IN SUMMARY
FETAL SURVEILLANCE

FETAL SURVEILLANCE

An Example of a Fetal Heart Rate Tracing

Figure removed due to copyright restrictions.

Variability

- Beat to be rate changes reflect CNS activity
- Vagal tone is modulated by CNS activity
- Variability is a measure of fetal (or adult) arousal state
- REM sleep produces considerable variability
- REM sleep associated with fetal breathing
- Variability is reduced or eliminated by
  - Drugs (barbiturates, narcotics, MgSO4, diazepam)
  - Infection
  - Hypoxia
  - Prematurity
- Long term variability reflects continuous changes in the sympathetic-parasympathetic balance
- Sinus rhythm exhibits fluctuations around the mean heart rate
- Frequent small adjustments in heart rate are made by cardiovascular control mechanisms (the details of this are not well worked out)
- Results in periodic fluctuations in heart rate
- The main periodic fluctuations are
  - Respiratory
  - Sinus arrhythmia
  - Baroreflex-related
  - Thermoregulation-related

• Inspiratory inhibition of the vagal tone: heart rate shows fluctuations with a frequency equal to the respiratory rate
• This inspiratory inhibition is evoked primarily by central production of impulses from the medullary respiratory to the cardiovascular center
• Peripheral reflexes due to hemodynamic changes and thoracic stretch receptors contribute to respiratory sinus arrhythmia
• Respiratory sinus arrhythmia can be abolished by atropine or vagotomy - parasympathetically mediated (esp. in fetus)
• 10-second rhythm in heart rate originates from self-oscillation in the vasomotor part of the baroreflex loop
IN SUMMARY

FETAL SURVEILLANCE

This results from negative feedback in the baroreflex and are accompanied by synchronous fluctuations in blood pressure.

– The frequency of the fluctuations is determined by the time delay of the system.
– Augmented when sympathetic tone is increased decrease with sympathetic or parasympathetic blockade.

• Peripheral vascular resistance also exhibits intrinsic oscillations of low frequency.
• These oscillations can be influenced by thermal changes in the skin.
• Thought to arise from thermoregulatory peripheral blood flow adjustments.
• Fluctuations in peripheral vascular resistance accompanied by fluctuations with the same frequency in blood pressure and heart rate.
• Mediated by the sympathetic nervous system.

Sleep State

• Investigations in the fetus and newborn have revealed that during rapid eye movement (REM) sleep LTV is increased and STV is decreased compared to during non-REM sleep.
• These differences between REM and non-REM sleep are due mainly to a shift in the vagal-sympathetic balance from a higher sympathetic.
• Vagal tone during REM sleep shifts to higher vagal tone during non-REM sleep.
• In addition, the slower and more regular breathing in non-REM sleep (more respiratory sinus arrhythmia, thus more STV) contributes to the differences found.

Adults

• Adult heart rate variability has been investigated primarily in awake adults.
• Enables investigators to instruct the participants to breath at fixed frequencies.
• Heart rate variability studies in adults have revealed that body posture influences heart rate variability.
• In the upright position baroreflex-related heart rate variability is enhanced due to an increased sympathetic tone.

• Respiratory sinus arrhythmia is augmented in the supine position.

Fetal and Neonatal Heart Rate Variability

• In obstetrics it has been noticed that acute hypoxia resulted in an increase in heart rate variability.
• Chronic hypoxemia was accompanied by low heart rate variability.
• Low heart rate variability is associated with low Apgar scores and pH at birth.
• Attributed to depression of the central nervous system.
• Persistent fixed fetal heart rate pattern was also described in anencephaly and fetal decerebration.
• Reduction in heart rate variability appears to be a rather late sign of fetal compromise.

Fetal and Neonatal Heart Rate Variability

• In asphyxiated newborns, diminished heart rate variability is also found.
• Transient loss of heart rate variability indicates a good prognosis.
  – Due to cerebral edema,
• Sustained loss of heart rate variability.
  – Predicts neurologic sequelae.
  – Neonatal death.
  – Probably due to irreversible damage to the brain or brain stem.


**Fetal and Neonatal Heart Rate Variability**

- Severe neonatal respiratory distress syndrome is accompanied by a reduction in low-frequency heart rate variability
  - transient depression of the medulla oblongata due to elevated pCO₂ levels and acidosis
- If the respiratory distress improves --> heart rate variability increases
- Reduction in LTV in newborns with clinically significant patent ductus arteriosus
  - ascribed to a marginal oxygen supply of the myocardium that limits fluctuations in heart rate
- Loss of heart rate variability also has been found in infants with periventricular hemorrhage
  - damage of vasomotor areas in the medulla oblongata
  - due to increased intracranial pressure
- In infants who subsequently died of the sudden infant death syndrome
  - higher heart rate
  - lower heart rate variability

**Time Domain Analysis**

- Two types of heart rate variability indices
- Beat-to-beat or short-term variability (STV)
  - Represent fast changes in heart rate.
- Long-term variability (LTV) indices
  - Slower fluctuations (fewer than 6 per minute)
- Calculated from the R-R intervals occurring in a chosen time window (usually between 0.5 and 5 minutes)
- Example of a simple STV
  - Standard deviation (SD) of beat-to-beat R-R interval differences within the time window
- Examples of LTV indices
  - SD of all the R-R intervals
  - difference between the maximum and minimum R-R interval length, within the window

**Fourier Analysis**

- Respiratory sinus arrhythmia gives a spectral peak around the respiratory frequency
- Baroreflex-related heart rate fluctuations are found as a spectral peak around 0.1 Hz in adults
- Thermoregulation-related fluctuations are found as a peak below 0.05 Hz
- CNS (cortical) contribution seen as higher frequency components

- Heart rate variability can be assessed in two ways
  - statistical operations on R-R intervals (time domain analysis)
  - by spectral (frequency domain) analysis of an array of R-R intervals
- Both methods require **accurate timing of R waves**
- Analysis can be performed on
  - Short electrocardiogram (ECG) segments (lasting from 0.5 to 5 minutes)
  - 24-hour ECG recordings.

- Spectral analysis introduced as a method to study heart rate variability
- Increasing number of investigators prefer method to that of calculation of heart rate variability indices
- Main advantage of spectral analysis of signals
  - Possibility to study their frequency-specific oscillations (not only the amount of variability)
IN SUMMARY
FETAL SURVEILLANCE

- The oscillation frequency
  - Decomposing the series of sequential R-R intervals into a sum of sinusoidal functions of different amplitudes and frequencies

- Fourier transform algorithm
  - Displays as a power spectrum with the magnitude of variability as a function of frequency
  - Power spectrum reflects the amplitude of the heart rate fluctuations present at different oscillation frequencies

Such mathematical transformations may be used to analyze drug effects on CNS

<table>
<thead>
<tr>
<th>FUNDAMENTAL QUESTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What is the difference between beat-to-beat rate and average rate?</td>
</tr>
<tr>
<td>2. Why do changes in BTB rate occur?</td>
</tr>
<tr>
<td>3. What is the significance of reduced BTB variability?</td>
</tr>
<tr>
<td>4. What is the effect of hypoxia, narcotics, barbiturates and benzodiazepines on BTB variability?</td>
</tr>
<tr>
<td>5. Describe three ways of quantifying BTB variability?</td>
</tr>
<tr>
<td>6. What is the effect of placental insufficiency on fetal heart rate in labor?</td>
</tr>
<tr>
<td>7. What is the effect of umbilical cord compression? What is the mechanism?</td>
</tr>
<tr>
<td>8. What happens to fetal pH during normal labor?</td>
</tr>
<tr>
<td>9. What is the long term impact of intrapartum asphyxia?</td>
</tr>
</tbody>
</table>
IN SUMMARY
FETAL SURVEILLANCE