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ORIGINAL ARTICLE

Effectiveness and reliability of the four-step STANDING algorithm performed by interns and senior emergency physicians for predicting central causes of vertigo

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Abstract

Background: For emergency physicians (EPs), acute vertigo is a challenging complaint and learning a reliable clinical approach is needed. STANDING is a four-step bedside algorithm that requires (1) identifying spontaneous nystagmus with Frenzel glasses or, alternatively, a positional nystagmus; (2) characterizing the nystagmus direction; (3) assessing the vestibuloocular reflex (head impulse test); and (4) assessing the gait. The objective was to determine its accuracy for diagnosing central vertigo when using by naïve examiners as such as interns and its agreement with senior EPs.

Methods: This was a prospective 1-year diagnostic cohort study among patients with vertigo, vestibulovisual symptoms, or postural symptoms seen by 20 interns trained in the four-step examination. The algorithm was performed first by an intern and second by a senior EP and categorized as either worrisome when indicating a central diagnosis and benign or inconclusive when indicating a peripheral diagnosis. The reference test was diffusion-weighted brain magnetic resonance imaging.

Results: Among 312 patients included, 57 had a central diagnosis including 33 ischemic strokes (10.5%). The main etiology was benign paroxysmal positional vertigo (32.7%). The likelihood ratios were 4.63 and 10.33 for a worrisome STANDING, 0.09 and 0.01 for a benign STANDING, and 0.21 and 0.35 for an inconclusive STANDING, for interns and senior EPs, respectively. The algorithm showed sensitivities of 84.8% (95% CI 75.6%–93.9%) and 89.8% (95% CI 82.1%–97.5%), negative predictive values of 96.2% (95% CI 93.7%–98.6%) and 97.5% (95% CI 95.5%–99.5%), specificities of 88.9% (95% CI 85.1%–92.8%) and 91.3% (95% CI 87.8%–94.8%), and positive predictive values of 64.1% (95% CI 53.5%–74.8%) and 70.7% (95% CI 60.4%–81.0%), respectively. The agreement between interns and senior EPs was very substantial (B-statistic coefficient: 0.77) and almost perfect for each step: (1) 0.87, (2) 0.98, (3) 0.95, and (4) 0.99.

Conclusions: With a single training session, the algorithm reached high accuracy and reliability for ruling out central causes of vertigo in the hands of both novices and experienced EPs. A future multicenter randomized controlled trial should further its impact on unnecessary neuroimaging use and patient's satisfaction.

ClinicalTrials.gov registration: NCT04919187.

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KEYWORDS
emergency department, eye movements, magnetic resonance imaging, validation study, vertigo

INTRODUCTION

Background

Acute vertigo, loss of balance, and unsteadiness are common chief complaints reported by about 4% of patients visiting emergency departments (ED).[1] In a symptom-quality paradigm, emergency physicians (EPs) commonly encounter two clinical settings: the acute and the episodic vestibular syndromes (AVS and EVS).[2,3] Benign paroxysmal positional vertigo (BPPV) is the leading cause of EVS,[4,5] and posterior circulation strokes must be adequately differentiated from vestibular neuritis as they concerned 15% of AVS.[6] Given the concern for stroke, EPs are challenged from a diagnostic and a management standpoint: relying on reliable clinical features, deciding adequately either to perform or to defer neuroimaging, and either referring patients to an otologist consultation or admitting them in the neurology department. Without a reliable clinical approach due to lack of learning about vestibular conditions,[7] this dilemma could lead to overuse neuroimaging in benign disorders. However, brain computed tomography (CT) is commonly available around the clock, but very insensitive at detecting posterior ischemic strokes (28.5%).[8,9] Brain magnetic resonance diffusion-weighted imaging (MRI-DWI) is the then criterion standard diagnostic examination, but it is less available and may also miss one in five small ischemic strokes within 48 h after symptoms onset (up to 53%).[10,11]

In the emergency setting, all these deficiencies could result in a significant proportion of missed central causes (about 6%), while about one-quarter of benign disorders could be falsely considered as worrisome diseases.[12] Because even negative neuroimaging may be falsely reassuring, EPs need to be comfortable with a workable approach. The underlying etiologies of vestibular symptoms are usually associated with objective clinical features such as eye movements, abnormal vestibuloocular reflex, or gait impairments.[11,13–16] Over the past decade, the three-step clinical rule named HINTS (i.e., head impulse, nystagmus, test of skew) has been validated against MRI-DWI and has near perfect accuracy for predicting strokes in AVS, but only in patients with persistent spontaneous nystagmus.[11,13] The four-step STANDING algorithm is less familiar to EPs, although it is probably more relevant for managing vertigo in the ED population.[17–19] It adds two relevant clinical steps to the HINTS test: it starts by differentiating spontaneous from positional nystagmus, and it ends by differentiating worrisome from normal gait. The first step is very pivotal because it allows clinicians to assess patients having a triggered EVS by testing semicircular canals and consequently to make a definitive bedside diagnosis of BPPV.[5,12]

Importance

While recognizing the importance of ocular motor and gait testing, many studies questioned the learning of vestibuloocular assessment by EPs with no prior experience of this examination.[16,20–23] Previous cohort studies evaluating the STANDING algorithm showed high sensitivities (ranging from 75% to 94%) and specificities (ranging from 75% to 87%) in the hands of senior EPs trained by otologists.[18,19,24] However, it is unclear whether this intensive training is relevant to the quality of use of the algorithm, nor how naïve examiners will adopt it, nor how experience will affect accuracy of its results.

Goals

Our hypothesis was that a single training session based on videos plus a supervised examination could be sufficient to validate the four-step STANDING algorithm performed by untrained clinicians such as ED interns. The objective of this study was to determine the diagnostic accuracy of the STANDING algorithm performed by ED interns to predict central causes of AVS and EVS. Our secondary goals were to compare the accuracy of the STANDING algorithm made by ED interns to that made by senior EPs and to evaluate the interns' opinions on its use.

METHODS

Study design

This was an investigator-initiated, single-center, prospective assessment of the effectiveness and reliability of the four-step STANDING algorithm performed by emergency interns who received training, to predict central causes of AVS or EVS, using MRI-DWI as a the criterion standard. Patients were recruited in the ED of a tertiary hospital, in Paris, France. This hospital has a stroke unit with on-site thrombolysis availability and both a neurology and an otology department. Eligible patients were enrolled by a senior EP[19] in the ED, after the four-step STANDING algorithm has been performed by the intern caring for the patient.

Selection of participants

Adults presenting an AVS or an EVS—as defined by the international classification of vestibular disorders[3]—were included in our 24/7 ED during 1 year. Eligible patients presented at least one category

of the following symptoms: spontaneous or triggered vertigo (i.e., false sense of motion of spinning or nonspinning quality), vestibulovisual symptoms (i.e., blur, false sensation of motion or oscillopsia), and postural symptoms (i.e., loss of balance or unsteadiness), within the past week. As in the original study of Vanni et al.,[18] dizziness (i.e., sensation of disturbed or impaired spatial orientation without a false or distorted sense of motion) was not included among the eligible complaints because the international classification warned that dizziness was an "umbrella term" encompassing vertigo but also presyncope (a sensation of impending faint) and nonspecific sensations as disordered thinking (mental confusion) or detachment from reality (depersonalization or derealization) when such sensations are not accompanied by a sense of spatial disorientation.[3] Patients with concomitant localizing neurologic signs (abnormalities of cranial nerves except the eighth, meningeal syndrome, sensitive or motor deficit) or another differential diagnosis on admission (systolic blood pressure < 100 mm Hg, blood glucose ≤ 4 mmoL/L, anemia < 10 g/L, acute alcohol, or drug use), and those who could not consent or be assessed (i.e., Glasgow Coma Scale < 15, dementia, oculomotor nerve palsy), were excluded. A patient could only be included once in the study.

Ethics statement

The trial was approved by an ethics committee (IRB 00012157). The consent of each participant was obtained and recorded in the patient's record. The authors are solely responsible for the design and conduct of this study, the statistical analysis, the drafting and editing of the paper, and its final contents. The authors vouch for the accuracy and completeness of the data and analyses and for the fidelity of the study to the protocol. The study was registered on clinicaltrials.org as NCT04919187.

Training

During the study period, two groups of 10 interns were trained by the principal investigator at the beginning of their ED internship (6-month duration; Table S1). Participants were on average 26 years old, and their specialties were as follows: family medicine (70%), emergency medicine (20%), and geriatric medicine (10%).The training session comprised 2 h of individual lectures[17–19,25] and 2 h of collective work using slideshows, videos, and demonstrations on normal volunteers including brief reminders about the anatomy and pathophysiology of the vestibular system, scopes of the vestibuloocular examination through HINTS test,[26] STANDING algorithm[27] (including Dix–Hallpike[28,29] and supine head roll tests[28,30]), Fukuda test,[31] BPPV liberatory maneuvers (Semont and Epley maneuvers),[32] and clinical training cases. Prior to the start of patients' recruitment, all interns observed one vestibuloocular examination performed by the principal investigator and performed one proctored examination with a patient with vertigo in the ED. Data acquisition started 1 h after the end of the interns training. One week and 6 months after their training, they were asked to complete a knowledge assessment form (Table S2) and an assessment form about their opinions on both the use and the interpretation of the four-step examination.

Measurements

Index test: the four-step STANDING algorithm

The ED interns and senior EPs used the four-step STANDING algorithm proposed by Vanni et al.[18] (Figure S1):

- First step—look for a spontaneous nystagmus with and without Frenzel glasses (Faromed GmbH, Meizintechnik, Art-No 08-423): either spontaneous and persistent, either positional or absent. If no spontaneous nystagmus is detected, a positional nystagmus found by Dix–Hallpike or supine head roll tests indicates a BPPV (posterior or lateral semicircular canal, respectively).
- Second step—assess the spontaneous nystagmus direction as such as a gaze-evoked, vertical, or multidirectional nystagmus indicating a potentially worrisome etiology.
- Third step—if there is a spontaneous nystagmus, assess the vestibulooocular reflex through head impulse test (HIT), a bilaterally normal HIT indicating a potentially worrisome etiology and a positive HIT (i.e., overt or covert catch-up corrective saccades) indicating an acute peripheral vestibulopathy.
- Fourth step—if there is a positional nystagmus or a positive HIT, systematically search for an abnormal standing position as such as ataxic gait (unsteady gait), mild to severe imbalance, directional impulse for autonomous walking, or inability to stand related to lethargy, all indicating a potentially worrisome etiology.

For all eligible patients consenting to the study, this four-step examination was performed first by the ED intern alone and second by a trained senior EP[19] in the ED. They both categorized the STANDING outcome *worrisome* when it predicted a central cause diagnosis, *benign* when it predicted a peripheral cause diagnosis (acute peripheral vestibulopathy or BPPV), or *inconclusive* when the examiner found neither spontaneous nystagmus nor positional nystagmus and the gait was considered normal, i.e., benign.

Reference standard

The reference test used for differentiating central from peripheral diagnoses was brain MRI-DWI, except in two cases: (a) a typical diagnosis of BPPV found by the senior EP and validated by the examination of an otologist through positional tests plus videonystagmography or video-HIT, according to the standard of care in our hospital, and (b) a MRI contraindication—in this case, a brain CT with angiography of the circle of Willis (CTA) was used as reference standard. Central cause diagnoses were defined as

the presence of an acute brain process in posterior fossa or in the vestibular cortex detected on neuroimaging either directly on ED neuroimaging, or on a brain MRI used at least 48 h after symptoms onset, in the hospital or in the ambulatory setting. The remaining patients were considered as having peripheral diagnoses. To refine peripheral etiologies, an otologist examination was arranged for reappraisal of MRI result and performing videonystagmography or video-HIT.

In the standard of care for ED neuroimaging order, MRI-DWI was used applying current guidelines after agreement of the neurologist, limited to high suspected acute ischemic strokes within 4 h and 30 min of symptoms onset.[33] Urgent CTA was used applying current guidelines after agreement of the neurologist, limited to suspected acute ischemic events within 24 h after symptoms onset.[34] Urgent noncontrast head CT was used in suspected brain hemorrhages only. In patients having a typical BPPV through positional diagnostic tests, no neuroimaging was performed in the ED. After the ED workup, definitive diagnoses were established through a composite follow-up based on MRI result and otologist or neurologist conclusions. MRI-DWI was performed either in the hospital or in the ambulatory setting; hospitalized patients underwent MRI within 72 h in the neurology department (if it has not previously been performed in the ED) and discharged patients received an MRI appointment within 1 month (even if an initial CT/CTA has been performed in the ED). Depending on the MRI result, patients were then referred to the otologist or to the neurologist, within a maximum of 3 months. Patients discharged from the ED with a typical diagnosis of BPPV were directly referred to the otologist consultation before their MRI appointment to validate the diagnosis (positive positional tests and normal video HIT) and adjust the treatment if necessary.

Outcomes

The primary outcome was the diagnostic accuracy (sensitivity and specificity) of the STANDING algorithm performed by interns for diagnosing central causes of AVS and EVS. The secondary outcomes were (a) comparison of accuracy between the STANDING algorithm performed by interns and that performed by senior EPs, (b) agreement of the four-step STANDING algorithm performed by interns and that performed by senior EPs, and (c) the opinions of interns about of the use and interpretation of the algorithm at the beginning and at the end of their internship in the ED.

Data collection

Results of each step of the STANDING algorithm, the overall STANDING outcome, testing times, and clinical features were immediately collected and reported on a dedicated datasheet in the ED: first by an intern and second by a senior, always before imaging (Figure S1). Data follow-up was performed up to 3 months after the ED visit. Patients were considered lost to follow-up when no medical information, MRI performance, or otologic examination was found between inclusion and three completed months. The national death registry was queried for each included patient.

Sample size

The approximate incidence of AVS due to stroke has been estimated by Tarnutzer et al.[6] around 25% ± 15%. From the literature, sensitivity of the STANDING algorithm to diagnose central causes of acute vertigo ranged from 92% to 95% and specificity ranged from to 71% to 87%.[17–19] According to a query of our clinical database from a previous study, 660 patients were recorded as having central or peripheral causes of vertigo over 18 months.[19] Therefore, the recruitment of around 300 patients appeared feasible over 12 months. With a stroke prevalence of 10%, we could expect 30 patients in the central cause's diagnosis group. Using a sensitivity of 92% the precision of estimate (95% confidence interval [CI]) will be 76%–99%, with an expected specificity of 71% the 95% CI will be 65% to 76%. These precisions were considered as acceptable. The 95% CI was calculated with the Clopper–Pearson method.

Statistical analysis

The reporting followed the Standard for Reporting Diagnostic Accuracy Studies (STARD) statement (Table S3). Continuous variables were reported as means with standard deviations (SDs) or medians with interquartile ranges (IQRs) and compared with Student's t-test or Wilcoxon test as appropriate. Qualitative variables were reported as number (%) and compared with the chi-square test or the Fisher's exact test as appropriate. The diagnostic accuracy of the STANDING algorithm has been summarized by calculating the sensitivities, specificities, positive predictive values (PPVs), negative predictive values (NPVs), positive likelihood ratios (PLRs), and negative likelihood ratios (NLR), with their 95% CIs. The STANDING test was considered positive, i.e., predictive of a central worrisome diagnosis, when at least one of the following items was present: (1) spontaneous vertical or multidirectional nystagmus, (2) spontaneous unidirectional nystagmus with normal HIT, and (3) abnormal standing position.[18] Both benign and inconclusive STANDING results were considered as negative, i.e., predictive of peripheral diagnoses. Diagnostic metrics were calculated for each step of the algorithm by considering patients involved at each of these steps and, for the overall algorithm result, by considering all included patients. Accordingly, the overall sensitivity of the algorithm was the proportion of positive STANDING tests in patients with a final central diagnosis and the specificity was the proportion of benign or inconclusive STANDING tests in patients with a final peripheral diagnosis. To compare the accuracy of interns with senior EPs, the

method proposed by Roldán-Nofuentes[35] has been used. The inter-observer coefficients of agreement were calculated in all enrolled patients, by comparing the result of the algorithm performed by an intern to that of one senior on the same patient. Agreement was estimated using the B-statistic coefficient proposed by Shankar and Bangdiwala[36] for each step (presence or absence of worrisome criteria) and for the overall algorithm (presence or absence of worrisome STANDING). All statistical tests were two-tailed at 0.05 level of significance. All data analysis was completed with R version 4.0.4 (R Core Team, 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, https://www.R-project.org/).

Interns' opinions about each step of the STANDING algorithm have been measured on a 5-points Likert scale. Interns were asked to indicate how easy they perceived the practice and interpretation of each item from (1) very difficult to (5) very easy at the beginning and end of their internship.

RESULTS

Characteristics of patients

From May 7, 2021, to May 2, 2022, a total of 329 patients were included in the study and 17 were lost to follow-up at 3 months. A cohort of 312 patients was analyzed comprising, based on imaging, 59 patients with central diagnoses and 253 with peripheral diagnoses (Figure 1). Characteristics of patients (mean ± SD age 59.1 ± 18.6 years, 60.6% of women) are summarized in Table 1. Among them, 34 (11.0%) had a history of stroke, 64 (20.5%) had an otologic history and 27 (8.7%) had migraine headache. In patients with central diagnoses, falls and head trauma were five times and three times more frequent, respectively, while otologic symptoms, vomiting, and anxiety were seven times and three times less frequent, respectively, compared to patients with peripheral diagnoses.

The 312 final diagnoses were classified as either central or peripheral, based on 267 MRI-DWI (Table 2; 16 ED imaging, 251 additional imaging) and 203 otologist examinations. Among the 45 patients who did not undergo MRI-DWI, 32 had a definitive diagnosis of BPPV validated during an otologist consultation and did not perform MRI, 10 had a MRI contraindication and received a CTA as a reference test, and three had an unequivocal central diagnosis based on either CT or CTA and did not perform additional MRI in the neurology department. Among the 59 central diagnoses, the main causes were acute ischemic strokes (55.9%), mostly related to atherosclerosis (60.6%), followed by intracranial hemorrhages (16.9%; Table 3). Among the 253 peripheral diagnoses, vestibular conditions were the leading causes (73.5%), followed by migraines (12.6%). More than half of vestibular conditions were BPPV (54.8%), mostly involving a posterior semicircular canal (73.5%; Table 3).

Accuracy and reliability

Based on imaging, the STANDING algorithm performed by interns missed nine central diagnoses (one benign result, eight inconclusive results) when those performed by senior EPs missed six central diagnoses (six inconclusive results; Figure 1). The main characteristic of these patients was high systolic blood pressure on admission (mean of 161 mm Hg). The misdiagnoses are summarized in Table 3. Compared to senior EPs, the three mistakes of interns occurred by considering two worrisome gaits as normal (two acute atherosclerotic strokes) and by considering a bidirectional nystagmus as a unidirectional nystagmus in a patient with positive HIT (one acute embolic stroke in the anterior inferior cerebellar artery (AICA) territory due to patent foramen ovale). False positive were more frequent when the examiners were interns rather than senior EPs (28 vs. 22; Figure 1) and involved mainly BPPV diagnoses (25%; Table 3). Among the 105 patients with an inconclusive STANDING algorithm, BPPV was the leading final diagnosis (29.9%), followed by miscellaneous causes of pseudo-vertigo (21.6%) and migraine (20.6%; Table 4).

Corresponding values of the STANDING algorithm diagnostic properties are summarized in Table 5. The effectiveness of the algorithm was better when used by senior EPs rather than interns with respective likelihood ratios (LRs) of 10.33 (95% CI 9.49–11.25) versus 4.63 (95% CI 4.35–4.93) for a worrisome result, LR of 0.01 (95% CI 0.00–0.66) versus 0.09 (95% CI 0.01–0.67) for a benign result, and LR of 0.35 (95% CI 0.26–0.48) versus 0.21 (95% CI 0.17–0.27) for an inconclusive result. Sensitivity ($p = 0.18$), NLR ($p = 0.07$), and NPV ($p = 0.06$) did not differ significantly between interns and senior EPs, whereas specificity ($p = 0.012$), PLR ($p = 0.023$), and PPV ($p = 0.023$) were significantly better in the group of senior EPs than in interns group. Comparing accuracies of each step, the item having a highest sensitivity was a bilaterally normal HIT for both interns and senior EPs (83.3% [95% CI 53.5%–100.0] and 100.0% [95% CI 40.0–100.0], respectively). The item with the best specificity was the abnormal gait for interns (94.5% [95% CI 91.7–97.4]) and a multidirectional or vertical nystagmus direction for senior EPs (96.5% [95% CI 92.6–100.0]).

The interexaminer agreement of the STANDING algorithm between interns and senior EPs has been calculated for the 329 consecutive patients (Figure 2). For the whole algorithm, there was a substantial agreement (B-statistic 0.77). There was an almost perfect agreement for each step: 0.87 for detecting a spontaneous nystagmus, 0.98 for finding a central nystagmus direction, 0.95 for finding a bilaterally normal HIT, and 0.99 for reporting an abnormal standing position.

Only one patient (1.7%) experienced a central cause misdiagnosis, i.e., a central disease overlooked before hospital discharge (Table 2). This involved one of the six patients with an inconclusive STANDING and a final central diagnosis. It concerned a 77-year-old woman who reported blurred vision without spinning sensation within the past week, with no headache or neck pain. She had a systolic blood pressure of 181 mm Hg on admission. No objective

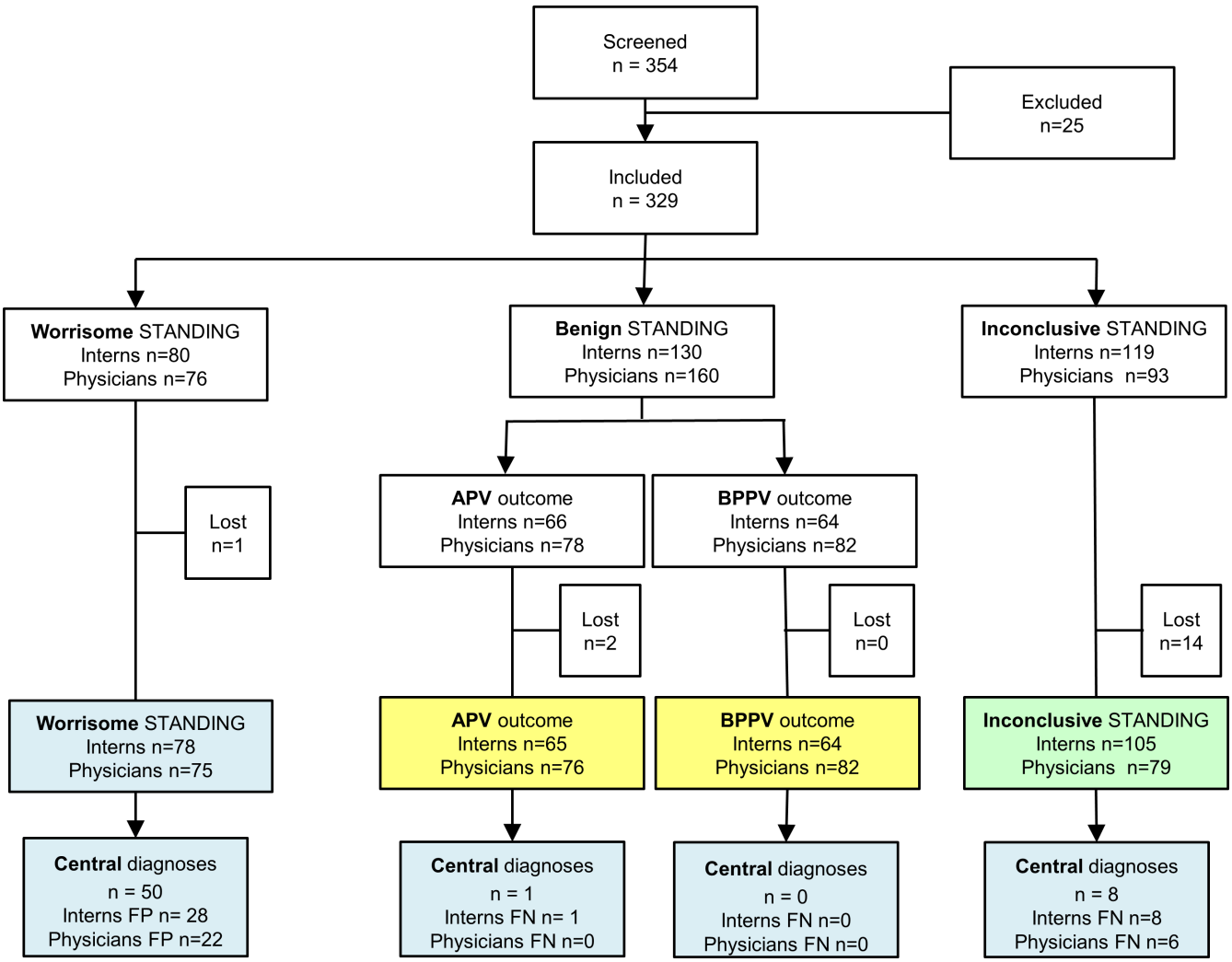

FIGURE 1 Flow chart. *Note*: Screened—patients assessed for eligibility; excluded—two patients refused consent, and 23 patients had exclusion criteria (22 dizziness alone, one acute alcohol use); inconclusive—no anomaly detected following the STANDING algorithm, i.e., absence of spontaneous nystagmus plus bilaterally normal HIT plus absence of positional nystagmus with Dix–Hallpike and supine head roll tests plus normal gait; lost—17 patients lost at 3-month follow-up (i.e., no information on medical outcome, on MRI performance, or on an otologist examination) and excluded from the analysis (national death registry queries—zero death). APV, acute peripheral vestibulopathy; BPPV, benign paroxysmal positional vertigo; FN, false negative; FP, false positive; HIT, head impulse test.

abnormality has been found through neurologic and vestibulooc-ular examinations performed by both an intern and a senior EP (i.e., both inconclusive STANDING). She underwent an urgent CTA that showed no anomaly and had been discharge from the ED. Seven days later, MRI-DWI showed multiple acute cerebellar ischemic lesions with microbleeds, matching with an amyloid an-giopathy. Among the remaining five patients with an inconclusive STANDING, four final central diagnoses were established on ED im-aging (two atherosclerotic strokes, one cervical artery dissection, and one idiopathic intracranial hypertension), and one patient had been hospitalized by the neurologist despite a normal urgent MRI-DWI (vertebrobasilar insufficiency).

Opinions about the algorithm

The 20 interns' opinions about the four-step STANDING exami-nation at the beginning and the end of their internship are sum-marized in Figure 3. All reported an improvement of the ease of performing the full four-step examination. By considering each step, characterizing a nystagmus direction was the most difficult clinical step for a half of interns at the beginning of the study. The positional tests (Dix–Hallpike or supine head roll) showed the best improvement in the ease of achievement. Two interns reported a higher difficulty while performing the liberatory maneuvers at the end rather the beginning of their internship.

TABLE 1 Characteristics of the study population according to the final diagnosis

	Overall ($N = 312$)	Central diagnoses ($n = 59$)	Peripheral diagnoses ($n = 253$)
Age (years)	59.1 ± 18.6	66.8 ± 16.9	57.3 ± 18.5
Sex, women	189 (60.6)	27 (45.8)	162 (64.0)
History			
Cardiovascular risk factors ≥ 2	91 (29.2)	28 (47.5)	63 (24.9)
Otologic history	64 (20.5)	4 (6.8)	60 (23.7)
Previous stroke or TIA	34 (11.0)	14 (23.7)	20 (8.0)
Migraine	27 (8.7)	0 (0.0)	27 (10.8)
Chronic alcoholism	12 (3.9)	8 (13.6)	4 (1.6)
Symptoms onset			
<4:30 h	77 (24.8)	14 (23.7)	63 (25.0)
4:30–24 h	107 (34.4)	19 (32.2)	88 (34.9)
24 h–7 days	127 (40.8)	26 (44.1)	101 (40.1)
Context			
Fall	31 (9.9)	16 (27.1)	15 (5.9)
Head trauma	16 (5.1)	7 (11.9)	9 (3.6)
Infection	14 (4.5)	1 (1.7)	13 (5.1)
Psychological stress	26 (8.3)	2 (3.4)	24 (9.5)
Ototoxic use	20 (6.4)	4 (6.8)	16 (6.3)
Clinical features			
Systolic blood pressure (mm Hg)	144.4 ± 24.2	152.8 ± 27.1	142.5 ± 23.1
Vertigo	201 (64.4)	26 (44.1)	175 (69.2)
Vestibulovisual symptom	103 (33.0)	14 (23.7)	89 (35.2)
Unsteadiness	143 (45.8)	47 (79.7)	96 (37.9)
Imbalance	111 (35.6)	39 (66.1)	72 (28.5)
Headache	73 (23.4)	21 (35.6)	52 (20.5)
Neck pain	12 (3.8)	5 (8.5)	7 (2.8)
Nausea or vomiting	189 (60.6)	12 (20.3)	177 (70.0)
Positive Fukuda test ($n = 288$)	80 (27.8)	8 (18.2)	72 (29.5)
Skew deviation	0 (0.0)	0 (0.0)	0 (0.0)
BPPV tests ($n = 160$)			
Positive Dix–Hallpike	65 (40.6)	0 (0.0)	65 (42.2)
Positive supine head roll	18 (11.3)	0 (0.0)	18 (11.7)
BPPV liberatory maneuvers	70 (84.3)	0 (0.0)	70 (84.3)
Successful liberatory maneuvers	34 (48.6)	0 (0.0)	34 (48.6)
Acute hearing loss	4 (1.3)	1 (1.7)	3 (1.2)
Other otologic symptoms	44 (14.1)	1 (1.7)	43 (17.0)
Anxiety	87 (27.9)	7 (11.9)	80 (31.6)

Note: Data are reported as mean ± SD or number (%). Other otologic symptoms included tinnitus or otalgia or full ear sensation.

Abbreviations: BPPV, benign paroxysmal positional vertigo; TIA, transient ischemic attack.

DISCUSSION

In the current literature, providing training about vestibulooocular examination in emergency medicine education has been increasingly identified as an important need to improve bedside diagnosis.[20,21,37] There was evidence that EPs did not usually test spontaneous nystagmus and vestibuloocular reflex, but also misuse the Dix–Hallpike test in eligible patients.[23,38,39] To our knowledge,

TABLE 2 Diagnostic workup of the study population according to the final diagnosis

	Overall ($N = 312$)	Central diagnoses ($n = 59$)	Peripheral diagnoses ($n = 253$)	p-value
Emergency diagnostic workup				
Intern testing times (min)	10.0 (5.0–11.0)	6.0 (5.0–10.0)	10.0 (5.0–13.5)	0.066
Senior EP testing times (min)	5.0 (5.0–10.0)	5.0 (5.0–7.0)	6.0 (5.0–10.0)	0.177
Imaging	164 (52.6)	55 (93.2)	109 (43.1)	<0.0001
CTA	137 (43.9)	43 (72.9)	94 (37.1)	0.032
MRI-DWI	16 (5.1)	10 (16.9)	6 (2.3)	–
NCT	11 (3.5)	2 (3.4)	9 (3.6)	–
Post–emergency care pathway				
Hospitalization	74 (23.7)	43 (72.9)	31 (12.3)	<0.0001
Additional imaging	253 (81.1)	46 (78.0)	207 (81.8)	0.496
Delay (days)	7.00 (2.0–14.0)	2.00 (2.0–4.0)	7.50 (3.0–14.0)	<0.0001
CTA	1 (3.2)	0 (0.0)	1 (3.9)	–
MRI-DWI	251 (80.4)	46 (77.9)	205 (81.0)	–
Otologist consultation	203 (65.1)	7 (11.9)	196 (77.5)	<0.0001
Central misdiagnosis ($N = 59$)	1 (1.7)	1 (1.7)	0 (0.0)	–

Note: Data are reported as number (%), mean ± SD, or median (IQR). Ten patients had CTA because of MRI contraindication. Testing times correspond to the duration of the four-step STANDING examination. Central misdiagnosis corresponded to central diagnoses missed at hospital discharge.

Abbreviations: CTA, brain computed tomography with angiography of the circle of Willis; MRI-DWI, brain magnetic resonance imaging with diffusion-weighted imaging, NCT, noncontrast head computed tomography.

our study is the first to assess both accuracy and reliability of a bedside diagnostic algorithm in the hands of novice examiners as such as interns, learning vestibuloocular assessment during their ED internship.

Over the past decade, novel approaches have been described to help EPs toward the initial management of acute vertigo.[2,16,25] The three components of the HINTS test have been shown to be accurate for predicting stroke in the hands of experts examining high-risk patients with a persistent spontaneous nystagmus.[11] However, despite this advance in neurophysiology knowledge, the adoption of the HINTS test by EPs remains low.[22,23] First, the HINTS test is not applicable to patients with triggered vertigo.[11] Second, a unidirectional nystagmus is not exclusive to peripheral diagnoses and some strokes in anteroinferior cerebellar arteries may also result in abnormal HIT.[40] In our cohort, one gaze-evoked nystagmus had been mistaken for unidirectional in a patient having an abnormal HIT and then being correctly identified by the senior EP in a young patient having an acute embolic stroke in the AICA territory. Third, a seemingly minor difference is critical to recognize the usefulness of the STANDING algorithm designed by Vanni et al.[18] a few years later. Some cases of direction-changing nystagmus triggered by head movement are related to otoliths adhering to the horizontal semicircular canal.[7] This mistake occurred only in one case of lateral BPPV that was correctly diagnosed by the senior EP thanks to the supine head roll test. We also noted that no patient had skew deviation.

By comparing the accuracy of the STANDING algorithm performed by interns with that of senior EPs in the study of Vanni et al.,[18] we found a lower sensitivity (84.8% vs. 95%), a higher specificity (88.9% vs. 87%), a lower NPV (96.2% vs. 99%), and a higher PPV (64.1% vs. 48%). Therefore, provided that naïve examiners receive appropriate training, we have shown that the STANDING algorithm is highly usable within 10 min at the bedside. We have shown that the median time to complete the STANDING algorithm was twice as short for EPs as for interns (5 min vs. 10 min), especially with patients having a final peripheral diagnosis (6 min vs. 10 min). We hypothesized that this difference was due to the time required to perform the BPPV diagnostic tests, which may need to be repeated. In the hands of senior EPs, we found results similar to those in the primary study. This could be explained by the experience gained by EPs having routinely practiced the vestibuloocular assessment since they were trained in our prior research project.[19] Although prior studies involved large training needs, the reliability of the STANDING algorithm was almost better with a shorter learning time based on many videos.[17–19] In the original study, Vanni et al.[18] mentioned a 6-h workshop plus 10 proctored examinations, followed by 1-month use in daily practice, our prior study have required 4 h of individual lectures plus 2 h of workshop, repeated 7 months later,[19] while our current study involved only a single morning training course (2 h of individual lectures and 2 h of collective workshop) completed by one observation and one proctored examination.

Although we found that the HIT and gait assessment had better agreements between interns and senior EPs than in the original study (0.95 vs. 0.74 and 0.99 vs. 0.81), the overall agreement of the algorithm was slightly lower than that reported by Vanni et al.[18]

TABLE 3 Final diagnoses and results of the STANDING algorithm performed by interns based on the criterion standard

Central diagnoses ($N = 59$)			False negatives ($n = 9$)
Ischemic stroke	33	(55.9)	7 (77.8)
Atherosclerosis	20	(33.9)	4 (50)
Lacunes	5	(8.5)	—
Embolism	4	(6.8)	1 (100)
Amyloid angiopathy	3	(5.1)	1 (12.5)
Cervical artery dissection	1	(1.7)	1 (12.5)
Hemorrhage	10	(16.9)	—
Tumor	5	(8.5)	—
Cerebellum	3	(5.1)	—
Brain stem	1	(1.7)	—
Schwannoma with CPA involvement	1	(1.7)	—
Gayet Wernicke disease	3	(5.1)	—
Vertebrobasilar insufficiency or TIA	3	(5.1)	1 (12.5)
Miscellaneous	5	(8.5)	1 (12.5)
Peripheral diagnoses $N = 253$			**False positives ($n = 28$)**
Vestibular disorders	184	(72.7)	20 (71.4)
BPPV	102	(40.3)	7 (25.0)
Posterior semicircular canal	75	(29.6)	4 (14.3)
Lateral semicircular canal	27	(10.7)	3 (10.7)
Vestibular neuritis or labyrinthitis	33	(13.0)	7 (25.0)
Endolymphatic hydrops or Meniere disease	33	(13.0)	2 (7.1)
Presbyvestibulopathy	9	(3.6)	—
Other vestibular disorder	7	(2.8)	4 (14.3)
Migraine	32	(12.6)	3 (10.7)
Ototoxicity	4	(1.6)	—
Peripheral neuropathy	4	(1.6)	3 (10.7)
Miscellaneous	29	(11.5)	2 (7.1)

Note: Data are reported as number (%). Miscellaneous central diagnoses: one intracranial hypertension, one autoimmune paraneoplatsic cerebellar degeneration, one central pontine myelinosis, one acute hydrocephalia, and one downbeat nystagmus syndrome. Other vestibular disorders: two superior canal dehiscences, two labyrinthine concussions, one intrameatal schwannoma, one neurovascular conflict, one congenital nystagmus. Peripheral neuropathies: two vitamin deficiencies, one Guillain–Barré syndrome, one Miller–Fisher syndrome. Miscellaneous peripheral diagnoses: nine cervical vertigo, nine hypertensive crisis, eight orthostatic hypotension, three anxiety disorders.

Abbreviations: CPA, cerebellopontine angle, TIA, transient ischemic attack.

TABLE 4 Final diagnoses in patients with an inconclusive STANDING algorithm performed by interns based on the criterion standard

Central diagnoses ($n = 59$)	False negatives ($n = 8$)
Ischemic stroke	6 (75)
Atherosclerosis	4 (50)
Lacunes	—
Embolism	—
Amyloid angiopathy	1 (12.5)
Cervical artery dissection	1 (12.5)
Hemorrhage	—
Tumor	—
Cerebellum	—
Brain stem	—
Schwannoma with CPA involvement	—
Gayet Wernicke disease	—
Vertebrobasilar insufficiency or TIA	1 (12.5)
Intracranial idiopathic hypertension	1 (12.5)
Peripheral diagnoses ($n = 253$)	**True negatives ($n = 97$)**
Vestibular disorders	51 (52.6)
BPPV	29 (29.9)
Posterior semicircular canal	20 (20.6)
Lateral semicircular canal	9 (9.3)
Vestibular neuritis or labyrinthitis	6 (6.1)
Endolymphatic hydrops or Meniere disease	9 (9.3)
Presbyvestibulopathy	7 (7.2)
Guillain Barré syndrome	1 (1.0)
Migraine	20 (20.6)
Ototoxicity	3 (3.1)
Peripheral neuropathy	1 (1.0)
Miscellaneous	21 (21.6)

Note: Data are reported as number (%). Miscellaneous peripheral diagnoses: seven hypertensive crisis, six orthostatic hypotension, five cervical vertigo, three anxiety disorders.

Abbreviations: CPA, cerebellopontine angle; TIA, transient ischemic attack.

(0.77 vs. 0.83).[18] This difference was due to the proportion of inconclusive results, which was one-third of patients for interns and one quarter for senior EPs. Therefore, the STANDING algorithm showed one restrictive application in a clinical subgroup frequently seen in the ED. These patients reported vestibular symptoms at the time of the clinical examination but no objective worrisome criteria were found, unlike patients who no longer had symptoms in the ED (transient symptoms) and were therefore excluded of the study. For these patients, three causes of spontaneous and triggered EVS accounted for the majority of final diagnoses: BPPV, migraine, and pseudo-vertigo. However, the proportion of ischemic

TABLE 5 Accuracies of the four-step STANDING algorithm performed by emergency interns and senior EPs for predicting central diagnoses

Step	1	2	3	4	Full
Item	Spontaneous nystagmus	Multidirectional or vertical nystagmus	Bilaterally normal HIT	Abnormal standing	STANDING algorithm
Interns	***n* = 312**	***n* = 97**	***n* = 77**	***n* = 280**	***n* = 312**
Se	30.5 (18.8–42.3)	66.7 (44.9–88.4)	83.3 (53.5–100.0)	78.6 (66.2–90.9)	84.8 (75.6–93.9)
Sp	68.8 (63.1–74.5)	89.9 (83.2–96.5)	90.1 (83.2–97.1)	94.5 (91.7–97.4)	88.9 (85.1–92.8)
PPV	18.6 (10.8–26.3)	60.0 (38.5–81.5)	41.7 (13.8–69.6)	71.7 (58.7–84.7)	64.1 (53.5–74.8)
NPV	80.9 (75.7–86.2)	92.2 (86.2–98.2)	98.5 (95.5–100.0)	96.2 (93.7–98.6)	96.2 (93.7–98.6)
PLR	0.98 (0.89–1.07)	6.58 (5.00–8.66)	8.45 (6.15–11.61)	14.38 (12.32–16.80)	7.66 (7.15–8.20)
NLR	1.01 (0.99–1.03)	0.37 (0.30–0.46)	0.18 (0.04–0.95)	0.23 (0.19–0.27)	0.17 (0.14–0.21)
Senior EPs	***n* = 312**	***n* = 105**	***n* = 88**	***n* = 283**	***n* = 312**
Se	32.2 (20.3–44.1)	73.7 (53.9–93.5)	100.0 (40.0–100.0)	85.0 (73.9–96.1)	89.8 (82.1–97.5)
Sp	66.0 (60.2–71.8)	96.5 (92.6–100.0)	91.6 (85.6–97.5)	95.1 (92.3–97.8)	91.3 (87.8–94.8)
PPV	18.1 (10.7–25.5)	82.4 (64.2–100.0)	41.7 (13.8–69.6)	73.9 (61.2–86.6)	70.7 (60.4–81.0)
NPV	80.7 (75.3–86.1)	94.3 (89.5–99.1)	100.0 (96.0–100.0)	97.5 (95.5–99.5)	97.5 (95.5–99.5)
PLR	0.95 (0.87–1.03)	21.12 (10.84–41.17)	11.86 (9.18–15.32)	17.21 (14.61–20.28)	10.33 (9.49–11.25)
NLR	1.03 (1.01–1.05)	0.27 (0.20–0.36)	0.10 (0.00–3.51)	0.16 (0.12–0.21)	0.11 (0.08–0.15)

Note: Data are reported as % (95% CI). Respective LR (95% CI) of the STANDING algorithm used by interns and senior EPs for the three possible STANDING outcomes: LR 4.63 (4.35–4.93) and 10.33 (9.49–11.25) for a worrisome result, LR 0.09 (0.01–0.67) and 0.01 (0.00–0.66) for a benign result, and LR 0.21 (0.17–0.27) and 0.35 (0.26–0.48) for an inconclusive result. *p*-values: sensitivity $p = 0.18$, specificity $p = 0.012$, VPP $p = 0.023$, VPN $p = 0.06$, PLR $p = 0.023$, NLR $p = 0.07$.

Abbreviations: HIT, Head Impulse test; NLR, negative likelihood ratio; NPV, negative predictive value; PLR, positive likelihood ratio; PPV, positive predictive value; Se, sensitivity; Sp, specificity.

strokes cannot be neglected in this subgroup (5.6%). If considering inconclusive outcomes as potentially serious diseases, the implementation of the algorithm could reach a "number needed to image" (i.e., the number of imaging examinations needed to have one positive imaging test) around two or three, comparable to that obtained by Vanni et al.[18] with neuroimaging examinations. When neuroimaging is increasingly used in crowded EDs, the adoption of the STANDING algorithm may help to reduce both the number of ineffective resource utilization and the ED length of stay.[41] Several history-based scores have already been proposed to stratify the risk of stroke by avoiding a vestibuloocular examination,[42,43] but recent works have proven that doing so in ED patients would lower the quality of care, by increasing the number of requests for neuroimaging without lowering the number of missed strokes to an acceptable rate.[13,19] The value of LRs of the algorithm (i.e., 10.33, 0.35, and 0.001 for worrisome, inconclusive, and benign outcomes, respectively) suggested that EPs should shift their paradigm in patients with no objective anomaly through the four-step algorithm, by relying timing and triggers of symptoms.[2,7] Experience gained from the routine practice of BPPV testing would likely reduce the number of inconclusive outcomes as they were more frequent among interns than among senior EPs. Indeed, as with other chief complaints in emergency medicine, appropriate identification of vestibular symptoms causes call for EPs of all experience levels to adopt evidence-based diagnostic tools in their practice.[7,24] The training implemented in this study requires reasonable time and effort that should be feasible in many EDs. While the management of vertigo has been described as a complex task,[21] novices' opinions but also rates of successful BPPV positional maneuvers (48.6%) were highly encouraging for effective implementation of future guidelines.[7,44]

LIMITATIONS

Our study has several limitations. First, our data lacked results for the DWI-MRI reference standard in 32 patients with a definitive diagnosis of BPPV refined by otologic examination. A recent review found that central positional vertigo may account for up to 12% of positional nystagmus, but this rate was estimated from small retrospective case series and included all types of central causes.[45] We tried to limit this risk by ensuring that all patients were examined by expert otologists. However, applying this probability to the 32 involved patients with at least one cerebrovascular risk factor ($n = 12$), we may have missed one to two strokes in the study population. Second, Kattah et al.[11] and Newman-Toker et al.[13] demonstrated that early MRI-DWI could be falsely negative during the 48 h after symptom onset in high-risk patients (12%–14%). Therefore, optimal assessment of definitive diagnoses should have required repeating MRI in 22 patients with AVS who

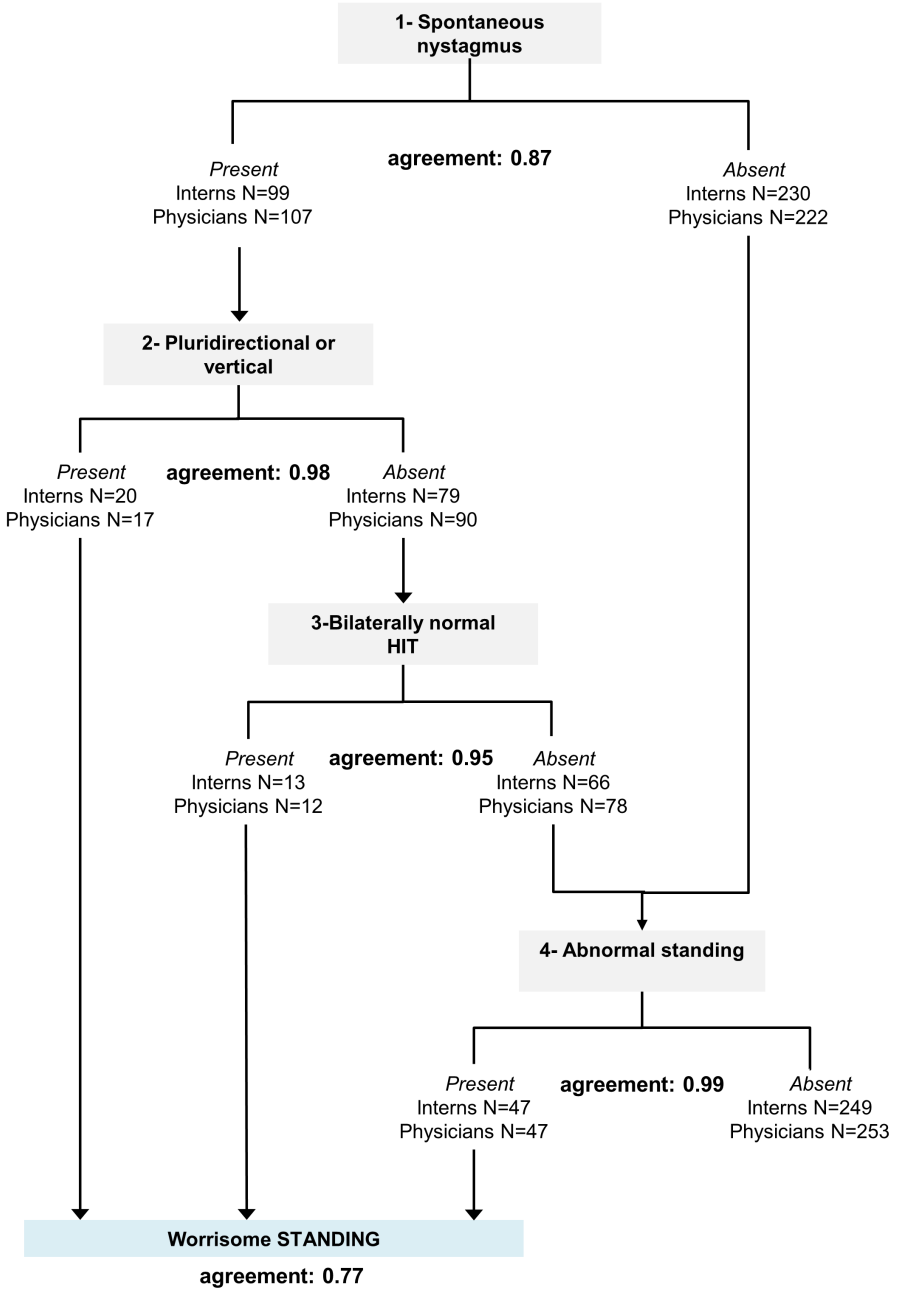

FIGURE 2 Agreement of the STANDING algorithm between emergency interns and senior EPs. The agreement has been calculated for each step by using the B-statistic coefficient proposed by Shankar and Bangdiwala.[36]

received it within 48 h of symptom onset with a normal result, regardless of whether the algorithm was worrisome ($n = 1$), inconclusive ($n = 9$), or benign ($n = 12$).[11,13] Third, it is a single-center study. A multicenter prospective study could have provided a better external validity, but few French hospitals guarantee MRI and otologist appointments in standard of care, to design a validation study without lack of definitive diagnoses. In this large ED cohort, we found that the incidence of stroke (10.5%) was similar to that in another study using imaging as the reference standard (10.9%),[46] but the rate of hemorrhage (3.2%) was slightly higher than in previous ED studies (1%–2%).[17–19] By querying the clinical database of these patients, we found predominant features such as high mean systolic blood pressure at 165 mm Hg and high proportions of headache and ataxia (both 70%), whereas head trauma, bidirectional or vertical nystagmus, and unidirectional nystagmus with normal HIT were less frequent (20%, 30%, and 10%, respectively). Then, we were unable to provide learning curves of the vestibuloocular assessment because of the variable number of examinations performed by the 20 interns who participated in the study (from 1 to 26, with a mean of 14). Thus, it might have been useful to conduct a medicoeconomic analysis to evaluate the impact of the STANDING algorithm before implementation. Because a large number of EPs had already been trained as part of a previous research work and were applying a four-step vestibuloocular approach in routine practice,[19] we were unable to conduct an unbiased randomized trial.

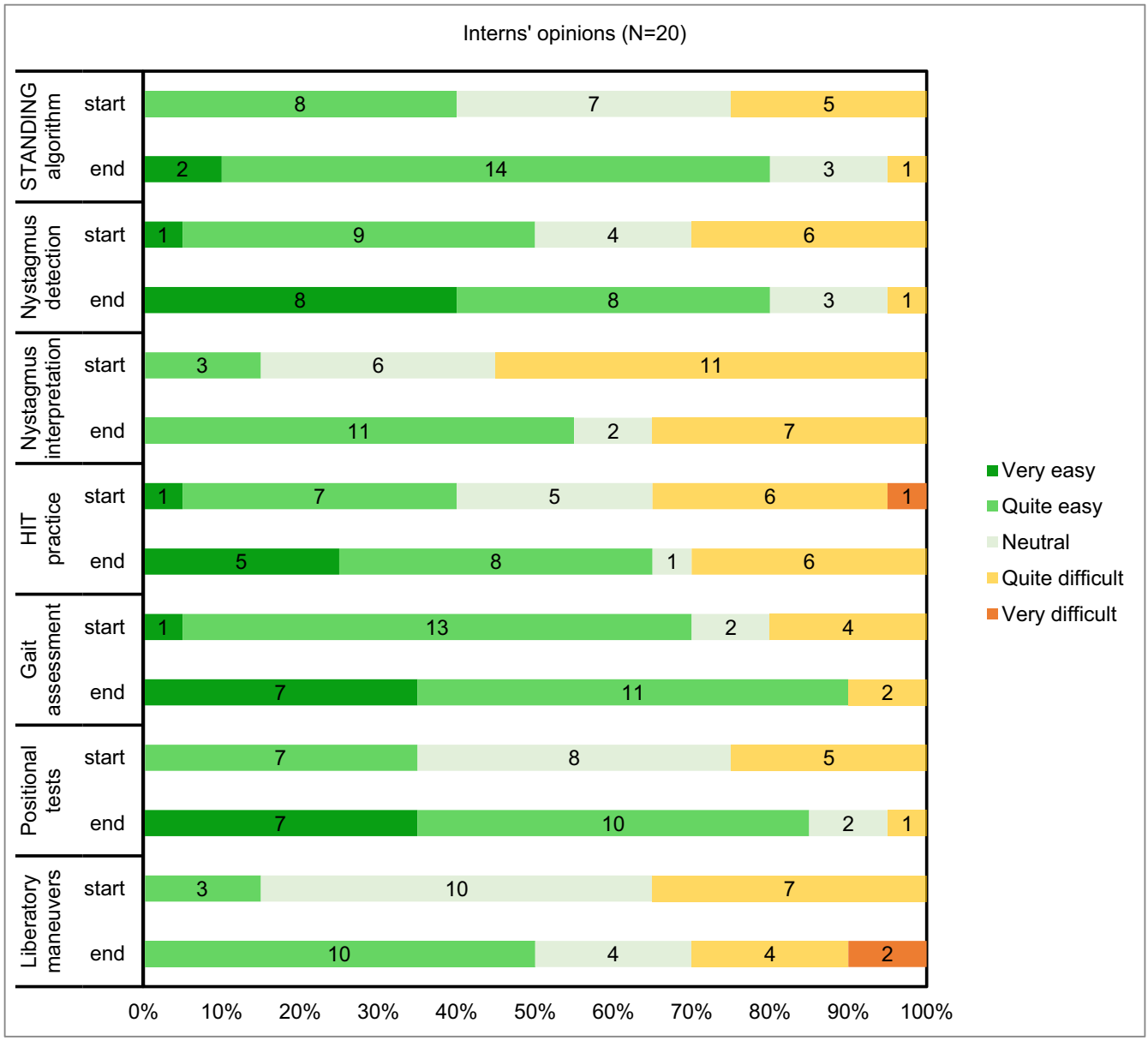

FIGURE 3 Interns' opinions about the performance of the STANDING algorithm at the beginning and at the end of their internship. HIT, head impulse test.

CONCLUSIONS

In summary, after a suitable learning, the fur-step bedside STANDING algorithm showed high effectiveness and reliability for predicting central causes of vestibular symptoms, in the hands of both emergency interns and senior emergency physicians. This study should further the adoption of vestibuloocular learning by emergency physicians of all experience levels and raises future multicenter randomized trial needs to estimate its impact on both unnecessary emergency neuroimaging and patients' satisfaction.

AUTHOR CONTRIBUTIONS

Camille Gerlier, Audrey Fels, and Gilles Chatellier had full access to all data in the study and take responsibility for the integrity of data and accuracy of data analysis. Study concept and design—Camille Gerlier, Audrey Fels, Olivier Ganansia, and Gilles Chatellier. Acquisition of data—Camille Gerlier. Analysis and interpretation of data—Camille Gerlier, Audrey Fels, Gilles Chatellier. Statistical expertise—Audrey Fels and Gilles Chatellier. Draft manuscript—Camille Gerlier, Audrey Fels, and Gilles Chatellier. Proofreading of the manuscript—Camille Gerlier, Audrey Fels, Hélène Vitaux, Carole Mousset, Alberto Perugini, Olivier Ganansia, and Gilles Chatellier.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

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ENDNOTE

Abbreviations: BPPV, benign paroxysmal positional vertigo; TIA, transient ischemic attack

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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What We're Seeking:

- MD, DO, or foreign equivalent
- BC/BE by ABEM or ABOEM
- Leadership experience
- Outstanding patient care qualities
- Ability to work collaboratively within a diverse academic and clinical environment

FOR MORE INFORMATION PLEASE CONTACT:

Heather Peffley, PHR CPRP
Physician Recruiter
Penn State Health

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Website: careers.pennstatehealth.org

What the Area Offers:

Located in a safe family-friendly setting, Hershey, PA, our local neighborhoods boast a reasonable cost of living whether you prefer a more suburban setting or thriving city rich in theater, arts, and culture. Known as the home of the Hershey chocolate bar, Hershey's community is rich in history and offers an abundant range of outdoor activities, arts, and diverse experiences. We're conveniently located within a short distance to major cities such as Philadelphia, Pittsburgh, NYC, Baltimore, and Washington DC.