Electroencephalography: EEG
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Anesthesia

• Case Contingent to TARGET PATTERN
  – Carotid
    • This is WAR
  – Cerebral Aneurysm
    • This is B.S.
  – Elective Hypothermia
    • This is NOTHING
Medical Necessity

• Case Contingent to ICD-10 CODE
  – INVOLVES THE DIAGNOSIS OF “SEIZURE” OR “EPILEPSY”
  – Hourly Code is NOT reimbursed when the EEG codes are billed
Number of Channels

- CPT CODE AND NUMBER OF CHANNELS
  - Know your LCD BY PAYER
- CAROTID-CHANNELS?
- BURST SUPPRESSION-CHANNELS?
- HYPOTHERMIA-CHANNELS?
- SPINE-MEDICALLY NECESSARY?
The International 10-20 System

- Provides standardized electrode placement
- Internationally recognized
- Odd Number: Left side
- Even numbers: Right side
- Z’s: Midline

Intraoperative Electroencephalography – EEG CNIM
## EEG Frequency Bands

<table>
<thead>
<tr>
<th>Frequency Bands</th>
<th>Frequency Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delta</td>
<td>0 - 4 Hz</td>
</tr>
<tr>
<td>Theta</td>
<td>4 - 7 Hz</td>
</tr>
<tr>
<td>Alpha</td>
<td>8 - 13 Hz</td>
</tr>
<tr>
<td>Beta</td>
<td>&gt; 13 Hz</td>
</tr>
</tbody>
</table>

*Alpha (α): 6-13 Hz
Occipitally*
**Intraoperative Electroencephalography – EEG CNIM**

<table>
<thead>
<tr>
<th>Frequency Bands</th>
<th>Frequency Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAMMA</td>
<td>A <strong>gamma wave</strong> is a pattern of neural oscillation in humans with a frequency <strong>between 25 and 100 Hz</strong>, though <strong>40 Hz</strong> is typical. <strong>Related to depth of anesthesia (patient state index)</strong></td>
</tr>
</tbody>
</table>
### A Short Lesson in EEG

<table>
<thead>
<tr>
<th>Anesthetic</th>
<th>Dominant Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Medication</td>
<td>Alpha Dominant with Eyes Closed Awake O₁ &amp; O₂</td>
</tr>
<tr>
<td>Versed Twilight</td>
<td>Low Voltage Diffuse Theta</td>
</tr>
<tr>
<td>Asleep</td>
<td>Generalized Delta with Superimposed Fast Activity (BETA)</td>
</tr>
<tr>
<td>Deeper Sleep</td>
<td>Burst Suppression</td>
</tr>
<tr>
<td>&gt; Meds</td>
<td>Iso-electric or “Flat” EEG</td>
</tr>
</tbody>
</table>
➢ 10 SECONDS PER PAGE
➢ LOCATE O1 & O2 ELECTRODES

➢ ALPHA: 8-13 HZ O1 & O2

STAGE I AWAKE
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STAGE II
THETA & DELTA
EARLY STAGES OF ANESTHESIA
A Short Lesson in EEG

STAGE III
GENERALIZED OR DIFFUSE DELTA
A Short Lesson in EEG

STAGE III
GENERALIZED OR DIFFUSE DELTA WITH SUPERIMPOSED BETA
A Short Lesson in EEG

STAGE IV
BURST SUPPRESSION
A Short Lesson in EEG

STAGE V
ISO-ELECTRIC OR “FLAT” EEG
# A Short Lesson in Quantified EEG

<table>
<thead>
<tr>
<th>EEG Format</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CSA</strong></td>
<td><strong>Compressed Spectral Array</strong></td>
</tr>
<tr>
<td><strong>FFT</strong></td>
<td><strong>FAst Fourier Analysis</strong></td>
</tr>
<tr>
<td><strong>SEF</strong></td>
<td><strong>Spectral Edge Frequency</strong></td>
</tr>
</tbody>
</table>
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SPECTRAL EDGE FREQUENCY FOR CAROTID ENDARTERECTOMY: 90 – 97% of EEG Power
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- EEG **Monitoring**
  - Monitors fluctuation from baseline
  - Carotid Endarterectomy
  - Cardiopulmonary Bypass
  - Intracranial aneurysm clipping

- EEG **Testing**
  - Utilized for localization of brain function or disturbance
  - Epilepsy Surgery
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- **EEG Monitoring**
  - Physician available real-time, on-line for interpretation
  - Technologist provides data description only

- **EEG Testing**
  - EEG Cortex is exposed
  - Electrocorticography
  - Physician MUST BE PRESENT (Direct Supervision)
EEG Monitoring
- Full International 10-20 Array of scalp electrodes
- Document changes in standard placement
- 16 channels minimum

EEG Testing
- Grids or strips utilized on cortex
- Placed by neurosurgeon
- Four Channels adequate
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CAROTID ENDARTERECTOMY MONITORING
Indication for Monitoring

Carotid endarterectomy:
- Surgical procedure designed to prevent ischemic stroke by removing the atheromatous lesion at the carotid bifurcation and restoring the patency of the carotid vessels to an almost normal level.
Indication for Monitoring

- Detect Cerebral Ischemia particularly during carotid artery clamping. Insure *Collateral Perfusion*
- Indicates necessity for vascular shunt
- Selective shunting can reduce incidence of stroke 10-fold (Numerator 1993)
Which vessels play the largest role in collateral perfusion during Carotid Endarterectomy?

- Anterior Cerebral Artery
- Anterior Communicating Artery
- Basilar Artery
- Cerebellar Artery
- Internal Carotid Artery
- Middle Cerebral Artery
- Posterior Communicating Artery
- Circle of Willis
Which vessels play the largest role in collateral perfusion during Carotid Endarterectomy?

- Anterior Cerebral Artery
- Anterior Communicating Artery
- Basilar Artery
- Cerebellar Artery
- Internal Carotid Artery
- **Middle Cerebral Artery**
- Posterior Communicating Artery
- **Circle of Willis**
Monitoring Modalities:

- EEG
- Upper Median Nerve SSEP
  - Right Carotid-Left Upper SEP
  - Left Carotid-Right Upper SEP
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EEG in Carotid:

Circle of Willis

➢ 50% of population have an intact and functioning circle (estimated)

➢ Only 25% have the classic configuration
EEG in Carotid: Anesthesia

- If EEG monitoring is being used in ANY case, including carotids, the recommendation is to never use propofol.
- Propofol, at even very low infusion rates can cause modes burst suppression and render the EEG modality useless.
- Recommendation is isoforane or desforane and narcotic.
Intraoperative Baselines~Anesthesia

■ Steady-state anesthesia required and:
  ■ Minimum of 10 minute baseline pre-clamp recording
  ■ Minimum of 10 minute recording period following restoration of blood flow upon clamp release
EEG in Carotid:
Pre-operative Studies

Pre-existing hemispheric attenuation (flattening, amplitude decay, and hemispheric suppression) may prevent monitoring from providing a sensitive measure in surgical procedures where collateral perfusion is at risk (carotid endarterectomy).
EEG in Carotid: Amplifier Settings

- Sensitivity = 7 µV/mm - 2 µV/mm
- **Bandpass = 1 – 70 Hz**
- Sixty Cycle = Off or Disabled
- Paper Speed = 30 mm/sec or 10 seconds per page
What frequencies of brain activity are being assessed?
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EEG in Carotid: Montage

Bipolar anterior-posterior, montage

since it is less prone to artifact and ideal for inter-hemispheric comparative data.
EEG in Carotid:

EEG Patterns with sub-MAC concentrations of anesthetic agents:

**WAR**

*Widespread anteriorly maximum rhythm.*

(Blume & Sharbrough 1993)
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EEG in Carotid:

WAR*

- Rhythmic lower Beta or Alpha (8-14 Hz)
- Dominant over the anterior hemispheric region
- Lighter levels of steady state anesthesia, WAR pattern becomes generalized
Alarm Criteria-Onset of EEG Changes

- 80% changes appear <One minute
- 69% changes appear within 20 seconds
- Major changes begin earlier, with more than 80% of these occurring within the first 20 seconds

(Blume & Sharbrough 1993)
What is the maximum amount of time one would expect changes to occur in CAE?
Alarm Criteria

- Generalized or focal decrease in fast activity
- Focal, unilateral attenuation post-clamp indicates need for shunt
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EEG in Carotid:

Alarm Criteria: Nuwer 1994

- Greater than 50% loss of overall EEG amplitude or fast activity, or
- Greater than 50% increase in slow activity
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EEG in Carotid:

Alarm Criteria

After clamp, if 50% attenuation is noted at ANY TIME, the surgeon is alerted.

A SHUNT WILL THEN BE PLACED.
EEG in Carotid:
After shunt placement, focal EEG changes typically resolve in 2-7 minutes.
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CEREBRAL ANEURYSM & VASCULAR RECONSTRUCTION MONITORING
Indication for Monitoring

- Manages pharmacological cerebral protection of the brain during surgical manipulations utilizing Burst Suppression validation
- Cerebral ischemia always a risk
- Cerebral perfusion may be compromised by the placement of retractor and clips
EEG in Aneurysm:
EEG in Aneurysm:

- Burst Suppression Criteria:
  - Number of bursts/min – usually at 6-8/min
  - Burst length – usually 2-4 seconds
  - Burst Suppression ratio (BSR)
    - Burst length vs. suppression length
      - 1:4 – 1:5
    - Burst per minute needs to be compared to burst length or
    - Burst length verses the suppression length will both give the burst suppression ratio
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CARDIAC BYPASS & ASCENDING AORTIC ANEURYSM REPAIR
EEG in Ascending Aortic Aneurysm

Spinal cord ischemia in thoracoabdominal aortic surgery is caused by the imbalance of oxygen demand and oxygen delivery produced by aortic occlusion. Ischemia and reperfusion initiate neurochemical cellular responses that can exacerbate ischemia, which may in turn progress to infarction. The most important factors in protecting the spinal cord during and after thoracic and thoracoabdominal aortic replacement are perfusion, metabolism, and oxygen delivery to the spinal cord during the vulnerable period of aortic occlusion, when spinal cord blood flow is significantly reduced as well as after aortic replacement while the co-axial collateral network is recruited to return resting blood flow to near-normal levels.
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EEG in Ascending Aortic Aneurysm

Risk: Paralysis

History Taking:
Crawford Levels, Symptoms & Neurological Deficits
Crawford Classification-Four Types

Type 1: Aneurysm from the origin of the left subclavian to the suprarenal abdominal aorta
Type 2: From the subclavian to the aortoiliac bifurcation
Type 3: Distal thoracic aorta to the aortoiliac bifurcation
Type 4: Limited to the abdominal aorta below the diaphragm.

Significance has to do with the extent of the repair, the risk to the great vessels off the arch and the reimplantation of segmentals
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EEG in Cardiac Bypass

Indication for Monitoring

- Utilized during valve replacement & coronary artery bypass grafting (CABG) which use extracorporeal circulation
- Used to detect ischemia
- Indicates prompt for increase in pump pressure

CARDIOPULMONARY BYPASS MACHINE ALSO DELIVERS ANESTHESIA
 EEG in Cardiac Bypass

Indication for Monitoring

- Pumps may cause significant artifact preventing monitoring
- Hypothermia may introduce an isoelectric EEG
  - Most commonly seen at 15 degrees C
  - Some patients will have isoelectric EEG at 17-18 degrees C
  - Some may need cooling to 11 degrees C (rare)
- Isoelectric EEG is sometimes used to validate an environment of cerebral protection (Nurger 1993)
Indication for Monitoring
The EEG may be used for monitoring brain function during cardiovascular surgery (involving extracorporeal circulation and hypothermia). Hypothermia is induced to protect brain function during periods of prolonged circulatory arrest. The state of ECS induced by profound hypothermia is considered a state of cerebral inactivity protecting the brain against the effects of hypoxic-ischemia.
Indication for Monitoring
EEG changes first consist in a slowing of background rhythms (at 29–30 °C) followed by a burst-suppression pattern at 20–22 °C, and electrocerebral silence (ECS) at 15–18 °C (Prior, 1973). ECS is considered the endpoint for hypothermic circulatory arrest. SEP changes consist of a latency increase of all components, followed by the gradual disappearance of N30 (at a mean temperature of 30 °C), P27 (27 °C), N20 (21 °C), and P14 (17 °C) (Guer’rit et al., 1990; Fig. 3).
Elective Hypothermia

Name the two main tools for monitoring?
Name the criteria for each tool.
Name the temp known to insure ideal hypothermia.
Long OR Case?