Routine Visual Evoked Potentials

Clinical Neurophysiology

1. Purpose
This guideline provides recommendations regarding best practice to support high quality visual evoked potentials (VEP) practice throughout Queensland public health facilities.

2. Scope
This guideline provides information for all clinical measurement practitioners who perform routine VEP.

This guideline relates to the performance of pattern reversal (PR) (checkerboard) and flash VEP’s in clinical practice for children and adults who have the ability to concentrate and comply with the test requirements.

This guideline provides minimum requirements for recording a routine VEP.

3. Related documents

Authorising Policy and Standard/s:
- This Guideline is primarily based on the International Society for the Clinical Electrophysiology of Vision (ISCEV) standard for Clinical Visual Evoked Potentials (2010). References from alternate sources of information have been identified in this document.

Procedures, Guidelines and Protocols:
- Queensland Health Guide to Informed Decision-making in Healthcare ¹
- Australian Guidelines for the prevention and control of infection in healthcare (CD33:2010)²
- International Organisation of Societies for Electrophysiological Technology (OSET) Guidelines for Infection Control in the Clinical Neurophysiology Department 1999 ³

Forms and templates:
- Consent to clinical digital images ⁴
4. Guidelines for performing routine visual evoked potentials (VEP)

4.1. Emergency Protocol

• Follow Hospital and Health Service (HHS) protocols in the event of an emergency.

4.2. Infection Control Procedures

• International Organisation of Societies for Electrophysiological Technology (OSET) Guidelines for Infection Control in the Clinical Neurophysiology Department 1999
• Local Hospital and Health Service guidelines.

4.3. Gaining Consent

• Gain the patient’s consent using the Queensland Health Guide to Informed Decision-making in Healthcare document.

4.4. Identifying Indications/Contraindications

The indication for performing a VEP is for investigation of function of the visual sensory pathway. This can include but is not limited to:

• clinically silent central nervous system lesions in multiple sclerosis
• visual field defects such as hemianopia
• central scotoma.

Contraindications for performing a PRVEP include:

• marked visual impairment
• acute optic neuritis
• inability to co-operate with the testing procedure.

Note: If clinically indicated a flash VEP may be appropriate in these instances.

4.5. Facilities and equipment

• Perform the routine VEP within a quiet, temperate room with controllable light levels.
• Ensure the patient can sit comfortably for the duration of the set up and recording.
• Ensure the patient is able to view and concentrate on the stimulus pattern comfortably and with minimal disruption for the duration of the recording.
4.6. Personnel and training requirements

Relevant training includes:

- Undergraduate course(s) offered at Central Queensland University and Charles Sturt University
- Graduate Certificate in Clinical Neurophysiology offered at Charles Sturt University

4.7. Test Procedure

4.7.1. Electrodes

*Electrode Placement*

This guideline will refer to the 10/20 system of electrode placement as the internationally recognised standard.[5]

For the performance of routine visual evoked potentials, place the electrodes in accordance to the International 10/20 System of Electrode Placement.[6]

Place the recording electrodes at O1, Oz, O2. T5 and T6 can be placed if there are available recording channels. Place a reference electrode at Fz and a ground electrode at Cz.[7]

The Queen Square electrode placement can be utilised as an alternative method and has been shown to be useful when investigating hemi field defects.[5,8]

*Electrode Choice*

For electrodes used to record a VEP, ensure undistorted recordings of no less than a frequency range of 10 –100Hz.[6]

Ensure the electrodes used are of the same material - preferably silver/silver chloride (Ag/AgCl) or gold cup.[9]

*Electrode Impedance*

Measure electrode impedance prior to each recording. Electrode impedance should also be measured at any time during the VEP where an electrode needs to be altered or adjusted. Electrode impedance should be 5Kohms or below and be of a similar value, i.e. within 3kohm range of each other.[5]

4.7.2. Machine parameters

*Common Mode Rejection Ratio*

For common mode rejection to work effectively, ensure the active and reference electrodes are of equal impedance and all input electrode impedances maintained below 5Kohms.[10]

For VEP’s, set the common mode rejection ratio to 120dB or greater.[6]
**Input impedance of pre-amplifiers**
Set the pre-amplifiers for the performance of VEP’s to at least 100MΩ.

**Analogue to digital signal conversion**
Ensure the sample rate is a minimum of 500 samples per second per channel with a minimum resolution of 8 bits.

**Automatic artefact rejection**
Ensure automatic artefact rejection excludes signals that exceed +/- 50-100uV in amplitude and return to baseline rapidly following a high amplitude artefact.

**Filters**
For the purpose of VEP’s filters shall be set to the following levels:
- low Pass/High Frequency Filter ≥ 100Hz
- high Pass/Low Frequency Filter ≤ 1Hz.

The use of the 50Hz ‘notch filter’ is strongly discouraged. Any applicable artefact can be rectified by addressing the source of the interference, such as nearby electrical equipment or the recording electrodes.

**Sweep duration**
Generally 250ms post stimulus for adults is sufficient however if major response components are significantly prolonged or delayed, a longer analysis time may be required to obtain reproducible results (up to 500ms).

In children an analysis time of up to 400ms post stimulus may be required, or enough to adequately visualise a response.

**Averaging**
At least 100 individual trials to be averaged – more may be required (up to 400) to ensure reproducibility in low amplitude responses and to ensure that a stable waveform is recorded with minimal noise.

The quality of the recorded data shall be monitored while averaging the signal to ensure integrity and patient compliance/alertness. If compliance or fixation wanes during the recording, more trials may need to be averaged.

At least two total runs should be obtained and superimposed to verify reproducibility of waveform morphology, latency and amplitude.

### 4.7.3. Recording

**Patient Information**
Document the following details as minimum, with any VEP recording:
- patient name
- hospital reference number or unit record (UR) number
- date of birth
Determine the visual acuity of the patient prior to performing any VEP procedure. Allow the patient to wear their prescription glasses or contact lenses. It is important to make a note of any extreme pupil sizes or any anisocoria. For pattern reversal stimuli the patient must not have had any mydriatic or miotic drugs. Confirm the pupils are not dilated prior to the VEP using flash stimuli.

**Note:**

*Patient Attention*

Monitor the patient’s attention throughout the recording to ensure alertness and compliance with the requirements of the test.

If the patient becomes drowsy and loses the ability to readily fixate on a point, use encouragement and interaction to ensure that the latency of responses is accurate.

**4.7.4. Pattern reversal full field**

An alternating, high contrast black and white checkerboard is the standard pattern stimulus used.

If an abnormal VEP is obtained in a patient with visual symptoms, perform a pattern electroretinogram (pERG) if available. See section 4.7.8 and Appendix 1 for further information relating to pERG.

Example of Full Field Recording Montage (5 channel and 3 channel, respectively):

- Channel 1: T5 to Fz
- Channel 2: O1 to Fz
- Channel 3: O2 to Fz
- Channel 4: Oz to Fz
- Channel 5: T6 to Fz

Channel 1: O1 to Fz
Channel 2: Oz to Fz
Channel 3: O2 to Fz
Ground: Cz
**Pattern Reversal Full Field Markers:**

N75 – 1st negative peak (1st upward deflection)
P100 – 1st positive peak (1st downward deflection)
N145 – 2nd negative peak (2nd upward deflection)

![Pattern Reversal Full Field Markers](image)

Figure 1: Taken from Liveson (1992): Example of pattern reversal VEP waveforms.

**Note:** Please note, this image is provided as an example of waveform morphology only; not amplitude and latency.

**Settings**

**Stimulus Type**
- alternating high contrast (black and white) checkerboard

**Stimulus rate**
- 1-3 reversals per second or 200ms on and 400ms off

**Phases**
- responses to phases are averaged with the opposite phase

**Brightness contrast:**
- contrast between black and white shall be greater than 80%

**Intensity:**
- Ensure the mean luminance of the stimulus is greater than 50 cdm-2 and there is no change in mean luminance during the reversal of the pattern.
- Ensure the luminance is uniform and varies no less than 30% between the centre and periphery of the visual field.
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- Lighting within the recording room should be homogenous with an average room luminance equal to the average stimulus luminance; however the luminance of the background beyond the checkerboard stimulus is not critical to the results.

Stimulation
- Monocular stimulation is used to ensure that there is no masking of a unilateral conduction abnormality.

Check width
- Different check sizes can be used separately; large or small.
- Large checks should measure 60’ of arc (1˚ ± 20%); small checks should measure 15’ (0.25˚ ± 20%).

Field Size
- While it is not necessary to use a square field (for example computer monitor displaying the stimulus pattern does not need to be square) ensure the aspect ratio between width and height does not exceed 4:3 and the field size is at least 15˚ (of visual angle) at the smallest point.

Check colour
- Use an equal number of black and white checks.

Fixation point
- The fixation point shall be located in the centre of the screen positioned at the corner of four checks.

Distance of stimulus from patient
- The distance between the patient and the stimulus can range from 50 -150 cm, dependent on the visual arc required. Measure the distance from the nasion to the fixation point on the screen.

4.7.4.1. Pattern reversal hemi field

Each eye is tested separately to both left and right hemi-field stimulation; whereby the pattern is presented to one half of the visual field on one side of the fixation point.

Example of Hemi Field Recording Montage, Queen Square method (5 channel and 3 channel, respectively):

Channel 1: L10 to Fz    Channel 1: L5 to Fz
Channel 2: L5 to Fz    Channel 2: M0 to Fz
Channel 3: M0 to Fz    Channel 3: R5 to Fz
Channel 4: R5 to Fz    Ground: Cz
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Channel 5: R10 to Fz                Ground: Cz

Pattern Reversal Hemi Field Markers:
N75 – 1st negative peak, 1st upward deflection
P100 – 1st positive peak, 1st downward deflection
N145 – 2nd negative peak, 2nd upward deflection

Settings:
As for full field stimulation settings, except for the following:
Stimulus rate
- maximum of 4 reversals per second
Brightness contrast
- Ensure the contrast between black and white checks is at least 50%.
Stimulation
- Monocular stimulation is used to ensure there is no masking of a unilateral conduction abnormality.
- Each eye is tested to both left and right hemi-fields separately.
Check width
- Different check sizes can be used separately; large or small.
  - Large checks should measure 60’ of arc (1° ± 20%); small checks should measure 15’ (0.25° ± 20%).
Field size
- While it is not necessary to use a square field (for example computer monitor displaying the stimulus pattern does not need to be square) ensure the aspect ratio between width and height does not exceed 4:3 and the field size is at least 15’ (of visual angle) at the smallest point.
Fixation point:
- The fixation point is still to be located at the centre of the stimulus screen, however it will only be located in the corner of 2 checks for hemi-field stimulation.
4.7.5. Flash stimulus

Flash stimulus VEP’s are used infrequently and are reserved primarily for infants and other patients that cannot maintain fixation and when reduced visual acuity cannot be rectified.

Example of Full Field Flash Recording Montage (5 channel and 3 channel):

Channel 1: T5 to Fz  Channel 1: O1 to Fz
Channel 2: O1 to Fz  Channel 2: Oz to Fz
Channel 3: Oz to Fz  Channel 3: O2 to Fz
Channel 4: O2 to Fz  Ground: Cz
Channel 5: T6 to Fz  Ground: Cz

Flash Recording Markers

6 peaks appear in the first 250ms and are labelled as:
- I or N1 (negative peak 1)
- II or P1 (positive peak 1)
- III or N2 (negative peak 2)
- IV or P2 (positive peak 2)
- V or N3 (negative peak 3)
- VI or P3 (positive peak 3)

Figure 2: 1 Taken from Smith (2006) pg 131

Note: This image is provided as an example of waveform morphology only; not amplitude and latency, also the polarity is reversed on this example.
4.7.6. Stimulus Type/Pattern generator:

A white flashing light is the stimulus utilised in flash VEP’s. This can be delivered to the patient via a stroboscope lamp (similar to that used in photic stimulation in EEG) or via a ganzfeld stimulator.

Stimulus rate
- Ensure the stimulus of flashes of white light occurs at 1-2Hz.

Intensity
- Ensure the luminance of the flash is at least 3cd/sm².

Stimulation
- Monocular stimulation is used to ensure that there is no masking of a unilateral conduction abnormality.

Field Size
- Ensure the flash stimulus subtends a visual field of at least 20°.

Distance of stimulus from patient
- The distance between the patient and the flash stimulus is 30 cm.

4.7.8 Pattern Electro Retino-gram (pERG)

Use the PERG (if available) in a patient with an abnormal visual evoked potential to establish whether a retinal (macular) disorder is present, and thus differentiate between macular and optic nerve dysfunction as a cause for the VEP abnormality.

For the purpose of incorporating the pERG in the VEP test set up, the VEP stimulating visual arc, luminance, contrast and reversal rate parameters are used.

Example montages for full field pattern reversal or flash stimulation incorporating an ERG channel:

**10:20 System**
- Channel 1: iERG - iOC
- Channel 2: O2 to Fz
- Channel 3: Oz to Fz
- Channel 4: O1 to Fz
- Ground: Cz

**Queens Square**
- Channel 1: iERG - iOC
- Channel 2: R5 to Fz
- Channel 3: MO to Fz
- Channel 4: L5 to Fz
- Ground: Cz
Electrodes

• A fibre electrode can be placed on the lower eyelid and tethered at the nasal canthus and lower outer canthus of the eye \(^{16}\).
• Place a reference electrode at the ipsilateral outer canthus (iOC) of each eye \(^{16}\).
• Impedances of the reference and ground electrodes should be less than 5K\(\Omega\) and equal. It is recommended not to measure impedance when the recording electrode is on the eye unless explicitly specified by the particular equipment manufacturer \(^{16}\). This applies current to the eye which is contraindicated.

4.8. Quality Control Procedures

Refer to the International Organisation of Societies for Electrophysiological Technology (OSET) Guidelines for Digital EEG \(^{17}\).

Normal Values

• Establish normative data using standard stimuli and recording parameters for each neurophysiology laboratory \(^{6}\).
• Recording parameters such as ambient light, pattern luminance and contrast shall be the same for all patients tested and for all subjects from which normative data is obtained \(^{11}\).
• Normative values from other institutions or sources may only be utilised if equivalent stimulation and recording parameters are employed and only after testing the validity of the adopted normal values on at least 10 locally gathered subjects under normal recording conditions \(^{18}\).
• Note that normative values may be influenced by age, gender and differences in visual acuity; and that acquired normative data for adults must be in a given age range. Additional normative data may need to be acquired for elderly (>60) or paediatric (<5) populations \(^{6,7}\).

External checks of stimuli and recording parameters \(^{10}\)


5. Review

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

Date of Last Review: New Document

Supersedes: Nil
## 6. Business Area Contact
Dane Enkera – Statewide clinical measurements network (Chair)

## 7. Definitions of terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition / Explanation / Details</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common mode rejection ratio</td>
<td>The tendency of a differential amplifier to reject input signals common to both input leads</td>
<td>Fundamentals of EEG Technology, Tyner, et al 1983</td>
</tr>
<tr>
<td>Filters</td>
<td>Separate a range of frequencies to allow only specific frequencies to be examined.</td>
<td>Spehlmann’s Evoked Potential Primer, 2001</td>
</tr>
<tr>
<td>Luminance</td>
<td>The brightness of a light-emitting source (e.g., a view box or computer monitor). Measured in cd·s·m⁻² (candela-seconds per meter squared)</td>
<td>Mosby's Medical Dictionary, 8th edition. © 2009, Elsevier.</td>
</tr>
<tr>
<td>Anisocoria</td>
<td>Inequality of the size of the pupils of the eye.</td>
<td>The American Heritage® Medical Dictionary Copyright © 2007, 2004 by Houghton Mifflin Company. Published by Houghton Mifflin Company. All rights reserved.</td>
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8. Approval and Implementation

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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
- Association of Neurophysiological Technologists Australia (ANTA)
- Dr Robert Henderson – Consultant Neurologist (RBWH)
- Dr Kate Rinney - Consultant Paediatric Neurologist & Epileptologist (Mater)
- Dr Stefan Blum – Consultant Neurologist (Redcliffe Hospital / RBWH)
- Queensland Health Neurophysiology Laboratory Managers (as of 15/07/2011)

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9. Appendices

Appendix 1 – Pattern reversal electroretinogram (PERG)

The PERG (if available) shall be used in a patient with an abnormal visual evoked potential to establish whether a retinal (macular) disorder is present, and thus differentiate between macular and optic nerve dysfunction as a cause for the VEP abnormality.

Electrodes

A number of different types of electrodes can be used but the most practical and less invasive type is a fibre electrode that can be placed on the lower eyelid and tethered at the nasal canthus and lower outer canthus of the eye. Reference electrodes are placed at the ipsilateral outer canthus of each eye.

A ground electrode can be placed anywhere on the head.

Impedances of the reference and ground electrodes should be less than 5KΩ and equal. It is recommended not to measure impedance in situ of the actual recording electrode unless explicitly specified by the particular equipment manufacturer.

Recording Parameters

Stimulus:

Use the following stimulus parameters:

- reversing checkerboard pattern with check size of 8° and the mean of the width and height of the stimulus field at 15°
- luminance that does not vary during stimulation and is at a ‘photopic’ luminance level of 80 cd/m².
- contrast of the black and white checks are at 100% and no less than 80%.
- PERGs are performed in a dim room with no direct lights in the patient’s field of view
- the reversal rate is delivered at 2Hz.

Recording Equipment

Use the following parameters of the recording equipment:

- minimum input impedance of 100MΩ
- the bandwidth range from 1-100Hz
- sweep time is 150ms or more
- limits for artefact rejection are set no higher than ± 50 uV
- a minimum sampling rate of 1000Hz
Recording Procedure

Position
Position the patient in a comfortable chair with a head rest. Ensure the pupils are not dilated.

Fixation
Locate a fixation point in the centre of the screen.

Acuity
Test the visual acuity and the patient’s vision, corrected with lenses if available.

Stimulation
Binocular recording is preferable over monocular stimulation.
Monocular stimulation can be used if the VEP and PERG and recorded simultaneously.16

Averaging
Obtain at least 100 artefact free sweeps. More may be required to improve the signal to noise ratio. Duplicate the test to ensure reproducibility.

Example Waveforms
Obtain normal values for each department.

10. Suggested Readings and References

10.1. Suggested readings

- ISCEV standard for clinical visual evoked potentials (2009 update) http://www.springerlink.com/content/53p616266t26n100/fulltext.pdf
- Guidelines for calibration of stimulus and recording parameters used in clinical electrophysiology of vision http://www.springerlink.com/content/u5531q5268381707/fulltext.pdf

10.2. References