

Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Journal of the Neurological Sciences

journal homepage: www.elsevier.com/locate/jns

Prevalence of stroke in acute vertigo presentations: A UK tertiary stroke centre perspective

Mohammad Mahmud^{*,1}, Abdel Rahman Saad¹, Zaeem Hadi, Jordan Elliot, Mabel Prendergast, Joseph Kwan, Barry Seemungal^{*}

Department of Brain Sciences, Charing Cross Hospital, Imperial College London, Fulham Palace Road, London W6 8RF, UK

ARTICLE INFO

Keywords:

Stroke
Dizziness
Vertigo
Imbalance
Nystagmus
Vestibular neuritis
Magnetic resonance imaging (MRI)

ABSTRACT

The reported prevalence of stroke amongst patients presenting to hospital with acute vertigo and/or imbalance is c. 5%, leading to the pervasive notion amongst emergency and stroke physicians, that stroke is uncommon in this cohort.

To interrogate the veracity of this notion, we systematically and retrospectively screened the electronic care records in our institution of patients referred as suspected stroke, to a hyperacute stroke service at a large tertiary referral centre.

We screened 24,310 consecutive patients' electronic case records presenting to our hospital as an emergency over a 4-month period, 332 of whom were referred as suspected stroke whose case records were assessed via structured review. Of these 332 cases, 61 presented with a vestibular syndrome, i.e. having at least one of imbalance, dizziness or vertigo. Of the 61 vestibular cases, 38 (62%) were diagnosed as stroke confirmed by imaging in 25/38 or upon clinical grounds only (13/38). None of the 38 vestibular stroke cases received thrombolysis or thrombectomy treatment.

In a UK urban population (2.5mn), acute vestibular syndrome cases referred to stroke services have a 50% stroke prevalence. None of the vestibular stroke cases received hyperacute stroke treatment e.g., thrombolysis, due to delay in diagnosis. The high stroke prevalence in our cohort may indicate an excessively high threshold for referring acute vestibular cases for stroke, implying a high number of missed stroke cases. We suggest that early access to vestibular neurologists in acute vestibular cases should improve the proportion of vestibular stroke cases receiving definitive stroke treatment.

1. Introduction

Patients with acute vertigo and imbalance are a diagnostic challenge to physicians. Causes of acute vertigo and imbalance range from benign inner ear diagnoses such as a vestibular neuritis to life threatening conditions such as a posterior circulation stroke. Given that the management options differ according to diagnosis, from home management of vestibular neuritis to emergency in-patient care of acute stroke patients, including thrombolysis or thrombectomy, it follows that rapid and accurate triage is important to discriminate between non-stroke and stroke diagnoses. Making a precise diagnosis also enables the efficient management of resources, e.g. cases with a clinical diagnosis of vestibular neuritis do not need MR imaging and often can be managed at home.

Despite modern imaging techniques and our improved understanding of posterior circulation strokes and its diagnosis, patients with acute vertigo and/or imbalance, have a high chance of misdiagnosis. [1] CT brain scanning displays low sensitivity in diagnosing posterior circulation strokes [2,3] and hyper-acute MRI brain, still has false-negative rates of 12%–19% in detecting stroke with acute vestibular syndrome (AVS) in the first 48 h [4–6]. Kattah and colleagues showed that a 3-step bedside oculomotor examination (HINTS: Head-Impulse—Nystagmus—Test-of-Skew) performed by vestibular experts, was more sensitive at detecting stroke than a brain MRI performed within 24 h of AVS onset [6]. Krishnan et al., in their review, demonstrated a pooled sensitivity and specificity of 95.5% and 71.2% respectively for HINTS in diagnosing stroke [7]. Thus, the evidence shows that the current gold standard in diagnosing hyperacute stroke in patients with

* Corresponding authors at: Centre of Vestibular Neurology, Imperial College London, W6 8RF, UK.

E-mail addresses: msm05@ic.ac.uk (M. Mahmud), bmseem@ic.ac.uk (B. Seemungal).

¹ Joint first authors.

<https://doi.org/10.1016/j.jns.2022.120416>

Received 6 May 2022; Received in revised form 3 September 2022; Accepted 5 September 2022

Available online 13 September 2022

0022-510X/© 2022 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

an acute vestibular syndrome is clinical assessment by a vestibular expert.

Whilst the superior performance of expert clinical assessment in diagnosing stroke in acute vestibular presentations supports earlier assessment by such experts, the relative rarity of stroke in this cohort, viz. 3–5% [8], weakens the case for early referral of these cases to vestibular experts. The hyperacute stroke referral pathway in the UK involves cases referred directly to hyperacute stroke services by ambulance services arriving as stroke calls or via patients self-presenting to the emergency department physicians who then refer cases on to the stroke team if stroke is suspected. This UK-specific pathway could lead to a different risk profile and hence prevalence of stroke in patients presenting with acute vertigo and/or imbalance compared to previous reports. Indeed, we previously reported a stroke prevalence of 5% [9] in our institution 15 years earlier, however, the hyperacute stroke services underwent a radical reorganization in London in 2010 (i.e. subsequent to this report) with stroke services centralized to just 8 hyperacute stroke units for a population of 8.2million. Hence in this study, we aimed to update the relative prevalence of stroke in patients with an acute vestibular syndrome being referred to the hyperacute stroke services in London.

2. Methods

2.1. Setting and design

This retrospective study was conducted in the emergency department (ED) of a large tertiary hyperacute stroke centre (HASU) in London. In this study we screened all patients presenting to ED from August 2021 to November 2021 ($n = 24,310$). Inclusion criteria: above 18 years old; referred to stroke team for evaluation, all patients who had acute dizziness, vertigo, or imbalance in their presenting symptoms. Exclusion criteria: Not seen or accepted by stroke team.

2.2. Data acquisition

Data was extracted from the documentations found on the electronic record system. Patients were identified in a prospective fashion from the ED patient's list and information extracted from notes on initial assessment and in some cases from progress notes in case of ambiguity of history and examination from initial assessment to 6months later. Data acquisition was done by two trained reviewers (MM, ARS) and parameters were recorded according to the accepted definitions in the literature. These included features of the presenting illness, associated symptoms, physical exam findings, and investigations done. We also included demographic data, their length of stay, final diagnosis and whether they were referred or seen by a neurologist with vestibular expertise."

2.3. Outcome of interest

The aim of this study is to evaluate the prevalence of stroke in patients referred to a tertiary stroke service. In addition, we explore the different phenotypes of those patients including isolated vestibular syndrome (defined as no other neurological symptom or sign), the sensitivity and specificity of non-expert assessments, diagnoses and outcomes of patients who are assessed by stroke team presenting with acute vertigo and/or imbalance. We looked at the clinical assessment (including HINTS), NIHSS scores, imaging, investigations, diagnosis, and management (including thrombolysis or thrombectomy).

2.4. Ethical approval

The Health Research Authority (HRA) and Health and Care Research Wales (HCRW) approved this research.

2.5. Statistical analysis

Data was input on Microsoft Excel and statistical analysis was performed via Excel and R (<https://www.r-project.org>). Correlations between the NIHSS score and a diagnosis of stroke were calculated using the Fisher exact probability test with a two tailed p value <0.05 considered as a statistically significant result. R was used to generate graphs. Sensitivity and specificity analysis of stroke diagnosis was performed for the HINTS examination.

3. Results

We screened 24,310 patients presenting to the emergency department Between August 2021 and November 2021. Of these, 23,978 patients were not referred or seen by stroke and were excluded. Of the 332 cases referred to and seen by stroke services, with a suspicion of a cerebrovascular accident, 61 presented with acute onset dizziness, vertigo, or imbalance (Fig. 1).

The mean age of our cohort was 62 (SD ± 15) years and 34 were female (Table 1). 22 of the 61 cases were discharged after stroke assessment from ED and the remaining were admitted to the stroke unit. The mean baseline Modified Rankin Score (mRS) score for the 61 cases was 0.7 (<1). 10 cases out of the 61 were direct ambulance transfer to stroke and 7 of those had a stroke. The average NIHSS score on presentation was 1.9 (SD ± 3) for all the vestibular presentations and 2.4 for those found to have stroke (Fig. 2).

Based upon the records, 22 of the vestibular presentations could be classified as an acute vestibular syndrome presentation or 'AVS' [10] while the remainder who fall under the three other vestibular syndromes – Episodic triggered, Episodic spontaneous and Continuous triggered. 43% (26/61) of patients presented with isolated vestibular symptoms of which 10 (38%) had a stroke. Imbalance was the commonest vestibular symptom amongst our cohort affecting 44/61 (71%) of the patients referred to the stroke team. Of those 44 patients, 12/44 (27%) had isolated imbalance with no other accompanying vestibular symptoms, with 11/12 (91%) having a confirmed stroke. Our data show that the symptom of isolated imbalance is a strong predictor of a stroke with a specificity up to 96%, 95% CI (78.05–99.89) and a positive predictive likelihood ratio of 6.6. Headache was present in 29 of the 61 cohort (40%) and did not help to differentiate between stroke and non-stroke diagnoses. Only 43 cases had an eye movement assessment recorded of which 16 had nystagmus recorded and of whom 5/16 were noted as 'bi-directional'. The HINTS examination was only fully recorded in 10 of the 22 cases who presented with AVS. The HINTS assessment was also used in 8 cases with an episodic vestibular syndrome. When calculating the sensitivity and specificity, we used only those cases that had a

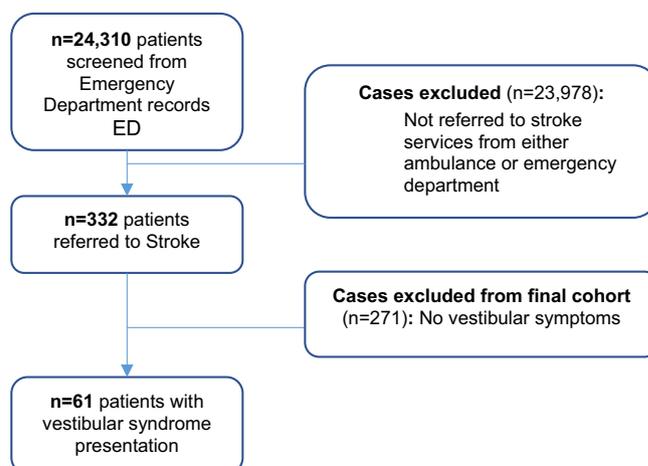


Fig. 1. Flow diagram of case screening and inclusion.

This supports (and extends) the long-held clinical red flag for stroke in acute vertigo cases of a patient who is unable to walk. Although we found the presence of other focal neurology such as, unilateral weakness or sensory loss, visual defects, hearing loss or facial weakness predicts stroke (as previously documented [11]), isolated imbalance better predicts stroke than non-vestibular focal neurological features with a positive predictive value of 91% vs. 79%. The literature described posterior circulation strokes mostly in the context of the Acute Vestibular Syndrome, labeled as presentations of acute severe dizziness, vertigo, or imbalance, with examination findings of nystagmus and/or gait unsteadiness. [10,12] Only 22 out of our 61 cases presented with an acute vestibular symptom [10], and 15/22 (68%) of them had stroke. A large number of stroke presentations, 23/38 (60%), did not meet the criteria for AVS and were either episodic or transient vestibular syndromes. In their paper in 2020, Tong et al. found that 60% of stroke patients presenting with vestibular symptoms had in fact presented with transient, episodic and recurrent vestibular presentations, i.e., Episodic Vestibular Syndrome [13,14]. 23 of the 39 cases presenting with episodic symptoms in our cohort were diagnosed as stroke, which reflects these previously reported findings [13]. In addition, subjective symptoms alone are unreliable in making a precise diagnosis in acute vestibular syndromes indicating the key role for clinical examination in diagnosis [15].

7 out of the 25 imaging confirmed strokes had strokes outside of the normal PCA territory that one would expect. Furthermore, this distinction also applies to isolated vestibular syndromes, and this showed a strong right sided preponderance (67%). The link between cortical strokes and vestibular symptoms should be interpreted cautiously and requires additional prospective and mechanistic studies, since our data were obtained retrospectively. Importantly, other common causes of vestibular symptoms, such as an acute migraine causing vestibular symptoms could conceivably be linked indirectly to stroke, triggered by the stressors of an acute admission (including sleep deprivation), or directly, since cortical spreading depression has been linked to cortical ischaemia [16]. Indeed, there have been case series documenting migraine presentations triggered by acute stroke [17]. In a recent study, the claimed link between cortical strokes and “spinning vertigo”, however this link was interrogated by asking patients ‘did you see the world spin round like a merry-go-round’, which is a question about oscillopsia, which in turn is linked to a nystagmus, which is not typically seen in acute cortical stroke (although this can be seen in subcortical presentations) [18]. In a previous acute prospective acute stroke study recruiting hemispheric stroke, we did not find any cases out of c. 100 patients screened for recruitment [19]. Certainly, in a large prospective study of acute stroke (351 cases), acute spinning vertigo was not seen in any cortical cases, although mild ‘dizziness’ was reported, although migraine or headache of any description was not documented (an important confound). The take home message is that overt vertigo (either a sensation of self-motion or feeling the room move, both with eyes closed) or oscillopsia (seeing the room spin with eyes open, which equates to a nystagmus) indicates a posterior circulation stroke or at least subcortical involvement. Cortical strokes causing vertigo are poorly documented and it is unclear if migraine could account for the rare case reports.

The HINTS exam has higher sensitivity in diagnosing posterior circulation stroke in patients presenting with AVS than hyperacute MRI (100 vs. 72%) [6,7]. However, examination has previously been shown to be both under-utilized and inadequate when performed by non-experts. [8] Our data show that, although the HINTS battery was used as a diagnostic aid in patients with vestibular symptoms, its use was inconsistent, sometimes inappropriately applied or incorrectly interpreted. A full HINTS examination was performed in only 31% of the acute vestibular presentations. Our data show the diagnostic accuracy of stroke by HINTS exam by the referring emergency and stroke doctors had a sensitivity and specificity of 100% and 8% respectively. Notably the high a priori likelihood of stroke in the cohort referred to the stroke

team means that a HINTS high sensitivity is to be expected. On the other hand, the concern is that many stroke cases are being missed and not referred due to a lack of access to vestibular experts. Indeed, the low specificity supports the notion that clinicians assessing these cases had relatively low competency in vestibular assessment.

Over 60% of cases in our cohort received an MRI scan with the majority of scans performed within 48 h of presentation. Of the 10 cases diagnosed with DWI negative stroke only one had a repeat MRI. Oppenheim et al. found that the false-negative DWI rate for acute posterior circulation stroke was much higher than that of the anterior circulation (19% vs. 2%). Moreover, up to a third of patients in their study who presented with vertebro-basilar ischemic symptoms had positive DWI MRI on follow-up after an initial false-negative DWI study during the first 24 h. [4] The patients in our study who had only one DWI negative MRI performed within 24 h and were diagnosed as “non-stroke” may have had a false-negative results and received the wrong diagnosis and management.

The NIH severity scale (NIHSS) score underestimates clinical severity in posterior circulation strokes. [20] Patients with clinical presentations of posterior circulation stroke have lower NIHSS scores compared to those of anterior circulation. Subsequently, patients with posterior circulation stroke are less likely to be offered reperfusion therapy. [21] Marchis et al. reported a median NIHSS scores of 4 and 8 for posterior circulation and anterior circulation strokes respectively with a $p = 0.004$. NIHSS scores were consistently lower in non-stroke cases compared to stroke ($p = 0.02$) (Fig. 2). A median NIHSS score of one, and average of 2, in imaging confirmed stroke patients in our cohort suggests that further work is needed to develop scoring systems appropriately weighted for posterior circulation strokes. Perhaps the addition of gait and truncal ataxia would improve the prognostic accuracy and hence the therapeutic value of NIHSS scores in patients with posterior circulation strokes with mild to moderate symptoms [22].

There are several limitations to this study. Data extracted from the electronic medical record, depends on the completeness and accuracy of written record. Our study only included patients who were referred and seen by a stroke physician. Thus, patients where a stroke opinion was given over the phone were not captured and so the overall prevalence of stroke in vestibular presentations could likely be altered by this. One concern is that cases with stroke may not be reviewed by the stroke service. When reviewed, the low specificity of diagnostic accuracy may reflect the need for an early vestibular expert review. However, in our cohort 10 of the 61 cases were direct ambulance transfers for stroke assessments and 7 of the 9 had stroke diagnosed and so it still seems that the prevalence of cases remains high outside of stroke phone referrals our study does not capture (Table 1).

Another possibility is that we overestimate stroke prevalence in this cohort due to the inclusion of clinically diagnosed TIAs. However, one could argue that we could have overestimated non-strokes too, since around 10% of our cohort had no specific diagnosis on discharge and were not included as a stroke diagnosis. In such a scenario, if TIA clinical diagnoses are not included, imaging confirmed stroke diagnoses still make up 41% of our total cohort. This remains >10-fold the number compared to those presenting to ED [11] and suggests that our recommendations for a very high suspicion are valid and should remain.

5. Conclusion

Acute vertigo and/or imbalance referred by ambulance or ED to a UK based hyperacute stroke unit from the community have a prevalence of stroke of 60% based on imaging and clinical assessment. This is >10 fold the prevalence previously reported in patients presenting with acute vertigo from the community [9,11]. The high prevalence of stroke in our cohort indicates that clinicians should have a low threshold for diagnosing stroke and perhaps suggests that early referral to a vestibular expert may provide the best diagnostic pickup rather than early MRI scan. More concerning is that the threshold for accepting a referral for

review by the stroke service may in fact be too high, leading to missed stroke cases. The low diagnostic specificity by the stroke clinicians supports the view for early review by of these cases by a vestibular neurologist. In departments without expert vestibular neurologists, repeat MRI, out of the 48 h window may need to be more common practice in all initially MRI negative patients without a clear diagnosis.

Given our findings, we recommend that stroke services who receive ED referrals of cases with vestibular symptoms should have a lower threshold in accepting stroke referrals, and referring all cases in whom there is not a clear stroke cause - even prior to MR brain imaging - since early expert clinical assessment remains the gold standard in diagnosis for patients with an acute vestibular presentation.

Appendix A. Appendix

Table 1
Demographic and characteristics of 61 cases of acute vestibular presentations to the HASU.

Total	61 (100%)	
Age (years), (mean ± SD)	62 ± 15	
Male	27(44)	
Discharged from ED	22(36)	
AVS	22(36)	
Type of Referral		
Emergency Department	51(83)	
Stroke		31(51)
Ambulance	10(17)	
Stroke		7(70)
Description of presenting symptom(s)		
Vertigo	28(46)	
Dizziness	34(56)	
Imbalance	44(72)	
Signs		
Nystagmus	16(26)	
Unsteady Gait	24(39)	
Unilateral weakness	9(15)	
Sensory impairment	10(16)	
Cranial nerve deficit	17(28)	
Visual Impairment	19(31)	
HINTS test		
Recorded	19(31)	
Partially recorded	27(44)	
Not recorded	15(25)	
Imaging performed		
MRI	38(62)	
DWI positive		17/38(44)
CT head	59(96)	
CT Angiography	39(63)	
Time from presentation to MRI in hours	53 h (44 if outlier 360 h is removed)	
Diagnosis		
Stroke	38(62)	
Posterior stroke		31/38(82)
Anterior stroke		7/38(18)
Non-stroke	15(25)	
BPPV		5
Vestibular Migraine		4
Vestibular Neuritis		2
Miscellaneous		4
No diagnosis	8(13)	
Past Medical History		
Hypertension	33(54)	
Diabetes Mellitus	17(28)	
Ischaemic Heart Disease	10(16)	
Atrial Fibrillation	7(11)	
Cerebrovascular accident	17(28)	
Vestibular history	7(11)	
Average Length of stay	98 h	

Table 2
Breakdown of findings in patients with distinct lesions on imaging. This includes the Location, laterality, presence of non-vestibular findings, vascular deformities, and type of stroke (ischemic vs hemorrhagic). R: Right, L: Left, B/L: Bilateral, NAD: Normal, ND: Not done.

Patient	Location	Laterality	Anterior vs posterior circulation	Isolated vestibular presentation	Vascular malformation	Type of stroke
1	Insula	L	Anterior	Y	Proximal M3 occlusion	Ischemic
2	Hemipons	R	Posterior	N	NAD	Ischemic
3	Medulla	B/L	Posterior	N	Vertebral occlusion	Ischemic
4	Occipital	L	Posterior	N	Subocclusive stenosis of L PCA	Ischemic

(continued on next page)

Table 2 (continued)

Patient	Location	Laterality	Anterior vs posterior circulation	Isolated vestibular presentation	Vascular malformation	Type of stroke
5	Hemipons	L	Posterior	N	Multifocal stenosis in intracranial arteries (V4, P2, M1)	Ischemic
6	Intraventricular	R		Y	NAD	Haemorrhagic
7	Basal ganglia	B/L	Anterior	N	NAD	Ischemic
8	Pons	L	Posterior	N	NAD	Haemorrhagic
9	Thalamus	R	Posterior	N	Vertebral dissection	Ischemic
10	Cerebellum	R	Posterior	Y	Nonstenotic bilateral carotid atherosclerosis	Haemorrhagic
11	Medulla	R	Posterior	N	Calcification at origin of right vertebral artery and stenosis of post PICA right vertebral artery	Ischemic
12	Corona radiata	L	Anterior	N	Tortuous basilar artery	Ischemic
13	Cerebellum	B/L	Posterior	Y	Left V2 free floating thrombus	Ischemic
14	Temporal	R		N	NAD	Ischemic
15	Frontal	R	Anterior	Y	Distal cavernous left ICA stenotic plaque	Ischemic
16	Pons	R	Posterior	N	Bilateral Carotid bifurcation atheromas	Ischemic
17	Medulla	L	Posterior	N	Left PICA dissection	Ischemic
18	Cerebellum and Thalamus	B/L	Posterior	N	Bilateral Vertebral dissection	Ischemic
19	Cerebellum	L	Posterior	N	NAD	Haemorrhagic
20	Temporoparieto-occipital	R	Posterior	Y	NAD	Haemorrhagic
21	Amygdala	L	Anterior	N	ND	Haemorrhagic
22	Precentral gyrus	R	Anterior	Y	NAD	Ischemic
23	Multiple MCA territory	L	Anterior	N	Significant stenosis bilateral ICA bifurcation with left floating component	Ischemic
24	Thalamus	R	Posterior	Y	NAD	Ischemic
25	Occipital	L	Posterior	Y	NAD	Ischemic

Table 3

Breakdown of the findings, clinical and radiological, in patients diagnosed with TIA. HIT: Head impulse test, N: None, NAD: No abnormality detected, –ve: Negative. Vascular RFs include: CVA, IHD, HTN, Dyslipidaemia, Obesity, Smoking and AF.

Patient	Central findings	Neurological findings	Imaging	RFs	AF	Other explanations excluded
1	HIT -ve	N	NAD (mild calcification of bilateral ICA)	3	N	
2	HIT -ve / Rt GEN	L weakness /numbness /ataxia	NAD	1	N	
3	HIT -ve	Slurred speech	ND	1	N	
4	HIT -ve	Slurred speech	Bilateral Vertebral artery fibromuscular dysplasia	0	N	
5	HIT -ve / Rt GEN	N	ND	3	N	-ve Halpike
6	HIT -ve	R numbness	Basilar tip stenosis, right P2 segment of PCA stenosis	4	N	
7	HIT -ve	Slurred speech	NAD	3	Y	
8	HIT -ve / Bidirectional nystagmus / Skew deviation	Diplopia	ND	4	N	
9	HIT -ve	LUL Ataxia	NAD	1	N	
10	HIT -ve	Slurred speech	NAD	2	N	-ve Halpike
11	HIT -ve	RUL ataxia	NAD	1	Y	
12	HIT -ve	Right facial weakness/ increased tone right side	NAD	1	N	
13	HIT -ve	N	NAD	1	N	-ve Halpike

References

[1] A.E. Arch, D.C. Weisman, S. Coca, K.V. Nystrom, C.R. Wira, J.L. Schindler, Missed ischemic stroke diagnosis in the emergency department by emergency medicine and neurology services, *Stroke*. 47 (3) (2016 Mar) 668–673.

[2] J.A. Edlow, D.E. Newman-Toker, S.I. Savitz, Diagnosis and initial management of cerebellar infarction, *Lancet Neurol*. 7 (10) (2008 Oct) 951–964.

[3] J.A. Chalela, C.S. Kidwell, L.M. Nentwich, M. Luby, J.A. Butman, A.M. Demchuk, et al., Magnetic resonance imaging and computed tomography in emergency assessment of patients with suspected acute stroke: a prospective comparison, *Lancet (Lond. Engl.)* 369 (9558) (2007 Jan) 293–298.

[4] C. Oppenheim, R. Stanescu, D. Dormont, S. Crozier, B. Marro, Y. Samson, et al., False-negative diffusion-weighted MR findings in acute ischemic stroke, *AJNR Am. J. Neuroradiol*. 21 (8) (2000) 1434.

[5] J.J. Marx, F. Thoenke, A. Mika-Gruettner, S. Fitzek, G. Vucurevic, P.P. Urban, et al., Diffusion-weighted MRT in vertebrobasilar ischemia. Application, sensitivity, and prognostic value, *Nervenarzt*. 75 (4) (2004 Apr) 341–346.

[6] J.C. Kattah, A.V. Talkad, D.Z. Wang, Y.H. Hsieh, D.E. Newman-Toker, HINTS to diagnose stroke in the acute vestibular syndrome: three-step bedside oculomotor examination more sensitive than early MRI diffusion-weighted imaging, *Stroke*. 40 (11) (2009 Nov) 3504–3510.

[7] K. Krishnan, K. Bassilious, E. Eriksen, P.M. Bath, N. Sprigg, S.K. Brækken, et al., Posterior circulation stroke diagnosis using HINTS in patients presenting with acute vestibular syndrome: a systematic review, *Eur. Stroke J*. 4 (3) (2019 Sep) 233–239.

[8] R. Ohle, R.A. Montpellier, V. Marchadier, A. Wharton, S. McIsaac, M. Anderson, et al., Can emergency physicians accurately rule out a central cause of vertigo using the HINTS examination? A systematic review and meta-analysis, *Acad. Emerg. Med*. 27 (9) (2020 Sep) 887–896.

[9] N.J. Cutfield, B.M. Seemungal, H. Millington, A.M. Bronstein, Diagnosis of acute vertigo in the emergency department, *Emerg. Med. J*. 28 (6) (2011 Jun) 538–539.

[10] K.K. Steenerson, Acute vestibular syndrome, *Continuum (Minneapolis)*. 27 (2) (2021 Apr) 402–419.

[11] K.A. Kerber, D.L. Brown, L.D. Lisabeth, M.A. Smith, L.B. Morgenstern, Stroke among patients with dizziness, vertigo, and imbalance in the emergency department: a population-based study, *Stroke*. 37 (10) (2006 Oct) 2484–2487.

[12] K.A. Kerber, Acute vestibular syndrome, *Semin. Neurol*. 40 (1) (2020 Feb) 059–066.

- [13] D.M. Tong, X.D. Chen, Y.W. Wang, Y. Wang, L. Du, J.J. Bao, Acute and episodic vestibular syndromes caused by ischemic stroke: predilection sites and risk factors, *J. Int. Med. Res.* 48 (4) (2020 Apr) 1–12.
- [14] J.A. Edlow, K.L. Gurley, D.E. Newman-Toker, A new diagnostic approach to the adult patient with acute dizziness, *J. Emerg. Med.* 54 (4) (2018 Apr) 469.
- [15] D.E. Newman-Toker, L.M. Cannon, M.E. Stofferahn, R.E. Rothman, Y.H. Hsieh, D. S. Zee, Imprecision in patient reports of dizziness symptom quality: a cross-sectional study conducted in an acute care setting, *Mayo Clin. Proc.* 82 (11) (2007 Nov) 1329–1340.
- [16] E. Aufferberg, U.B.S. Hedrich, R. Barbieri, D. Miely, B. Groschup, T.V. Wuttke, et al., Hyperexcitable interneurons trigger cortical spreading depression in an Scn1a migraine model, *J. Clin. Invest.* [Internet] (2021 Nov 1), <https://doi.org/10.1172/JCI142202> [cited 2022 Sep 3];131(21). Available from.
- [17] M.J. Waters, E. Cheong, J. Jannes, T. Kleinig, Ischaemic stroke may symptomatically manifest as migraine aura, *J. Clin. Neurosci.* 55 (2018 Sep 1) 62–64.
- [18] Y. Man Chan, Y. Wong, N. Khalid, S. Wastling, A. Flores-Martin, L.A. Frank, et al., Prevalence of acute dizziness and vertigo in cortical stroke, *Eur. J. Neurol.* 28 (9) (2021 Sep) 3177–3181.
- [19] D. Kaski, S. Quadir, Y. Nigmatullina, P.A. Malhotra, A.M. Bronstein, B. M. Seemungal, Temporoparietal encoding of space and time during vestibular-guided orientation, *Brain* [Internet] 139 (2) (2016 Feb 1) 392–403, <https://doi.org/10.1093/brain/awv370>.
- [20] I. Linfante, R.H. Llinas, G. Schlaug, C. Chaves, S. Warach, L.R. Caplan, Diffusion-weighted imaging and National Institutes of Health stroke scale in the acute phase of posterior-circulation stroke, *Arch. Neurol.* 58 (4) (2001) 621–628.
- [21] Inoa Abraham Aron Ilene Staff Gilbert Fortunato Lauren, H. Sansing, VW, Hospital H., Lower NIH stroke scale scores are required to accurately predict a good prognosis in posterior circulation stroke, *Cerebrovasc. Dis.* 37 (2014) 251–255.
- [22] F. Alemseged, A. Rocco, F. Arba, J.P. Schwabova, T. Wu, L. Cavicchia, et al., Posterior National Institutes of Health stroke scale improves prognostic accuracy in posterior circulation stroke, *Stroke.* 53 (2021 Dec) 1247–1255.