Non-Routine Electroencephalography

Clinical Neurophysiology

1. Purpose
This guideline provides recommendations regarding best practice for electroencephalography (EEG) in a non-routine setting, to support high quality EEG practice throughout Queensland public health facilities.

2. Scope
This guideline provides information for all clinical measurement practitioners who perform EEG in a non-routine setting, including:

- portable EEG
- neonatal EEG
- EEG monitoring in critical care environments
- EEG in suspected electro-cerebral silence (ECS).

3. Related document
Authorising Policy and Standard/s:
- Nil

Procedures, Guidelines and Protocols:
- Queensland Health Guide to Informed Decision-making in Healthcare
- Australian Guidelines for the prevention and control of infection in healthcare (CD33:2010)

Forms and templates:
- Consent to clinical digital images

4. Guideline for non-routine electroencephalography (NR-EEG)

4.1. Emergency Protocol
Follow local Hospital and Health Service protocols in the event of a seizure.
Follow relevant Hospital and Health Service protocols or procedures in the event of an emergency.
4.2. Infection Control Procedures

- [Australian Guidelines for the prevention and control of infection in healthcare](CD33:2010) 

4.3. Gaining Consent

- Gain consent using the Queensland Health Informed Decision-making in Healthcare document. Document the consent appropriately according to local work guidelines eg in the patient’s medical record.
- Epilepsy and photosensitive seizure disorders are not considered a contraindication for photic stimulation; however the patient should be made aware that there is a slight risk of provoking a seizure during Intermittent Photic Stimulation (IPS)⁵,⁶. This also applies to hyperventilation.
- Signed consent is required from the patient (or their legal guardian/carer) to record their digital image during the EEG. File the signed consent document in the patient’s medical record³.

4.4. Identifying Indications and Contraindications for performing NR-EEG

- The primary indication for performing an EEG is to obtain supportive evidence for the clinical diagnosis of an epileptic disorder⁷.
- In the critical care setting this may be expanded for the investigation of frequent epileptic seizures, status epilepticus, encephalopathy, an encephalitic process. ECS and locked-in syndrome.
- Please refer to suggested readings for a list of possible indications for performance of non-routine EEG.

4.5. Facilities and equipment

**Testing Facilities**

- Perform the non-routine EEG within a quiet, temperate room with controllable light levels, if possible.
- Recline the patient comfortably for the duration of the set up and recording.
- Use portable equipment for recordings performed outside of the routine EEG recording environment.

**Personnel and training requirements**

Relevant training includes:

- Undergraduate course(s) offered at Central Queensland University and Charles Sturt University
4.6. Test Procedure

4.6.1. Electrodes

**Electrode Placement**
Place the electrodes in accordance with the International 10/20 System of Electrode Placement (Appendix 1). Use a minimum of 19 electrodes, as well as reference and ground electrodes. Additional polygraphic channels of ECG and EOG are standard included for neonatal EEG.

**Electrode Choice**
To record a routine EEG, use electrodes that allow undistorted recordings within a frequency range of 0.5 – 70Hz. The electrodes used are to be of the same material - preferably silver/silver chloride (Ag/AgCl) or gold cup.

**Electrode Impedance**
Measure electrode impedance prior to each recording and at any time during the EEG when an electrode is altered or adjusted. Measure the impedances of all electrodes to ensure the impedance is 5Kohms or below and of similar value, i.e. within 3kohm range of each other.

4.6.2. Pre-test checks

**Calibration**
Record a square wave calibration signal of known input for a minimum of 10 seconds prior to the EEG recording and store this with the EEG. This square wave calibration recording documents the machine parameters (filters and sensitivity settings) used during the EEG recording.

**Biological Calibration**
Record, where possible, a biological calibration of no less than 10 seconds and store this with the EEG.

**All Electrode Check**
Perform an electrode check by recording a period of no less than 10 seconds with the primary reference montage (digital EEG recording systems) displaying all recording electrodes. Perform this at the beginning of the EEG recording and store with the EEG.

4.6.3. Portable EEG

- If performing EEG in a non-routine setting - apart from ICU, neonatal unit or similar - refer to the Queensland Health Guideline: Routine Electroencephalography (EEG).
- Please note that portable EEG recordings performed in a non-routine environment are more likely to be technically and clinically challenging and should be performed or supervised by an experienced Neurophysiology Clinical Measurements Practitioner.
4.6.4. Neonatal EEG

Electrodes

Measure electrode positions in accordance with the International 10/20 System where possible \(^\text{11-13}\). In most cases a full number of electrodes can be applied to a neonate's head. In the case of neonates at 24-26 weeks gestational this may not be possible due to small head size, therefore a reduced number of electrodes may be applied. This is to ensure an adequate inter electrode distance is achieved \(^\text{11-13}\). Any change to the routine placement of electrodes must be documented in the written report.

The minimum electrodes are Fp1, Fp2, C3, C4, Cz T3, T4, O1, O2, and A1, A2 (mastoid electrodes) with an example derivation shown in Fig 1 \(^\text{11,13}\).

![Example derivation for neonatal EEG with limited placements](image)

Figure 1. Taken from Neonatal EEG (1999), Example derivation for neonatal EEG with limited placements \(^\text{13}\).

Note: Combining both images gives a representation of a single montage with additional polygraphic channels noted.

Polygraphic electrodes

Monitoring should routinely include but not be limited to Electrocardiogram (ECG), Electro-oculogram (EOG), Electromyograph (EMG) and Respiratory monitors \(^\text{7,13}\).

During the routine EEG it may be necessary to record from additional polygraphic channels generally with the purpose of distinguishing artefact from cerebral potentials.

ECG – Electrocardiogram (heart beat) shall always be recorded in conjunction with the EEG and displayed on all recording pages.
**Patient Information**

Document patient information including: patient name, hospital reference (UR) number, date of birth, recording date, referring doctor, recording scientists initials name, recording time, clinical details (last seizure, handedness, last meal, and behavioural state) current medications and any sedation given prior to the test. Include notation of any skull defects or sites of previous surgery within the factual report or within information supplied to the reporting medical officer. 

Patient and clinical information is required for recording EEG in neonates which shall include but not be limited to:

- conceptual and gestational ages
- medical history (e.g. asphyxia)
- history of abnormal movements
- Apgar score
- medications (including time of cessation of medications, if applicable)
- mechanical ventilation
- cooling protocol (is patient on this protocol?)
- head circumference
- skull defects/malformation/oedema
- time of last feeding
- time of last event if applicable.

**Annotations**

Make regular annotations to mark any changes in the EEG or the patient’s state and behaviour throughout the recording. This includes any movement of the patient, any external stimuli, artefacts, instructions given etc. 

Continuous observation and annotation is important and should include but is not limited to:

- patient state (awake/indeterminate sleep/active sleep/quiet sleep)
- behaviour/movements (gross and subtle)
- physiologic parameters (changes in oxygen saturation, heart rate etc)
- administration of medication (time and type) if applicable
- assisted eye closure, if performed
- reactivity to stimuli from the environment
- features of clinical events.
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Montages
Use a selection of recording montages during the baseline EEG. Use a minimum of anterior-posterior bipolar and transverse bipolar montages. Incorporate a reference montage (e.g. common, average and / or source) into the routine EEG. Represent all recording electrodes on the montages, at some time during the recording.

Length of Recording
The neonatal recording should include both awake and sleep cycles. A minimum recording of 60 minutes should therefore be performed.

Machine Settings - Display
Record within the range of the following parameters:
- sensitivity – 5-10µV/mm of trace deflection
- low Frequency Filter – No higher than 1Hz
- high Frequency Filter – No lower than 70Hz
- notch filter – Not be used in the routine setting and only to be used when all technical means have been employed to reduce 50Hz interference
- paper speed – 30mm/sec or 10 seconds per page/screen for standard screen size

Settings
- low pass filter – 0.16-0.3Hz
- high pass filter – 70Hz
- screen sensitivity 7 – 10uV/mm
- sampling rate – 256Hz.

Stimulation
Tactile and auditory stimuli should be applied toward the end of the recording and reactivity noted in the annotations.

4.6.5. EEG Monitoring in Critical Care Environments

Electrodes
When possible, measure electrode positions in accordance to the International 10/20 System of Electrode Placement. If the head cannot be measured due to clinical constraints, document this information for the reporting clinician.

Note: Any deviation from the placement system should also be documented e.g. in the instance of a surgical wound at a measured electrode placement.
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**Recording**

If a high level of electrical interference is present on the EEG recording the 50Hz notch filter may be utilised. If so, this should be documented in the technical notes. A 50Hz notch filter shall only be used after all other methods of eliminating mains interference, such as reduction of electrode impedances and/or appropriate earthing and positioning of mains equipment, have been fully explored.\(^{16}\)

**Patient Information**

Additional patient and clinical information is required for recording EEG in the critical care unit which should include but not be limited to:

- all medications and dosages including sedative agents and any agents introduced during the recording period
- how long prior to the EEG any sedative agents were ceased (if applicable)
- site of skull defects and or surgical wounds if present
- details of intracranial pathology and lateralisation, if known
- details of seizures (if applicable)
- description of clinical events
- time of last noted clinical event
- metabolic disorders
- results of relevant investigations (MRI, CT etc)
- current Glasgow Coma Scale (GCS).

**Annotations**

Continuous observation and annotation is important and should include the following where appropriate (but is not limited to):

- change to or the administration of medication during the recording including dosage
- nursing intervention/patient interaction
- environmental stimuli such as ward noise
- heart rate, SpO2 level and blood pressure at regular intervals and for any noted changes
- any intentional stimulation including the nature of the stimulation both when it is applied and ceased
- any clinical features/events or changes to the patients state.
Montages

Use a selection of recording montages during the baseline EEG. Use a minimum of anterior-posterior bipolar and transverse bipolar montages. Incorporate a reference montage (common, average and source) into the routine EEG. Represent all recording electrodes on the montages, at some time during the recording.

Length of Recording

The EEG should be no less than 20 minutes of technically satisfactory, artefact free baseline recording where possible.

If any type of status epilepticus is suspected and appears evident from the recording or the recording is grossly abnormal, appropriate medical advice should be sought whilst still recording. e.g. contact the Specialist Consultant or Registrar for continuation advice.

Stimulation

Any comatose patient should be stimulated during the EEG recording to determine the clinical and EEG reactivity of the stimulus. In patients who are not sedated this has proven to yield prognostic value.

Stimulation should include but not be limited to:

Auditory Stimulation

- Loud claps should be performed close to both sides of the patients head for auditory stimulation. It is important to stimulate bilaterally as there may be blockage of an ear canal or unknown partial hearing of one side. This should be annotated along with any EEG or clinical changes. A minimum of 20 seconds should be left between each set of claps to determine any developing changes to the EEG that may occur.
- The patient’s first name or preferred name (if known) should be called loudly next to each of the patient’s ears. This should be annotated along with any EEG or clinical changes. There should be a 20 second pause between side stimulation.

Painful Stimulation

- Reactivity of the EEG can be tested with painful stimuli. An example of this could be pressure for 5 seconds applied to the nail bed at the base of the nail of each big toe and thumb with a 20 second pause between each limb. This is to take into account any unknown hemiplegia or hemi paresis. This should be annotated with any EEG or clinical changes.

Central Stimulation

- If the patient is intubated ask the nurse to suction the patient. This should again be annotated and any EEG or clinical changes should also be annotated.
4.6.6. EEG in Suspected Electroencephalographic Silence (ECS) 20

**Electrodes**
A full complement of EEG electrodes (21) should be used.

**System Integrity**
The integrity of the recording system should be confirmed if, after recording for a period of time at an increased sensitivity, there is evidence of electro-cerebral silence.

This is done by touching each electrode in the montage with a cotton tipped applicator to produce an artefact potential on the record. This will confirm that all recording electrodes are working effectively and will prove that the montage settings match the electrode placements.

**Montages**
Montages for recording in suspected ECS should represent inter-electrode distances of 10 cm or more. This is to ensure that low-voltage cerebral potentials are not overlooked, as can sometimes occur with shorter inter-electrode distances.

To achieve this, specialised montages comprised of double distance electrode linkages should be available to use. This does not exclude the use of pre-selected laboratory montages during the recording however, any EEG evidence of ECS should be further viewed with montages containing longer inter-electrode distances.

**Sensitivity**
Sensitivity of the EEG recording will need to be increased in order to view any cerebral potentials of 2 µV and less (criterion for ECS).

The EEG in cases of suspected ECS should be recorded at a sensitivity of at least 2 µV/mm for a minimum of 30 minutes.

**Calibration**
The calibration signal should be similar in voltage to the potentials recorded. In suspected ECS it is therefore appropriate to calibrate at 2 µV or 5 µV.

**Polygraphic Recording**
Electrocardiogram (ECG) must be recorded to ensure correct recognition of ECG artefact in the recording (due to recording at an increased sensitivity).

Other polygraphic recordings such as surface EMG and EOG may also be included.

**Length of Recording**
EEG recordings in cases of suspected ECS should be no less than 30 minutes in duration in order to be certain that intermittent low voltage cerebral activity is not missed.
**Stimulation**

Any comatose patient should be stimulated during the EEG recording to determine the clinical and EEG reactivity of the stimulus. In patients who are not sedated this has proven to yield prognostic value. Stimulation should include but not be limited to:

**Auditory Stimulation**

- Loud claps should be performed close to both sides of the patients head for auditory stimulation. It is important to stimulate bilaterally as there may be blockage of an ear canal or unknown partial hearing of one side. This should be annotated along with any EEG or clinical changes. A minimum of 20 seconds should be left between each set of claps to determine any developing changes to the EEG that may occur.

- The patient's first name or preferred name (if known) should be called loudly next to each of the patient's ears. This should be annotated along with any EEG or clinical changes. There should be a 20 second pause between side stimulation.

**Painful Stimulation**

- Reactivity of the EEG can be tested with painful stimuli. An example of this could be pressure for 5 seconds applied to the nail bed at the base of the nail of each big toe and thumb with a 20 second pause between each limb. This is to take into account any unknown hemiplegia or hemi paresis. This should be annotated with any EEG or clinical changes.

**Central Stimulation**

- If the patient is intubated ask the nurse to suction the patient. This should be annotated together with any EEG or clinical changes.

**Note:** EEG’s in cases of suspected ECS should always be performed or supervised by an experienced Neurophysiology Scientist.

**Note:** The temperature of the patient should be documented in the technical notes to assist with accurate reporting of the EEG, for example when having had hypothermia treatment.

**4.6.7. Scientist Preliminary Report Writing**

A concise descriptive factual report should be prepared by the scientist covering the procedure employed, electrographic findings and clinical events but without clinical interpretation. This can include but is not limited to:

- describing normal values of frequency, amplitude, distribution and amount in relation to age using standard terms to describe the data.
- describing the correlation of normal rhythms/variants with changing physical state
- describing the effect of stimulation/activation
describing abnormal features using standard terms to describe the data.

4.7. Quality Control Procedures

For calibration techniques and machine checks for digital EEG machines, please refer to:

4.8. Review

This Guideline is due for review on: 07/12/2016

Date of Last Review: New document

Supersedes: Nil

5. Business Area Contact

Dane Enkera - Statewide Clinical Measurements Network (Chair)

6. Definitions of terms used in the policy and supporting documents

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition / Explanation / Details</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apgar</td>
<td>APGAR is a quick test performed at 1 and 5 minutes after birth. The 1-minute score determines how well the baby tolerated the birthing process. The 5-minute score assesses how well the newborn is adapting to the new environment. The rating is based on a total score of 1 to 10, with 10 suggesting the healthiest infant.</td>
<td><a href="http://www.nlm.nih.gov/medlineplus/ency/article/003402.htm">http://www.nlm.nih.gov/medlineplus/ency/article/003402.htm</a></td>
</tr>
<tr>
<td>Electrocerebral silence</td>
<td>No EEG activity over 2 uV when recording from scalp electrode pairs 10 or more cm apart with interelectrode impedances under 10,000 Ohms (10 KOhms), but over 100 Ohms.</td>
<td>American Clinical Neurophysiology Society Guideline 3: Minimum Technical Standards for EEG Recording in Suspected Cerebral Death, 2006. <a href="http://www.acns.org/">http://www.acns.org/</a></td>
</tr>
<tr>
<td>GCS</td>
<td>Glasgow Coma Scale - standard measurement of depth of coma using a scale developed by Teasdale, G., Jennett, B. (1974) Assessment of coma and Impaired</td>
<td></td>
</tr>
</tbody>
</table>
### Term | Definition / Explanation / Details | Source
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Department of Health: Non-routine Electroencephalography (NR-EEG) | the Neurosciences Department of Glasgow University in 1974. The lower the total mark is, the more severe the brain injury. The lowest total mark on the scale is 3. The highest total mark is 15. As a patient comes out of coma, the mark he/she gains on the scale rises. | Consciousness. The Lancet. 304;7822, pg 81-84


**Hemiparesis** | Partial paralysis (weakness) affecting only one side of the body. | [http://dictionary.reference.com/browse/hemiparesis](http://dictionary.reference.com/browse/hemiparesis)

**Hemiplegia** | Paralysis of one side of the body. | [http://dictionary.reference.com/browse/hemiplegia](http://dictionary.reference.com/browse/hemiplegia)

**Lateralisation** | Localisation of a function to the right or left side of the brain. | [http://www.thefreedictionary.com/lateralization](http://www.thefreedictionary.com/lateralization)

**Neonatal** | Of, or relating to infants, especially in the first week of life up to 4 weeks since birth. | [http://www.thefreedictionary.com/neonatal](http://www.thefreedictionary.com/neonatal)

**Sleep cycles (neonates)** | Consist of quiet sleep (analogous to NREM sleep) and active sleep (REM equivalent). Quiet sleep is characterised by minimal large or small muscle movements and rhythmic breathing cycles. During active sleep, sucking motions, twitches, smiles, frowns, irregular breathing, and gross limb movements (converse to the typical REM sleep paralysis seen at later ages) are seen. | [http://www.medscape.com/viewarticle/471909_4](http://www.medscape.com/viewarticle/471909_4)

### 7. Approval and Implementation

**Policy Custodian:**
Julie Hulcombe – Chief Allied Health Officer
Department of Health: Non-routine Electroencephalography (NR-EEG)

Responsible Executive Team Member:
Dr Michael Cleary
Deputy Director General
Health Services and Clinical Innovation

Approving Officer:
Dane Enkera – Statewide Clinical Measurements Network (Chair)

Consulting stakeholders:
Key stakeholders (position and business area) who reviewed this version are:
- Queensland Health Clinical Neurophysiology Working Party (Emma Fetherston, Fred Tremayne, Jo Wex, Carolin Healion, Annett Koenig, Kane Curtis, Susan Koklas)
- Clinical Measurements Advisory Group (CMAG) for Clinical Education and Training
- State-wide Clinical Measurements Network (SWCMN)
- Epilepsy Society of Australia – EEG Committee (Chairman Dr John Dunne)
- Association of Neurophysiological Technologists Australia Inc (ANTA)
- Dr Lata Vadlamudi – Consultant Neurologist and Epileptologist (RBWH)
- Dr Kate Rinney - Consultant Paediatric Neurologist & Epileptologist (Mater)
- Queensland Health Neurophysiology Laboratory Managers

Approval date: 07/12/2013
Effective from: 07/12/2013
8. Appendices

APPENDIX 1 - International 10/20 System of Electrode Placement

1. Locate and mark the required skull landmarks: inion, nasion and pre-auricular points.

2. Measure along the midline from the nasion to the inion with the centimetre tape. eg. 100%: 34cm
   a. Determine the mid point, 50% of the inion – nasion distance, e.g., 17cm.
      i. Mark the mid point; this is Cz.
   b. Determine 10% of the total inion - nasion distance, e.g., 3.4cm.
      i. Mark 3.4cm (10%) superior from the nasion along the midline. This is reference point Fpz.
   c. Determine 20% of the total distance, e.g. 6.8cm.
      i. From Fpz reference (not the nasion) measure 6.8cm (20%) back along the midline. This is the location of Fz.
      ii. Measure 6.8cm (20%) of the total distance back from Cz. This is the location for Pz.
   d. Locate Oz which is 6.8cm (20%) back along the midline from Pz.
   e. Verify that Oz is 3.4cm (10%) above the inion.

3. Measure the distance between the right and left pre-auricular points making sure that the tape goes through Cz. eg. 100%: 35cm.
   f. Determine the mid point, 50% of this distance, e.g. 17.5cm,
      i. Place a second mark for Cz. This completes the two marks for the Cz position.
   g. Keeping the tape in place through Cz, measure up 3.5cm (10%) from the right pre-auricular point and mark. This is one mark for T4.
   h. Determine 20% of the pre-auricular distance; e.g., 7cm.
      i. Mark 7cm laterally and inferior to Cz toward T4 (or 7cm superior to T4); this is the C4 marking which is also mid way between Cz and T4.
      i. Follow the same procedure on the left side of the head for C3 and T3

4. Measure the circumference of the head making sure that the tape goes through the frontal pole (Fpz), the occipital (Oz) reference point and T3 and T4 (mid temporal); eg. 100%: 54cm.
   a. Divide the total circumference by 2, (27cm) and calculate 10% (2.7cm) and 20% (5.4cm)
   These distances will be used for the following measurements:

   j. Measure 2.7cm to the left and right of FPz; this is Fp1 and Fp2 respectively.
   k. From Fp2 put the tape measure along the circumference line and continue moving posteriorly:
i. Mark 5.4cm (20%) from Fp2; this is the F8 mark.

ii. Mark 5.4cm (20%) from F8, and mark vertically through the previous T4 mark (section 3g above)

NOTE: this position may not be directly above the pre-auricular point.

iii. Mark 5.4cm (20%) posteriorly from T4; this is the T6.

iv. Mark 5.4cm (20%) posteriorly T6; this is the first mark for O2.

l. Repeat this procedure for the left side of the head, working posterior from the Fp1 mark previously made. One mark for F7, T5 and O1 should be established during this step and the T3 location is completed.

m. With the tape measure, verify that the distance between O1 and O2 is 20% (5.4cm) as well. (O1 → 10% → Oz → 10% → O2)

Placement checks to note: Fp1 and FP2 should be equidistant from the midline at the front of the head and O1 and O2 should be equidistant from the midline at the back of the head. T3 and T4 should be in the same position with respect to the ear on each side of the head.

5. To determine the second coordinate for each of the positions identified in the previous step (commonly referred to as the temporal or lateral chain of electrodes) place the tape measure at Fpz and the other at T4.

a. Mark along the straight edge of the tape through Fp2 and F8.

b. Repeat the same process from T4 to O2, marking along the straight edge of the tape horizontally through T6.

c. Repeat for the left side (placing tape from Fz to T3 marking through Fp1, and F7, then placing tape from T3 to O2 marking T5).

6. Measure the distance from Fp2 to O2 going through C4 (100%; 22cm).

a. Determine the mid point (50%; 11cm) from Fp2; this is the second measurement for C4.

b. Determine 25% (5.5cm) and mark this point halfway between Fp2 and C4; this is F4.

c. Using the calculation in the above step; mark 5.5cm from C4 to O2 (the half way point between C4 & O2); this is the P4 mark.

Repeat this procedure on the right hemisphere measuring from Fp1 to O1

d. Determine the mid point 50%: 11cm from Fp1; this is the second measurement for C3.

e. Determine 25% (5.5cm) and mark this point halfway between Fp1 and C3; this is F3.

n. Using the calculation in the above step; mark 5.5cm from C3 to O1 (the half way point between C3 & O1); this is the P3 mark.

7. With the tape, measure the distance from F7 to F8 through Fz (100%; 12cm).

a. Determine one half, 50%; 6cm, of this distance and mark. This becomes the final mark for Fz.
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o. The final mark for F3 (25%; 6cm) is placed halfway between Fz and F7.
p. Similarly, the final mark for F4 (25%; 6cm) is halfway between F8 and Fz.

8. Measure the distance from T5 to T6 through Pz (100% 18cm).
   a. Determine one half, 50%: 9cm, of this distance. This mark completes the Pz location.
   q. Determine 25%:4.5cm of the distance, and mark 4.5cm from Pz to T6 (also the mid point between the two); This is the P4 mark final point.
   r. Mark 4.5cm (25%) from Pz to T5, this the final mark for P4.

There will be two coordinates for each of the 19 standard electrode positions on the scalp. Ear electrodes, A1 and A2, make a full complement of 21 electrodes.

Figure 2: International 10/20 System of Electrode Placement

9. Suggested Readings and References

9.1. Suggested readings


9.2. References