Cumulative Incidence of Stroke Disability and Mortality Following Emergency Department Discharge for Dizziness: A Cohort Study

Kevin A. Kerber, MD, MS*; Navdeep Sangha, MD; James F. Burke, MD, MS; Molly O. Jancis, MD; Aileen Baecker, PhD; Ernest Shen, PhD; Huong Nguyen, PhD; Sanaz Monjazeb, MD; Prasanth Manthena, MD; Stacy Park, PhD; Adam L. Sharp, MD, MSc; William J. Meurer, MD, MS

*Corresponding Author. E-mail: kevin.kerber@osumc.edu.

Study objective: The incidence of stroke after emergency department (ED) dizziness visits is low, indicating that missed strokes, a subset of subsequent strokes, are infrequent. However, little is known about the outcomes of individuals with subsequent stroke. This study estimates the incidence of stroke disability/mortality after ED dizziness visits.

Methods: We conducted a retrospective cohort study from January 2016 to December 2020 within Kaiser Permanente Southern California. We included all index visits for adults discharged home after an ED dizziness visit. Stroke hospitalization and stroke hospitalization with disability/mortality (subsequent stroke hospitalization discharged to any setting other than back to home) were captured over a 30-day follow-up period. Cumulative incidence of stroke disability/mortality was calculated using Kaplan-Meier estimates. Acute stroke management and stroke location on imaging were also summarized.

Results: We identified 77,315 index ED dizziness visits discharged home. The 30-day cumulative incidence of stroke hospitalization was 0.12% (95% confidence interval [CI] 0.10 to 0.15; n=94; 1 in ∼830), and the cumulative incidence of stroke hospitalization with disability/mortality was 0.04% (95% CI 0.03 to 0.06; n=33; 1 in ∼2,500). Among subsequent strokes, most lesions were in the anterior fossa on imaging (59%; 55/94). The frequency of acute interventions was as follows: 1% (1/94) thrombolytics, 5% (5/94) thrombectomy, 2% (2/94) suboccipital craniotomy, 3% (3/94) tracheostomy, 3% (3/94) gastrostomy, and 10% (9/94) mechanical intubation.

Conclusion: At the individual level, stroke that results in death or severe disability after discharge to home from an ED dizziness visit is rare. Because only a subset of the subsequent visits are likely to be directly related to the index visit, the frequency of missed strokes leading to death or disability should be considered to be even lower. [Ann Emerg Med. 2025;■:1-11.]

Please see page XX for the Editor's Capsule Summary of this article.

Keywords: Stroke, Dizziness, Vertigo, Cumulative incidence.

0196-0644/$-see front matter

https://doi.org/10.1016/j.annemergmed.2025.09.029

SEE EDITORIAL, P. XXX.

INTRODUCTION

Background

Dizziness is a common reason that patients present to the emergency department (ED).[1] Although the symptom is typically caused by a general medical (eg, hypotension) or peripheral vestibular disorder, it can be caused by stroke or transient ischemic attack.[1,2] Patients with dizziness-stroke can be difficult to identify because about half lack typical stroke features like speech/language problems, focal weakness, or sensory loss.[3,4] In addition, computed tomography scans in early presentations of dizziness-stroke are not sensitive for acute infarction in general and particularly for posterior fossa lesions, and obtaining a magnetic resonance imaging (MRI) in ED visits has many logistical challenges. It is therefore not surprising that there has been concern about missing stroke specifically in dizziness visits.[5-7] However, it is a challenge to judge the magnitude of this problem due to limited data about both the frequency and result of potentially missed stroke in this circumstance.

Several studies have reported the cumulative incidence of stroke after ED dizziness visits. However, lacking from these studies is information that links the events and informs the severity of the subsequent strokes. These data have been used as a proxy of missed stroke even though the time association does not confirm a direct relationship.

Editor's Capsule Summary

What is already known on this topic

Diagnosing stroke in emergency department (ED) patients with dizziness as the primary symptom is challenging.

What question this study addressed

What is the 30-day incidence of stroke-related disability or death among patients with dizziness treated and discharged from EDs?

What this study adds to our knowledge

In a retrospective review from 13 affiliated sites, the incidence of stroke-related disability or death within 30 days of the index ED dizziness visit discharge was low (approximately 1 of 2,500).

How this is relevant to clinical practice

Currently, after ED discharge, stroke-related poor outcomes for those with dizziness are infrequent. How to change that residual small frequency of events is unclear.

These studies found that the incidence of subsequent stroke is low overall (0.13% to 0.30% at 30 days; 1 in 333 to 769 patients).[8-11] Given the difficulty in determining actual rates of missed stroke, more information about the outcomes of subsequent strokes may provide additional context to evaluate the magnitude of the problem. For example, if most strokes after dizziness visits were due to posterior fossa lesions (the dominant lesion location for dizziness-stroke), it would favor that most of the initial dizziness presentations were missed strokes.[3] Similarly, if basilar occlusion or malignant cerebellar infarction—both associated with mortality and severe disability—account for a high proportion of the strokes after dizziness visits, then the magnitude of the problem of missed strokes after dizziness visits would naturally increase.[12] Alternatively, it is also possible that these subsequent strokes may be in distributions infrequently associated with dizziness and/or are not disabling.

Importance

In addition to the frequency of subsequent stroke after ED dizziness visits, the associated disability and mortality are important for understanding the magnitude of the problem of potentially missed stroke diagnoses among ED dizziness presentations.

Goals of This Investigation

The primary aim of this study was to describe the cumulative incidence of stroke mortality/disability in patients who were discharged home from the ED after presenting with dizziness. We secondarily aimed to describe acute stroke location and stroke management to inform the relatedness of the events and the severity of stroke at hospital discharge in this population.

METHODS

Study Design and Setting

This was a retrospective analysis of prospectively collected data at 13 Kaiser Permanente Southern California (KPSC) medical centers, one of which is a comprehensive stroke center, and the others are primary stroke centers. KPSC is an integrated health system providing health care for more than 4 and a half million diverse members. The KPSC population has been shown to have similar sociodemographics to the Southern California census population.[13] An integrated electronic health record system captures comprehensive information on the care that members receive at KPSC-owned and contracting facilities. KPSC also obtains claims data on any out-of-network care that members receive.

Study Population

We searched the electronic health record (in network) and claims data (in and out of network) for all KPSC health plan members aged more than or equal to 18 years who presented to the ED with dizziness between January 1, 2016, and December 31, 2020, and were discharged home from the ED. We did not exclude visits that had been under observation status. We only included individuals with continuous Kaiser Permanente health plan membership for 31 days before and after the ED encounter or death within 90 days of the ED encounter. Dizziness was defined as having either a primary ED dizziness discharge diagnosis (International Classification of Disease [ICD] Tenth edition code of dizziness not otherwise specified (R42.xx), a vestibular disorder (H81.xx, H82.xx, H83.xx), or related diagnoses (R26.0, R26.2, R26.81, R26.89, R27.xx, and A88.1) (Appendix E1, available at http://www.annemergmed.com), or dizziness selected as the primary chief complaint at triage. The dizziness chief complaint terms were dizzy, vertigo, gait problem, gait abnormality, lightheadedness, and balance problems. For individuals with more than one dizziness visit, only the first visit was included in our analysis. We excluded those who were not discharged to home or home health (eg, admitted, died, discharged to facility, and transferred to other facility), and also non-Kaiser Permanente members or those with do not intubate/do not resuscitate/hospice status given likely baseline disability, a trauma code (codes, S00-T79, W00-W19), or a stroke diagnosis at the index visit. We did not limit the population further (eg, by more specific diagnoses or by age) because there is concern about missed dizziness-stroke particularly among patients otherwise perceived to be low risk such as those receiving medical diagnoses and young people who could harbor vascular dissection.[12,14,15]

Main Outcomes and Measurements

The primary outcome measures were stroke hospitalization and stroke hospitalization with mortality/disability. Stroke hospitalization was defined as a subsequent hospitalization with either a primary or principal discharge diagnosis of stroke (ischemic or nontraumatic hemorrhage) (Appendix E1) identified through in-network medical records or out-of-network claims.[16,17]Out-of-network claims were last queried on June 1, 2022, 18 months after last cohort capture on December 31, 2020. Observation status was not considered hospitalization. Mortality/disability was defined as a stroke hospitalization that resulted in discharge to any facility, hospice service, or death. Prior studies have found that stroke patients discharged home have lower stroke severity and minimal functional impairment.[18-20] All-cause mortality was determined primarily from KPSC hospital and administrative records and supplemented with data from the National Death Index (end capture date December 31, 2021) for out-of-network deaths.

We also captured secondary outcomes of stroke management that reflect stroke severity, including thrombolysis, thrombectomy, mechanical ventilation, craniectomy, and gastrostomy tube using previously defined methods (Appendix E1). These are captured for all KPSC facilities and through claims for KPSC members at non-KPSC facilities. We obtained the modified Rankin scale (mRS) score from a datafile of routinely manually abstracted stroke hospitalizations at KPSC performed by research staff. This scoring was performed without knowledge of the current study's objectives. These staff were trained on mRS abstraction by a research manager. Data quality assurance for the mRS abstraction is routinely monitored using 10% reabstraction. The mRS obtained was from the last physical therapy or occupational therapy standard evaluations prior to discharge from subsequent visits for patients discharged from KPSC facilities. The 10% reabstraction is used for data monitoring but formal statistics on agreement are not calculated. In the event of discrepancies in mRS abstraction, a third review was performed to resolve the discrepancy. Patients with known death at the stroke hospitalization were assigned an mRS of 6. Stroke location was manually abstracted into REDCap forms with categoric variables by neurologists from brain imaging reports and images. Interrater reliability of stroke location abstraction was not assessed.

Relevant demographic, clinical, comorbidity, and medication data (Appendix E1) were also obtained using structured data from electronic health and administrative records. Patient age, sex, and race or ethnicity were obtained from administrative records, and patient socioeconomic status was measured with the census block-level median income based on patients' home zip codes. The Elixhauser comorbidity index was calculated using diagnoses from encounters the prior year or from the patient's problem list.

Statistical Analysis

We calculated descriptive statistics, including counts and percentages or medians and interquartile ranges (IQR) by stroke and stroke mortality/disability status during follow-up. Time to the outcome (stroke or death) in days was calculated from subtracting the index ED presentation date to the date of the subsequent stroke hospitalization, with cases censored at death before the stroke hospitalization or December 31, 2020. The potential of loss to follow-up was addressed through inclusion criteria requiring continuous enrollment in KPSC, capture of out-of-network hospitalizations through claims data, and capture of death through the National Death Index. Cumulative risk for stroke after dizziness presentation was determined using the Kaplan-Meier product limit estimates. We performed 3 sensitivity analyses: (1) limiting the study population to those with a dizziness diagnosis as the primary diagnosis (ie, excluding individuals with a dizziness primary chief complaint but not a dizziness diagnosis); (2) to assess differences in the cumulative incidence function across EDs, we included a categoric variable for ED facility and conducted Gray's test for equality of cumulative incidence functions, with the null hypothesis of no difference between sites; and (3) adding stroke deaths (eligible stroke ICD-10 code recording as the cause of death) captured exclusively by the National Death Index (ie, did not have a subsequent stroke hospitalization) to the stroke outcome. Missing data were categorized and

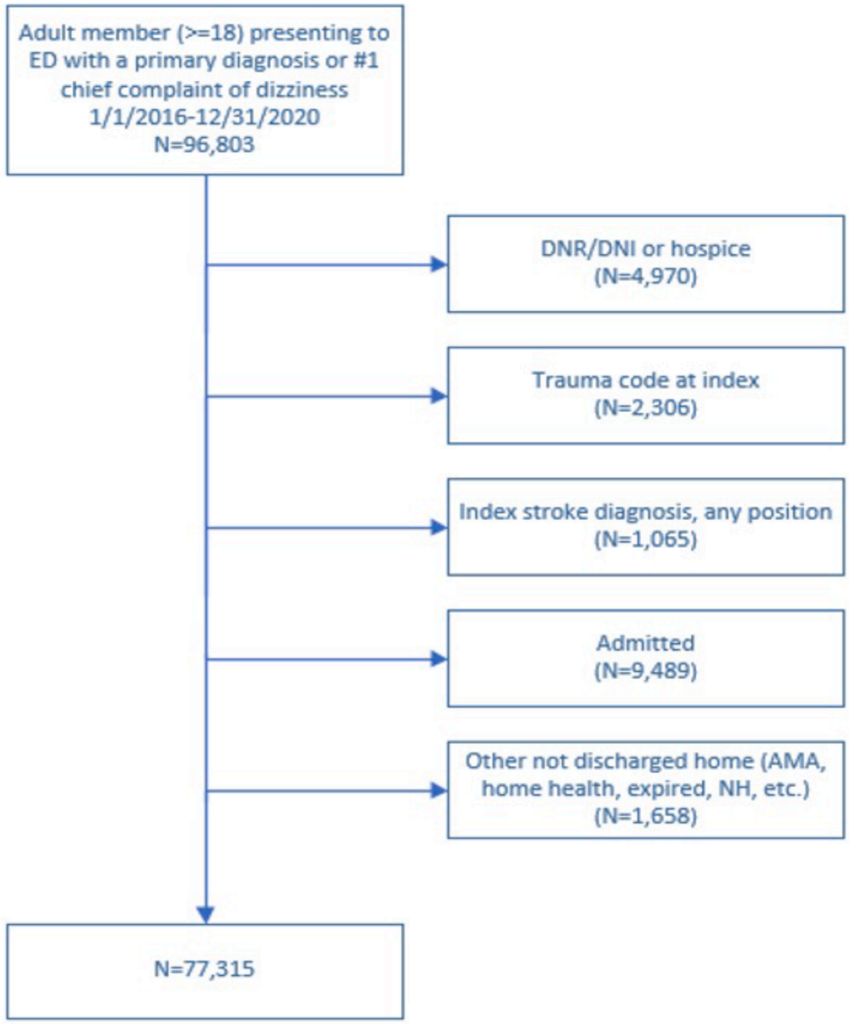

Figure 1. Flow diagram. *DNI*, do not intubate; *DNR*, do not resuscitate; *NH*, nursing home; *AMA*, against medical advice.

described. All analyses were performed using SAS 9.4 (SAS Institute, Cary, NC). All tests of statistical significance were 2 sided with α=0.05. This study was approved by the KPSC Institutional Review Board. We adhered to the EQUATOR Strengthening the Reporting of Observational Studies in Epidemiology reporting guidelines.

RESULTS

Characteristics of Study Subjects

We identified 96,803 index dizziness visits from January 1, 2016, to December 31, 2020. After excluding patients with do not resuscitate/do not intubate or hospice status, trauma code, index stroke diagnosis, and those admitted to the hospital or not discharged home, the study population was 77,315 patients (Figure 1). Demographics and clinical characteristics are present in Table 1. Twenty-three percent of the population was taking an antiplatelet or anticoagulant prior to the index ED visit. At the index visit, a head CT was performed in 34% (26,103) and MRI in 10% (7,496).

Stroke Hospitalization and Stroke Hospitalization With Mortality/Death Within 30 Days

The 30-day cumulative incidence of stroke hospitalization was 0.12% (95% confidence interval [CI] 0.10 to 0.15; n=94; ∼1 in 830) and the cumulative incidence of stroke disability/mortality was 0.04% (95% CI 0.03 to 0.06; n=33; ∼1 in 2,500) (Table 2; Figure 2). By ICD-10 classification, the type of stroke was ischemic in 78% (73 of 94), intracerebral hemorrhage in 14% (13 of 94), and subarachnoid hemorrhage in 9% (8 of 94). Patients who had a subsequent stroke were older, more likely to be male, had a higher frequency of vascular risk

Table 1. Characteristics of the study population.

			30-d Subsequent Stroke Hospitalization[‡]		
Characteristics	**Study Population**	**No 30-d Subsequent Stroke Hospitalization**	**All**	**Without Disability/Death**	**With Disability/Death**
N	77,315	77,221	94	61	33
Female sex	47,841 (62%)	47,790 (62%)	51 (54%)	32 (53%)	19 (58%)
Age (median IQR)	59.0 (44.0, 71.0)	59.0 (44.0, 71.0)	65.5 (53.0, 77.0)	62.0 (46.0, 74.0)	69.0 (65.0, 77.0)
Race/ethnicity					
Asian/Pacific Islander	9,838 (13%)	9,821 (13%)	17 (18%)	12 (20%)	5 (15%)
Black	9,489 (12%)	9,476 (12%)	13 (14%)	7 (12%)	6 (18%)
Hispanic	33,571 (43%)	33,531 (43%)	40 (43%)	27 (44%)	13 (39%)
Others	1,440 (2%)	1,439 (2%)	1 (1%)	1 (2%)	0 (0%)
White	22,977 (30%)	22,954 (30%)	23 (25%)	14 (23%)	9 (27%)
Median income<50k	19,015 (25%)	18,991 (25%)	24 (26%)	15 (25%)	9 (27%)
Education some college+	57.1 (19.4)	57.1 (19.4)	53.4 (17.0)	53.1 (16.6)	53.8 (18.1)
Past medical history					
Stroke (within 90 d before dizziness visit)	254 (0.3%)	251 (0.3%)	3 (3%)	3 (5%)	0 (0.0%)
History of dizziness (within 90 d of dizziness visit)	7,227 (9%)	7,219 (9%)	8 (9%)	6 (10%)	2 (6%)
Coronary artery disease (within 90 d of dizziness visit)	4,309 (6%)	4,296 (6%)	13 (14%)	12 (20%)	1 (3%)
Hypertension	37,955 (49%)	37,884 (49%)	71 (76%)	46 (75%)	25 (76%)
Diabetes	19,787 (26%)	19,733 (26%)	54 (57%)	31 (51%)	23 (70%)
Elixhauser index (median IQR)	3.0 (1.0, 5.0)	3.0 (1.0, 5.0)	4.0 (2.0, 7.0)	4.0 (2.0, 7.0)	4.0 (3.0, 5.0)
Baseline medications					
Antiplatelets*,†	17,146 (22%)	17,114 (22%)	32 (34%)	20 (33%)	12 (36%)
Anticoagulants*	3,400 (4%)	3,387 (4%)	13 (14%)	12 (20%)	1 (3%)
Antiplatelets or anticoagulants	19,752 (26%)	19,712 (26%)	40 (43%)	27 (44%)	13 (39%)
Antihyperlipidemics*	22,370 (29%)	22,334 (29%)	36 (38%)	26 (43%)	10 (30%)
Antihypertensives*	30,420 (39%)	30,360 (39%)	60 (64%)	40 (66%)	20 (61%)
Neuroimaging studies at the Index visit					
Head CT	26,103 (34%)	26,065 (34%)	38 (40%)	22 (36%)	16 (49%)
MRI	7,496 (10%)	7,487 (10%)	9 (10%)	4 (7%)	5 (15%)
Primary diagnoses at the index visit					
Dizziness NOS (R42)	40,573 (53%)	40,524 (53%)	49 (52%)	33 (49%)	16 (62%)
Peripheral vestibular disorders (any H81.0x-H81.39)					
BPPV (H81.1x)	2,816 (4%)	2,812 (4%)	4 (4%)	3 (4%)	1 (4%)
Vestibular neuritis or labyrinthitis (H81.2x)	83 (0.1%)	83 (0.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Meniere's disease (H81.0x)	92 (0.1%)	92 (0.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Other peripheral vertigo (H81.3)	1,638 (2%)	1,636 (2%)	2 (2%)	2 (3%)	0 (0.0%)

BPPV, Benign paroxysmal positional vertigo; *CT*, computed tomography; *IQR*, interquartile range; *MRI*, magnetic resonance imaging; *NOS*, not otherwise specified (ie, ICD10 R42).
*Outpatient pharmacy file. See Appendix E1 for details.
†Self-reported in current medications list.
‡=20/94 (21%) of subsequent stroke hospitalizations were captured with out-of-network claims: 9/61 (15%) for those without disability/death and 11/33 (33%) for those with disability/death.

Table 2. Cumulative incidence of stroke hospitalization and stroke hospitalization with disability/death at time points of 2 to 30 days.

Study Population		Population: Primary Dizziness Diagnosis or Chief Complaint Subsequent Stroke Hospitalization		Subsequent Stroke Hospitalization With Disability/Death
Primary population*				
Days	Events/at risk		Events	
2	26/77,307	0.03% (0.02%-0.05%)	8	0.01% (0.01%-0.02%)
7	58/77,250	0.08% (0.06%-0.10%)	19	0.02% (0.02%-0.04%)
14	68/77,215	0.09% (0.07%-0.11%)	23	0.03% (0.02%-0.04%)
30	94/77,120	0.12% (0.10%-0.15%)	33	0.04% (0.03%-0.06%)
Limited to primary dizziness diagnosis at index visit†				
2	14/47,624	0.03% (0.02%-0.05%)	5	0.01% (0.00%-0.02%)
7	33/47,591	0.07% (0.05%-0.10%)	14	0.03% (0.02%-0.05%)
14	42/47,575	0.09% (0.06%-0.12%)	18	0.04% (0.02%-0.06%)
30	57/47,536	0.12% (0.09%-0.15%)	23	0.05% (0.03%-0.07%)
Primary population plus stroke captured by NDI included in outcome†				
2	26/77,309	0.03% (0.02%-0.05%)	8	0.01% (0.01%-0.02%)
7	59/77,259	0.08% (0.06%-0.10%)	20	0.03% (0.02%-0.04%)
14	69/77,247	0.09% (0.07%-0.11%)	24	0.03% (0.02%-0.05%)
30	98/77,219	0.13% (0.10%-0.15%)	37	0.05% (0.03%-0.07%)

NDI, National Death Index.
*Primary population and outcome.
†Sensitivity analyses.

factors (coronary artery disease, hypertension, diabetes), and more frequent baseline use of an antiplatelet or anticoagulant (43% versus 26%) than patients who did not have a subsequent stroke. The patients with a peripheral vestibular diagnosis had a similar probability of subsequent stroke hospitalization (6 of 4,629, 0.12%; 6 of the 94 stroke hospitalizations) or subsequent stroke mortality/disability (1 of 4,629, 0.02%; 1 of the 33 stroke hospitalizations). A dizziness symptom diagnosis was the primary diagnosis in 53% of the index visits, in 52% of the index dizziness visits that then had a subsequent stroke hospitalization and in 62% of the index dizziness visits that then had subsequent stroke with mortality/disability. Yet, only 16 of 40,573 (0.04%) patients with a dizziness symptom diagnosis at the index visit had subsequent stroke mortality/disability. Intracerebral hemorrhage and subarachnoid hemorrhage by ICD-10 codes comprised a larger proportion of the strokes resulting in death or disability than those not resulting in death or disability (9/33 [27%] versus 12/61 [19.6%], respectively). The cumulative incidence of stroke disability was similar overall in the sensitivity analyses that limited the population to only those with a dizziness diagnosis (eg, excluded those with a dizziness chief complaint but not a dizziness diagnosis) or included deaths with the eligible ICD-10 stroke diagnoses as the cause of death from the National Death Index (4 additional cases) (Table 2). In the sensitivity analysis that assessed for differences in the cumulative incidence by site of the ED visit, the ED facility variable was not significant (P=.13).

Stroke Location and Severity of Stroke in Subsequent Stroke Visits

Stroke imaging results were available for 92 of the 94 patients. An acute infarct lesion was in the anterior fossa in 52 (55%) patients, posterior fossa in 38 (40%), no infarct in 6 (6%), and 2 (2%) with imaging results not available (Table 3). At the subsequent stroke hospitalizations, the frequency of acute stroke treatments was as follows: 1% (1/94) thrombolytics and 5% (5/94) thrombectomy. The frequency of stroke complication management was 2% (2/94) craniectomy, 3% (3/94) tracheostomy, 3% (3/94) gastrostomy, and 10% (9/94) mechanical intubation. In the population of patients with a documented mRS or death at the stroke hospitalization (n=80), the median mRS score at the

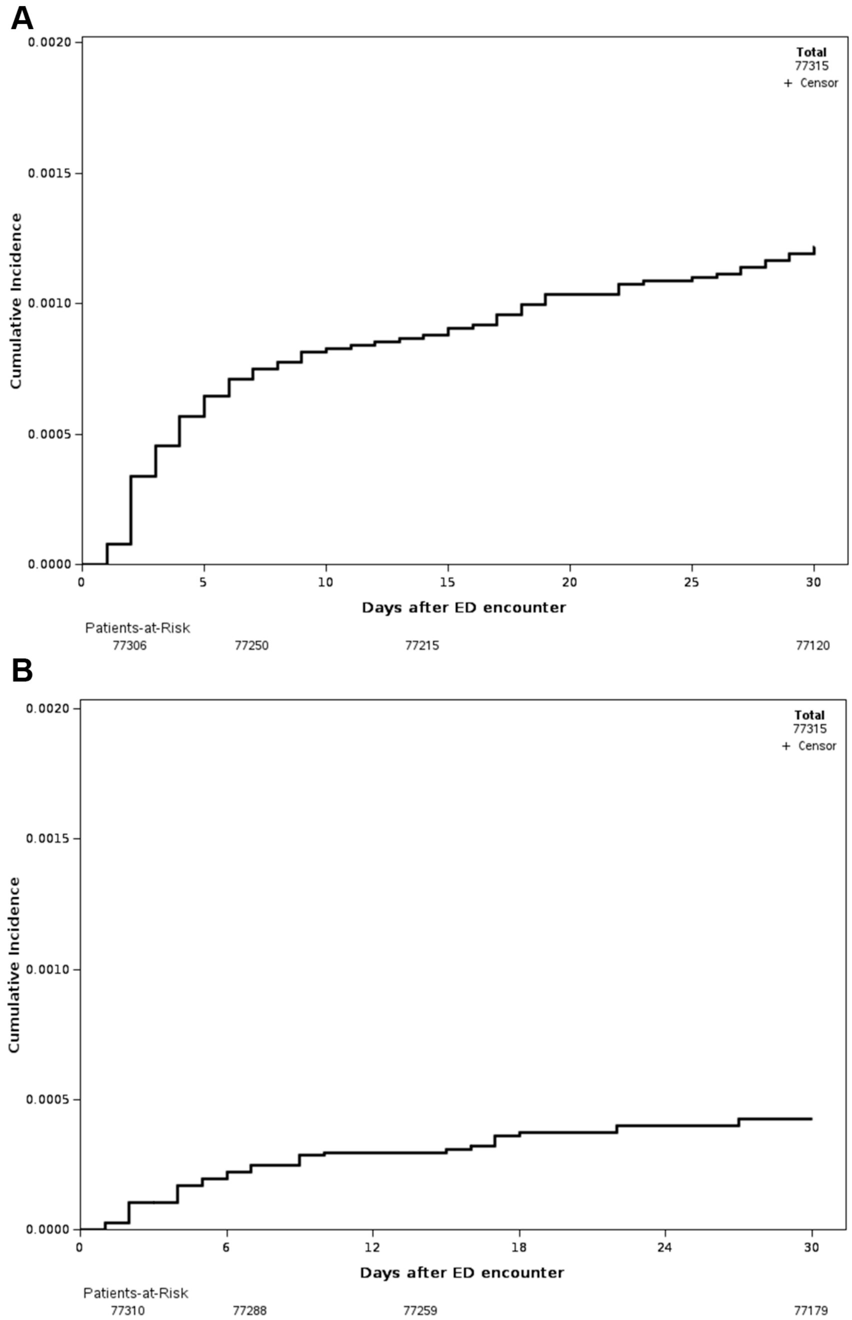

Figure 2. Cumulative incidence curve depicting stroke risk after emergency department dizziness presentations discharged home. Shaded areas represent 95% confidence intervals. *A*, Subsequent risk of stroke hospitalization. *B*, Subsequent risk of stroke hospitalization with mortality/disability.

time of the stroke hospitalization discharge was 2.5 (IQR: 0.0, 4.0). The median mRS was 1.0 (IQR: 0, 4) for those without stroke disability or death and 4.0 (IQR: 4, 5) for those with stroke mortality/death. mRS was missing for 11 (18%) of the nondisabled group and 3 (9%) of the disabled group because the events were at non-KPSC facilities. Overall, the majority of patients without missing mRS had scores at discharge indicating retained ability to walk without assistance (42 of 80; 53%). For the 11 patients classified as not disabled (based on the proxy of discharge location) but missing mRS scores, a manual review of the available medical records found that 6 had documentation of ambulating independently, 2 had no mention of problems with walking or other disability, and 3 had documentation of using a walker.

Table 3. Stroke characteristics, disability, frequency of stroke treatments, and stroke complication management in patients with a subsequent stroke hospitalization.

Type of Stroke	All Subsequent Stroke Hospitalizations (n=94)	Without Disability/Death (n=61)	With Disability/Death (n=33)
Stroke type*			
Ischemic stroke	73 (77.7%)	49 (80.3%)	24 (72.7%)
Intracerebral hemorrhage	13 (13.8%)	7 (11.5%)	6 (18.2%)
Subarachnoid hemorrhage	8 (8.5%)	5 (8.2%)	3 (9.1%)
Stroke location†			
Anterior fossa	52 (55%)	33 (54%)	19 (58%)
Posterior fossa	38 (40%)	25 (41%)	13 (39%)
No lesion on imaging	6 (6%)	4 (7%)	2 (6%)
No report/image available	2 (2%)	1 (2%)	1 (3%)
mRS (median, IQR) at stroke visit	2.5 (0.0, 4.0)	1.0 (0.0, 4.0)	4.0 (4.0, 5.0)†
Missing	14 (15%)	11 (18%)	3 (9%)
0, No symptoms	26 (33%)	20 (40%)	6 (20%)
1, No significant disability	6 (8%)	6 (12%)	0 (0%)
2, Unable to carry out all previous activities, but able to look after own affairs without assistance	5 (6%)	5 (10%)	0 (0%)
3, Requiring some help, but able to walk without assistance	5 (6.3%)	5 (10%)	0 (0%)
4, Unable to walk and attend to bodily needs without assistance	26 (33%)	13 (26%)	13 (43%)
5, Bedridden, incontinent and requiring constant nursing care and attention	5 (6%)	1 (2%)	4 (13%)
6, Dead	7 (9%)	0 (0%)	7 (23%)
Management at the subsequent stroke hospitalization			
Thrombolytic	1 (1%)	1 (2%)	0 (0%)
Thrombectomy	5 (5%)	1 (2%)	4 (12%)
Ventriculostomy	4 (4%)	0 (0%)	4 (12%)
Craniectomy	2 (2%)	0 (0%)	2 (6%)
Tracheostomy	3 (3%)	1 (2%)	2 (6%)
Gastrostomy	3 (3%)	1 (2%)	2 (6%)
Invasive mechanical ventilation	9 (10%)	1 (2%)	8 (24%)
All-cause 30-day death	7 (7%)	0 (0%)	7 (21%)

IQR, Interquartile range.
mRS was clinically assessed at the last physical therapy or occupational therapy session prior to discharge.
*Based on ICD-10 codes.
†Based neurologist manual review of imaging reports and scans.

LIMITATIONS

This study was limited by the retrospective design. Although the KPSC population has similar sociodemographics to the Southern California census population, our study population, including 43% Hispanics, may not be representative of the general population of patients visiting the ED for dizziness.[13] Specifically, research indicates that Hispanics have a higher stroke incidence than non-Hispanics but equal stroke recurrence.[21,22] The use of MRI at the index visit was 10%, which might increase capture of stroke relative to EDs with less frequent MRI use. In addition, frequent MRI use likely increases capture of stroke at subsequent visits. Some subsequent strokes may have been missed if patients did not seek medical evaluation; however, this is likely uncommon in our insured population. Missed stroke-related hospitalizations or deaths are also unlikely, given capture through in-network encounters, out-of-network claims, and the National Death Index. Our method to capture subsequent strokes (ie, ICD-10 codes) has a sensitivity generally more than 82% and specificity more than 95%.[17] As a result, some misclassification of stroke status is possible, although the absolute amount of misclassification is unlikely to meaningfully affect the cumulative incidence estimates. We limited the follow-up period to 30 days, which would exclude stroke hospitalizations occurring beyond that window. However, prior studies have shown that the cumulative incidence of stroke following ED visits for dizziness is concentrated within the first 7 to 14 days—when the risk of re-presentation due to an initial misdiagnosis is presumed to be highest.[8,10,23,24] Our primary measure of stroke-related disability (ie, discharge location) is routinely available and known to indicate stroke severity and functional impairment.[18-20] However, discharge location could have underestimated stroke disability in some patients because about one-fourth of those discharged home needed assistance (mRS more than or equal to 4). On the other hand, discharge location could have overestimated the final stroke disability level in other patients because hospital discharge typically occurs early in the recovery phase, about a fifth of those not discharged home did not need assistance based on the mRS, and prior population-based studies indicate that 8% to 10% of stroke patients have a pre-stroke mRS more than or equal to 4.[25,26]

DISCUSSION

In this study of more than 77,000 patients, we found that about 1 in 2,500 patients discharged home after an ED dizziness visit had a subsequent stroke hospitalization within 30 days that resulted in death or disability based on a disability proxy measure of discharge to a facility or hospice service. The very low estimated incidence of death or disability was aligned with additional findings: acute interventions used to treat severe strokes were very infrequent, and the functional status of most patients at the stroke hospitalization discharge was at the level of able to walk without assistance or better.

This study builds on the findings of previous reports about the cumulative incidence of stroke after ED dizziness visits by being, to our knowledge, the first to describe stroke outcomes in this circumstance.[8-11,23] Because dizziness as a stroke symptom is generally considered localizing to the posterior circulation, it was possible that disabling stroke would be typical as occurs with basilar occlusion or large cerebellar stroke. Instead, we found that most of the strokes after ED discharge for dizziness were not disabling even though our disability measure was taken from the time of hospital discharge prior to the end of expected functional improvement in the months after stroke.[27,28]

From the perspective of ED clinicians discharging patients at an index dizziness event, the incidence of missed stroke, and particularly missed stroke that results in disability or death, is a rare event. Furthermore, there are 2 important reasons that the actual incidence of *missed* stroke is likely even lower than the cumulative incidence of stroke. First, it is likely that some of the subsequent strokes are not related to the prior dizziness visit at all. A previous study indicates that at least 10% of the subsequent strokes are not related to the index dizziness event based on the relative incidence of subsequent strokes after ED visits for medical reasons compared with after ED visits for dizziness.[10] The proportion of subsequent strokes that are not related to the index dizziness visit may be even higher in our population because the proportion with ischemic stroke type was lower (78%) than the more than or equal to 90% expected with actual missed stroke presenting as dizziness.[3,23,29] Second, we should also assume that some of the subsequent strokes are only indirectly related to the index dizziness visit and therefore not considered missed at the index visit. For example, hypertension or diabetes could both cause nonstroke dizziness visit and also increase the risk of a subsequent stroke. This point is relevant because an indirect relationship means that the stroke was not present at the index visit and therefore was not missed. Lastly, the high prevalence of anterior fossa lesions indicates that a large proportion of the subsequent strokes were not missed cerebellar or brainstem strokes, which are the primary concerns for missed dizziness strokes.[30] This finding suggests that these strokes were either not directly related to the index dizziness visit or were related in a way that differs from the current construct that missed dizziness-stroke presentations typically stem from cerebellar or brainstem lesions.[30]

Our finding that potentially missed strokes, and particularly missed strokes that result in disability at discharge, are rare events contrasts with perspectives that frame the issue starting with the population diagnosed with stroke and then either look back for potentially missed events (eg, prior ED dizziness visits) or compare ED-documented diagnosis to neurologist-documented diagnosis.[7] A recent report published by the Agency for Healthcare Research and Quality used those framings to make a rough estimate that up to 40% of patients with stroke presenting with dizziness/vertigo are initially missed.[7] The framing that starts with the outcome event rather than the exposure event is misleading when the data are being used to identify or justify priorities for intervention efforts. That framing is misleading because it does not use the proper denominator (ie, the population at risk) that is necessary when judging the effect of potential interventions on future events. Instead, starting with the exposure event and determining the probability of the outcome can be used to precisely judge the potential effect of future interventions and also key information such as calculating the sample size in interventional studies.

Our findings are relevant for efforts to develop stroke decision support specifically for dizziness. It is the very low incidence of subsequent stroke, particularly the low incidence of subsequent stroke with death or disability that is attributable to missed stroke at the index visit, that poses 2 major challenges for efforts to maximize the accuracy of stroke diagnosis at index dizziness visits using diagnostic tools. The first challenge caused by these low outcome event rates is that a large sample size would be required to properly test the result of any intervention on these stroke outcomes. Such a study would need more than 200,000 index dizziness visits for adequate power to detect even a robust 50% reduction in risk of subsequent stroke disability/mortality. Smaller reductions would require an even higher sample size given the very low event rate. A second major challenge of the low incidence of outcome events is that the use of even a nearly perfect diagnostic test would be expected to result in many more false positive stroke classifications than true positives. If a test with 98% sensitivity and 99% specificity was applied in this population, we should expect 25 false positives for every 1 true positive. This ratio would plummet to 250 to 1 if the specificity in routine practice was as low as 90%.

A method to mitigate the challenges mentioned about decision support in identifying stroke at ED dizziness visits would be to focus specifically on patients with a much higher pretest probability of stroke. There is some concern that patients diagnosed with a dizziness symptom (ie, R42) or those with a peripheral vestibular disorder are at high risk of missed stroke.[10] However, we found that patients discharged with these diagnoses are still at a very low risk of having a subsequent stroke or stroke death/disability. Characteristics that have been shown to define a high risk of stroke among patients presenting with dizziness are new onset symptoms, no obvious medical cause, a negative Dix-Hallpike test for benign paroxysmal positional vertigo, and either nystagmus (spontaneous or gaze evoked) or new imbalance. Patients with these characteristics have about a 10% probability of stroke on imaging from a study that used both clinical and research MRIs to identify stroke.[3] Vascular risk factors also clearly increase the probability of stroke.[3,31,32] In patients with a 10% probability of stroke, a diagnostic test with 90% sensitivity and specificity would produce only one false positive for every true positive. Although these characteristics define a higher risk for stroke population, it is possible that ED clinicians are already accurately identifying high-risk patients. Because it is possible that the missed rate is actually low and the stroke management in this context is usually focused on optimizing medical management of vascular risk, a broader focus on pragmatic therapeutics (eg, reducing vascular risk among all or most patients with ED dizziness visits) might ultimately be more effective and efficient at preventing future stroke than a focus on precision diagnosis.

In conclusion, the cumulative incidence of stroke hospitalization with disability/mortality for patients discharged from the ED to home after an ED dizziness visit is very low. These data are important for contextualizing efforts to optimize outcomes of patients presenting to the ED for dizziness.

The authors thank the patients of Kaiser Permanente for helping to improve care through the use of information collected through our electronic health record systems.

Supervising editor: Robert D. Welch, MD, MS. Specific detailed information about possible conflict of interest for individual editors is available at https://www.annemergmed.com/editors.

Author affiliations: From the Department of Neurology (Kerber, Burke), Ohio State University, Columbus, OH; Department of Neurology (Sangha, Manthena), Kaiser Permanente Southern California, Los Angeles Medical Center, Los Angeles, CA; Department of Emergency Medicine (Jancis), Kaiser Permanente Southern California, Los Angeles Medical Center, Los Angeles, CA; Department of Research and Evaluation (Baecker, Shen, Nguyen, Park), Kaiser Permanente Southern California, Pasadena, CA; Department of Neurology (Monjazeb), Kaiser Permanente Southern California, Los Angeles Medical Center, Los Angeles, CA; Galvan Health (Sharp), Los Angeles, CA; Department of Emergency Medicine (Meurer), University of Michigan Health System, Ann Arbor, MI.

Author contributions: KK, WM, AS, JB, AB, and ES conceived and designed the study. AB performed the data analysis. KK drafted the initial manuscript and made final editorial decisions; all authors contributed substantially to its revision. KK, WM, and HN are the study's principal investigators. KK takes responsibility for the study as a whole.

All authors attest to meeting the four ICMJE.org authorship criteria: (1) Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND (2) Drafting the work or revising it critically for important intellectual content; AND (3) Final approval of the version to be published; AND (4) Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Data sharing statement: The data are available for use through collaboration with the KPSC study investigators under the conditions of sufficient funding by the requestor and data use

agreements between all institutions that govern data access, storage, and short- and long-term use. Qualified researchers trained in human subject confidentiality protocols interested in collaborating with the KPSC study team can contact Dr. Huong Nguyen (huong.q2.nguyen@kp.org).

Funding and support: By *Annals'* policy, all authors are required to disclose any and all commercial, financial, and other relationships in any way related to the subject of this article as per ICMJE conflict of interest guidelines (see www.icmje.org). Research reported in this publication was supported by the National Institute on Deafness and Other Communication Disorders of the National Institutes of Health under Award Number R01DC012760. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. The authors have declared that no competing interests exist.

Publication dates: Received for publication March 18, 2025. Revisions received June 18, 2025, and September 9, 2025. Accepted for publication September 19, 2025.

Presentation information: An abstract version of this work was presented at the 2023 International Stroke Conference, February 8-10, 2023 in Dallas, Texas.

REFERENCES

1. Kerber KA, Meurer WJ, West BT, et al. Dizziness presentations in U.S. emergency departments, 1995-2004. *Acad Emerg Med*. 2008;15:744-750.
2. Kerber KA, Brown DL, Lisabeth LD, et al. Stroke among patients with dizziness, vertigo, and imbalance in the emergency department: a population-based study. *Stroke*. 2006;37:2484-2487.
3. Kerber KA, Meurer WJ, Brown DL, et al. Stroke risk stratification in acute dizziness presentations: a prospective imaging-based study. *Neurology*. 2015;85:1869-1878.
4. Tarnutzer AA, Berkowitz AL, Robinson KA, et al. Does my dizzy patient have a stroke? A systematic review of bedside diagnosis in acute vestibular syndrome. *CMAJ*. 2011;183:E571-E592.
5. Eagles D, Stiell IG, Clement CM, et al. International survey of emergency physicians' priorities for clinical decision rules. *Acad Emerg Med*. 2008;15:177-182.
6. Finnerty NM, Rodriguez RM, Carpenter CR, et al. Clinical decision rules for diagnostic imaging in the emergency department: a research agenda. *Acad Emerg Med*. 2015;22:1406-1416.
7. Newman-Toker D, Peterson SM, Badihian S, et al. Diagnostic errors in the emergency department: a systematic review. Comparative Effectiveness Review No. 258. (Prepared by the Johns Hopkins University Evidence-based Practice Center under Contract No. 75Q80120D00003.) AHRQ Publication No. 22(23)-EHC043. Rockville, MD: Agency for Healthcare Research and Quality; December 2022. 2022. https://doi.org/10.23970/AHRQEPCCER258.
8. Kim AS, Fullerton HJ, Johnston SC. Risk of vascular events in emergency department patients discharged home with diagnosis of dizziness or vertigo. *Ann Emerg Med*. 2011;57:34-41.
9. Grewal K, Austin PC, Kapral MK, et al. Missed strokes using computed tomography imaging in patients with vertigo: population-based cohort study. *Stroke*. 2015;46:108-113.
10. Atzema CL, Grewal K, Lu H, et al. Outcomes among patients discharged from the emergency department with a diagnosis of peripheral vertigo. *Ann Neurol*. 2016;79:32-41.
11. Lee CC, Su YC, Ho HC, et al. Risk of stroke in patients hospitalized for isolated vertigo: a four-year follow-up study. *Stroke*. 2011;42:48-52.
12. Savitz SI, Caplan LR, Edlow JA. Pitfalls in the diagnosis of cerebellar infarction. *Acad Emerg Med*. 2007;14:63-68.
13. Koebnick C, Langer-Gould AM, Gould MK, et al. Sociodemographic characteristics of members of a large, integrated health care system: comparison with US Census Bureau data. *Perm J*. 2012;16:37-41.
14. Edlow JA, Newman-Toker DE, Savitz SI. Diagnosis and initial management of cerebellar infarction. *Lancet Neurol*. 2008;7:951-964.
15. Gottesman RF, Sharma P, Robinson KA, et al. Clinical characteristics of symptomatic vertebral artery dissection: a systematic review. *Neurologist*. 2012;18:245-254.
16. Zachrison KS, Li S, Reeves MJ, et al. Strategy for reliable identification of ischaemic stroke, thrombolytics and thrombectomy in large administrative databases. *Stroke Vasc Neurol*. 2021;6:194-200.
17. McCormick N, Bhole V, Lacaille D, et al. Validity of diagnostic codes for acute stroke in administrative databases: a systematic review. *PLoS One*. 2015;10:e0135834.
18. Burton JK, Ferguson EEC, Barugh AJ, et al. Predicting discharge to institutional long-term care after stroke: a systematic review and metaanalysis. *J Am Geriatr Soc*. 2018;66:161-169.
19. Tseng HP, Lin FJ, Chen PT, et al. Derivation and validation of a discharge disposition predicting model after acute stroke. *J Stroke Cerebrovasc Dis*. 2015;24:1179-1186.
20. ElHabr AK, Katz JM, Wang J, et al. Predicting 90-day modified Rankin Scale score with discharge information in acute ischaemic stroke patients following treatment. *BMJ Neurol Open*. 2021;3:e000177.
21. Morgenstern LB, Smith MA, Lisabeth LD, et al. Excess stroke in Mexican Americans compared with non-Hispanic Whites: the Brain Attack Surveillance in Corpus Christi Project. *Am J Epidemiol*. 2004;160:376-383.
22. Sozener CB, Lisabeth LD, Shafie-Khorassani F, et al. Trends in stroke recurrence in Mexican Americans and non-Hispanic whites. *Stroke*. 2020;51:2428-2434.
23. Kerber KA, Zahuranec DB, Brown DL, et al. Stroke risk after nonstroke emergency department dizziness presentations: a population-based cohort study. *Ann Neurol*. 2014;75:899-907.
24. Kerber KA, Damschroder L, McLaughlin T, et al. Implementation of evidence-based practice for benign paroxysmal positional vertigo in the emergency department: a stepped-wedge randomized trial. *Ann Emerg Med*. 2020;75:459-470.
25. Myint PK, Clark AB, Kwok CS, et al. The SOAR (Stroke subtype, Oxford Community Stroke Project classification, Age, prestroke modified Rankin) score strongly predicts early outcomes in acute stroke. *Int J Stroke*. 2014;9:278-283.
26. Quinn TJ, Taylor-Rowan M, Coyte A, et al. Pre-stroke modified Rankin scale: evaluation of validity, prognostic accuracy, and association with treatment. *Front Neurol*. 2017;8:275.
27. Hankey GJ, Spiesser J, Hakimi Z, et al. Rate, degree, and predictors of recovery from disability following ischemic stroke. *Neurology*. 2007;68:1583-1587.
28. Dhamoon MS, Moon YP, Paik MC, et al. Long-term functional recovery after first ischemic stroke: the Northern Manhattan Study. *Stroke*. 2009;40:2805-2811.
29. Kerber KA, Burke JF, Brown DL, et al. Does intracerebral haemorrhage mimic benign dizziness presentations? A population based study. *Emerg Med J*. 2012;29:43-46.
30. Edlow JA, Carpenter C, Akhter M, et al. Guidelines for reasonable and appropriate care in the emergency department 3 (GRACE-3): acute dizziness and vertigo in the emergency department. *Acad Emerg Med*. 2023;30:442-486.
31. Ohle R, Savage DW, Roy D, et al. Development of a clinical risk score to risk stratify for a serious cause of vertigo in patients presenting to the emergency department. *Ann Emerg Med*. 2025;85:122-131.
32. van Patot ET, Roy D, Baraku E, et al. Validation of the Sudbury Vertigo Risk Score to risk stratify for a serious cause of vertigo. *Acad Emerg Med*. 2025;32:863-873.