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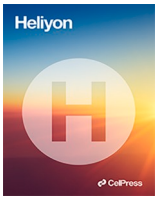

Research article

Characteristics and risk of stroke in emergency department patients with acute dizziness

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ABSTRACT

Background: Acute dizziness is a common symptom in the emergency department (ED), with strokes accounting for 3 %–5 % of cases. We investigated the risk of stroke in ED patients with acute dizziness and compared stroke characteristics diagnosed during and after the ED visit.
Methods: We identified adult patients with acute dizziness, vertigo, or imbalance using a hospital research-based database. Patients with abdominal or flank pain were used as the comparison group. Patients with dizziness were 1:1 matched to comparison patients. Each patient was traced for up to one year until being hospitalized for a stroke.
Results: Out of the 24,266 eligible patients, 589 (2.4 %) were hospitalized for stroke during the ED visit. For the remaining 23,677 patients, the risk of stroke at 7, 30, 90, and 365 days after ED discharge was 0.40 %, 0.52 %, 0.71 %, and 1.25 % respectively. Patients with dizziness had a higher risk of stroke compared to the comparison group at 7, 30, 90, and 365 days. The risk ratios decreased from 5.69 (95 % confidence interval [CI], 3.34–9.68) to 2.03 (95 % CI, 1.65–2.49). Compared to patients hospitalized for stroke during the ED visit, those hospitalized for stroke after the ED visit had greater stroke severity despite a lower initial triage acuity. Patients with early stroke (≤7 days) after ED discharge were less likely to have hypertension, diabetes, hyperlipidemia, and atrial fibrillation. They mostly experienced posterior circulation stroke. Patients with late stroke (>7 days) were older and less likely to have hypertension and hyperlipidemia but more likely to have a history of prior stroke and ischemic heart disease. Their strokes were mainly located in the anterior circulation territory.
Conclusions: The risk of stroke after ED discharge was higher in patients with dizziness than in the comparison group, with gradually decreasing risk ratios in the following year. Patients hospitalized for stroke during and after the ED visit had different profiles of vascular risk factors and clinical characteristics.

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1. Introduction

Acute dizziness is a common complaint in the emergency department (ED) [1]. However, the notion of "dizziness" may vary among patients and treating physicians, ranging from giddiness, lightheadedness, vertigo, or even a feeling of imbalance [2]. After ruling out dizziness caused by a general medical condition such as anemia, the first-line emergency physician must differentiate whether it is caused by a benign peripheral vestibular disorder or a more serious central nervous system disease, such as a stroke [3,4]. In the United States, an estimated 4.4 million emergency visits occur yearly due to dizziness. Approximately 34 % of these visits (1.5 million) are attributed to benign peripheral vestibular disorders, and 3 %–5 % (130,000 to 220,000) are attributed to cerebrovascular diseases [5].

In the busy and stressful environment of the ED, it can be challenging to quickly and accurately determine whether a patient's dizziness is caused by a stroke [6–8]. Up to 35 % of strokes with dizziness, vertigo, or imbalance as initial symptoms are not diagnosed in time and are therefore overlooked in the ED [2]. The implications of missed stroke diagnoses in patients presenting with acute dizziness are significant. A missed or delayed diagnosis of stroke carries high risks of permanent disability and death [9]. This is likely due to delayed and inappropriate stroke management.

Some studies suggest that among ED visits suspected to be due to a transient ischemic attack (TIA), patients presenting with transient dizziness or vertigo are less likely to experience a subsequent stroke than those presenting with other symptoms [10,11]. This led to the assumption that most patients with acute dizziness or vertigo carry no increased stroke risk and are thus discharged from the ED. However, other studies have revealed that patients discharged from the ED with a tentative diagnosis of peripheral vestibular disorders still carry a significant risk of stroke in the following years [12,13].

Although most strokes with vestibular symptoms affect the brainstem or cerebellum [14], existing studies have also linked hemispheric strokes to vestibular symptoms [15,16]. While strokes identified during the ED visit for acute dizziness often involve the cerebellum [17], current knowledge regarding the characteristics of strokes occurring after discharge from ED visits is still limited. Understanding the risk and characteristics of subsequent stroke can greatly influence clinical decision-making and patient outcomes. This understanding can guide the selection of diagnostic tests, enhance shared decision-making, facilitate the development and use of decision aids, and potentially address the current disparities in stroke care and outcomes.

This study aimed to determine if patients who visited the ED with acute dizziness (including vertigo, lightheadedness, gait imbalance, or general dizziness) are at a higher risk of stroke, either ischemic or hemorrhagic, within one year of discharge compared to a matched cohort presenting with symptoms of a similarly low risk of stroke. In addition, we examined whether stroke territories, stroke severity, and clinical characteristics were similar between patients diagnosed with stroke during the ED visit and those diagnosed after ED discharge. By identifying the characteristics and timing of stroke risk in patients with acute dizziness, this study could offer insights that might enhance diagnostic protocols in the ED, potentially reducing stroke-related morbidity and mortality.

2. Methods

2.1. Study setting and data source

This retrospective study was conducted at the Ditmanson Medical Foundation Chia-Yi Christian Hospital, a 1000-bed tertiary care teaching hospital in southern Taiwan. The hospital's annual ED volume ranged from 75,000 to 105,000 visits. The study data were extracted from the Ditmanson Research Database (DRD), a deidentified research-based database containing administrative claims data, electronic medical records, and vital status information provided by the National Death Index. The details of the DRD have been described elsewhere [18]. Briefly, the DRD holds clinical information for approximately 1.6 million patients who visited the study hospital. It includes structured data such as demographics, ED triage information, diagnoses, procedures, prescriptions, physiological measurements, and laboratory results, as well as unstructured textual data such as physician notes, nursing notes, laboratory reports, radiology reports, and pathology reports.

2.2. Study population

All EDs in Taiwan use a complaint-oriented triage system, the Taiwan Triage and Acuity Scale [19], adapted from the Canadian Triage and Acuity Scale. This system classifies presenting complaints under different organ systems. Upon arrival at the ED, the triage nurse determines the most relevant complaint for each patient. The study population was selected based on these presenting complaints.

Supplementary Figs. 1 and 2 illustrate the derivation of the study population. Complaints related to dizziness included vertigo, lightheadedness, gait imbalance, or otherwise undifferentiated dizziness. By querying the triage information in the DRD using standard structured query language (SQL) commands, we identified patients aged 20 years or older who presented to the ED with a chief complaint of acute dizziness between 2012 and 2021. For each patient, if multiple ED visits for dizziness were identified, only the first ED visit was considered, and the remaining visits were eliminated. Patients who were lost to follow-up and did not attend any visit within two years after the ED visit were excluded. Patients with a confirmed diagnosis of stroke during the ED visit were designated as a separate dizziness-stroke cohort. The remaining patients comprised the dizziness cohort.

Following the ideas of previous studies [13,20], patients aged 20 years or older presenting with abdominal or flank pain were chosen as the comparison cohort because they are common in the emergency setting, often discharged home from the ED, and generally not associated with poor outcomes. Similarly, only the first ED visit was considered if they had repeat ED visits for abdominal or flank pain. Patients who were lost to follow-up and did not attend any visit within two years after the ED visit were excluded.

Patients without a confirmed stroke diagnosis during the ED visit composed the comparison cohort. Each patient was traced from the ED visit until the first hospital admission for stroke, death, their last visit to the study hospital, or 365 days after the ED visit, whichever occurred first.

2.3. Variables

Demographic data, ED triage information, outpatient claims records, and hospitalization claims records were obtained from the study database using a unique patient identifier. Triage acuity was categorized into five levels, with decreasing acuity [21]. Patients' past medical history of comorbidities, including hypertension, diabetes, hyperlipidemia, atrial fibrillation, prior stroke, and ischemic heart disease, was identified using validated algorithms [22,23]. In short, a patient was considered to have a past medical history of the comorbidity in question if they had one inpatient diagnosis or two outpatient diagnoses of the comorbidity within two years before the ED visit.

2.4. Outcome measures

The primary outcome measure was hospital admission for stroke within 7 days after the ED visit. We extracted the diagnosis codes, based on the International Classification of Diseases (ICD), from the hospitalization records in the study database for all patients. Stroke was defined as ICD-9 codes 430, 431, 433, and 434 [24,25] or ICD-10 codes I60, I61, and I63 [26,27]. The secondary outcome measures were hospital admission for stroke within 30, 90, and 365 days, stroke severity, and stroke location. Specifically, we compared stroke territories, stroke severity, and clinical characteristics between patients diagnosed with stroke during the ED visit and those diagnosed after ED discharge.

Stroke severity was determined using a validated claims-based method [28–30]. In brief, this method calculated the stroke severity index (SSI) for each patient based on whether they received the following treatments or procedures: airway suctioning, bacterial sensitivity test, stay in the general ward, stay in the intensive care unit, nasogastric intubation, osmotherapy, and urinary catheterization. The SSI was obtained by adding the coefficients of the above seven claims items, depending on whether an item was present in the patient's hospitalization claims record. These coefficients were developed using linear regression analyses, separately for patients with ischemic stroke [28] and those with hemorrhagic stroke [30]. The SSI has been proven as a valid proxy for stroke severity. This is evidenced by its high correlation with the National Institutes of Health Stroke Scale (NIHSS) score [28,30]. The SSI was then converted to the estimated NIHSS score. For patients with ischemic stroke, the conversion was as follows: estimated NIHSS score $= 1.1722 \times$ SSI - 0.7533 [29]. For those with hemorrhagic stroke, the conversion was: estimated NIHSS score $= 1.3894 \times$ SSI - 3.6788 [30].

Stroke location was classified into anterior (ACS) and posterior circulation stroke (PCS) through a manual review of discharge summaries and radiology reports using the criteria from previous studies [31,32]. Based on the Oxfordshire Community Stroke Project classification [33], strokes exhibiting at least two of the following three features: hemiparesis (or hemisensory loss), dysphasia (or other cortical dysfunction), and homonymous hemianopia, i.e., those classified as partial or total anterior circulation strokes, were considered ACS. Strokes displaying brainstem or cerebellar signs or isolated homonymous hemianopia [33] were considered PCS. Patients with lacunar syndrome [33], such as pure motor stroke, pure sensory stroke, sensorimotor stroke, and ataxic hemiparesis, were diagnosed as ACS or PCS based on imaging findings. Patients whose neuroimaging showed new lesions in both anterior and posterior circulation territories were classified as mixed. Patients with lacunar syndromes where neuroimaging did not find any corresponding lesion were classified as unknown.

2.5. Statistical analysis

We assessed the characteristics and outcomes of patients using descriptive statistics. Categorical variables are presented as counts and percentages, while continuous variables are reported as medians and interquartile ranges.

Patients in the dizziness cohort were matched to those in the comparison cohort by propensity score matching using the R package "MatchIt". The propensity score was estimated using logistic regression, with covariates including age, sex, hypertension, diabetes, hyperlipidemia, atrial fibrillation, prior stroke, and ischemic heart disease. These covariates were chosen because of their close associations with dizziness and stroke. Using the derived propensity score, patients in the dizziness cohort were matched 1:1 without replacement to patients in the comparison cohort using a greedy nearest neighbor matching algorithm. Matching was performed on the logit of the propensity score using a caliper width of 0.1 of the standard deviation. Balance in baseline covariates was assessed by calculating standardized differences. A standardized difference of 0.1 or less indicated a negligible difference between the two cohorts.

The outcomes of the matched cohorts are reported using crude incidence. The absolute risk difference and relative risk were calculated based on these probabilities. Since the two cohorts were related, McNemar's tests were used to compare the proportions of the outcomes between the matched cohorts. The cumulative incidence curves up to 365 days were plotted using the Kaplan-Meier method for both cohorts, and differences were assessed with the log-rank test. For sensitivity analysis, a multivariable Cox proportional hazards analysis was performed to assess the effect of death on the outcome. The covariates included age, sex, hypertension, diabetes, hyperlipidemia, atrial fibrillation, prior stroke, and ischemic heart disease.

The outcome (stroke admission) was regressed on the patient cohort (dizziness versus comparison), with death as a censoring event. The assumption of proportional hazards was examined using the Schoenfeld test. Since this assumption was not met, we conducted landmark analyses at 7, 30, and 90 days. In the landmark analysis, we excluded patients who were censored or experienced the outcome before the selected landmark time [34].

To better understand stroke in ED patients with acute dizziness, we compared clinical characteristics, stroke severity, and stroke location between patients who were diagnosed with stroke during the ED visit (dizziness-stroke cohort) and those in the dizziness cohort who were hospitalized for stroke after ED discharge. We defined stroke occurring within 7 days as early stroke, and stroke occurring between 8 and 365 days as late stroke. We used Chi-square tests for categorical variables and *t*-tests or Mann-Whitney U tests for continuous variables to test for differences between patient groups.

All statistical analyses were performed using Stata 15.1 (StataCorp, College Station, Texas). Two-tailed *p*-values of 0.05 were considered significant.

3. Results

Among the 926,488 ED visits during the study period, a total of 41,342 visits were due to acute dizziness (Supplementary Fig. 1). After excluding repeat visits made by the same patient and those without follow-up visits within two years after the initial ED visit, 24,266 patients were identified. Of these, 589 (2.4 %) were diagnosed with a stroke during their initial ED visits and comprised the dizziness-stroke cohort. The remaining 23,677 patients comprised the dizziness cohort (Supplementary Table 1). The mean age of the dizziness cohort was 59.0 years, and the majority were female (60.8 %; Table 1). At 7, 30, 90, and 365 days, 95 (0.40 %), 122 (0.52 %), 167 (0.71 %), and 295 (1.25 %) patients, respectively, had been hospitalized for a stroke (Table 2).

Table 1 shows that 22,478 (94.9 %) patients in the dizziness cohort were successfully matched to patients presenting with abdominal or flank pain, who comprised the comparison cohort (Supplemental Fig. 2). Within 7 days, 91 (0.40 %) patients in the matched dizziness cohort had been hospitalized for a stroke (Table 2), compared to 16 (0.07 %) in the matched comparison cohort, with a risk ratio of 5.69 (95 % confidence interval [CI], 3.34–9.68). The risk ratio decreased to 3.23, 2.80, and 2.03 at 30, 90, and 365 days after the ED visit, respectively.

The Kaplan-Meier curves (Fig. 1) show a significantly different risk of stroke (log-rank test, $p < 0.001$) between the matched dizziness and comparison cohorts. However, the difference becomes less pronounced after 30 days following the ED visit. In the sensitivity analysis, the hazard ratios of stroke risk within 7, 30, 90, and 365 days were 5.38 (95 % CI, 3.16–9.15, $p < 0.001$), 2.99 (95 % CI, 2.05–4.37, $p < 0.001$), 2.54 (95 % CI, 1.86–3.47, $p < 0.001$), and 1.76 (95 % CI, 1.43–2.16, $p < 0.001$), respectively, for patients with acute dizziness compared to those with abdominal or flank pain. The landmark analysis revealed hazard ratios of stroke risk were 1.29 (95 % CI, 1.02–1.62), 1.30 (1.01–1.67), and 1.22 (0.92–1.62) at the landmark time of 7, 30, and 90 days, respectively.

As compared to those diagnosed with a stroke during the ED visit, patients with early stroke post-ED discharge (Table 3) were less likely to have hypertension, diabetes, hyperlipidemia, and atrial fibrillation. They tended to be assigned lower ED triage acuity but had significantly higher stroke severity. As compared to those diagnosed during the ED visit, patients with late stroke post-ED discharge (Table 4) were older and less likely to have hypertension and hyperlipidemia but more likely to have a history of prior stroke and ischemic heart disease. They also tended to be assigned lower ED triage acuity but had significantly higher stroke severity. Additionally, they were more likely to have an anterior circulation stroke.

4. Discussion

We found that, out of every 80 ED patients with acute dizziness who were discharged without a stroke diagnosis, one (1.25 %) subsequently experienced a stroke within 365 days. Patients with dizziness had a significantly higher risk of stroke than matched patients with abdominal or flank pain. The relative risk was highest within 7 days after ED discharge and gradually decreased in the following year. Compared to those diagnosed with stroke during the ED visit, patients with early stroke after ED discharge had a lower prevalence of conventional vascular risk factors and lower ED triage acuity but greater stroke severity. Patients with late stroke after ED discharge also had a different profile of vascular risk factors than those diagnosed with stroke during the ED visit. Additionally, they were older and more likely to have an anterior circulation stroke.

Table 1
Characteristics of the study population.

Characteristic	Dizziness cohort n = 23,677	Matched dizziness cohort n = 22,478	Matched comparison cohort n = 22,478	Standardized mean difference
Age	59.0 (17.8)	58.0 (17.7)	57.6 (17.5)	0.02
Female	14,400 (60.8)	13,609 (60.5)	13,715 (61.0)	0.01
Hypertension	7845 (33.1)	6925 (30.8)	6538 (29.1)	0.04
Diabetes	4583 (19.4)	4055 (18.0)	3828 (17.0)	0.03
Hyperlipidemia	4164 (17.6)	3509 (15.6)	3237 (14.4)	0.03
AF	667 (2.8)	605 (2.7)	445 (2.0)	0.04
Prior stroke	1454 (6.1)	1365 (6.1)	920 (4.1)	0.08
IHD	2115 (8.9)	1698 (7.6)	1551 (6.9)	0.02

Data are given as n (%) and mean (standard deviation).
AF, atrial fibrillation; IHD, ischemic heart disease.

Table 2
Hospitalized strokes at 7, 30, 90, and 365 days.

Days from the ED visit	Dizziness cohort, n (%)	Matched dizziness cohort, n (%)	Matched comparison cohort, n (%)	Risk difference, % (95 % CI)	Risk ratio (95 % CI)	*P*
7	95 (0.40)	91 (0.40)	16 (0.07)	0.33 (0.24–0.43)	5.69 (3.34–9.68)	<0.001
30	122 (0.52)	113 (0.50)	35 (0.16)	0.35 (0.24–0.46)	3.23 (2.21–4.72)	<0.001
90	167 (0.71)	151 (0.67)	54 (0.24)	0.43 (0.30–0.56)	2.80 (2.05–3.82)	<0.001
365	295 (1.25)	272 (1.21)	134 (0.60)	0.61 (0.44–0.79)	2.03 (1.65–2.49)	<0.001

CI, confidence interval; ED, emergency department.

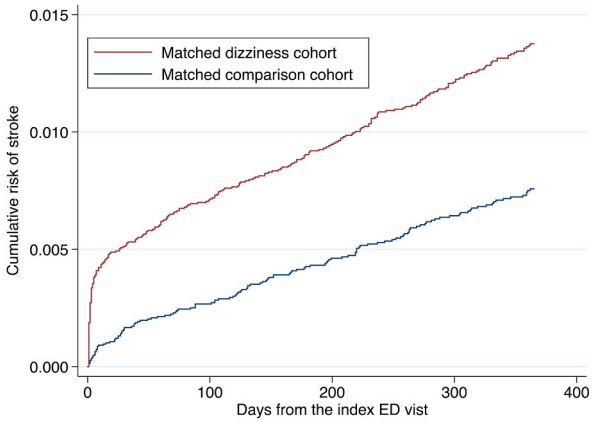

Fig. 1. Cumulative incidence curves of stroke risk in matched patients with acute dizziness versus those with abdominal or flank pain. ED, emergency department.

Table 3
Comparisons of patients with early stroke (within 7 days) after ED discharge and those diagnosed during the ED visit.

Characteristic	Patients hospitalized for stroke after ED discharge n = 95	Patients diagnosed with stroke during the ED visit n = 589	P
Age	67.4 (12.3)	68.0 (12.9)	0.664
Female	33 (34.7)	250 (42.4)	0.157
Hypertension	41 (43.2)	461 (78.3)	<0.001
Diabetes	24 (25.3)	255 (43.3)	0.001
Hyperlipidemia	25 (26.3)	345 (58.6)	<0.001
AF	4 (4.2)	67 (11.4)	0.034
Prior stroke	16 (16.8)	95 (16.1)	0.861
IHD	8 (8.4)	71 (12.1)	0.304
ED triage level			0.014
1	0 (0)	1 (0.17)	
2	35 (36.8)	319 (54.2)	
3	60 (63.2)	267 (45.3)	
4	0 (0)	2 (0.34)	
Estimated NIHSS	8.6 (6.4)	7.1 (5.3)	0.014
Stroke type			0.072
Ischemic	88 (92.6)	506 (85.9)	
Hemorrhagic	7 (7.4)	83 (14.1)	
Stroke location			0.906
ACS	28 (29.5)	156 (26.5)	
PCS	51 (53.7)	329 (55.9)	
Both	12 (12.6)	83 (14.1)	
Unknown	4 (4.2)	21 (3.6)	

Data are given as n (%) and mean (standard deviation).
ACS, anterior circulation stroke; AF, atrial fibrillation; CI, confidence interval; ED, emergency department; IHD, ischemic heart disease; NIHSS, National Institutes of Health Stroke Scale; PCS, posterior circulation stroke.

Table 4
Comparisons of patients with late stroke (between 8 and 365 days) after ED discharge and those diagnosed with stroke during the ED visit.

Characteristic	Patients hospitalized for stroke after ED discharge n = 200	Patients diagnosed with stroke during the ED visit n = 589	*P*
Age	71.4 (11.8)	68.0 (12.9)	<0.001
Female	91 (45.5)	250 (42.4)	0.451
Hypertension	139 (69.5)	461 (78.3)	0.012
Diabetes	82 (41.0)	255 (43.3)	0.571
Hyperlipidemia	65 (32.5)	345 (58.6)	<0.001
AF	16 (8.0)	67 (11.4)	0.179
Prior stroke	47 (23.5)	95 (16.1)	0.019
IHD	37 (18.5)	71 (12.1)	0.022
ED triage level			0.001
1	0 (0)	1 (0.17)	
2	76 (38.0)	319 (54.2)	
3	123 (61.5)	267 (45.3)	
4	1 (0.50)	2 (0.34)	
Estimated NIHSS	9.7 (7.1)	7.1 (5.3)	<0.001
Stroke type			0.455
Ischemic	176 (88.0)	506 (85.9)	
Hemorrhagic	24 (12.0)	83 (14.1)	
Stroke location			<0.001
ACS	92 (46.0)	156 (26.5)	
PCS	65 (32.5)	329 (55.9)	
Both	27 (13.5)	83 (14.1)	
Unknown	16 (8.0)	21 (3.6)	

Data are given as n (%) and mean (standard deviation).
ACS, anterior circulation stroke; AF, atrial fibrillation; CI, confidence interval; ED, emergency department; IHD, ischemic heart disease; NIHSS, National Institutes of Health Stroke Scale; PCS, posterior circulation stroke.

4.1. Diagnostic challenge of dizziness in ED

Dizziness is a nonspecific symptom that describes a subjective sensation of giddiness, lightheadedness, vertigo, or imbalance [2]. It can be caused by various factors, including dehydration, low blood pressure, inner ear problems, medications, and central nervous system disorders. During the study period, dizziness accounted for 4.5 % of all ED visits, which is similar to the percentage reported in the United States (~4 %) [35].

Traditionally, the evaluation of dizzy patients relies on delineating the type or quality of dizziness. Vertigo can indicate vestibular dysfunction; presyncope denotes cardiovascular disorders; lightheadedness suggests anemia; disequilibrium implies neurological disorders; and nonspecific dizziness indicates psychiatric or metabolic origin. However, an overemphasis on this approach may lead to a missed stroke diagnosis [36,37], posing a diagnostic challenge to ED physicians. This study, in line with previous ones [11,17,20], found that ED patients presenting with acute dizziness have a non-negligible risk of stroke even after being discharged from the ED without a stroke diagnosis. Several new observations that may extend current knowledge regarding this issue are discussed as follows.

4.2. Early stroke after ED discharge

Compared to their matched counterparts who presented with abdominal or flank pain, dizzy patients had the highest risk of stroke during the early post-ED discharge period. The risk was approximately 6 times higher at 7 days and gradually declined with increasing time from discharge. Similar results have been shown in several prior studies [11,20,38,39].

There are a couple of possible reasons for this. First, dizziness is a symptom of posterior circulation TIAs or strokes [40,41], and the risk of stroke is particularly high in the early period after a TIA or stroke [42,43]. Therefore, it is not surprising that dizzy patients who are misdiagnosed as having a non-cerebrovascular disorder during their initial ED visits are likely to experience a stroke during the early post-ED discharge period. Second, symptoms of PCS may progress gradually, particularly in patients with slowly occluding atherosclerotic lesions [44]. Dizziness might be the very first symptom of the culprit stroke, which is just missed at the ED. Patients then revisit the ED after the symptoms and signs of stroke have become more discernible. Both theories can be partly supported by the study findings that strokes occurring within 7 days after ED discharge were mostly PCS, just like those diagnosed during the ED visit.

On the other hand, patients with early stroke post-ED discharge were different from those diagnosed with stroke during the ED visit. The former group had fewer vascular risk factors and tended to have lower triage acuity. As a result, ED physicians might develop a false sense of safety and overlook the possibility of cerebrovascular diseases. Consequently, this group of patients may miss the opportunity for timely stroke diagnosis and even hyperacute stroke therapy at the ED [21,45]. Missed stroke diagnoses at the ED could have potentially detrimental consequences for patients with early stroke post-ED discharge, as evidenced by the greater stroke severity experienced by these patients compared to those diagnosed during the ED visit.

4.3. Late stroke after ED discharge

After the early post-ED discharge period, patients with dizziness still had a more than two-fold risk of stroke within 365 days after

ED discharge, compared to those with abdominal or flank pain. Consistent with previous studies [11,20], the increased risk of stroke in dizzy patients gradually decreased over time. According to a prior study [20], the heightened stroke risk appeared to disappear after one year. However, based on the landmark analysis, the increased stroke risk became insignificant for patients who remained stroke-free 90 days after ED discharge.

Patients with late stroke after ED discharge shared some characteristics with those with early stroke. Both groups had lower percentages of hypertension and hyperlipidemia, as well as lower triage acuity, but had higher stroke severity than those diagnosed with stroke during the ED visit. However, compared to those diagnosed with stroke during the ED visit, patients with late stroke were older and more likely to have a history of prior stroke and ischemic heart disease, indicating a patient group with a relatively high cerebrovascular risk. It is worth noting that patients with late stroke tended to have ACS rather than PCS, suggesting that their strokes might be unrelated to the preceding dizziness symptoms. Patients might experience a stroke long after ED discharge simply due to their high baseline cerebrovascular risks, even though ACS involving specific cerebral cortical areas has been reported to present with acute dizziness and vertigo [15,46].

4.4. Clinical implications

Although diffusion-weighted magnetic resonance imaging is more sensitive than computed tomography for detecting early infarction [47], it is expensive and not universally available in every ED. Given the high volume of acutely dizzy patients in emergency settings, more cost-effective diagnostic approaches are needed to help identify the underlying cause of dizziness. Previous studies have shown that the head impulse, nystagmus type, test of skew (HINTS) test is highly sensitive and specific in differentiating stroke from non-stroke causes of acute dizziness in the ED [48,49]. Portable video-oculography, which allows quantitative eye movement recordings in emergency settings, facilitates the differential diagnosis of dizziness and vertigo [50]. These tools can guide advanced neuroimaging for patients with acute dizziness and vertigo.

It is also crucial to provide close follow-up care for acutely dizzy patients because the risk of stroke remains high even after discharge from the ED, particularly within the first 90 days. Using a stroke risk stratification tool like the age, blood pressure, clinical features, duration of symptoms, and diabetes ($ABCD^2$) score [51] may be beneficial. This tool was designed to evaluate stroke risk after a TIA. Although the $ABCD^2$ score is less effective than the HINTS test for ED patients with acute dizziness [48,49], its value in follow-up care for these patients may warrant further investigation. Future research could focus on developing or validating predictive models for subsequent stroke risk, specifically in ED patients with dizziness, or investigating the effectiveness of different diagnostic strategies in this population.

4.5. Strengths and limitations

This study included over 24,000 patients, providing a robust dataset for analyzing stroke risk in patients with acute dizziness. The large sample size contributed to the statistical power and reliability of the findings. While previous research has explored the immediate risk of stroke in dizzy patients, this study uniquely investigated long-term stroke risk and types of strokes post-ED discharge. Moreover, this study utilized data from the DRD, a hospital research-based database containing long-term and varied healthcare data for a large patient population [18]. The comprehensive nature of the DRD further enhanced the study's capability to capture and analyze relevant outcomes.

This study has several limitations. Firstly, it is a single-center study, so the generalizability of its findings is uncertain. Secondly, as with all retrospective analyses, it may be subject to various biases. For example, patients with acute dizziness were identified using triage information. As the current complaint-oriented triage system [19] allows for only one complaint per patient, dizzy patients with multiple complaints could have been excluded, potentially leading to selection bias. Thirdly, there might be information bias, such as outcome misclassification, because stroke hospitalizations outside the study hospital were not included. However, this misclassification should not differ between patients with dizziness and those in the matched comparison cohort.

Fourthly, this retrospective observational study was based on routine clinical practice. Sensitive diagnostic tools to detect brain ischemia, such as brain magnetic resonance imaging, and equipment to differentiate peripheral from central vestibular causes, such as video-oculography, were not used in every ED patient with dizziness in the study hospital. Consequently, the incidence of stroke might be underestimated because small and non-disabling strokes could be missed. Fifthly, stroke severity was not assessed using the NIHSS but instead estimated using surrogate information from claims data. Nonetheless, the estimated NIHSS has demonstrated a high correlation to the NIHSS in previous multicenter studies [28–30]. Finally, variables that may be associated with the risk of stroke, such as body mass index, smoking habits, lipid profile, and red blood cell count, were not available for matching cases and controls and were not adjusted for in the multivariable analyses.

5. Conclusions

The findings of this study have important clinical significance. The results demonstrated that patients with acute dizziness who were discharged from the ED without a stroke diagnosis were at a significantly higher risk of stroke compared to matched controls. The highest risk of stroke occurred within 7 days after ED discharge. This highlights the need for increased vigilance and follow-up care for these patients, as the risk of stroke remains elevated even after the ED visit.

Patients hospitalized for stroke after the ED visit had greater stroke severity, despite a lower triage acuity during the initial ED visit, compared to those hospitalized for stroke during the ED visit. Patients with early stroke after ED discharge mostly had PCS, whereas

those with late stroke mainly experienced ACS. The differences in stroke severity and location between patients hospitalized for stroke during the ED visit and those hospitalized after the ED visit suggest that further research is needed to better understand the underlying mechanisms and optimize diagnostic strategies.

Ethics statement

The study protocol was approved by the Institutional Review Board of Ditmanson Medical Foundation Chia-Yi Christian Hospital (approval number: 2022111) on December 15, 2022. Because of the retrospective design, the requirement for written informed consent was waived by the Institutional Review Board of Ditmanson Medical Foundation Chia-Yi Christian Hospital. The study data were maintained with confidentiality to ensure the privacy of all participants.

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Data availability statement

The authors do not have permission to share data.

CRediT authorship contribution statement

Yu-Sung Chang: Writing – original draft, Investigation, Conceptualization. **Ming-Jen Tsai:** Writing – original draft, Investigation, Formal analysis. **Cheng-Yang Hsieh:** Writing – original draft, Investigation, Formal analysis. **Sheng-Feng Sung:** Writing – review & editing, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e30953.

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