DEFENSIVE Stroke Scale: Novel Diagnostic Tool for Predicting Posterior Circulation Infarction in the Emergency Department

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Background: Dizziness is the most common posterior circulation symptom; however, diagnosing a posterior circulation infarction is difficult due to a lack of typical symptoms. We aimed to investigate the frequency of misdiagnosis of a posterior circulation infarction in patients who presented with dizziness and to develop a new stroke scale that increased the diagnostic accuracy for stroke among these subjects. *Methods:* We retrospectively analyzed consecutive data from subjects hospitalized with ischemic stroke who presented with dizziness (the developmental phase). Based on these results, we created a novel stroke scale, which was used as a diagnostic procedure in the prospective validation phase. We compared the rate of misdiagnosis of ischemic stroke between phases. *Results:* During the development phase, 115 subjects were hospitalized for ischemic stroke accompanied by dizziness. Six ischemic stroke subjects were not properly diagnosed (6/115, 5.2%). We created the new DisEquilibrium, Floating sEnsation, Non-Specific dizziness, Imbalance, and VErtigo (DEFENSIVE) stroke scale to prevent underdiagnosis of a posterior circulation infarction. During the validation phase, 949 subjects with dizziness were examined with the DEFENSIVE stroke scale; among these subjects, 100 were hospitalized for ischemic stroke accompanied by dizziness. No subject with ischemic stroke was overlooked. The new DEFENSIVE stroke scale had a sensitivity of 100% and decreased the rate of improper diagnosis of stroke (5.2% versus 0%; $P = .022$). *Conclusions:* Our new stroke recognition instrument for a posterior circulation infarction presenting with dizziness and related symptoms (the DEFENSIVE stroke scale) is easy to administer and has good diagnostic accuracy.
Key Words: Stroke scales—posterior circulation—dizziness—diffusion-weighted imaging—lateral medullary infarction—emergency department

Introduction

Dizziness, disequilibrium, a floating sensation, imbalance, and vertigo are relatively common complaints in the emergency department. They are often combined and difficult to distinguish each other in clinics. Stroke is diagnosed in 3.2%-4.1% of all subjects with these symptoms,[1,2] and the most common posterior circulation symptom is dizziness.[3] A posterior circulation infarction due to

occlusion of the basilar or vertebral arteries may develop as rapid deterioration in neurological status, leading to coma and often death. This risk of stroke is particularly high during the acute phase of dizziness[4]; thus, obtaining an early correct diagnosis is crucial.

However, accurate diagnosis of a posterior circulation infarction is difficult because dizziness and related symptoms are usually caused by more common and benign disorders. Indeed, emergency department physicians

reportedly fail to diagnose stroke in subjects with dizziness, vertigo, or imbalance in approximately 35% of cases.[1] Similarly, nausea and vomiting are associated with a longer delay between examination in the emergency department and neurological evaluation and are substantially associated with delayed treatment.[5] In addition, the NIH stroke scale (NIHSS) is of limited value regarding evaluation of neurological symptoms or severity of a posterior circulation stroke compared with an anterior circulation stroke[6] because the NIHSS cutoff, which most accurately predicts the outcome, is 4 points higher for an anterior circulation infarction than for a posterior circulation infarction.[7] In a neuroimaging study, 19% of subjects with a posterior circulation infarction also had a false-negative in the initial diffusion-weighted imaging (DWI) study.[8] Therefore, NIHSS and neuroimaging may be less useful for the diagnosis of posterior circulation stroke than for the diagnosis of anterior circulation stroke.

Few stroke scales specialize in posterior circulation strokes. Although the Cincinnati Pre-Hospital Stroke Scale (CPSS),[9] Los Angeles Pre-Hospital Stroke Screen (LAPSS)[10] and Recognition of Stroke in the Emergency Room Scale (ROSIER)[11] are widely used as prehospital and emergency department scale recognition screening instruments, they are less sensitive for detecting posterior circulation strokes than for detecting anterior circulation strokes. Furthermore, no systematic studies have investigated the misdiagnosis of posterior circulation infarctions. Thus we investigated the accuracy of the diagnosis of a posterior circulation infarction with dizziness and related symptoms in the emergency department. Based on the results, we developed and validated a stroke recognition tool named the DisEquilibrium, Floating sEnsation, Non-Specific dizziness, Imbalance, and VErtigo (DEFENSIVE) stroke scale[12] to increase the diagnostic accuracy for stroke in subjects presenting to the emergency department with acute dizziness and related symptoms.

Patients and Methods

Standard Protocol Approvals, Registration and Participant Consent

This study conformed to the Ethical Guidelines for Medical and Health Research Involving Human Subjects endorsed by the Japanese government. The Institutional Review Board of the Japanese Red Cross Nagoya Daini Hospital approved this study, and all participants were permitted to opt out of study participation.

Study Design

We enrolled the consecutive subjects who visited the emergency department with acute dizziness and related symptoms: disequilibrium, floating sensation, imbalance, and vertigo. We defined the related symptoms as follows: dizziness as a sensation of spinning around and losing one's balance; disequilibrium as a loss or lack of equilibrium or stability; floating sensation as a feeling of light headedness and floating; imbalance as a lack of balance; and vertigo as a sensation of tilting within stable surroundings, being in tilting, or spinning surroundings. This study was divided into retrospective and prospective cohort phases. First, during the development phase, clinical characteristics of ischemic stroke with dizziness and related symptoms were retrospectively collected between January 2009 and December 2010 to design the DEFENSIVE stroke scale. Second, during the prospective validation phase, we applied the DEFENSIVE stroke scale to consecutive subjects with dizziness and related symptoms in the emergency department between January 2011 and December 2012. Then, we validated the efficacy of the DEFENSIVE stroke scale in accordance with Standards for Reporting of Diagnostic Accuracy 2015.[13] In both periods, emergency department physicians undertook neurological screening, while neurologists performed systemic neurological examinations for subjects presenting with dizziness and related symptoms. Eye movement assessments include ocular position, external ocular movement, and nystagmus.

Data sources and study population

This study was performed in a single medical center serving as a regional stroke referral center.[14,15] Approximately 45,000 outpatients and more than 9000 ambulances come to this center every year. At a minimum, a neurologist, neurosurgeon, more than 5 emergency department physicians and 3 technologists are present in the hospital all day. Doctors are always available to order computed tomography, magnetic resonance imaging (MRI), magnetic resonance angiogram and cerebral angiography. MRI imaging includes axial T2, fluid-attenuated inversion recovery, T2* and axial and coronal DWI performed with a 1.5-T MRI unit (GE Signa CV/i Ver.9.1, Milwaukee, WI).[16] Brain magnetic resonance angiogram is performed simultaneously with the MRI. In both phases, we examined neuroimaging for the hospitalized subjects using the same protocol. We also examined second neuroimaging test results for the hospitalized subjects using the same protocol. The emergency department physicians determined the presence of DWI-positive lesion(s) on the first MRI, and 2 neurologists performed this task at the second MRI. We defined DWI-negative ischemic stroke as follows; though DWI was negative on the first MRI, second one was positive. The types of ischemic stroke were defined using Trial of ORG 10172 in Acute Stroke Treatment criteria.[17-19]

In the development phase, we retrospectively investigated consecutive subjects hospitalized with an ischemic stroke who presented with dizziness and related symptoms at the emergency department between January 1, 2009, and December 31, 2010, using our hospital database. We also assessed consecutive outpatients who were discharged from

the emergency department but were diagnosed with ischemic stroke afterwards. By analyzing the clinical features of the subjects whose acute ischemic strokes were not properly diagnosed at the emergency department, we created the DEFENSIVE stroke scale to discriminate patients with stroke accompanied by dizziness and related symptoms, particularly a posterior circulation infarction.

In the validation phase, all subjects presenting to the emergency department with acute dizziness and related symptoms were consecutively assessed using the DEFENSIVE stroke scale between January 1, 2011, and December 31, 2012. Evaluation of the DEFENSIVE stroke scale was conducted by trained emergency department staff. If one or more items of this scale were positive, the staff consulted a neurologist or otolaryngologist.

In both phases, visiting the outpatient neurology or otolaryngology department on the following business day was recommended even if no abnormality was observed in the systemic neurological examination.

Outcome measures

The outcome measures were as follows: (1) the proportion of subjects with a stroke who were not properly diagnosed in the emergency department; (2) the sensitivity, specificity, positive predictive value and negative predictive value of the ischemic stroke diagnosis; (3) the proportion of subjects with a DWI-negative infarction; and (4) the NIHSS scores.

Data analysis

Data were entered into a Microsoft Access database, and statistical analysis was performed using SPSS version 23. A P value less than .05 was considered significant. Differences in continuous variables were compared using unpaired t test and expressed as mean $\pm$ SD, whereas differences in categorical variables between groups were compared using the chi-square test and Fisher's exact test. The sensitivity, specificity, positive predictive value and negative predictive value were all determined.

Results

In the development study phase between January 1, 2009, and December 31, 2010, a total of 1185 subjects visited the emergency department with acute dizziness and related symptoms (Fig 1). Among the 186 subjects who were hospitalized in the neurology or otolaryngology department, 115 actually had ischemic stroke; among these subjects, 109 were properly diagnosed with stroke at the emergency department. Conversely, in 6 out of 999 subjects who were not diagnosed with stroke at the emergency department, a follow-up examination in the outpatient department revealed acute ischemic stroke. Thus, 6 out of the 115 subjects who were hospitalized due to ischemic stroke (6/115, 5.2%) were not properly diagnosed in the emergency department (Table 1). Among these 6 patients, 4 had an infarction in the posterior inferior cerebellar artery (PICA) territory, and 2 of these patients had a lateral medullary infarction. The remaining 2 subjects had an infarction in the paramedian pontine artery territory and basilar artery territory. These subjects had ischemic stroke in the posterior circulation but were diagnosed with acute peripheral vestibulopathy in the emergency department. In 5 out of 6 subjects who were misdiagnosed, the neurological examinations were either incompletely or poorly documented, especially for ataxia, sensory disturbances, and ocular deficits. The corresponding probability of a correct diagnosis by the emergency department staff was as follows: sensitivity, 94.8%; specificity, 83.0%; positive predictive value,

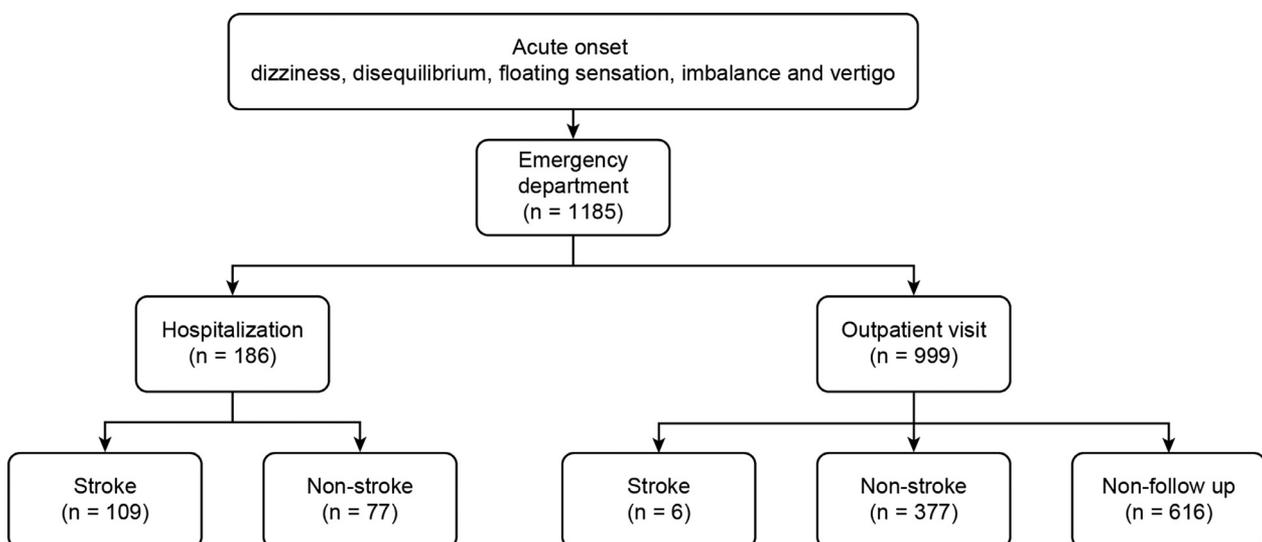**Figure 1.** *Diagnostic flow of subjects with dizziness, disequilibrium, a floating sensation, imbalance and vertigo in the development study phase. In the development study phase, 1185 subjects visited the emergency department with acute dizziness and related symptoms. Among the 115 subjects who were hospitalized due to ischemic stroke, 6 were not properly diagnosed at the emergency department.*

Table 1. *Subjects with stroke who were not properly diagnosed in the emergency department*

Subject	1	2	3	4	5	6
Sex	Male	Female	Male	Female	Female	Female
Age	41	49	67	88	73	86
Risk factors	HT, DL	–	HT, DL, DM	HT	HT	DL
Symptoms	Vertigo	Vertigo Hand numbness Unsteady gait	Floating sensation Hand numbness Dysarthria	Disequilibrium	Dizziness	Imbalance
Signs (1st visit)	*	Sensory disturbance Ataxia (Trunk)	Nothing in particular	*	*	*
Signs (2nd visit)	Sensory disturbance Ataxia (Trunk)	Sensory disturbance Ataxia (Limbs and Trunk) Blepharophimosis	Dysarthria	Ataxia (Limbs)	Sensory disturbance Ataxia (Trunk)	Ataxia (Limbs) Hemiplegia Dysarthria Nystagmus
MRI-DWI[1]	+	-	-	+	-	-
Artery types	PICA Small artery occlusion	PICA Dissection	PPA Cryptogenic	PICA Large artery atherosclerosis	PICA Large artery atherosclerosis	BA Large artery atherosclerosis
LMI	+	+	-	-	-	-
reasons	* **	* **	**	* **	* **	* ** ***

Abbreviations: BA, basilar artery; DWI, diffusion-weighted imaging; DL, dyslipidemia; DM, diabetes mellitus; LMI, lateral medullary infarction; HT, hypertension; PICA, posterior inferior cerebellar artery; PPA, paramedian pontine artery.

(1) Initial MRI-DWI in the emergency department
*Poorly documented neurological examinations.
**No abnormality detected by neuroimaging.
***Insufficient neurological examination.

DEFENSIVE Stroke Scale

This research targets patients who have acute-onset dizziness (DisEquilibrium, Floating sEnsation, Non-Specific dizziness, Imbalance and VErtigo). After systemic neurological examination, if even one symptom on this scale was observed, please consult a neurologist or otolaryngologist.

I. Sensory disturbance

A. Subjective sensory disturbance in the face, contralateral limbs or body

N☐ Y☐

B. Objective sensory disturbance in the face, contralateral limbs or body (reduced pin-prick sensations and temperature)

N☐ Y☐

II. Ataxia

A. Laterality in finger-nose-finger test or knee-heel test

N☐ Y☐

B. Ability to stand on one leg while unsupported and with eyes open

N☐ Y☐

III. Ocular deficit

A. Blepharophimosis

N☐ Y☐

B. Anisocoria

N☐ Y☐

※ After systemic neurological examination, even if an abnormality was not observed, please refer the patient to a neurologist or otolaryngologist the following day.

※※ Neuroimaging was not necessarily examined in these patients as a condition for discharge.

Figure 2. *DEFENSIVE stroke scale. The details of the DEFENSIVE (DisEquilibrium, Floating sEnsation, Non-Specific dizziness, Imbalance and VErtigo) stroke scale are shown. Emergency department physicians referred the subjects to a neurologist or otolaryngologist the following day even if no abnormality was observed. Neuroimaging was not necessarily performed in these subjects when they were discharged from the emergency room.*

58.6% and negative predictive value, 98.4%. Among the 6 subjects with strokes who were not properly diagnosed in the emergency department, 1 patient had no vascular risk factors, and 2 were under 50 years old. These factors potentially hampered the correct diagnosis in the emergency department. Importantly, 4 of the 6 subjects with stroke who were not properly diagnosed in the emergency department had negative DWI at their first scan. In this group of subjects, neurological deficits included sensory disturbance (66.7%, 4/6), ataxia (50.0%, 3/6), dysarthria (33.3%, 2/6), motor disturbance (16.7%, 1/6), and blepharophimosis (16.7%, 1/6). Sensory disturbances included a reduced pin-prick sensation and temperature in the face, contralateral limbs and body. One patient had blepharophimosis, which has the highest predictive value favoring a diagnosis of posterior circulation infarction, in addition to crossed sensory deficits and oculomotor nerve palsy.[20] Based on the development phase results, we created the DEFENSIVE stroke scale, which included items for sensory disturbance (subjective and objective), ataxia (limbs and trunk), and ocular deficits (blepharophimosis and anisocoria) (Fig 2).

The DEFENSIVE stroke scale was validated between January 1, 2011, and December 31, 2012, using a dataset derived from 1014 consecutive subjects who presented to the emergency department with acute dizziness and related symptoms (Fig 3). We excluded 65 subjects whose neurological examinations were incomplete or poorly

documented. In 224 subjects, at least 1 abnormal symptom was documented, and the emergency department staff consulted with the neurologist or otolaryngologist. Then, the staff judged that hospitalization was unnecessary for 47 subjects who were experiencing exacerbated chronic dizziness and related symptoms or had no abnormality on the neurological examination. The remaining 177 subjects were hospitalized in the neurology or otolaryngology department, including 13 subjects without documented neurological deficits who were hospitalized on the grounds of living in solitude or extreme anxiety. Thirty-six subjects who were unable to stand were also hospitalized even if peripheral dizziness was strongly suspected. When ischemic stroke was strongly suspected, the patients were not ordered to stand on 1 leg due to the risk of a fall and aggravation of neurological deficits. As a result, ischemic stroke was diagnosed in 10.5% (100/949) of all subjects with acute dizziness and related symptoms using the DEFENSIVE stroke scale. Posterior circulation stroke was found in 73 subjects; among these subjects, 9 had a lateral medullary infarction. Subjects presenting with dizziness and related symptoms in the emergency department were encouraged to visit our hospital the next day if they were discharged from the emergency room. A total of 84.3% (651/772) of the subjects were confirmed to not have stroke. No subject with stroke was misdiagnosed in the emergency department during the validation phase. The corresponding probability of the
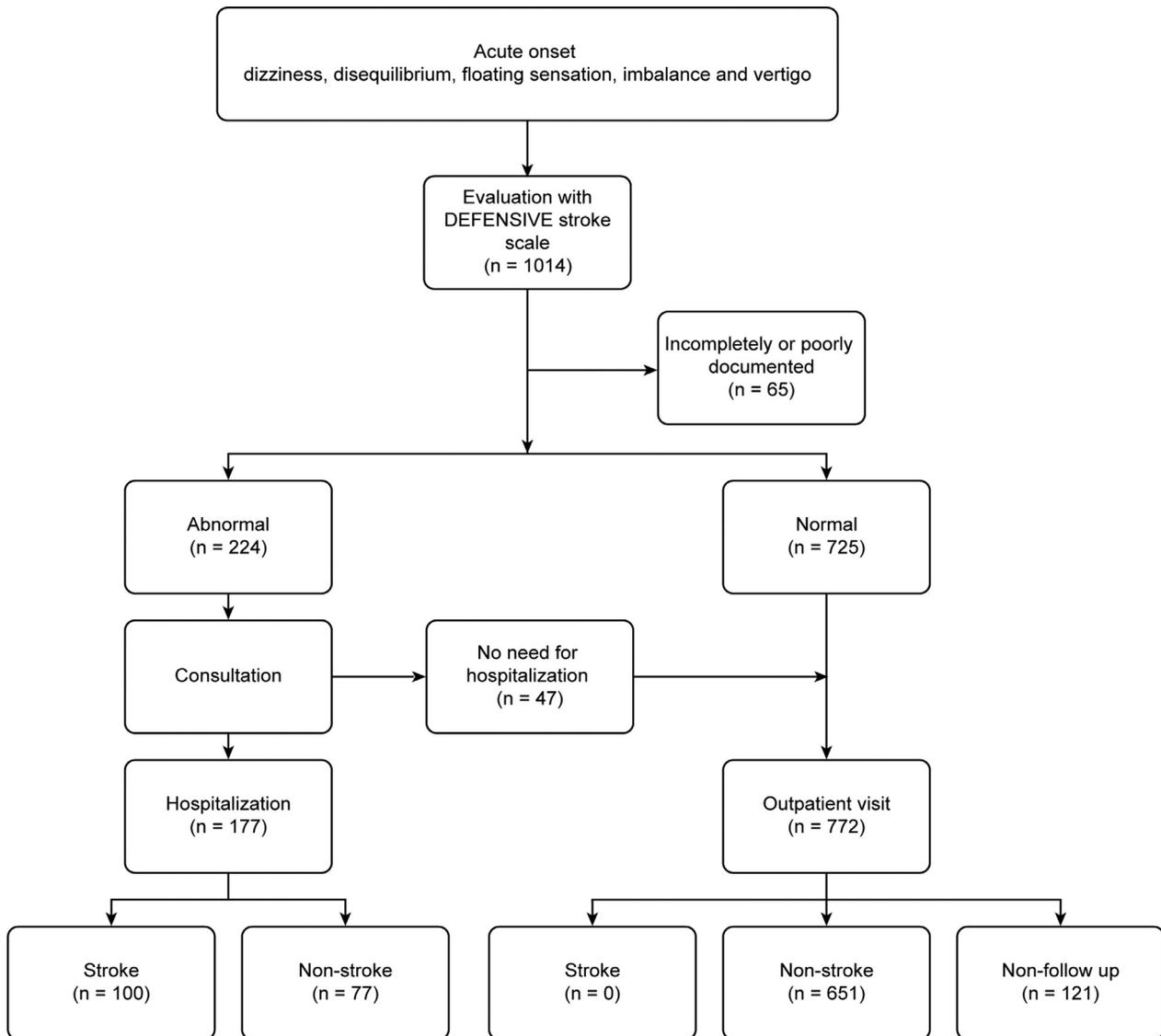
Figure 3. *Diagnostic flow of subjects with dizziness, disequilibrium, a floating sensation, imbalance and vertigo in the validation phase. Internal validation of the DEFENSIVE stroke scale was undertaken for 1014 subjects presenting to the emergency department with acute dizziness and related symptoms. Although 224 subjects had at least one abnormal symptom, neurologists or otolaryngologists judged that there was no need for 47 subjects to be hospitalized, because their symptoms were chronic or they had no abnormality on the neurological examination. A total of 177 subjects were hospitalized in the neurology or otolaryngology department, including 13 subjects who had a strong will to be hospitalized even though they had no neurological deficit.*

emergency department staff correctly diagnosing stroke using the DEFENSIVE stroke scale was as follows: sensitivity, 100%; specificity, 89.4%; positive predictive value, 56.5%; and negative predictive value, 100%.

Internal validation of the DEFENSIVE stroke scale was undertaken for 1014 subjects presenting to the emergency department with acute dizziness and related symptoms. Although 224 subjects had at least 1 abnormal symptom, neurologists or otolaryngologists judged that there was no need for 47 subjects to be hospitalized because their symptoms were chronic or they had no abnormality on the neurological examination. A total of 177 subjects were hospitalized in the neurology or otolaryngology department, including 13 subjects who had a

strong will to be hospitalized even though they had no neurological deficit.

In total, 215 subjects were admitted to our hospital for ischemic stroke with acute dizziness and related symptoms between January 2009 and December 2012 during the development and validation study phases. The clinical characteristics of the study population, including age, sex, vascular risk factors, types of ischemic stroke, and modified Rankin Scale scores, were equivalent between the development and validation study phases (Table 2). The DEFENSIVE stroke scale contributed to a reduction in the misdiagnosis rate in the emergency department in the prospective validation phase compared with that in the development study phase (5.2% versus 0%, $P = .022$)

Table 2. *Clinical characteristics of the subjects in the development and validation study phases*

	Development study phase (n = 115)	Validation study phase (n = 100)	*P* value
Characteristics			
Age at examination	69.4 ± 12.6	69.3 ± 13.2	N.S.
Female	46 (40.0%)	46 (46.0%)	N.S.
Stroke risk factors			
Hypertension	72 (62.6%)	66 (66.0%)	N.S.
Dyslipidemia	41 (35.7%)	30 (30.0%)	N.S.
Diabetes mellitus	33 (28.7%)	18 (18.0%)	N.S.
Atrial fibrillation	14 (12.2%)	8 (8.0%)	N.S.
Current smoker	21 (18.3%)	16 (16.0%)	N.S.
Symptoms and signs			
Sensory disturbance	25 (21.7%)	27 (27.0%)	N.S.
Ataxia	34 (29.6%)	31 (31.0%)	N.S.
Anisocoria	1 (0.9%)	2 (2.0%)	N.S.
Blepharophimosis	1 (0.9%)	2 (2.0%)	N.S.
Motor disturbance	40 (34.8%)	47 (47.0%)	N.S.
Dysarthria	46 (40.0%)	39 (39.0%)	N.S.
Visual disturbance	5 (4.3%)	2 (2.0%)	N.S.
mRS	.43 ± .93	.48 ± 1.03	N.S.

Abbreviations: NS, not significant; mRS, modified Rankin Scale. Data are shown as the mean ± SD.

Table 3. *Diagnostic accuracy of the DEFENSIVE stroke scale*

	Development study phase (n = 115)	Validation study phase (n = 100)	*P* value
Subjects with stroke who were not properly diagnosed	6 (5.2%)	0 (0%)	.022
DWI-negative stroke	7 (6.1%)	16 (16.0%)	.001
Expected responsible territory			
Anterior	25 (21.7%)	27 (27.0%)	N.S.
Posterior	90 (78.3%)	73 (73.0%)	N.S.
Stroke subtypes			
Lacunar	28 (35.7%)	28 (28.0%)	N.S.
Atherothrombotic	37 (28.7%)	34 (34.0%)	N.S.
Cardiogenic	16 (12.2%)	11 (11.0%)	N.S.
Cryptogenic or others	34 (18.3%)	27 (27.0%)	N.S.
Lateral medullary infarction	11 (9.6%)	9 (9.0%)	N.S.
NIHSS	2.8 ± 3.6	2.3 ± 4.4	N.S.

Abbreviations: DWI, diffusion-weighted imaging; NIHSS, National Institute of Health Stroke Scale; N.S., not significant.
Data are shown as the mean ± SD.

(Table 3). Although lateral medullary infarction was overlooked in 2 patients during the development study phase, all subjects with this condition were accurately diagnosed during the validation study phase. We also detected DWI-negative ischemic stroke at a rate of 16.0% (16 out of 100) during the validation phase, which was significantly higher than the rate during the development phase (Table 3). When restricted to posterior circulation infarctions, this rate was 21.9% (16 out of 73) during the validation phase but 7.8% during the development phase. The NIHSS score was not significantly different between the patients in both phases but tended to be lower during the validation phase.

Discussion

In the present study, stroke was overlooked in 5.2% of patients presenting with dizziness and related symptoms at the emergency department; moreover, the DEFENSIVE stroke scale prevented these underdiagnoses. In the majority of subjects with posterior circulation infarctions who were misdiagnosed in the emergency department, the neurological examinations were either incompletely or poorly documented, especially for ataxia, sensory disturbances, and ocular deficits. This issue is why we focused on symptoms and signs of PICA territory strokes, such as sensory disturbance, ataxia and ocular deficits, to develop the DEFENSIVE stroke scale.

The proportion of stroke cases in the emergency department with dizziness and related symptoms in our study (10.5%, 100/949) was higher than that reported in a population-based study (3.2%).[1] The potential reasons for this increase could be as follows: first, we included not only dizziness but also nonspecific dizziness, such as disequilibrium, a floating sensation, imbalance, and vertigo, in this study to achieve high versatility for emergency physicians; and second, we included patients with ischemic stroke who had negative DWI at their first scan and were later diagnosed by a second MRI scan. The false-negative rate for DWI in acute ischemic stroke is 5.8%-10.0%,[8,21] and this rate is even higher for ischemic strokes of the posterior circulation territory (19%).[8] These figures are nearly the same as those observed in our study, indicating that the diagnostic value of DWI is limited during the early period of ischemic strokes. Therefore, importantly, our study revealed that even DWI-negative ischemic strokes in subjects with dizziness and related symptoms can be diagnosed with the DEFENSIVE stroke scale.

Existing scales (i.e., the CPSS,[9] LAPSS,[10] and ROSIER[11] scales) are commonly used for the initial differentiation of acute strokes in prehospital settings and in the emergency department due to the particularly high sensitivity and/or specificity of an anterior circulation infarction. However, some brain stem and cerebellar strokes may be misdiagnosed by the application of the CPSS, LAPSS, or ROSIER criteria. The ROSIER scale avoids selecting items such as gait or limb ataxia due to the difficulty of assessment in the emergency department.[22] Therefore, instruments that are recognized to improve the identification of posterior circulation symptoms, such as sensory disturbance, ataxia, and ocular deficits, should be developed.[21] In this view, Head-Impulse, Nystagmus, and Test-of-Skew (HINTS) have advantages for diagnosing acute vestibular syndrome.[23] The HINTS approach may be appropriate for screening, and its sensitivity appears to be higher than the sensitivity of any other published diagnostic strategy for the assessment of stroke subjects with risk factors for acute vestibular syndrome in the initial emergency department screen.[24] However, several technical aspects of this study must be mentioned, particularly those that were based on direct visual observation of the patient. A lack of patient cooperation or understanding may result in a false-negative assessment. Conversely, a degree of overinterpretation by the examiner of subtle changes in eye position that are mistaken as corrective saccades[25] may lead to false positive results. Thus, the use of HINTS should be strongly considered when adequate expertise or technology is available, but caution should be exercised when examiners lack relevant training in eye examination skills.[24] In contrast, our newly introduced stroke scale was easily used by inexperienced emergency department physicians and improved the quality of documentation of neurological examinations, especially for patients with ataxia, sensory disturbances and ocular deficits. In comparison with HINTS, the sensitivity of

DEFENSIVE stroke scale is equal (100% versus 100%) and specificity is lower (96% versus 89.4%).[23] Specificity of our study was relatively low, because our approach is not restricted to high-risk subjects whereas HINT does and we included young subjects without vascular risk factors in our study. Nevertheless, DEFENSIVE stroke scale is of particular value for patients without risk factors, because some young subjects without vascular risk factors may have posterior circulation infarctions in particular PICA territories that are not properly diagnosed in the emergency department. At 49 years of age, one of our patients had ischemic stroke due to arterial dissection, which is an important cause of juvenile ischemic strokes.[26,27] In the validation phase, the sensitivity, specificity, and positive predictive value were higher than the values obtained during the development phase, but no effect was observed for the negative predictive value. Therefore, we propose a novel algorithm for subjects with acute-onset dizziness, disequilibrium, a floating sensation, imbalance, and vertigo (Fig 4).

Lateral medullary infarction is the most common syndrome related to PICA or intracranial vertebral artery occlusion in which blood flow through perforating branches to the lateral medulla is impaired. Virtually no study has investigated the diagnostic accuracy of lateral medullary infarctions. To the best of our knowledge, this study is the first report concerning the diagnostic accuracy of lateral medullary infarctions. If such stroke is suspected, physicians should scrutinize diagnostic signs, including a reduced pinprick sensation and temperature
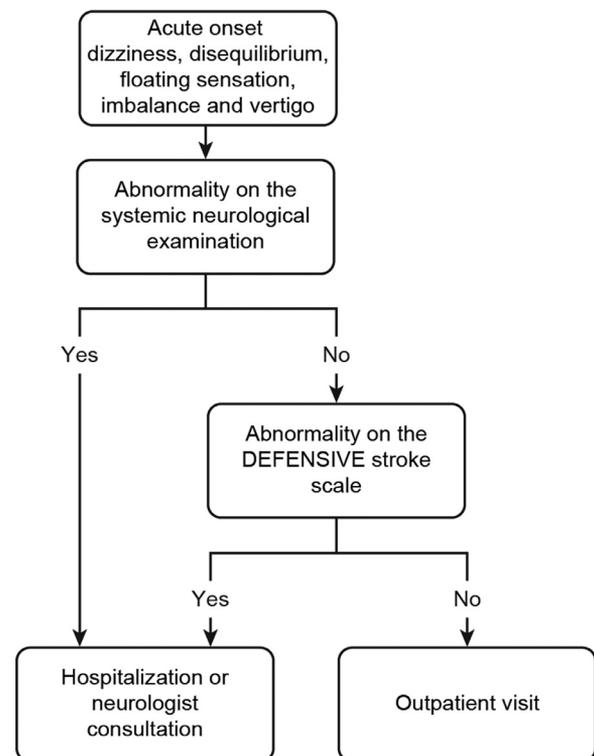

Figure 4. *Proposed algorithm for subjects with acute-onset dizziness, disequilibrium, a floating sensation, imbalance, and vertigo.*

in the face, contralateral limbs, and body.[28] From this perspective, the DEFENSIVE stroke scale is also applicable to lateral medullary infarctions because it includes representative signs of these types of stroke.

Our study has several limitations. First, because this study is an observational study without randomization, dissecting the direct effects of DEFENSIVE on improvement of the total diagnostic system in the emergency department is difficult. Education of the emergency department staff may also influence the outcome. Second, not all subjects who were discharged from the emergency department visited the outpatient clinic or received second MRI evaluation, we cannot exclude the possibility that there were more patients with ischemic stroke than we estimated. Although we assumed that these patients did not visit the hospital because they had no symptoms thereafter, we could not be assured that these patients did not have ischemic stroke. Third, although the duration and triggers should have been considered, we included the subjects who had acute dizziness and related symptoms, regardless of the duration or presence of triggers. Future studies need to adopt the duration and triggers of dizziness and related symptoms as a criteria for inclusion/exclusion. Fourth, we cannot compare the performance of DEFENSIVE stroke scale with that of HINTS in this population, because HINTS was not assessed in this study. Fifth, in the development phase, it was difficult to distinguish patients who had negative neurological findings from those for whom physicians forgot to assess the findings. From this point of view, we did not exclude incompletely or poorly documented patients from retrospective analyses. Finally, the DEFENSIVE instrument is not necessarily suitable for every type of stroke. For example, ischemic stroke in the anterior inferior cerebellar artery with isolated audiovestibular loss and no central symptoms or signs[29] is difficult to triage using this stroke scale alone.

In summary, we designed and prospectively validated the DEFENSIVE stroke scale, a new stroke recognition instrument that predicts posterior circulation infarction for subjects presenting to the emergency department with acute dizziness, vertigo, a floating sensation, imbalance, disequilibrium, or nonspecific dizziness. The DEFENSIVE stroke scale has good diagnostic accuracy and is easy to administer. It is also useful in subjects with insufficient neurological examinations.

Acknowledgments

Declaration of conflicting interests

The authors declare that there is no conflict of interest.

Informed consent

All participants were permitted to opt out their anonymized information to be published in this article.

Ethical approval

The Institutional Review Board of the Japanese Red Cross Nagoya Daini Hospital approved this study (REC number: 1053).

Contributorship

S.Y.: drafting/revising the manuscript, analysis/interpretation of the data, acquisition of data, research project execution, study design and concept, and statistical analysis.

K.Y.: acquisition of data, research project execution, revising the manuscript and study design and concept.

Y.K.: acquisition of data and research project execution.

Y.H.: research project organization, revising the manuscript and research project execution.

M.K.: research project organization and revising the manuscript.

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