perforation of eardrum: 160 dBa
Dräger’s IICS-90 Warmer (not an incubator)
Analyzers for Fetal-Maternal Monitors

- Fluke ProSim 8
- Datrend FMS-3 (can simulate triplets)

...and others with options
Fluke Biomedical’s “Incu”:
Datrend’s “IncuTest”:

and...

vPad-IN
The Next Generation Infant Incubator & Radiant Warmer Testing System
Phototherapy lights for neonates

> Light converts excessive bilirubin (a yellow breakdown product of heme, often found in newborn infants) to other chemicals that can be excreted safely.

> Use light at a wavelength between 420 nM to 470 nM

> Often called “Bili Lights”

> Therapy may last from hours to days
Emission Spectra of Blue LEDs in Relation to Bilirubin Absorption

Peak absorption wavelength of bilirubin (458 nm)
Light enclosure

- With a simple flip of a switch, change from single (conventional, 12-15 µW/cm²/nm) to double (intensive, > 30 µW/cm²/nm) phototherapy
- Unique red target light enables precise centering of light over baby
- Can be adjusted both horizontally and vertically, and tilted over a wide angle range
- Rubber feet supplied allow stable placement directly onto incubator
The “Bili-Blanket”:
emits phototherapy directly from a blanket
Phototherapy output testers for biomed:

Typical output range @ 440nm:
198 µW/cm² to 1760 µW/cm²

At 18” distance
The uterus transplant was a success. I'm sure you'll find your husband much more understanding now.