**FETAL DEVELOPMENT (Reissland, Kisilevsky)**

**6. Fetal Behavioral and Psychoneurological Development**

**Abstract**

* Behavioral/sleep states independent of birth
* Described in terms of…
  + Cardiotocographic pattern
  + Presence/absence of body
  + Eye movements
* Intercostal-to-phrenic inhibitory reflex and fetal habituation as measures of memory
* Complex; requires testing of multiple aspects

**Introduction**

* Cardiotocography (CTG) and ultrasonography allow for observation of behavior during gestation
* Rapid maturation in fetuses
* Behavioral aspects: heart rate/patterns, body movement, eye movement, breathing, fetal sucking, mouthing
* Behavior must be assessed in gestational context
* Birth does not significantly alter developmental pathways

**Fetal Body Movements**

* Normal movements ~ good fetal condition
* Movement emerges 7-15 weeks into gest.
* 15 distinct patterns
* Comparing quantifiers (need to define period b/t movements)
  + % of time fetus moves
  + # of movements
* Movement more infrequent after 24 weeks
  + Rest-activity cycles (sleep/behavioral states)
* Quality of movements
  + Normal: spontaneous, whole body, seconds-minutes, variable sequence and intensity, gradual onset/end

**Fetal Heart Rate/Patterns**

* Basal: 70-80 bpm at 7/8 weeks; peak 180 bpm at 10 weeks; 110-150 after
* Good bandwidth, variability/accelerations ~ good condition
* As fetus ages, basal FHR decreases and FHR variability increases (curve)
* Other factors (disease, medicine, time of day, etc.) affect FHR and variability
* Amount of time spent in low variation FHR increases during pregnancy (sleep states)
* FHR classified as…
  + A – stable heart rate, narrow oscillation bandwidth, few accelerations
  + B – stable, wide bandwidth, frequent accelerations (movements)
  + C – stable, wide bandwidth, no accelerations
  + D – unstable, large/long-lasting accelerations

**Fetal Behavioral States**

* Linkage b/t variables at 36 weeks
* “Constellation of physiological and behavioral variables which are stable over time and recur repeatedly…”
  + 3 minute “state transitions”
* Four behavioral states
  + 1F: FHRP A, brief gross body movements, no eye movements (non REM sleep)
  + 2F: FHRP B, frequent gross movements + extremities, eye movements (REM sleep)
  + 3F: FHRP C, no gross body movements, eye movements (quiet wakefulness)
  + 4F: FHRP D, continual activity (active wakefulness)
* Post-term fetuses more awake in utero (at expense of 2F)
* Possibility of state 5F (“fetal crying”)

**Neurology**

* Global assessment with biophysical profile (0-2 pts. for 5 aspects)
  + But not consistent for 1F, e.g.
* Intercostal-to-phrenic inhibitory reflex is possible approach for assessing FCNs (Didn’t really work, though)
* Fetal habituation
  + Indicates recognition and memory of stimuli in fetuses
  + Fetuses with Down’s syndrome take longer to habituate
  + Time period of stimulus habituation changed to measure LTM/STM
  + Tested with different nutritional/biological factors
* Acoustic stimulus (startle response) for testing neurology
  + Present at 26-27 weeks (around time of fetal hearing)
  + Alcohol slightly delays response
* Handedness considered, too

**7. Linear and Nonlinear Analysis of Fetal Heart Rate Variability**

**Abstract**

* CTG for detecting hypoxia
* Most analyses of CTG rely on linear time-domain indices
* Linear frequency analyses, nonlinear methods (i.e. entropy), and fetal gender identification useful
  + Identify acidemia
  + Identify intrauterine growth-restriction

**Introduction**

* CTG is continuous recording of FHR and uterine contraction
* Pathophysiology of fetal hypoxia
* Many studies look at 24-26 weeks fetuses
* Program designed to track changes, reduce inconsistencies
  + e.g. Omniview-SisPorto
  + Linear time-domain indices limits understanding
* Linear frequency-domain indices and nonlinear techniques (entropy) provide additional information
  + Low blood pH, e.g.

**Methods of Fetal Heart Rate Variability Analysis**

* Linear time-domain indices (represent changes in FHR average/variability
  + **,** sm(i)=x(i) on each 2.5 sec period
* Frequency domain linear analysis (use Fourier transform)
  + 0-0.03 Hz, very low frequency
  + 0.03-0.15 Hz, low frequency
  + 0.15-0.50 Hz, movement frequency
  + 0.50-1.00 Hz, high frequency
  + LF ~ sympathetic system (arousal); HF ~ parasympathetic system (relaxation)
  + LF/HF and LF/(MF+HF) ~ balance b/t/ sym. and parasym.
* Nonlinear analysis: Poincare plot
  + Time series points vs. preceding points
* Nonlinear analysis: Entropy
  + Measure signal irregularity/complexity
  + Approximate: ApEn(m, r), where r = .1, .15, .2 STD threshold, m=2 embedding dimension
  + Multi-scale: Divide original time series into non-overlapping windows, average data in each window, entropy plotted as function of window scale factor
* Nonlinear analysis: Compression
  + Quantifies different features of signal

**Fetal Behavioral States**

* Active states ~ more autonomic activity, sympatho-vagal imbalance
* Sleep patterns have higher irregularity than wakefulness patterns

**Gestational Age**

* Complexity (entropy) of FHR signals increases significantly from 24 to 38 weeks
* Sympatho-vagal imbalance increases from 24 to 38 weeks, then decreases

Other influencing factors

* Gender
* Mode of acquisition
* Sampling parameters

**8. Fetal Auditory Processing: Implications for Language Development**

**Abstract**

* Auditory processing abilities
  + Attention
  + Discrimination
  + Recognition
  + Learning
* Reliable characterizing at third trimester
* Perception influenced by…
  + Gest. age
  + Arousal
  + Maternal/Fetal conditions
  + Sound frequency, intensity, duration
* Differences in response to audio stimuli may serve as markers of neuropathology
* What are mechanisms behind audio processing deficits? How might some markers lead to pathology? How can we treat them with prenatal intervention?

**Introduction/Background**

* Study of fetal audio response began in 60s with advent of ultrasound
* DOHaD explains how one genotype can give rise to range of phenotypes
* Factors in fetal development lead to long-term effects (programming)
  + Biological: under nutrition, iron deficiency, alcohol, etc.
  + Behavioral
* Fetal behavior assesses brain function
* Fetal experience affects biological development
* Behavioral factors may thus serve as markers for neuropathology

**Auditory System Development**

* Cochlear hair cells🡪 mature cochlea🡪 Auditory cortex pathways🡪 Myelination🡪 Brainstem pathway conduction🡪 Hearing (29 weeks)🡪Mature axonal conduction (40 weeks)
* Onset of hearing coincides with auditory responses
* Fetal hearing from bone and fluid conduction

**Fetal Auditory Processing**

* Fetus picks up internal and external sounds
* Pitch curves retained, but voices muffled
  + Low frequencies retained more
* Fetuses more responsive in active environments
* Increasing complexity, frequency, or intensity increases *magnitude* of FHR acceleration
* Fetuses discriminate different sounds/voices at third trimester
* Higher decibels, short duration sounds elicit startle responses, increasing FHR
* Experiences influences response (i.e. respond different to mother than stranger)
  + Also differences between direct and tape speech, due to novelty vs. habituation
* Some characteristics of voice learned more from repeated exposure than others

**Influence on Language Development**

* Fetal growth restriction may affect auditory system development
* Growth restricted fetuses showed less of response (or less sustained) to mother’s voice (correlational)
* Interventions like system exposure to maternal voice recording may ameliorate some problems associated with premature infants

**FETAL DEVELOPMENT (Nijhuis)**

**4. Heart-rate patterns and fetal movements**

* Base-line variability >10 bpm and accelerations indicate well-being (Zuspan et al. 1979)
* FHR accelerations ~ fetal movements (Natale et al 1984)
  + Not causal (Bocking et al., 1985)
  + Both expressions of CNS
* Fetal behavioral state parameters (Nijhuis et al 1982)
* Most time in 1F and 2F states (95%)
* FHR measurements by abdominal ECG (HP 8030) or Doppler ultrasound (HP 8040)
* 1F state (FHR A)
  + 25% of time
  + 17+-8 min duration
  + Small FHR bandwidth/frequency variation (7 beats); little movement
  + Mouthing, breathing, and sucking cause clusters of heart rhythms, acceleration/deceleration periods, etc.
* 2F state (FHR B)
  + 60-70% of time
  + 34+-6 min duration
  + Body movement correlated with increased FHR
  + Hiccups, sucking, etc. increase FHR
* Early research interpreted ECG data visually, with subjective scoring system
* Type of movement and time of events impacts FHR pattern

**FETAL BEHAVIOR (Einspieler, Prayer, and Prechtl)**

**4. Behavioral States**

* Fetal heart rate patterns can be classified with programs like cf (Lange et al 2009)
* Response to vibroacoustic stimuli greatest during 1F (Devoe et al 1990)

**8. Functional Assessment of the Fetal Nervous System**