



Caloric Reflex Testing and Its Clinical Implications in Nursing Practice

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Abstract

Background: Caloric reflex testing, first described by Robert Bárány, is a cornerstone in vestibular and neurological assessment. It evaluates the functional integrity of the lateral semicircular canals and brainstem pathways through thermal stimulation of the external auditory canal, eliciting vestibulo-ocular reflex (VOR) responses.

Aim: This article aims to explore the clinical implications, techniques, interpretation, and limitations of caloric reflex testing in nursing and interprofessional practice.

Methods: A comprehensive review of caloric testing procedures—including bithermal, monothermal, and ice-water techniques—was conducted. The physiological basis, assessment parameters (interaural variability, directional preponderance), and calculation methods such as the Jongkee formula were analyzed.

Results: Caloric testing provides critical diagnostic insights into peripheral vestibular dysfunction, brainstem integrity, and cranial nerve lesions. It aids in differentiating central versus peripheral causes of vertigo, assessing comatose patients, and determining brain death. Nursing roles include patient preparation, monitoring for adverse effects, and accurate documentation. Limitations include procedural duration, interrater variability, patient discomfort, and restricted evaluation of high-frequency vestibular function.

Conclusion: Despite its limitations, caloric reflex testing remains indispensable in neuro-otological diagnostics. Its ability to provide objective, quantifiable data supports clinical decision-making across diverse settings, from ambulatory care to intensive care units. Complementary vestibular assessments are recommended for comprehensive evaluation.

Keywords: Caloric reflex test, vestibulo-ocular reflex, vestibular function, brainstem integrity, nursing care, neurocritical assessment.

Introduction

The caloric reflex test, originally described by Robert Bárány, serves as a critical assessment tool for evaluating the functional integrity of the lateral semicircular canals within the vestibular system [1][2]. This test relies on the brainstem-mediated vestibulo-ocular reflex (VOR), which generates compensatory eye movements in response to head rotations to maintain visual fixation on a stationary target [3]. The VOR produces a slow-phase eye movement in the direction opposite to the head motion, which is counterbalanced by saccadic corrections initiated by the frontal eye fields. These

saccades generate the rapid component of horizontal nystagmus that is observed during caloric testing [4]. As part of electronystagmography (ENG), the caloric test provides an essential measure of vestibular function and contributes to the assessment of brainstem reflexes, particularly in evaluating patients with suspected brainstem pathology. During the procedure, the external auditory canal is irrigated with water at a flow rate of approximately 350 ± 30 milliliters per minute, with the temperature set either 7 degrees Celsius above or below the patient's body temperature. The duration of irrigation typically ranges from 30 to 40 seconds [5]. This thermal

stimulation generates convection currents within the endolymph of the lateral semicircular canal, activating the vestibular sensory apparatus. Warm water irrigation induces ampullopetal endolymph movement, leading to depolarization of the vestibular hair cells and excitation of the vestibular nerve. Consequently, the fast phase of the horizontal nystagmus beats toward the irrigated ear. In contrast, cold water irrigation produces ampulofugal endolymph movement, hyperpolarization of hair cells, and inhibition of the vestibular nerve, resulting in a fast nystagmus component directed away from the stimulated ear [5].

Quantitative assessment of the vestibular response, including the magnitude and symmetry of nystagmus, is essential for clinical interpretation. The degree of reduced vestibular responsiveness and directional preponderance can be calculated using the Jongkee formula, which provides an objective measure of unilateral or bilateral vestibular dysfunction [5]. This evaluation is particularly relevant in patients presenting with vertigo, imbalance, or suspected brainstem lesions, as it allows clinicians to differentiate peripheral vestibular deficits from central neurological disorders. In nursing practice, the administration of the caloric reflex test necessitates careful attention to patient preparation, positioning, and safety. Nurses play a vital role in monitoring adverse responses, including excessive vertigo, nausea, or autonomic changes, and ensuring accurate recording of eye movements during the procedure. The interpretation of caloric test results, combined with comprehensive vestibular assessment, informs both diagnostic decisions and subsequent therapeutic interventions, emphasizing the test's integral role in vestibular and neurological nursing care. This procedure continues to be a cornerstone in vestibular evaluation due to its ability to isolate unilateral canal function and provide reliable information regarding both peripheral and central vestibular integrity [1][2][3][4][5].

Types of Caloric Testing

Caloric testing encompasses several techniques designed to evaluate the function of the vestibular apparatus, particularly the lateral semicircular canals, and to assess the integrity of the vestibulo-ocular reflex. The most commonly employed method is the bithermal caloric test. In this approach, either water or air is used to irrigate the external auditory canal. Water is typically applied at temperatures 7 degrees Celsius above or below the patient's body temperature, whereas air is delivered at 24 or 50 degrees Celsius [5]. The bithermal method allows for a comparative assessment of each ear's vestibular response by inducing both excitatory and inhibitory stimulation. This enables the detection of asymmetries in nystagmus, which may indicate unilateral or bilateral vestibular dysfunction. The calculation of reduced vestibular responsiveness and directional preponderance using the Jongkee formula

is commonly applied in conjunction with this method. The monothermal caloric test is a simplified variation that uses only one temperature, usually warm or cold, for the irrigation of the external auditory canal. Although it provides less comprehensive data than the bithermal test, it is advantageous in patients who cannot tolerate prolonged testing or are highly sensitive to vestibular stimulation. The monothermal approach can still identify gross asymmetries between the two sides, making it useful as a screening tool in clinical settings. The ice caloric test represents a less commonly used but clinically valuable method, particularly for patients with profound vestibular deficits or in situations where conventional temperatures fail to elicit a response. In this technique, ice-cold water is applied to the external auditory canal to induce maximal ampulofugal endolymph movement, producing a pronounced inhibitory response. It is often reserved for specialized diagnostic scenarios, including the assessment of brainstem integrity in comatose or non-communicative patients. Each caloric testing method provides unique information regarding peripheral and central vestibular function, and the choice of technique is guided by patient factors, tolerance, and the clinical objectives of the evaluation [5].

Assessment

The assessment of caloric test results involves a careful analysis of nystagmus responses to thermal stimulation of each ear. One key parameter is interaural variability, which refers to the difference in the vestibular response between the right and left ears. An interaural caloric paresis exceeding 22 to 25% is considered clinically significant and indicates a unilateral weakness of the vestibular apparatus [5]. This asymmetry suggests that the affected ear has a reduced ability to generate the expected horizontal nystagmus in response to either excitatory or inhibitory thermal stimulation. Identifying this imbalance is critical in localizing peripheral vestibular lesions and differentiating them from central causes of vertigo or imbalance. Another important measure is directional preponderance, which reflects a bias in the direction of nystagmus that may occur even when the vestibular function is relatively symmetrical between the two ears. A directional preponderance exceeding 26 to 30% is interpreted as abnormal and indicates that the nystagmus is more pronounced in one direction, independent of the ear being stimulated [5]. This finding can result from central adaptation mechanisms, vestibular asymmetry, or incomplete compensation following a prior vestibular insult. Both interaural variability and directional preponderance are calculated using standardized formulas, such as the Jongkee formula, which quantify the degree of asymmetry and directional bias. These calculations allow clinicians to interpret the functional capacity of each vestibular apparatus objectively and to monitor changes over time. A comprehensive assessment of caloric test results integrates these parameters with

clinical findings, including patient history, physical examination, and other vestibular or neurological

tests, to establish a precise diagnosis and guide appropriate management strategies [5].

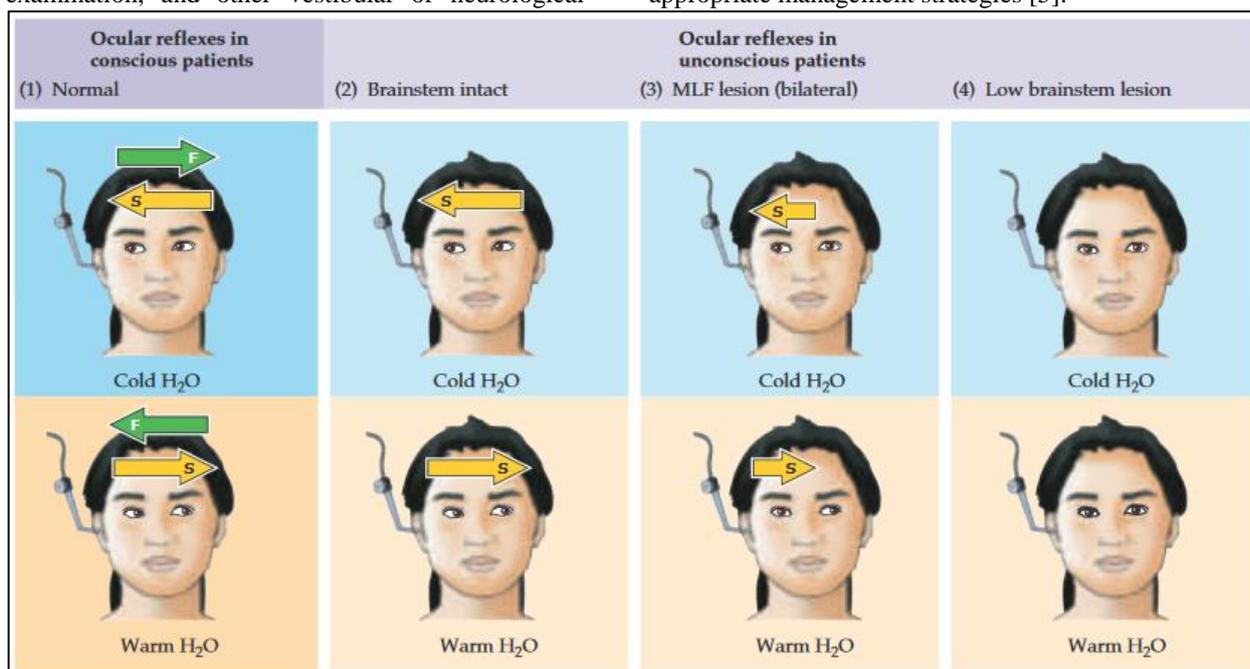


Fig. 1: Caloric Reflex test.

Issues of Concern

The interpretation of caloric testing is subject to several potential complications and anomalies that can affect diagnostic accuracy. Caloric inversion is one such concern, characterized by nystagmus responses that occur in directions opposite to those expected based on the stimulus. This phenomenon may arise from technical errors, such as incorrect electrode placement during electronystagmography, or from physiological conditions, such as testing an ear with a perforated tympanic membrane using air caloric stimulation [5]. Caloric inversion can lead to misleading results and may obscure the detection of underlying vestibular dysfunction if not recognized and accounted for during analysis. Caloric perversion is another significant issue and is often associated with central nervous system lesions, particularly within the floor of the fourth ventricle, or demyelinating diseases such as multiple sclerosis [5]. In this condition, the direction of the vertical component of the nystagmus deviates abnormally, reflecting disruption of normal central vestibular pathways. Identification of caloric perversion is crucial for differentiating central vestibular pathology from peripheral causes of imbalance, as it may indicate more serious neurological involvement requiring prompt evaluation and management. Dysrhythmia represents irregularities in the nystagmus pattern and is frequently observed in patients experiencing anxiety or heightened sympathetic activation during the test [5]. This can interfere with the measurement of nystagmus amplitude and velocity, complicating the assessment of vestibular asymmetry. Arreflexia, defined as an absent or markedly reduced vestibular

response, is commonly observed following bilateral peripheral vestibular injury, often resulting from exposure to ototoxic medications such as aminoglycosides or cisplatin [5]. This condition indicates a severe compromise of vestibular function and has important implications for patient management, including balance rehabilitation and fall prevention strategies. Recognizing these issues is essential for accurate interpretation of caloric testing and for guiding subsequent clinical decision-making.

Clinical Significance

Caloric reflex testing represents a fundamental diagnostic tool in both vestibular and neurological assessment, providing insight into the functional integrity of peripheral vestibular structures as well as central brainstem pathways. The test relies on the induction of endolymphatic flow within the semicircular canals, which generates tonic vestibular stimulation and triggers reflexive eye movements. In an awake individual, the vestibulo-ocular reflex (VOR) manifests as a slow deviation of the eyes opposite to the direction of endolymphatic flow, followed by a rapid corrective saccade mediated by the frontal eye fields to restore fixation on a visual target [6]. When warm water is introduced into the external auditory canal, the resulting ampullopetal flow depolarizes hair cells within the lateral semicircular canal, eliciting a slow eye movement away from the stimulated side and a compensatory fast saccade toward the stimulus. Conversely, cold water irrigation produces ampullofugal flow, hyperpolarizing the hair cells and generating a slow movement toward the irrigated side, with the corrective fast phase directed away from the stimulus [6][7]. In patients with

impaired consciousness, particularly those in a comatose state, the cortical contributions responsible for the fast corrective saccade are absent. As a result, only the slow tonic deviation of the eyes is observed, providing a direct measure of brainstem integrity. The persistence of this slow-phase response confirms that the reflex arc connecting the vestibular apparatus, cranial nerve VIII, and the brainstem nuclei is intact, allowing clinicians to distinguish between cortical and brainstem dysfunction [8]. In comatose patients, the caloric test serves as an essential adjunct when bedside assessments, such as the doll's eye maneuver, are inconclusive. Monothermal cold caloric irrigation, in particular, generates a stronger vestibular stimulus than conventional VOR testing, allowing for more reliable detection of subtle brainstem deficits. An absence of slow-phase deviation following cold irrigation indicates a lesion within the brainstem pathways and may suggest severe neurological compromise [8].

Detailed evaluation of eye movement during caloric testing can yield precise localization of cranial nerve or brainstem lesions. For instance, if the ipsilateral eye fails to abduct following cold water stimulation, this implies a dysfunction of the abducens nerve, whereas loss of adduction in the contralateral eye indicates a lesion of the medial longitudinal fasciculus or internuclear ophthalmoplegia [7]. This capacity for functional localization highlights the utility of caloric testing not only in identifying global brainstem compromise but also in pinpointing discrete neurological deficits, which is particularly valuable in acute neurocritical care settings. Caloric reflex testing is also instrumental in differentiating the spectrum of peripheral vestibular disorders. Bithermal caloric testing, when combined with electronystagmography (ENG), enables the quantification of lateralized vestibular hypofunction. A complete absence of response, or caloric areflexia, is indicative of bilateral vestibulopathy, which may arise from exposure to ototoxic agents such as aminoglycosides or cisplatin [6]. Such findings have critical implications for patient management, guiding both pharmacologic and rehabilitative strategies aimed at preserving balance and mitigating the risk of falls. In patients with severe neurological compromise, caloric testing aids in the evaluation of brainstem death. In these individuals, both slow and fast components of horizontal nystagmus are absent, reflecting complete disruption of brainstem reflexes [6][7]. In contrast, patients in a persistent vegetative state retain the slow-phase component, indicating preserved brainstem function, while the fast corrective saccade remains absent due to cortical inactivity [9]. These distinctions provide crucial information for prognostic counseling and the ethical management of life-sustaining interventions.

Caloric testing can also serve as a diagnostic tool in patients presenting with functional or psychogenic disorders, including pseudocoma. In such cases, monothermal cold caloric stimulation elicits a

classical vestibular response, including the fast-phase nystagmus, which is preserved because the reflex is mediated independently of cortical awareness. The abrupt awakening, often accompanied by nausea and vomiting, confirms the absence of true neurological impairment. Despite its high sensitivity and specificity for pseudocoma, the test must be conducted with caution due to the significant discomfort induced [9]. Overall, the caloric reflex test occupies a unique position in clinical practice by bridging peripheral vestibular assessment and central neurological evaluation. Its ability to distinguish between cortical, brainstem, and peripheral dysfunction enhances diagnostic accuracy across a wide range of clinical contexts. From detecting subtle vestibular asymmetries in ambulatory patients to confirming brainstem integrity in comatose individuals, caloric testing provides actionable information that directly informs patient management, prognostication, and therapeutic decision-making. The integration of caloric testing with ENG, imaging modalities, and bedside neurological assessment ensures a comprehensive evaluation of vestibular and brainstem function, underscoring its enduring relevance in contemporary clinical neurology and otoneurology [6][7][8][9].

The test's sensitivity to both peripheral and central pathology also underscores its value in multidisciplinary settings, including neurocritical care, otolaryngology, and neurosurgery. By delineating the functional status of the vestibular apparatus and brainstem reflex pathways, caloric testing facilitates early detection of neurological deterioration, informs surgical planning, and guides rehabilitative interventions. Moreover, its use in complex scenarios, such as differentiation of pseudocoma from true coma, exemplifies its capacity to provide objective physiological evidence in cases where clinical observation alone may be insufficient. This broad applicability affirms the caloric reflex test as an indispensable component of the neuro-otological diagnostic armamentarium. In conclusion, caloric reflex testing serves as both a diagnostic and prognostic tool with broad clinical implications. It evaluates the functional integrity of the lateral semicircular canals, brainstem reflex pathways, and cranial nerves, offering critical insight into both peripheral and central vestibular function. Its application spans ambulatory assessment of unilateral vestibular deficits, acute neurocritical care, evaluation of persistent vegetative states, and differentiation of psychogenic disorders. The test's ability to provide objective, quantifiable, and physiologically grounded information ensures its continued relevance in modern clinical practice, guiding management decisions, prognostic assessments, and the optimization of patient outcomes in a wide range of neurological and otoneurological conditions [6][7][8][9].

Limitations of Caloric Reflex Testing

Despite its established clinical utility, caloric reflex testing presents several inherent limitations that affect its accuracy, feasibility, and patient tolerability. One of the primary drawbacks is the time-intensive nature of the procedure. Each ear must be tested separately with multiple temperature stimulations, and adequate intervals are required between irrigations to prevent residual thermal effects from influencing subsequent measurements. This prolonged duration can limit the practicality of the test, particularly in acute or high-volume clinical settings where rapid assessment is needed [5]. Interrater variability represents another significant limitation. The interpretation of nystagmus responses relies heavily on the examiner's skill, experience, and observational precision. Variations in electrode placement for electronystagmography, visual estimation of nystagmus velocity, or differences in calibration of recording equipment can introduce inconsistencies. Consequently, reproducibility between clinicians may be limited, and the reliability of the test can be compromised, particularly in multicenter studies or when longitudinal comparisons are required [5]. Patient compliance is also frequently problematic. The procedure induces significant discomfort, including vertigo, nausea, and vomiting, which can provoke anxiety or involuntary movement, further complicating the recording of accurate eye movement responses. This discomfort may be more pronounced in pediatric populations or in individuals with heightened vestibular sensitivity, resulting in partial or incomplete testing that diminishes diagnostic accuracy [5].

Anatomical factors, including the size and shape of the external auditory canal, substantially influence the generation of endolymphatic convection currents. Variations in canal diameter or irregularities in the tympanic membrane can alter the thermal gradient, leading to inconsistent vestibular stimulation and variability in nystagmus amplitude. These anatomical influences must be considered when interpreting results, as they may account for apparent asymmetries that do not reflect true vestibular dysfunction [5]. Finally, caloric testing inherently evaluates only the lateral semicircular canal and does so at low-frequency stimulation. This limitation means that high-frequency vestibular function, which may be critical in daily activities such as head rotations or balance control, is not adequately assessed. Additionally, other vestibular structures, including the anterior and posterior semicircular canals and the otolithic organs, are not directly tested. Consequently, isolated lesions in these regions may remain undetected, potentially leading to incomplete or misleading conclusions regarding overall vestibular function [10]. In summary, while caloric reflex testing remains a valuable diagnostic tool, its limitations—including procedural duration, interrater variability,

patient discomfort, anatomical influence, and frequency-specific canal stimulation—necessitate cautious interpretation of results and often require complementary vestibular assessments for comprehensive evaluation [5][10].

Nursing, Allied Health, and Interprofessional Team Interventions

The caloric reflex test plays a pivotal role in the intensive care unit, particularly in the evaluation of comatose patients. Its execution and interpretation require close collaboration among nursing, allied health professionals, and the broader interprofessional team to ensure patient safety, accuracy, and optimal clinical decision-making. Nursing staff are primarily responsible for continuous and meticulous monitoring of vital signs, including heart rate, blood pressure, respiratory rate, and oxygen saturation, throughout the procedure. Given that the test can provoke transient hemodynamic changes or precipitate discomfort, nurses must be vigilant for signs of autonomic instability, respiratory compromise, or seizure activity. Their role extends to patient positioning, ensuring the head and neck are appropriately aligned to facilitate accurate vestibular stimulation, and providing supportive measures to minimize potential adverse events during the test. The intensivist assumes the central role in determining the etiology of the coma, integrating caloric reflex test findings with other neurological and systemic assessments to establish severity and prognosis. This includes correlating observed eye movement responses with structural or functional brainstem integrity. Decisions regarding further diagnostic workup, therapeutic interventions, and prognostication depend on these interpretations. The pharmacist contributes by evaluating and monitoring medications that could influence vestibular function or neurological responsiveness, including sedatives, neuromuscular blockers, or vasoactive agents. Adjustments to dosing or timing may be necessary to avoid confounding the results and to prevent adverse effects during testing [10].

Neurology consultation is often essential for comprehensive evaluation. Neurologists interpret caloric test outcomes in the context of other clinical findings, such as pupillary responses, motor reflexes, and electroencephalography results, helping to differentiate between peripheral vestibular lesions, central brainstem pathology, or psychogenic states such as pseudocoma. Allied health professionals, including respiratory therapists and rehabilitation specialists, may also be involved in the pre- and post-test care, ensuring airway patency, appropriate oxygenation, and readiness for potential complications such as aspiration. The monothermal ice water cold caloric test is particularly critical in brainstem reflex assessment. Its application assists in the identification of generalized or localized brainstem dysfunction and is integral to determining brain death. Accurate and

timely interpretation of these responses informs decisions regarding prognosis, potential withdrawal of life-sustaining measures, and suitability for organ donation. In this context, the test becomes part of the interprofessional workflow involving organ transplant coordinators, critical care physicians, nursing staff, and ethical committees. Each team member contributes specialized expertise to ensure the patient is evaluated according to accepted clinical and legal standards, maintaining both scientific rigor and ethical integrity. In summary, the caloric reflex test exemplifies the necessity of coordinated interprofessional collaboration. Nursing vigilance, critical care management, neurological interpretation, pharmacological oversight, and allied health support converge to ensure safe and accurate assessment of brainstem function. The test not only guides clinical decision-making for comatose patients but also supports ethically and legally sensitive processes such as brain death determination and organ transplantation, highlighting its value across multiple domains of intensive care practice [10].

Conclusion:

Caloric reflex testing continues to hold significant clinical value as a diagnostic and prognostic tool in modern healthcare. By assessing the functional integrity of the lateral semicircular canals and brainstem reflex pathways, it provides objective evidence crucial for differentiating peripheral vestibular disorders from central neurological conditions. Its application spans a wide spectrum—from evaluating vertigo in ambulatory patients to confirming brainstem function in comatose individuals and guiding ethically sensitive decisions such as brain death determination.

However, clinicians must recognize its inherent limitations, including time-intensive procedures, patient discomfort, and restricted scope to low-frequency vestibular stimulation. These factors necessitate cautious interpretation and often require integration with complementary assessments such as video head impulse testing or vestibular evoked myogenic potentials for a holistic evaluation.

In nursing practice, the test underscores the importance of meticulous patient monitoring, safety measures, and interprofessional collaboration. Nurses play a pivotal role in ensuring procedural accuracy and mitigating adverse effects, thereby enhancing diagnostic reliability.

Ultimately, caloric reflex testing remains an indispensable component of neuro-otological diagnostics. Its enduring relevance lies in its ability to provide physiologically grounded, quantifiable insights that inform patient management, prognostication, and therapeutic strategies across diverse clinical contexts.

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