Monitoring

ECG features

Pulse Oximetry

Neurological monitoring

Neuromuscular monitoring

College requirements
ECG features

<table>
<thead>
<tr>
<th>Lead</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA</td>
<td>Right wrist</td>
</tr>
<tr>
<td>RL</td>
<td>Right ankle</td>
</tr>
<tr>
<td>LA</td>
<td>Left wrist</td>
</tr>
<tr>
<td>LL</td>
<td>Left ankle</td>
</tr>
<tr>
<td>V1</td>
<td>4th intercostal space, right of sternum</td>
</tr>
<tr>
<td>V2</td>
<td>4th intercostal space, left of sternum</td>
</tr>
<tr>
<td>V3</td>
<td>Between V2 and V4</td>
</tr>
<tr>
<td>V4</td>
<td>5th intercostal space, left midclavicular line</td>
</tr>
<tr>
<td>V5</td>
<td>5th intercostal space, left anterior axillary line</td>
</tr>
<tr>
<td>V6</td>
<td>5th intercostal space, left midaxillary line</td>
</tr>
</tbody>
</table>

**Change**

**ECG Response**

| Hypokalemia | ST segment depression |
| T wave flattening and inversion |
| Tall U wave |

| Hyperkalemia | Tall T wave |
| PR interval prolongation |
| ST segment depression |
| QRS widening |
| Ventricular fibrillation |

| Hypocalcemia | Prolonged Q-T interval |

| Hypercalcemia | Short Q-T interval |
| ST segment may disappear |

| Hypothermia | Bradycardia, prolonged PR, QRS and QT |
| Below 33˚C: J wave, T inversion, 1˚ AVB, AF |
| Below 30˚C: 3˚ AVB |
| Below 28˚C: VF increasingly common |
| Below 20˚C: asystole |

| Digoxin | Prolonged PR, short QT, ST depression “scooped” |
| Small or inverted T |

**ECG feature**

**Diagnosis**

| Upsloping ST depression | Likely ischaemia |
| Downslipping ST depression | Definite ischaemia |
| Inverted T wave | Subendocardial ischaemia |
| ST elevation | Transmural ischaemia |
| Q wave >0.03 s | Infarction |
Pulse Oximetry

Artefacts in SpO₂

- COHb, HbH: slight ↓ SpO₂ (appears as deoxyHb)
- MetHb: approaches 85%
- SulfHb: appears as MetHb on co-oximetry
- HbKöln: ↓ by 8-10%
- Dyes: ↓ variable severity
  - methylene blue > isosulfan blue > indigo carmine, indocyanine green
- Anaemia: increasing underreading with hypoxia

Venous pulsation, vasodilatation
↓ SpO₂ due to venous pulsation

Black henna, dark nail polish, deep pigmentation, tape, vasoconstriction
reduced signal

HbF, HbS, Hb substitutes, fluorescein, polycythaemia, red henna, jaundice
no effect
Neurological monitoring

EEG

Electrodes

"10-20 system"

- 20 electrodes in a standard arrangement
- < 5 kΩ resistance

Intraoperative use usually a smaller subset

Signal

- 10-50 µV, 4-20 Hz
- β: >13 Hz
- α: 8-13 Hz
- θ: 4-8 Hz
- δ: 4 Hz

Processing

- Full EEG is 16-20 channels
- Processed EEG
  - Power analysis (simple spectral analysis)
  - Spectral Edge Frequency 95% (95th centile frequency)
  - Median Frequency
  - Relative Delta Power (% in δ band)
  - Bispectral analysis
    - Includes phase data in analysis
    - Bispectral Index (BIS)
      - 0-100, 50% unconscious at 67, 95% at 50
      - Validity for amnesia, unconsciousness, prevention of response to surgery depends on the anaesthetic technique

Change with anaesthesia

- Standard pattern with increasing depth
  - Activation, frontal spindles, 1-3 Hz activity, burst suppression, silence
  - Produced by barbiturates, propofol, etomidate, benzodizepines (no silence), volatiles (except epileptiform activity with enflurane)

- Opioids
  - ↓ frequency, ↑ amplitude

- Ketamine
  - Frontal θ activity with ↑ amplitude
  - Higher doses, δ and β activity
  - No silence, slow recovery of normal pattern

- N₂O
  - Potentiates standard agents
  - Alone produces frontal >30 Hz activity

- Hypoxia
  - Slowing, silence with severe hypoxia

- Hypotension
  - Severe hypotension required for clear effects: low frequencies

- Hypothermia
  - Slowing, silence at 15-18°C

Transcranial Doppler ultrasound

- Principle
  - Continuous wave Doppler ultrasound
  - Applied to temples
  - Aligned with middle cerebral artery

- Function
  - Display of velocity spectrum against time
  - Derived values for an index of cerebral blood flow and pulsatility
  - Detection of emboli, vasospasm
Assessment of autoregulatory function by monitoring blood flow over a range of perfusion pressures

Jugular bulb oximetry
 Principle
 Oximeter inserted percutaneously into internal jugular vein
 Function
 Measured $\text{SvO}_2$ of venous drainage of brain
 Combined with $\text{SaO}_2$ allows calculation of an index of $\text{O}_2$ extraction
 Maximal $\text{O}_2$ extraction suggests ischaemia
 Problems
 Careful calibration required
 Assessment only of global perfusion
 Significant variability from side to side
 Bilateral placement might be necessary

Cerebral oximetry
 Principle
 Pulse oximeter applied to scalp
 Function
 Output related to scalp perfusion, no useful information about cerebral ischaemia

Evoked potentials
 Applications
 Cerebral injury: carotid surgery, craniotomy, CPA surgery
 Spinal injury: AAA, spinal cord and column surgery
 Peripheral nerve injury: parotidectomy...
 Visual evoked potentials
 Goggles with flashing patterns, occipital EEG
 Test retina, optic nerve, chiasm, radiation, occipital cortex
 Rarely used
 Somatosensory evoked potentials
 Transcutaneous nerve stimulation (20 Hz, 100-400 V)
 EEG monitoring (frequency tuned 1-2 $\mu$V amplitude)
 Measured: waveform amplitude and latency
 Latency ↑ 15%, amplitude ↓ 50% suggests injury
 Tests nerve, dorsal and ventrolateral tracts, cortex
 Median nerve → MCA territory
 Posterior tibial nerve → ACA territory
 Interference
 Drugs
 $\text{N}_2\text{O} >$ volatile $>$ propofol: ↓ amplitude
 opioids: minimal ↑ latency
 Hypothermia: ↑ latency 1.15 ms (5%) per °C
Neuromuscular monitoring

At 60 Hz

- 0.05 mA: microshock current for VF
- 0.3-0.5 mA: threshold of perception
- 0.1-2.5 mA: macroshock current for VF
- 1-2 mA: pain
- 8-20 mA: “cannot let go”