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Advances in the diagnosis and management of acute vertigo

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Abstract

Background. Patients presenting to the emergency department with acute vertigo pose a diagnostic challenge. While 'benign' peripheral vestibulopathy is the most common cause, the possibility of a posterior circulation stroke is paradoxically the most feared and missed diagnosis in the emergency department.

Objectives. This review will attempt to cover the significant advances in the ability to diagnose acute vertigo that have occurred in the last two decades. The review discusses the role of neurological examinations, imaging and specific oculomotor examinations. The review then discusses the relative attributes of the Head Impulse-Nystagmus-Test of Skew plus hearing ('HINTS+') examination, the timing, triggers and targeted bedside eye examinations ('TiTrATE'), the associated symptoms, timing and triggers, examination signs and testing ('ATTEST') algorithm, and the spontaneous nystagmus, direction, head impulse testing and standing ('STANDING') algorithm. The most recent technological advancements in video-oculography guided care are discussed, as well as other potential advances for clinicians to look out for.

Introduction

Around 4 per cent of patients who visit the emergency department report dizziness as their primary complaint.[1] As a result, emergency physicians are frequently called upon to assess these patients in a setting where demands are high and resources are limited. Physicians are also expected to cast a wide net, given the possibility of a large variety of causes such as ontological or vestibular, cardiovascular, respiratory, psychiatric, and neurological disorders.[2]

The acute vestibular syndrome refers to the presence of vertigo or dizziness, together with nausea or vomiting, imbalance and nystagmus, and accounts for 20 per cent of dizziness cases.[3] The most likely cause is an acute unilateral vestibulopathy due to a sudden disturbance in the vestibular nerve or vestibular labyrinth on one side.[4] However, this presentation can also be caused by brainstem or cerebellar strokes.

The other most frequent peripheral vestibular disease is benign paroxysmal positional vertigo (BPPV), characterised by vertigo that is episodic rather than continuous, induced by the migration of otoconia from the utricular macula into one or more semi-circular canal. This should be managed differently to the acute unilateral vestibulopathy, and the diagnosis is only confirmed by the presence of canal-specific nystagmus during diagnostic manoeuvres.[5] Once again, however, central disorders such as posterior fossa mass lesions can 'mimic' BPPV, necessitating a careful examination.

The risk of life-threatening disorders motivates emergency physicians to utilise diagnostic resources, such as computed tomography (CT) and magnetic resonance imaging (MRI) of the brain, when available. This raises the question of whether physicians employ these methods out of defensiveness, or because they are truly effective and required for the assessment of patients with dizziness and vertigo.

In light of the development of many bedside examination methods, the diagnosis of acute vertigo has advanced dramatically during the past decade or two. Nonetheless, the majority of this knowledge has not yet been integrated into clinical practice. Therefore, this article presents a practical evaluation and summary of the available evidence for the clinical care of vertigo in the emergency department.

Role of neurological examination and risk factors

The 'ABCD2' is a stroke risk assessment tool based on five parameters (age, blood pressure, clinical features, duration and presence of diabetes) that was initially developed to stratify patients with anterior cerebral ischaemia.[6] Newman-Toker *et al.*[7] examined 190 adults with acute vestibular syndrome, and found that relying on the 'ABCD2' score would have missed nearly 40 per cent of the stroke cases and over-diagnosed stroke in nearly 40 per cent of peripheral vestibular cases. As a result, relying on vascular risk factors is cited as a frequent error when triaging patients with vertigo and dizziness, contributing to misdiagnosis-related harms in young patients in particular.[8]

Regardless of vascular risk factors, around 30–60 per cent of patients with posterior circulation strokes will exhibit at least one deficit on neurological examination.[9,10] In their meta-analysis, Shah *et al.*[11] found that most neurological examination findings have low sensitivity and high specificity for a central cause, implying that the absence of typical neurological symptoms or signs should not be relied upon to exclude stroke in acute dizziness. Ten per cent of patients with a cerebellar infarct, usually in the medial branch of the posterior inferior cerebellar artery, will have isolated vertigo, without other localising findings on motor, sensory, reflex, cranial nerve or limb co-ordination examinations.[12]

There is increasing evidence to support that truncal ataxia is an important part of the neurological examination.[9,12,13] Carmona *et al.*[14] examined 114 patients with acute vestibular syndrome and found that patients who fell while standing upright likely had a central lesion as the cause of their acute vestibular syndrome, with a high degree of certainty (sensitivity of 67 per cent and specificity of 100 per cent). Although ataxia was less sensitive than the specific oculomotor examination, the authors argued that truncal ataxia is an easy sign that can be recognised even by physicians without specialised training. In another case series, Lee *et al.*[12] also found that 71 per cent of patients with cerebellar infarction and isolated vertigo will present with the inability to walk without support.

Another helpful vestibulospinal sign is the Babinski asynergy sign, which is the inability to sit up from a supine position without using the arms.[15] Carmona *et al.*[14] found that this sign had excellent sensitivity (93 per cent) and specificity (100 per cent), in the same study described previously. This seems particularly useful because it can also be administered to severely nauseous patients who are too symptomatic to walk, but the results may need replicating.

Role of imaging

Computed tomography scans are excellent at detecting intracerebral haemorrhage, but this rarely manifests as dizziness without other concerning physical signs.[16] The sensitivity of brain CT for posterior circulation acute ischaemic stroke ranges from 7 per cent to 42 per cent,[17–20] such that CT scans are typically not clinically useful and can be misleadingly reassuring.[21–24]

Magnetic resonance imaging, on the other hand, is the 'gold standard' for diagnosing acute ischaemic stroke. However, even an MRI with diffusion-weighted imaging sequences can miss up to 20 per cent of posterior fossa strokes in the first 48 hours,[25,26] which is specifically true in patients with dizziness.[27–29] Patients may therefore require a further delayed diffusion-weighted imaging MRI or final clinical diagnosis as the gold standard.

Oculomotor examination

Specific oculomotor examinations have been found to distinguish 'central' and 'peripheral' disorders in the acute vestibular syndrome (acute-onset, prolonged dizziness or vertigo).

The Head Impulse Test is used to assess the vestibulo-ocular reflex. An abnormal vestibulo-ocular reflex is usually a sign of a peripheral vestibular disorder, while a normal vestibulo-ocular reflex with the head impulse is a strong sign of a central problem.

Spontaneous nystagmus is usually present in the acute vestibular syndrome. 'Peripheral' nystagmus is unidirectional and horizontal-torsional. It worsens when looking in the direction of the fast phase (according to Alexander's Law) and suppresses with fixation. However, these features can also be seen with vestibular nuclei, cerebellar or brainstem lesions.[7,27,30] On the other hand, spontaneous vertical or direction-changing nystagmus should be presumed to have a central aetiology.[12]

The test of skew is used to look for skew deviation. Although skew deviation is not a sensitive marker of central pathology, it is specific for detecting brainstem lesions in patients with acute vestibular syndrome (15 per cent *vs* 98 per cent respectively).[31,32]

These tests make up the component parts of the Head Impulse-Nystagmus-Test of Skew ('HINTS') examination, as discussed below. However, there are other classes of eye movements to consider, such as saccadic dysmetria, impaired smooth pursuit, impaired vestibulo-ocular reflex suppression, ocular lateropulsion, ocular tilt reaction, subjective visual vertical test, eye range of movement, central patterns of head-shaking and central positional nystagmus. These can all complement the Head Impulse-Nystagmus-Test of Skew examination and allow for specific topographical diagnosis of central posterior fossa lesions in acute vertigo (see Fracica *et al.*[32] for a full review).

Head Impulse-Nystagmus-Test of Skew plus hearing examination

In 2009, Kattah *et al.*[27] published their seminal paper on the Head Impulse-Nystagmus-Test of Skew examination. Combining these tests addressed their individual shortcomings, as a 'central' finding on any of the tests leads to the assumption of central aetiology until proven otherwise. This is why it is a three-step test and not a one-step test. Another helpful acronym 'INFARCT' can be used to remember the dangerous signs: Impulse Normal, Fast-phase Alternating, and Refixation on Cover Test. In their analysis of consecutive patients with acute vestibular syndrome who had at least one stroke risk factor, a benign Head Impulse-Nystagmus-Test of Skew examination finding 'ruled out' stroke better than negative results on MRI with diffusion-weighted imaging in the first 24–48 hours after symptom onset, with excellent specificity (96 per cent).

Along with the Head Impulse-Nystagmus-Test of Skew examination, the evaluation of auditory function with finger rub was subsequently added in 2013, making up the Head Impulse-Nystagmus-Test of Skew plus hearing ('HINTS+') examination.[7] This is because hearing loss, when present as part of the acute vestibular syndrome, can indicate labyrinthine ischaemia, which is usually caused by anterior inferior cerebellar artery territory strokes,[33] especially if otoscopy findings are normal.

Since its creation, the Head Impulse-Nystagmus-Test of Skew has been replicated, and has been reported as more sensitive than diffusion-weighted imaging MRI in several reports.[34] Although the Head Impulse-Nystagmus-Test of Skew is therefore useful in acute vestibular syndrome cases when the patient is still exhibiting nystagmus in the emergency department, it does not address other relevant clinical presentations. Importantly, the original paper and subsequent reports also rely on subspecialist examiners rather than general emergency physicians. In their systematic review, Ohle *et al.*[35] concluded that the HINTS examination may not be sufficiently accurate to rule out a stroke in those presenting with acute vestibular syndrome when used in isolation by emergency physicians.

Timing, triggers and targeted bedside eye examinations algorithm

Classifying patients based on dizziness 'type', such as vertigo versus 'light-headedness', is not only non-specific, but patients frequently change their description over time.[1] Instead, Newman-Toker and Edlow[36] propose grouping patients based on the timing and triggers of dizziness. The timing, triggers and targeted bedside eye examinations ('TiTrATE') algorithm begins by helpfully triaging other general medical causes that are often apparent from the clinical context, co-symptoms and vital signs. The 'timing' is used to identify two acute syndromes (acute vestibular syndrome *vs* episodic), further subdivided into whether the symptoms are spontaneous or triggered, which is then used to select the appropriate targeted examination. For example, if a patient presents with an acute vestibular syndrome, which is spontaneous, the Head Impulse-Nystagmus-Test of Skew examination is performed. The result of the targeted examination then dictates the appropriate laboratory or imaging test required.

The advantage of the timing, triggers and targeted bedside eye examinations algorithm is that it helps to select the right patient for the right examination. It includes the Head Impulse-Nystagmus-Test of Skew examination for acute vestibular syndrome; however, it is much more extensive, as it is the only algorithm to consider presentations such as the acute vestibular syndrome following a traumatic or toxic exposure, or spontaneous episodic vestibular conditions such as Ménière's disease or migraine. It has been specifically designed to address the many common pitfalls observed in clinical practice.[8,37] However, it has not yet been fully validated amongst emergency physicians.

Associated symptoms, timing and triggers, examination signs and testing algorithm

The associated symptoms, timing and triggers, examination signs and testing ('ATTEST') algorithm is the revised and renamed timing, triggers and targeted bedside eye examinations paradigm, adopting the timing and triggers diagnostic approach in a simpler flow diagram.[38] It was created using the same evidence-based guidelines as the timing, triggers and targeted bedside eye examinations, although no clinical studies have been conducted.

Spontaneous nystagmus, direction, head impulse testing and standing protocol

Vanni *et al.*[39] published their four-step algorithm called 'STANDING' (SponTAneous Nystagmus, Direction, head Impulse test, standiNG) in 2014, and found excellent levels of sensitivity (100 per cent) and specificity (94 per cent). In their full validation study in 2017, they found similarly high levels of accuracy (88 per cent), sensitivity (95 per cent) and specificity (87 per cent).[13]

Similar to, but not as extensive as, the timing, triggers and targeted bedside eye examinations, the spontaneous nystagmus, direction, head impulse testing and standing protocol also includes guidelines on how to evaluate acutely dizzy patients who do not show spontaneous nystagmus, as it includes gait and positional testing. It does go further than the timing, triggers and targeted bedside eye examinations in terms of positional testing, however, as it suggests performing the Pagnini–McClure manoeuvre to assess for the horizontal

canal variant before performing the Dix–Hallpike manoeuvre, which is used to identify the more commonly affected posterior canal. In their validation study, Vanni *et al.*[13] found a 20 per cent rate of the horizontal canal BPPV variant, a higher figure than seen in non-acute settings.

The spontaneous nystagmus, direction, head impulse testing and standing protocol also differs from the Head Impulse-Nystagmus-Test of Skew examination in its approach to the acute vestibular syndrome, as it does not include the test of skew. The reason for this is not clear, but it seems it was not thought to be necessary given that a normal Head Impulse Test finding was the best bedside predictor of stroke in the study by Kattah *et al.*[27] Vanni *et al.*[13] also found that a negative Head Impulse Test finding, as well as altered equilibrium, were the most sensitive findings for central vertigo. The spontaneous nystagmus, direction, head impulse testing and standing protocol also omits hearing. Nevertheless, these omissions did not appear to result in unacceptable levels of sensitivity compared with final clinical diagnosis, although it should be noted that the emergency physicians performing the protocol had received extensive training. The use of emergency physicians in the validation is a particular strength of the spontaneous nystagmus, direction, head impulse testing and standing protocol, but it is not clear how the protocol will perform when implemented by less experienced examiners given that it places a relatively higher weighting on the Head Impulse Test, which probably requires the greatest level of skill and interpretation.

Table 1 provides a summary of the pros and cons of the diagnostic algorithms discussed above.

What does a 'good protocol' look like?

Comparing the Head Impulse-Nystagmus-Test of Skew examination to the timing, triggers and targeted bedside eye examinations, or the associated symptoms, timing and triggers, examination signs and testing algorithm, and the spontaneous nystagmus, direction, head impulse testing and standing algorithm, may be misleading because the Head Impulse-Nystagmus-Test of Skew examination is only concerned with acute vestibular syndrome, whereas the others include aetiologies such as BPPV. As a result, the Head Impulse-Nystagmus-Test of Skew examination should not be used in isolation for the differential diagnosis of vertigo in the emergency department.

Other protocols and pathways that have not yet been mentioned include minor modifications but adhere to similar principles, such as the one advocated by Johns and Rosenberg.[40] This algorithm, like the spontaneous nystagmus, direction, head impulse testing and standing algorithm, looks for the ability to stand or walk unaided in order to clearly identify strokes, and includes positional testing for BPPV, but incorporates the full Head Impulse-Nystagmus-Test of Skew examination in the case of the acute vestibular syndrome.

What these protocols do share is the principle that the most effective way to exclude a life-threatening disorder such as posterior cerebrovascular disease is to confirm the presence of a peripheral vestibular disorder. The spontaneous nystagmus, direction, head impulse testing and standing protocol, for example, had an excellent negative predictive value (99 per cent) but a poor positive predictive value (48 per cent), according to validation study by Vanni *et al.*[13] Therefore, clinical pathways should consider the tools required to recognise the most common peripheral vestibular disease resulting in acute vertigo.

Table 1. Pros and cons of diagnostic algorithms for differential diagnosis of vertigo in the emergency department

Algorithm	Description	Pros	Cons
HINTS+	– Head impulse – Nystagmus – Test of skew	– Excellent accuracy when used by subspecialists	– Used subspecialists in the validation – Does not address patient selection – Can only be used in people with AVS (with nystagmus persisting in the emergency department)
TiTrATE/ ATTEST	– Triage (other obvious dangerous causes) – Timing (episodic, acute or chronic) – Triggers (e.g. positional or exposures) – Targeted examination (specific bedside findings, emphasising targeted eye movement examination) – Test (laboratory or imaging when relevant)	– Addresses common pitfalls in patient selection – Includes main categories of patients presenting to acute services – Provides information relevant to all examination stages, including initial screening	– May be difficult to follow & complex – Requires validation – Does not include horizontal canal BPPV
STANDING	– Spontaneous or positional triggers – Nystagmus direction – Head Impulse Test – Standing	– Has been validated with emergency physicians – Uses an unselected group of dizzy patients	– Greater emphasis on HIT as part of AVS examination – Omits hearing loss & test of skew – Confusion could transpire when testing horizontal canal BPPV if mistakenly performed on someone with AVS

HINTS+ = Head Impulse-Nystagmus-Test of Skew plus hearing examination; AVS = acute vestibular syndrome; TiTrATE = timing, triggers and targeted bedside eye examinations; ATTEST = associated symptoms, timing and triggers, examination signs and testing algorithm; BPPV = benign paroxysmal positional vertigo; STANDING = spontaneous nystagmus, direction, head impulse testing and standing protocol; HIT = Head Impulse Test

Other vestibular disorders, such as vestibular migraine and Ménière's disease, may also present to the emergency department, and can be difficult to diagnose at first, even in the hands of subspecialists. As a result, emergency department physicians may need to use the bedside examination to rule out 'clear cases', rather than making a definitive diagnosis, to ensure patient safety. Although this would reduce specificity, it is preferable to low sensitivity.

Who should see these patients?

The success of any protocol depends on who carries it out. A common criticism of vertigo protocols is the lack of validation in non-specialist point of care emergency physicians.[35,41] These tests are not uniquely difficult to perform, although they do require some level of subjective interpretation.

Some localised protocols utilise allied health professionals instead. For example, one study from Australia found that utilising a specialist vestibular physiotherapist led to greater diagnostic specificity.[42] However, there was no reference standard used to measure diagnostic accuracy, and the pathway led to higher rates of hospital admission and longer length of stay.

In the end, the ideal person to see the patient is the one who is available and the most qualified to do so, but it is unclear what training is necessary to achieve competency. Emergency physicians carried out the spontaneous nystagmus, direction, head impulse testing and standing protocol, following 5 hours of didactic and practical sessions, including 15 proctored examinations.[39] This was then extended to 6-hour workshops, comprising 4-hour lectures and 2-hour demonstrations on normal volunteers, followed by 10 proctored examinations on emergency department patients and 1-month use in daily practice under the supervision of a neuro-otologist.[13]

In another study, Kotwal et al.[43] found that 9 hours of deliberate practice using a case library of virtual patients significantly increased the diagnostic skills of medicine interns evaluating real-world dizziness. There is a need for putting more resources into developing condensed educational experiences, such as virtual simulation training, to enhance diagnostic education.

Role of technology

Advances in technology have provided vestibular clinicians with a number of new methods for determining vestibular function. Video-oculography allows for quantitative recording of eye movements. In addition, the introduction of the video Head Impulse Test permits objective evaluation of the vestibulo-ocular reflex in the planes of all six semi-circular canals, a so-called 'eye ECG'.[44]

'AVERT' is an ongoing randomised, controlled diagnostic strategy trial (unique identifier: NCT02483429), which is focused on comparing such a novel video-oculography guided diagnostic strategy to standard care. The goal is for a fully automated 'eye ECG' conducted by local providers, with backup telediagnosis made by subspecialists. However, it is worth noting that technologies such as video Head Impulse Test systems come with their own challenges and pitfalls, requiring training and careful administration. The 'AVERT' study utilises the services of a specialist audiological scientist, and the review is conducted by an expert otoneurologist, not accessible in most emergency departments. Again, the ability and, more importantly, the willingness of emergency physicians to use these technologies would have to be evaluated.

In future, smartphones may be used to record and evaluate oculomotor examination findings. This would have several advantages, as these are readily available, quick to complete and should be easier to administer. Early proof of concept results are very promising.[45,46] 'Deep learning' models would allow nystagmus identification and interpretation,[47] but have some way to go before being commercially available.

Conclusion

There is compelling evidence in favour of specific bedside tests for the diagnosis of acute vertigo in the emergency department. Firstly, the neurological examination should not be overlooked, particularly when examining for signs that indicate a strong probability of stroke and are easy to look for, such as the inability to stand or sit up independently. The evidence does not support the use of CT to rule out stroke and

even early MRI has limitations. Instead, the evidence is growing for protocols that utilise a targeted oculomotor examination. The Head Impulse-Nystagmus-Test of Skew and Head Impulse-Nystagmus-Test of Skew plus hearing examinations have both been well validated when used by specialists. In addition, there are now guidelines, such as the spontaneous nystagmus, direction, head impulse testing and standing protocol, the timing, triggers and targeted bedside eye examinations algorithm, and the associated symptoms, timing and triggers, examination signs and testing algorithm, for selecting the right patients for relevant bedside tests. Other than a limited number of physicians in the spontaneous nystagmus, direction, head impulse testing and standing trial, there is little in the literature suggesting the evidence for emergency physicians using these tools and reporting the required training.

- There is compelling evidence in favour of specific bedside tests for the diagnosis of acute vertigo in the emergency department
- Neurological examination is an important part of the assessment process
- The evidence does not support the use of computed tomography to rule out stroke, and even early magnetic resonance imaging has limitations
- Evidence is growing for protocols that utilise a targeted oculomotor examination
- Some tests have been well validated when used by specialists, and there are now guidelines for selecting patients for relevant bedside tests

Advances in vestibular function testing have the potential to improve diagnostic accuracy even more, but they come with their own set of limitations. Smartphone technology, on the other hand, appears to be the most promising tool for assisting non-experts in identifying and interpreting nystagmus. More research into the training requirements and real-world applicability of these approaches is needed.

Competing interests. None declared

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