British Society of Audiology

Recommended procedure

The caloric test

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General forward

This document presents a Recommended Procedure by the British Society of Audiology (BSA). A Recommended Procedure provides a reference standard for the conduct of an audiological intervention that represents, to the best knowledge of the BSA, the evidence-base and consensus on good practice given the stated methodology and scope of the document and at the time of publication.

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1. Introduction

1.1. Background to the review

The bi-thermal caloric test was introduced into clinical practice in the early 1940s, mainly as a result of the development work of Fitzgerald and Hallpike (1942). Evaluation of the induced nystagmus was based upon the observer timing the duration of the response. Later recording techniques such as electro-nystagmography allowed the responses to be quantified in terms of the slow phase velocity and duration of nystagmus eye movements. Today a variety of techniques are in use in clinics throughout the United Kingdom.

The aim of this updated British Society Audiology (BSA) Recommended Procedure is to build on the work of the original document published in 1999 to include new developments in research and recording techniques. Some of the key changes relate to developments in the technology used to record eye movement (video-nystagmography), automatic analysis of eye movements, clarification of contraindications and advice and recommendations on the use of the mono-thermal caloric screening test and 'ice-cold' calorics.

This document supersedes the 1999 version of the BSA Recommended Procedure.

Sections 2, 3, 4 and 6 of this document cover general issues that apply to all caloric testing. Section 5 describes the specific recording techniques used in eye movement assessments.

1.2. Development of the recommended procedure

The review of the 1999 Recommended Procedure was conducted by the Steering Committee of the Balance Interest Group (BIG) of the BSA in consultation with its stakeholders (see Appendix A). The review included the identification and consideration of new evidence pertinent to the caloric test published since the previous document and before December 2009.

The Steering Committee would like to acknowledge the advice received from a range of professionals (see Appendix A), as well as the wider membership of the BSA who were invited to provide comments and feedback on earlier draft editions. The document was developed in accordance with BSA Procedure for Processing Documents (2003).

2. Scope

This document covers the technical procedures for recording of nystagmus by electro-oculography, referred to in this document as electro-nystagmography (ENG), and for video recording of nystagmus by video-nystagmography (VNG). It also recommends stimulus parameters for water and air irrigation. Procedures for direct observation of the caloric response are included in Appendix D, which provide an historical context for the test.

The results of the caloric test, in terms of the responses to four stimuli, are used to obtain a measure of canal paresis (also known as unilateral weakness) and directional preponderance. Canal paresis expresses a weakness in the induced nystagmus following caloric stimulation from one ear as compared to those obtained from the opposite ear. A directional preponderance indicates that the nystagmus response is greater in one direction as compared to the other.

The document is primarily written as a recommend procedure for carrying out the caloric test in adults. It is acknowledged that the caloric test is used to investigate vestibular function in babies and young children. However, it is beyond the scope of this document to describe the test modifications necessary and interpretation of results.

It is also beyond the scope of this document to describe and discuss the limitations of the caloric test. Although it is known to “reliably and accurately differentiate between normal vestibular output and abnormally reduced or increased output”, it establishes this for only the lateral semicircular canals and is equivalent to a low frequency sinusoidal harmonic acceleration rotation test (Baloh et al, 1989; Zapala et al, 2008).

3. General testing issues

3.1. Hygiene

Check that the irrigation system is clean and operating correctly. If water tanks are used, these should ideally be cleaned and re-filled at least weekly.
Use decontaminated irrigator nozzles for each patient (Baguley et al, 1991).
It is recommended that the department should comply with local infection control policy where this is indicated.

3.2. Stimulus parameters

The stimulus parameters should be checked at least weekly or when a problem is suspected. Check that the air or water temperature at the outlet of the irrigator and the flow rate in free-flow are as indicted in Table 1 (Barber and Stockwell, 1980; Jacobson et al, 1993).

Table 1

Stimulus parameters[1]

	Temperature: 'cold'	Temperature: 'warm'	Flow rate
Water	30 °C ± 0.4 °C	44 °C ± 0.4 °C	250 ml ± 10 ml in 30 s
Air	24 °C ± 0.4 °C	50 °C ± 0.4 °C	8 l ± 0.4 l in 60 s

3.3. Order of testing

Research suggests that there is no clinically significant systematic bias in the induced caloric response related to the order of testing (Lightfoot, 2004) and therefore the test order used for an individual subject can be decided on clinical grounds. In the absence of any such consideration, it is desirable that the four irrigations be carried out in the following order:

1. Warm irrigations (right or left first)
2. Cool irrigations (right or left first)

This would allow the tester to consider application of the mono-thermal caloric screening test (See Appendix C).

[1] Lightfoot (personal communication 2010) reports that the effectiveness of the stimulus in air calorics depends not only on the flow rate but also the speed of the column of air and therefore crucially on the diameter of the tip delivery system. Even if the irrigator provides the stimulus parameters described, users should collect their own normal limits and be aware of this dependency.

3.4. Calculation of canal paresis and directional preponderance

The caloric response should be measured in terms of either the maximum slow-phase velocity (SPV) of the nystagmus in degrees per second, ° s^{-1}, (see Section 5) or the duration of the nystagmus in seconds (see Appendix D).

The four responses are represented in this document by the following notations:

- WR − warm stimulus in right ear
- WL − warm stimulus in left ear
- CR − cool stimulus in right ear
- CL − cool stimulus in left ear

It is recommended that the following two summary statistics of the responses be calculated (see below for exceptions):

Canal paresis (%) is given by (Jongkees et al, 1962):

$$\frac{(WR + CR) - (WL + CL)}{WR + WL + CR + CL} \times 100$$

Directional preponderance (%) is given by:

$$\frac{(WR + CL) - (WL + CR)}{WR + WL + CR + CL} \times 100$$

An arithmetic correction for spontaneous nystagmus (see Section 6) should not be used when calculating these statistics, as the precise effect of spontaneous nystagmus on the caloric response is not understood. However, these statistics, and the overall caloric response pattern, should be interpreted in light of the direction and strength of any spontaneous nystagmus present.

These statistics should not be used with patients that have unilateral or bilateral tympanic membrane perforations (air or closed loop water caloric test) or unilateral middle ear pathology. This is because there is considerable potential for asymmetrical heat transfer from the ear canal to the semi-circular canal between the two sides. In such cases, responses indicate only the existence of semi-circular canal function.

If a caloric nystagmus is not induced and technical reasons have been ruled out, irrigation at temperatures below the minimum temperature indicated in 3.2 (Table I) may be considered. A suggested procedure is given in Appendix B.

4. Patient preparation

This section is related to actions taken prior to starting the caloric test and ensuring that the patient is prepared adequately to undertake the test.

4.1. Referral and medication advice

Only patients with a written referral by medical staff should undergo this test. Advice about stopping medication (e.g. vestibular sedatives) should be given by the referring physician during the pre-test consultation. Ideally the physician should advise the patient to stop relevant medication at least 48 hours before the test. Patients should be advised not to consume alcohol for 48 hours before testing (Jacobson et al, 1993). Staff responsible for carrying out the caloric test should check that the patient has adhered to this advice.

Local protocol should be in place to establish whose has responsibility for ensuring appropriate information is provided to the patient.

4.2. Patient Travel

Check travel arrangements and ensure that patient is aware that they will be advised not to drive immediately following the test.

4.3. Position of caloric test within the test battery

The caloric test, if requested, should normally be the **last** procedure to be performed in any vestibular or oculo-motor function test battery. However it is sometimes appropriate for other procedures to follow the caloric test (e.g. treatment for benign paroxysmal positional vertigo or recording vestibular evoked myogenic potentials for instance) providing the patient does not feel unwell.

4.4. Contraindications

It is the responsibility of both the referring physician and audiologist to ensure that the patient is fit to undergo the test before it is conducted.

It is usually inappropriate to conduct the caloric test if any of the following are present:

- History of hypertension (uncontrolled, acute or de-compensated phase)
- History of cardiac problems (arrhythmias especially bradycardia or Stokes-Adams attack; acute or de-compensated phase) e.g. if someone has unstable angina, a recent myocardial infarction (within last 3-6 months) or is undergoing cardiac investigations[2]
- Psychotic/neurotic disorders (acute or de-compensated phase)
- Epilepsy (acute or de-compensated phase)
- Eye surgery (within the previous 3 months)
- Ear surgery (within the previous 6 months)

The next list shows the second level of contraindications / special precautions, which should be checked for compliance at the time of the appointment by the testier as well as by the referring physician and which also may contraindicate performance of the caloric test:

- Significant degree of space occupying wax
- Otitis externa
- Middle ear fluid/effusion
- Hypermobile[3] or atrophic tympanic membrane - care should be taken for severe hyper-mobility and a second medical opinion obtained

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[2] Recent work by Kasbekar et al (2010) suggests that heart rate and mean arterial pressure are not significantly altered by the caloric test. Although this is only preliminary work and based on data from 18 patients, it should allow the researchers to study the effects on patients with stable cardiovascular disease. This may reduce the perceived risk of the caloric test with these types of patients.

[3] It is not clear what constitutes unsafe peak middle-ear compliance on tympanometry for water calorics. A hyper-mobile tympanic membrane has been defined as a peak compliance of greater than 1.8 ml although it may still be appropriate in some cases to proceed with water calorics with a peak compliance of 2.8 ml. If in doubt, medical advice should be sought.

- Tympanic membrane perforation (may be suitable for air calorics)
- Patients with mastoid cavities may be considered for air calorics, but interpretation should be carried out with caution.

Staff performing the test should be aware of these contraindications and the specific relevant specialist should be contacted for advice on individual patients.

4.5. Otoscopy and tympanometry

Perform otoscopy (BSA, 2010) and tympanometry (BSA, 1992) to check the condition of the external ear and tympanic membrane (e.g. look for signs of atrophic tympanic membrane) before the start of the caloric test (and after each irrigation).

4.6. Patient Instructions

Make the patient as comfortable and relaxed as possible. Explain to the patient that the test involves warming and cooling the external ear canal and that this may or may not result in dizziness lasting about two minutes. It may be reassuring to explain that any dizziness experienced is a normal reaction and that the test is not intended to provoke an episode of their own dizziness. Obtain verbal consent to proceed.

4.7. Caloric test position

The horizontal semi-circular canal should be brought into the vertical plane. As a first approximation, this can be achieved by having the subject supine with either his/her head or head and back inclined at 30 degrees to the horizontal (Coats and Smith, 1967). The angle is correct when the external auditory canals and the outer canthi are aligned vertically (Blanks et al, 1975).

5. Eye movement recording techniques

Several methods for recording eye movements are available, each with its own advantages and disadvantages. It is recommended that the following methods are available, if resources allow: measurement of the corneo-retinal potential using electrodes (electro-nystagmography, ENG) and/or direct measurement of movements of the pupils using infra-red video goggles (video-nystagmography,

VNG). It is recommended that VNG is used in preference and that ENG is used only when VNG is technically difficult.

The direct observation method has not been removed completely from this recommended procedure and may now be found in Appendix D, which should now reflect its historical rather than current importance. It also acknowledges the fact that there may be occasions when it is the only feasible method available.

Interpretation of eye movements may be difficult or impossible when testing either blind patients with spontaneous 'roving' eye movements or patients with congenital nystagmus. In such cases subjective magnitude of the symptomatic response may be helpful, although the patient's reported assessment may be misleading and must be interpreted with caution.

5.1. Testing using video-nystagmography (VNG)

5.1.1. Camera placement

Place the goggles containing the video cameras on the patient's face so that they are comfortable. Adjust the position of the goggles and/or the cameras to achieve a clear view of the pupils of the eyes even if the patient looks to the extremes of gaze. If the patient has any obvious eye abnormality (such as a prosthetic eye, squint / strabismus, dysconjugate eye movement) then monocular recording should be considered, covering the weaker or problem eye with an eye patch when appropriate to do so. Many VNG systems' abilities to correctly identify the pupil are disrupted if eye make-up such as mascara is used. Appropriate instructions about not using make-up should be included in any appointment letter.

5.1.2. Calibration

Calibration of eye movements should be performed in a dimly lit room and before the first irrigation. It is generally unnecessary to carry out further calibration, unless the cameras are moved within the goggles or if the goggles are removed or repositioned. Follow the procedure recommended by the manufacturer for positioning the patient relative to the light bar and for performing the eye calibration.

5.1.3. Tracking software

The tester should ensure that a clear view of the eyes is maintained throughout the caloric test, as the eye tracking software requires this.

5.2. Testing using electro-nystagmography (ENG)

5.2.1. Skin preparation and electrode attachment

Switch recording equipment on before connecting it to the patient. Do not switch off equipment whilst the patient is connected.

It is beyond the scope of this document to discuss the advantages and disadvantages of AC or DC recordings, but the tester should be aware of the type of system employed.

Using mildly abrasive gel, carefully rub the skin prior to electrode placement (forehead, near the right and left exterior canthi). When the patient is connected and disconnected from the equipment, the ground lead should be connected first and disconnected last. With the leads connected to the recording equipment, eye movement to the right produces an upward deflection of the trace and vice versa. The two horizontal channel electrodes are placed such that they lie on an imaginary line passing through the patient's pupils when looking straight ahead. They should be as close to the outer canthi as possible without restricting the patient's comfort or ability to blink. If the patient has any obvious eye abnormality (such as a prosthetic eye or squint etc.) that may affect the ENG, then an altered electrode placement should be considered such as monocular recording of the better eye.

Check the contact with an electrode impedance meter (ensure impedances below 10 kΩ and matched to within 2 kΩ).

5.2.2. Calibration

It is essential that calibration of eye movements be carried out, in a dimly lit room, immediately **before each caloric irrigation**. For computerised ENG systems with an integral light bar, follow the procedure recommended by the manufacturer for positioning the patient relative to the light bar and for performing the eye calibration. Failure to re-calibrate prior to individual irrigations is likely to lead to inaccuracies arising from fluctuations in the corneo-retinal potential (Lightfoot, 2004).

For other systems, two calibration points should be placed in the horizontal plane symmetrically in front of the patient at a distance such that they subtend an angle of 20 degrees at the patient's head. Instruct the patient to gaze alternately between the right and left calibration points and adjust the amplifier gain to produce a trace deflection of 20 mm (± 1 mm). In addition to the outer calibration points, a marker defining the straight-ahead position should be provided.
For paper chart recorders a paper speed of 10 mm s^{-1} should be used.

5.2.3. Recording Conditions

The optimal condition for recording caloric-induced nystagmus in the absence of visual fixation is with the eyes open in complete darkness with the patient instructed to gaze straight ahead. However, it is acknowledged that complete darkness is not achievable in many clinic rooms in which case room lighting should remain constant (dim lighting) throughout the test to minimise changes in the corneo-retinal potential and removal of fixation should be achieved by eye closure.

5.2.4. Problem with making recordings with eyes closed

Note that if recording eye movements during the caloric test with eyes closed and if Bell's phenomenon (elevation of the eyes in the orbit) is evident and compromising the recording with eye closure, then unlit Frenzel glasses can be used with eyes open in a darkened room to eliminate visual cues (Baloh et al, 1977).

6. Caloric irrigation, measurement and analysis of responses

The first part of this section describes the process of executing the caloric irrigation; the latter stages describe the measurement and analysis of eye movement generated by the stimulus.

6.1. Caloric irrigation

6.1.1. Set up the eye movement recording system as described in Section 5.

6.1.2. Before the first irrigation only, and with the patient in the caloric test position, check for spontaneous nystagmus with and without visual fixation. The patient should be instructed just as they will be during the recording phase of the test. They should be instructed to gaze ahead, visual fixation removed, and to perform a mental task that will minimise suppression of any nystagmus. Suitable mental tasks include simple conversation, asking the patient to describe a room in their house or asking him/her to perform mental arithmetic. It is important that the tester maintains a consistent level of the patient's alertness throughout the recording periods of the test (Kileny et al, 1980). It may be necessary to adjust any mental alerting task required to reduce blinks and other artefacts in order that a clear trace is obtained. For example, occasionally the extent of caloric-induced nystagmus is attenuated or even abolished if the patient's eyes are deviated to the extreme of lateral gaze. If this is apparent from inspection of the

eye image during recording, the patient should be given an immediate instruction that results in a return of their gaze to a more central direction. It is important to consider that sometimes the patient may think they are looking ahead and so to achieve a more central gaze direction, they should be instructed to "look slightly to the left (or right)".

6.1.3. If spontaneous nystagmus is present, note its direction, morphology and calculate the average slow phase velocity.

6.1.4. Examine the ears again prior to irrigation. Demonstrate the stimulus temperature to the patient by, for example, directing a small amount of the water/air to the pinna.

6.1.5. Stimulate the selected ear for the specified period (water, 30 s; air, 60 s).

6.1.6. Direct the stream of water/air straight down the external ear canal to achieve a good irrigation of the canal and tympanic membrane. Care should be taken with the irrigator nozzle to avoid injury to the ear. In particular, during the irrigation it is vital that the ear canal is not occluded by the nozzle and thus pressurised. The irrigation system must be such that the insertion depth of the nozzle into the ear canal is limited and that the tip of the nozzle cannot reach the tympanic membrane. For water irrigation, the patient's head should be slightly rotated in order to ensure that the external canal is horizontal, allowing air in the canal to escape as it is displaced by the water, thus preventing a pocket of air from remaining in the canal and invalidating the calibration of the delivered thermal stimulus. Following water irrigation the patient's head should be gently returned to a central alignment (it should be noted that this movement may induce one or two beats of nystagmus, which should be discounted when analysing the results; this occurs long before the normal peak in caloric induced nystagmus).

6.1.7. Recording, visual fixation removal and mental alerting can start either at the beginning or end of the irrigation.

6.1.8. The same procedure should be applied for each irrigation (including calibration if using ENG).

6.2. Measurement of the caloric response

6.2.1. Observe the induced nystagmus in the eye movement trace without fixation as it is recorded. Verify that it is regular and in the expected direction. Warm irrigations would be expected to induce a nystagmus beating towards the irrigated ear. Cool irrigations would be expected to induce a nystagmus beating away from the irrigated ear; following the convention that nystagmus is described in terms of the direction of the fast component.

6.2.2. Soon after the response has passed through the period of maximum activity, instruct the patient to fixate on a central target. After approximately 5 to 10 s remove fixation again and continue recording for at least a further five seconds.

6.2.3. The total recording time, following cessation of irrigation, should be at least 60 s.

6.2.4. After the period of recording check the quality of the irrigation using an otoscope to look for a 'tympanic flush'. The presence of a tympanic flush confirms a good irrigation (the converse is not necessarily true). This applies to warm irrigations only.

6.2.5. Allow a minimum of seven minutes[4] between the start of one irrigation and the start of the next irrigation in order to ensure that the results of one test do not affect the next. In cases where the patient is nauseous or produces evidence of caloric nystagmus at the end of this period (that cannot be accounted for from any spontaneous nystagmus measured as per Section 6.1.2), a further delay may be warranted (Beattie and Koester 1992).

6.2.6. Between irrigations, calculate the average slow-phase velocity of the nystagmus for the period of maximum response. Also calculate the visual fixation index (VFI). (NB It is sufficient that the test for VFI be carried out for two irrigations only, one for each direction of nystagmus.) See Section 6.3.4.

6.2.7. If there are serious doubts about the effectiveness of any irrigation, (e.g. lack of tympanic flush after warm irrigation, insufficient mental alerting causing reduction or suppression of nystagmus, or if one response is much weaker than the other three) the suspect irrigation should be repeated after the four standard irrigations.

6.3. Analysis of results

6.3.1. For automatic computerised eye movement measurement systems, verify that nystagmus has been correctly identified by examining the trace and editing where necessary. Check that the peak response has been correctly identified if this is done automatically and adjust if necessary.

6.3.2. Record or calculate representative slow-phase velocities as described above for each of the four responses in the test. If any nystagmus response is in the opposite direction to that expected, note this also.

[4] There is some evidence to suggest that the minimum period can be as little as 3 minutes or much longer. However, the most recent research suggests that a compromise figure of 7 minutes is employed.

6.3.3. Most computerised systems will calculate canal paresis and directional preponderance values automatically. Canal paresis (CP) and directional preponderance (DP) may also be calculated using the expressions given in Section 3.4 and users should be familiar with this method for verification purposes and/or if using a non-computerised system.

6.3.4. A change in nystagmus caused by visual fixation should be measured. Obtain an average, or a representative value, of the slow-phase eye velocity during the 5 seconds immediately before fixation (V1), during the period of fixation (V2), and during a 5-second period immediately after fixation (V3).

$$\text{Visual fixation index} = \frac{2V_2}{V_1 + V_3} \times 100\%$$

6.4. Normal Limits

6.4.1. It is recommended that individual laboratories collect their own data on what constitutes the normal range of caloric response particularly if the parameters of the caloric stimuli differ from those given in Section 3.2 (Jacobson et al, 1993) since it can be diagnostically useful to define an abnormally low or a hyperactive response as well as canal paresis and directional preponderance.

6.4.2. For air calorics it is recommended that normal limits be established even if the stimuli parameters in Table I are adhered to (Lightfoot 2010).

6.4.3. Canal paresis and directional preponderance are normally distributed variables and normal interpretive criteria should be based on mean ± 1.96 standard deviations (note that mean should be approximately zero). Alternatively, if normative data are not available, the normal limits of both canal paresis and directional preponderance may be taken as ± 20 % (Jacobson et al, 1993).

6.4.4. When establishing normative limits for SPV from individual irrigations a different approach is needed, as these variables have highly skewed distributions. Although 8 ° s^{-1} represents the lower 95 % confidence limit for median of all four irrigations, the 95 % confidence limits for individual irrigations are typically 5 ° s^{-1} and 57 ° s^{-1} (Lightfoot, 2004, and personal communication, 2007) with the warm irrigations often resulting in somewhat stronger nystagmus than the cool. The “total eye speed” of the maximum slow component velocity for all four irrigations may be calculated, as suggested by Zapala et al, 2008 and this figure used to infer either bilateral vestibular impairment (hypo-function) or hyper-function.

6.5. Reporting of Results

6.5.1. When reporting the CP, the statement should refer to the weaker ear (but not necessarily the one with the lesion). When reporting the DP, the statement should refer to the direction of the fastest beating nystagmus generated.

6.5.2. In patients where the maximum SPV for all four irrigation is ≤ 5 ° s^{-1}, the calculation of CP and DP is likely to be misleading, as the absolute values are similar to the possible systematic errors with this technique. [For example, if the SPV values were LW = 2 ° s^{-1}, RW = 3 ° s^{-1}, LC = 2 ° s^{-1}, RW = 4 ° s^{-1}, this would give a CP of 27 % of the left ear, whereas these figures either suggest function from both ears is impaired (or alternatively poor irrigations or the patient suppressing the response).]

6.5.3. The relevance of a significant CP is well understood; the relevance of a significant isolated DP perhaps less so and it is beyond the scope of this document to discuss the issues. However, the reader is directed towards Halmagyi (2000).

6.5.4. There is no general agreement as to the normal limits for the visual fixation index. For normal individuals and patients with peripheral vestibular disease, the visual fixation index (VFI) is usually less than 50 %. If this value is exceeded, central pathology might be suspected (Alpert, 1974; Takemori, 1977; Katsarkas and Kirkham, 1982).

6.5.5. If there is a complete or almost complete abolition of the nystagmus with fixation, calculation of the VFI is unnecessary. Also, unless there is a clear enhancement of nystagmus during the period of fixation, the index has little diagnostic value where the nystagmus in the absence of fixation is weak. It is important to consider the patient's visual acuity when interpreting the VFI.

6.6. Test modifications

Common test modifications, including the use of the caloric mono-thermal 'screening' test may be found in Appendix B and C.

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Stakeholder consultation on this revision occurred from 2008 to 2009. Earlier drafts have been available on the BSA website and comments where appropriate have been included in this final documentation.

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Appendix B. Common test modifications

B.01 Motion sickness

When testing patients with motion sickness it may be appropriate to reduce irrigation time to either 20 s or 25 s, depending on the severity of the motion sickness. Eye movements should be monitored, and the patients asked when they start to feel dizzy. Test modification should be noted in the records and interpretation should be made with caution (especially if patient feels very dizzy, but only low speeds of nystagmus generated i.e. $< 5\ ^\circ\ s^{-1}$).

B.02 'Ice water' caloric test

In patients with no clear caloric response to bi-thermal irrigations, colder water may be used to test for residual function. Actual temperature of water used should be noted. A suggested method for the ice water caloric test is provided below:

1. Place several ice cubes into a cup of chilled water and mix.
2. Measure the water temperature with a clinical thermometer and note the temperature achieved.
3. Put a 2 ml syringe in the iced water, drawing in and expelling the water a few times so that it reaches the correct temperature.
4. Perform otoscopy on the test ear. Incline patient's head to one side to an extent that is just sufficient to ensure that the test ear auditory canal runs slightly downward from the horizontal so that water will not immediately run out of the auditory canal. Place an absorbent tissue below the ear to be irrigated - there is no need to catch the water in a bowl, the tissue will absorb it.
5. Over a 5 to 10 s period introduce 2 ml of iced water into the canal.
6. Instruct the patient to maintain their head position during recording to ensure that the water does not immediately drain out of the canal. Alternatively, after a fixed period (e.g. 20 s) return the patient's head to a central alignment immediately prior to the removal of visual fixation.
7. Record, alert and remove fixation as usual.

Appendix C. The caloric mono-thermal 'screening' test

1. The calculation of canal paresis and directional preponderance requires the performance of all four components of the bi-thermal test. However, it is often possible to predict a normal outcome of the bi-thermal caloric test from the results of tests at a single temperature. In such circumstances it might be unnecessary for the patient to undergo the remaining two tests, thus saving clinic time and sparing the patient from unnecessary stimuli that occasionally result in nausea or vomiting.

2. The mono-thermal caloric asymmetry (MCA) is computed from the results of the two tests at the first temperature, thus: 100 x (R-L) / (R+L).

3. A number of studies have assessed the clinical utility of the mono-thermal screening test and a variety of mono-thermal caloric asymmetry (MCA) criteria have been suggested. Most studies have identified that the warm mono-thermal test offers superior performance to the cool and this corresponds to the way in which canal paresis and directional preponderance interact. A study by Lightfoot et al (2008) confirmed the advantage of the warm test and recommended that the test could terminate if certain strict criteria (see below) were satisfied, and concluded that a normal outcome was highly likely. This combination of criteria had a sensitivity of 95 % with a specificity of 71 % (only 29 % of patients with normal caloric results having to proceed to the bi-thermal test). The warm mono-thermal test could be recommended but that the cool could not. An MCA criterion of 10 % gives a higher sensitivity (about 98 %) but with a correspondingly poorer (50 %) false alarm rate.

4. The recommended criteria for mono-thermal caloric screening test are as follows:

   - MCA criterion of < 15 %
   - Any spontaneous nystagmus has a mean/peak SPV of no greater than 4 ° s^{-1}, and
   - Both warm caloric results must be > 8 ° s^{-1} in order to exclude the possibility of a bilateral canal paresis

5. If these criteria are not met the patient should complete the bi-thermal test, allowing canal paresis and directional preponderance to be computed.

6. The warm mono-thermal caloric (screening) test may therefore be used if desired when appropriate criteria are employed. It is important that audiologists, clinicians and students are familiar with the statistical compromise that such a test represents. Use of the cool mono-thermal test is not recommended.

Appendix D. Testing by direct observation

Recommended procedure for testing by direct observation:

1. Patient preparation as per Section 4 and check for spontaneous nystagmus as per Section 6.2

2. Use longer irrigation time with water stimulus (40 s).

3. Time the duration of the nystagmus. Timing starts at the beginning of the irrigation and ends at the last observable beat of the induced nystagmus (the 'end-point'). Note the direction of the nystagmus and any significant irregularity of the response.

4. At the end-point, switch the room lights off. Nystagmus is now likely to recur as a result of the removal of visual suppression. Observe this nystagmus using an infrared viewer or Frenzel glasses and time its duration (still continuing from start of irrigation). Observe for the end point.

5. The other irrigations should be carried out in a similar fashion.

6. Canal paresis and directional preponderance should be calculated using the expressions given in the previous Section 3.4, where WR, WL, CR and CL are now the durations of the response obtained from Section 9.4 (total time from start of irrigation to last observable beat) and compared to normal values. It is recommended that local normative data should be used as published literature on normal values by duration is scanty and that the limits of normal function should be $\pm$ 1.96 standard deviations from the mean.

7. Visual fixation index: A qualitative assessment of the effect of visual fixation can be made by waiting until the response ceases to be observable with visual fixation. Frenzel glasses or an infrared viewer can then be used in a darkened room to reduce or remove fixation. Watch for nystagmus to reappear in the absence of fixation.

$$\text{Visual fixation index (\%)} = \frac{\text{Duration with fixation}}{\text{Duration without fixation}} \times 100$$