

Clinical and electrographic findings in epileptic vertigo and dizziness

A systematic review



Alexander A. Tarnutzer,
MD
Seung-Han Lee, MD
Karen A. Robinson, PhD
Peter W. Kaplan, MD
David E. Newman-Toker,
MD, PhD

Correspondence to
Dr. Tarnutzer:
alexander.tarnutzer@access.uzh.ch

ABSTRACT

Objective: Seizures can cause vestibular symptoms, even without obvious epileptic features. We sought to characterize epileptic vertigo or dizziness (EVD) to improve differentiation from nonepileptic causes, particularly when vestibular symptoms are the sole manifestation.

Methods: We conducted a systematic review with electronic (Medline) and manual search for English-language studies (1955–2014). Two independent reviewers selected studies. Study/patient characteristics were abstracted. We defined 3 study population types: (1) seizures, some experiencing vertigo/dizziness (disease cohort); (2) vertigo/dizziness, some due to seizures (symptom cohort); (3) vertigo/dizziness due to seizures in all patients (EVD-only cohort).

Results: We identified 84 studies describing 11,354 patients (disease cohort = 8,129; symptom cohort = 2,965; EVD-only cohort = 260). Among 1,055 EVD patients in whom a distinction could be made, non-isolated EVD was present in 8.5%, isolated EVD in 0.8%. Thorough diagnostic work-ups (ictal EEG, vestibular testing, and brain MRI to exclude other causes) were rare (<0.1%). Ictal EEG was reported in 487 (4.3%), formal neuro-otologic assessment in 1,107 (9.7%). Localized EEG abnormalities (n = 350) were most frequently temporal (79.8%) and uncommonly parietal (11.8%). Duration of episodic vestibular symptoms varied, but was very brief (<30 seconds) in 69.6% of isolated EVD and 6.9% of non-isolated EVD.

Conclusions: Non-isolated EVD is much more prevalent than isolated EVD, which appears to be rare. Diagnostic evaluations for EVD are often incomplete. EVD is primarily associated with temporal lobe seizures; whether this reflects greater epidemiologic prevalence of temporal lobe seizures or a tighter association with dizziness/vertigo presentations than with other brain regions remains unknown. Consistent with clinical wisdom, isolated EVD spells often last just seconds, although many patients experience longer spells. *Neurology*® 2015;84:1595–1604

GLOSSARY

AED = antiepileptic drug; **EVD** = epileptic vertigo or dizziness; **i-EVD** = isolated epileptic vertigo or dizziness; **ni-EVD** = non-isolated epileptic vertigo or dizziness.

Vertigo (defined as a sensation of self-motion when no self-motion is occurring or as the sensation of distorted self-motion during an otherwise normal head movement)¹ or dizziness (defined as a sensation of disturbed or impaired spatial orientation without a false/distorted sense of motion)¹ are common symptoms, often reported by patients known to have epileptic seizures. These vestibular symptoms may be related to the seizure itself (i.e., representing an aura symptom), to side effects of antiepileptic drug (AED) therapy, or may be linked to a second, comorbid nonepileptic disorder (e.g., vestibular migraine). Episodic vestibular symptoms deemed to result directly from focal, intermittent epileptic discharges have been variously known as epileptic vertigo,² vestibular epilepsy,³ vestibular seizures,⁴ vertiginous seizures,^{4–6} or epilepsy tornado.⁷ In this article, we use the more inclusive term epileptic vertigo or dizziness (EVD).

Seminal work by Penfield and Jasper⁸ established the scientific basis for understanding the pathophysiology of EVD. By means of surface electrical stimulation, they elicited illusionary

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From the Department of Neurology (A.A.T.), University Hospital Zurich and the University of Zurich, Switzerland; the Department of Neurology (S.-H.L.), Chonnam National University Medical School, Gwangju, South Korea; the Departments of Medicine (K.A.R.), Neurology (D.E.N.-T.), and Otolaryngology Head & Neck Surgery (D.E.N.-T.), The Johns Hopkins University School of Medicine; and the Department of Neurology (P.W.K.), Johns Hopkins Bayview Medical Center, Baltimore, MD.

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transient sensations of rotation, translation, or undirected motion in their patients, mapping the extent of the vestibular cortex and demonstrating that seizures cause vertigo/dizziness because they lead to hyperactivity in vestibular cortical areas. They described EVD during both temporal and parietal lobe stimulation. These cortical areas were confirmed by Kahane et al.,⁹ reporting vestibular sensations after electrical stimulation centered around a lateral cortical temporo-parietal area, known as the temporo-peri-Sylvian vestibular cortex. Less frequently, Kahane et al. found vestibular sensations by stimulating within the occipital, frontal, and insular cortex. Congruent but somewhat more expansive than these experimentally derived results, epileptic discharges on ictal EEG in symptomatic EVD were individually localized to frontal,² frontotemporal,¹⁰ temporal,^{11,12} temporo-parieto-occipital,¹³ and

parietal¹⁴ areas, suggesting either processing of vestibular-related input across large cortical regions¹⁵ or spread of excitation to or from nearby regions. Lesion studies in humans provide additional insights into the extent of cortical network processing of vestibular/graviceptive inputs. Insular and parietal lesions dominate the literature on vertigo/dizziness from stroke,¹⁶ including the seminal study of Brandt et al.,¹⁷ reporting shifts in perceived verticality in lesions affecting the posterior insula.

The differential diagnosis for isolated episodic vertigo/dizziness is broad and cuts across medical specialties, including neurology (vestibular migraine, TIA, seizures), otolaryngology (Meniere disease, vestibular paroxysmia), internal medicine (hypoglycemia), cardiology (arrhythmia), and psychiatry (panic attacks), so knowing when (or when not) to consider EVD would be helpful. When obvious seizure-related symptoms or signs (e.g., a generalized convulsion) accompany vestibular symptoms, EVD is readily recognized. EVD causing isolated vestibular symptoms was reported,^{2,18,19} but there is limited information about prevalence and clinical characteristics (e.g., accompanying symptoms, duration) that might help distinguish it from nonepileptic causes.

We performed a systematic review of studies reporting on (1) vestibular symptoms in seizure patients (disease cohort), (2) seizures in vestibular patients (symptom cohort), and (3) clinical details in reports of patients with EVD (EVD-only cohort). The aim of this work was to better characterize the prevalence of non-isolated EVD (ni-EVD) and isolated EVD (i-EVD) in adults and children, seizure localization, and episode duration.

METHODS A MEDLINE search was performed (April 2014) to identify articles reporting on EVD using terms related to seizures/epilepsy and vertigo/dizziness. Both retrospective and prospective case series and single case reports were eligible. Studies sought for reported on the differential diagnosis of dizzy patients or on aura symptoms in patients with a given type of epilepsy. Specific search terms and inclusion/exclusion criteria can be found in appendix e-1 on the *Neurology*[®] Web site at Neurology.org. We identified 1,137 electronic citations for screening and included 84 studies (appendix e-1; flow chart). When extracting the data from the selected studies, we assessed the type of the study, whether the vestibular symptoms were isolated or accompanied by other seizure symptoms, the duration of EVD episodes, and EEG findings. In all EVD patients, we rated the quality of EEG and

Table 1 Rating of EEG and vestibular assessment and strength of association between seizures and vertigo/dizziness

Quality of EEG assessment	
High	Ictal (symptomatic ^a) EEG recordings
Medium	Interictal EEG recordings
Low	No EEG recordings noted ^b
Quality of vestibular evaluation	
Complete	Vestibular evaluation by a subspecialist neuro-otologist or specific description of vestibular testing that includes a measure of vestibulo-ocular reflex function (e.g., caloric tests or head impulse tests) and a search for nystagmus with suppression of visual fixation (e.g., Frenzel goggles) and positional tests
Partial	Any mention of neuro-otologic testing short of complete
None	No mention of any testing for vestibular disorders
Strength of association between seizures and dizziness/vertigo	
High	Ictal EEG demonstrating epileptiform discharges at the time of vertigo/dizziness
Medium	Episodic vertigo/dizziness with an ictal (nonvestibular symptoms) or interictal EEG demonstrating epileptiform discharges
Low	Episodic vertigo/dizziness with a clinical diagnosis of seizures/epilepsy (no confirmation by EEG or no EEG obtained ^c)

^aIctal EEG recordings may have been taken during nonvestibular seizures.

^bIf the report was unclear, the quality of EEG assessment was recorded as low.

^cIf the report was unclear, the strength of association was coded as low.

Table 2 Characterization of study sample

	Adults	Children	Age NR	Total
Study cohorts				
Disease cohort (seizures)	2,162	70	5,897	8,129
Symptom cohort (dizziness/vertigo)	920	596	1,449	2,965
EVD-only cohort	50	21	189	260
All cohorts pooled	3,132	687	7,535	11,354
Imaging				
Brain MRI	486	26	372	884
Brain CT	78	40	296	414
SPECT	32	1	0	33
Modality unclear	0	55	174	229
All brain imaging pooled	596	122	842	1,560
Reported diagnosis in dizzy patients^{a,b,c}				
Other disorders	10	25	857	892
Benign paroxysmal positional vertigo	1	10	391	402
Meniere disease	2	3	193	198
Psychogenic	13	24	130	167
Migraine ^d	7	85	56	148
Secondary to head trauma	22	104	12	138
Benign paroxysmal vertigo of childhood	0	95	4	99
Vestibular neuritis	12	20	65	97
Unresolved	15	23	55	93
Various cerebrovascular disorders	3	0	72	75
Labyrinthitis	1	53	8	62
Cerebellopontine angle tumors	4	27	4	35
Otitis media	10	5	15	30
Secondary to ototoxic substances	1	20	8	29
Multiple sclerosis	1	0	20	21
Meningitis	1	3	1	5
Perilymph fistula	1	4	0	5
Delayed endolymphatic hydrops	0	2	1	3
All diagnoses pooled	104	503	1,892	2,499

Abbreviations: EVD = epileptic vertigo or dizziness; NR = not reported.

^a Seizures are reported separately in tables 4 and 5.

^b Complete or partial vestibular evaluation was available from 29 studies. From those, specific diagnoses related to dizziness/vertigo were available in 12 studies (all belonging to the symptom cohort). Two other studies provided diagnoses in the dizzy patient only on the level of categories (peripheral-vestibular disorders, central disorders).^{57,58} The results from these studies are not shown in this table. In addition, 2 patients from the disease cohort and from the combined cohort each were diagnosed with migraine.

^c All except 3 of those patients belonged to the symptom cohort.

^d A diagnosis of migraine (no further distinction among migraine headaches, vestibular migraine, basilar-type migraine, or other) was made in 148 patients; however, the criteria applied to obtain a diagnosis of migraine were not specified. From these 148 patients, 147 had both migraine headaches and episodic dizziness, fulfilling the current international diagnostic criteria for possible vestibular migraine.⁵⁹

vestibular assessment and the quality of the association between seizures and vertigo/dizziness (table 1).

A single expert epileptologist (P.W.K.) assessed all published EEG recordings from the included studies for quality to establish a definitive diagnosis of EVD. Seizure location and laterality was

retrieved where EEG recordings were available and were coded as temporal, parietal, occipital, or frontal in origin. If the reported seizure location was linked to more than one of these areas (e.g., frontotemporal), a count was given to each lobe for calculating the relative frequency of discharges in different lobes.

RESULTS Demographic information. Eighty-four studies reporting on 11,354 patients matched the inclusion criteria (appendix e-2, table e-1, and table e-2). The majority of these 84 studies were retrospective case series (n = 52, 61.9%) or single cases (n = 26, 31.0%) (table e-1). The remaining 6 studies were prospective (n = 5, 6.0%) or ambispective (n = 1, 1.2%) case series. Retrospective case series were the most frequent study type both in the disease (81.1%, study size = 1–1,563 patients) and the symptom (83.3%, study size = 8–907 patients) cohort, while prospective case series were rare in either cohort (disease cohort: 8.1%, study size = 3–1,897; symptom cohort: 11.1%, study size = 70–142). Overall, 71.6% of patients were in the disease cohort, while 26.1% were in the symptom cohort. The remaining 2.3% fulfilled criteria for the EVD-only cohort (table 1). The distribution of adult and pediatric patients among the cohorts was distinct: 69% of all adults belonged to the disease cohort; 87% of all children were part of the symptom cohort. Various other diagnoses were reported in 2,499 patients (table 2).

Diagnostic testing. EEG findings were reported in 50.9% of patients. Surface recordings were available in 50.1%, intracranial recordings in 2.7%. We judged the quality of EEG assessment based on the presence/absence of EEG-documented seizures and clinical findings during these seizures. A high-quality (ictal) EEG assessment was found in 4.3%, a medium-quality (interictal) EEG assessment in 46.6%. In 49.1%, the electrographic assessment was considered low quality, and the diagnosis of seizures was made on the clinical history alone (table 3).

Neuroimaging was available in 13.7%, vestibular testing in 26.3% (table 3). In many of these patients, results from vestibular testing were not reported and only in 4 patients (0.04%) was complete vestibular testing accompanied by ictal EEG and MRI.

Fraction of patients with ni-EVD and i-EVD. From 11,354 patients included (disease cohort = 8,129; symptom cohort = 2,965; EVD-only cohort = 260), 1,055 patients (9.3%) had EVD, and were coded as ni-EVD (n = 967, 8.5% of total) or i-EVD (n = 88, 0.8% of total) (table 4). Of all EVD patients, 64.7% were in the disease cohort, 10.7% were in the symptom cohort. The frequency for diagnosing i-EVD or ni-EVD was about 2-fold greater for patients in the disease cohort (683/8,129, 8.4%) relative to the symptom cohort (113/2,965, 3.8%).

Table 3 Summary of vestibular and EEG assessment

	Patients, n			
	Adults	Children	Age NR	Total
Quality of EEG assessment				
High (ictal EEG)				
Disease cohort (IC seizures) ^a	150	9	314	473
Symptom cohort (IC vertigo/dizziness) ^b	0	0	0	0
EVD-only cohort ^c	7	7	0	14
All cohorts pooled	157	16	314	487
Medium (interictal EEG)				
Disease cohort (IC seizures) ^a	335	42	4,385	4,762
Symptom cohort (IC vertigo/dizziness) ^b	307	124	0	431
EVD-only cohort ^c	42	14	43	99
All cohorts pooled	684	180	4,428	5,292
Low (no EEG)				
Disease cohort (IC seizures) ^a	1,717	19	1,158	2,894
Symptom cohort (IC vertigo/dizziness) ^b	755	472	1,307	2,534
EVD-only cohort ^c	1	0	146	147
All cohorts pooled	2,473	491	2,611	5,575
Extent of vestibular assessment				
Complete				
Disease cohort (IC seizures) ^a	1	0	29	30
Symptom cohort (IC vertigo/dizziness) ^b	106	506	400	1,012
EVD-only cohort ^c	20	15	30	65
All cohorts pooled	127	521	459	1,107
Partial				
Disease cohort (IC seizures) ^a	48	0	0	48
Symptom cohort (IC vertigo/dizziness) ^b	160	69	1,596	1,825
EVD-only cohort ^c	1	0	0	1
All cohorts pooled	209	69	1,596	1,874
None				
Disease cohort (IC seizures) ^a	4,013	70	3,841	7,924
Symptom cohort (IC vertigo/dizziness) ^b	127	1	127	255
EVD-only cohort ^c	29	6	159	194
All cohorts pooled	4,169	77	4,127	8,373

Abbreviations: EVD = epileptic vertigo or dizziness; IC = inclusion criteria; NR = not reported.

^aThis cohort contains patients from studies that had a diagnosis of seizures as IC and the study reported on vertigo or dizziness.

^bThis cohort contains patients from studies that had dizziness or vertigo as IC and the study reported on seizures.

^cThis cohort includes patients from studies that required both the presence of vertigo or dizziness and seizures as inclusion criteria.

In the study sample, the overall fraction of EVD in children (73/687, 10.6%) and adults (300/3,132, 9.6%) was similar, but the distribution was heterogeneous across study cohorts. In the symptom cohort, EVD was diagnosed nearly 9-fold more often in children (52/596, 8.7%) than in adults (9/920, 1.0%);

by contrast, in the disease cohort, EVD was diagnosed just 1.3-fold more often in children (11/70, 15.7%) than adults (253/2,162, 11.7%).

Quality of the association between epilepsy and vertigo/dizziness. From all EVD patients, a high-quality association was found in 4.1% (43/1,055), while medium (512/1,055, 48.5%) or low (500/1,055, 47.4%) quality was noted in the remaining 95.9%. Published EEG traces from EVD cases ($n = 33$) were reviewed. From the 14 EEG recordings originally rated as ictal, this was confirmed in 11, while in 2 cases^{19,20} the EEG data presented was only probably consistent with an ongoing seizure and in one case²¹ no seizure was depicted. Diagnosis in the remaining 19 cases (interictal EEG changes) was confirmed.

Seizure location. Results from ictal/interictal EEG recordings were available in 580 EVD patients (table 5). EEG seizure locations ($n = 350$) were assigned as described in the Methods. Since more than one location was reported in 73 patients, the total count ($n = 391$) exceeded the number of EVD patients with localized EEG changes. The most frequent location was temporal (79.8%); parietal (11.8%), occipital (5.4%), and frontal (3.1%) seizures were found in small fractions.

Lateralization of focal EEG changes. From the 350 EVD cases with localized EEG changes, the side of the EEG focus was reported in 126 (36.0%). Right-hemisphere ($n = 51$) and left-hemisphere ($n = 57$) seizure foci occurred with similar frequency (40.5% vs 45.2%, Fisher exact $p = 0.50$). In 18 cases, a bihemispheric focus was observed. In ni-EVD ($n = 86$; 10 bilateral foci), right- and left-hemisphere foci had identical frequency ($n = 38$, 44.2% each). For i-EVD ($n = 40$; 8 bilateral foci), left-hemispheric foci were slightly more frequent than right-hemispheric foci (19 vs 13; 47.5% vs 32.5%, $p = 0.21$).

For cases with information on sidedness of focal EEG changes ($n = 126$), we assessed laterality by seizure location (total of 163 locations recorded). There were clinically meaningful but not statistically significant differences in sidedness based on the seizure location (right % [n] vs left % [n]): (1) temporal (37.8% [37] vs 44.9% [44], $p = 0.35$); (2) parietal (59.0% [23] vs 35.9% [14], $p = 0.06$); (3) occipital (62.5% [10] vs 25% [4], $p = 0.06$); and (4) frontal (30.0% [3] vs 70.0% [7], $p = 0.18$).

Duration of EVD and effect of treatment. Specific numbers on EVD duration were available in 108 patients (table 5). Comparing i-EVD and ni-EVD cases, brief spell duration (≤ 30 seconds) was noted in a much larger fraction in i-EVD cases than ni-EVD cases (69.6% vs 6.9%, $p < 0.001$).

Effect of treatment with various AEDs was reported in 110 patients (10.4%), with 90.0% considered

Table 4 Distribution of patients with EVD with regards to strength of association between EVD and EEG

	Diagnosis of non-isolated EVD, strength of association, ^a n				Diagnosis of isolated EVD, strength of association, n				All diagnoses of EVD, strength of association, n			
	High	Medium	Low	All	High	Medium	Low	All	High	Medium	Low	All
Symptom cohort (n = 2,965)												
Adults	0	4	5	9	0	0	0	0	0	4	5	9
Children	0	38	11	49	0	3	0	3	0	41	11	52
Age NR	0	3	48	51	0	1	0	1	0	4	48	52
% of cohort	0.0	1.5	2.2	3.7	0.0	0.1	0.0	0.1	0.0	1.7	2.2	3.8
Disease cohort (n = 8,129)												
Adults	13	69	155	237	3	13	0	16	16	82	155	253
Children	3	4	3	10	1	0	0	1	4	4	3	11
Age NR	13	262	131	406	0	13	0	13	13	275	131	419
% of cohort	0.4	4.1	3.6	8.0	0.0	0.3	0.0	0.4	0.4	4.4	3.6	8.4
EVD-only cohort (n = 260)												
Adults	2	28	1	31	2	5	0	7	4	33	1	38
Children	3	4	0	7	3	0	0	3	6	4	0	10
Age NR	0	21	146	167	0	44	0	44	0	65	146	211
% of cohort	1.9	20.4	56.6	78.8	1.9	18.8	0.0	20.8	3.8	39.2	56.5	99.6
All cohorts pooled												
No. identified cases (all ages pooled)	34	433	500	967	9	79	0	88	43	512	500	1,055
% of all cohorts	0.3	3.8	4.4	8.5	0.1	0.7	0.0	0.8	0.4	4.5	4.4	9.3

Abbreviations: EVD = epileptic vertigo or dizziness; NR = not reported.

^aStrength of association between EVD and EEG: high (dizziness or vertigo during EEG-documented seizure), medium (episodic dizziness or vertigo in a patient with EEG-confirmed seizures), low (episodic dizziness or vertigo in a patient with clinical diagnosis of seizures—may have had also normal EEG), all (high, medium, and low combined).

responders. Among responders with details on drug treatment (n = 54), phenytoin (n = 16), carbamazepine (n = 12), and valproate (n = 5) were applied most often (table e-2).

Type of vestibular and accompanying seizure symptoms.

A majority of studies did not provide definitions of the terms used to describe the vestibular spells (9,506 patients, 83.7%), including vertigo or vertiginous (6,302, 55.5%), dizziness (93, 0.8%), and vertigo or dizziness (3,114, 27.4%). Definitions for vertigo and dizziness were provided in 9 studies (vertigo = 304 patients [2.7%], dizziness = 2 patients [0.2%]) (appendix e-1). In 3 studies (1,539, 13.6%), the 4 categories brought forward by Drachman and Hart²² (dizziness vs vertigo vs lightheadedness vs faintness) were used. From the 1,055 EVD patients, definitions for vertigo (n = 135, 12.8%) and dizziness (n = 2, 0.2%) were provided in 137. Information about other seizure symptoms/signs occurring in the same epileptic attack could be retrieved from 171 EVD patients (table 6).

DISCUSSION Our systematic review of EVD in the medical literature offers quantitative confirmation for

the clinical intuition that EVD is uncommon, and isolated EVD is rare (although it is probably more prevalent in children presenting vestibular symptoms than in adults). It further confirms that, when EVD is isolated, episodes are most often very brief (lasting seconds), although our results also suggest that longer episodes (lasting minutes) are not uncommon. This study suggests 2 other findings that are somewhat unexpected: (1) epileptic foci causing EVD are much more likely to be temporal than parietal, and (2) they are equally likely to originate in the right and left hemispheres. These results may assist clinicians in determining whether their patients presenting vertigo or dizziness should be evaluated for seizures and whether those with epilepsy require further vestibular assessment.

EVD prevalence in adults and children. We cannot draw strong inferences about the incidence or prevalence of EVD in the general population, but our data offer some insights into the epidemiology of EVD. First, ni-EVD appears to be uncommon in both symptom (3.7%) and disease (8.0%) cohorts; since some of these might have actually been missed comorbid vestibular disorders (see below), and studies not reporting vertigo/dizziness in epilepsy or epilepsy in dizziness (i.e., with lower

Table 5 EEG findings in patients with ni-EVD or i-EVD and duration of dizzy spells

	ni-EVD, n (%)	i-EVD, n (%)	All EVD, n (%)
EEG findings in EVD			
No. of EEGs in EVD (% all EVD cases)^a			
All EEGs	459 (47.5)	75 (85.2)	580 (55.0)
EEGs with localized pathologies ^b	291 (30.1)	43 (48.9)	350 (33.2)
EEG seizure location (% all EEGs)			
Localized EEG changes	291 (63.4)	43 (57.3)	350 (60.3)
Generalized seizures	14 (3.1)	2 (2.7)	28 (4.8)
No seizure location	134 (29.2)	29 (38.7)	163 (28.1)
Seizure location looked for but not found	20 (4.4)	1 (1.3)	39 (6.7)
Breakdown EEGs with localized changes (% all localized EEGs)			
All counts with localized changes ^c	322 (100)	53 (100)	391 (100)
Temporal	256 (79.5)	40 (75.5)	312 (79.8)
Parietal	41 (12.7)	5 (9.4)	46 (11.8)
Occipital	16 (5.0)	5 (9.4)	21 (5.4)
Frontal	9 (2.8)	3 (5.7)	12 (3.1)
Duration of dizzy spells in EVD^d			
<1 min	4 (12.5)	38 (82.6)	52 (46.8)
≤30 s	2 (6.3)	32 (69.6)	34 (30.6)
30–60 s	2 (6.3)	4 (8.7)	6 (5.4)
No further separation possible	0 (0.0)	2 (4.3)	12 (10.8)
>1 min	13 (40.6)	8 (17.4)	44 (39.6)
Variable duration ^e	15 (46.9)	0 (0.0)	15 (13.5)
All	32 (100)	46 (100)	111 (100)

Abbreviations: EVD = epileptic vertigo or dizziness; i-EVD = isolated epileptic vertigo or dizziness; ni-EVD = non-isolated epileptic vertigo or dizziness.

^aIn one study reporting on both ni-EVD and i-EVD, no information could be retrieved on which EEG changes applied to the ni-EVD and which applied to the i-EVD cases.⁶⁰ These 46 cases (33 ni-EVD; 13 i-EVD) are therefore excluded from this part of the data analysis.

^bIn the study by Erkwow,⁶⁰ 16 cases with EVD of mostly (13/16) temporal lobe origin could not be separated into ni-EVD and i-EVD; therefore these cases are not included in the subgroup (ni-EVD and i-EVD) analysis.

^cIn 32 cases, epileptic discharges were localized to more than one of the 4 principal lobes; in these cases, one count was given to each area (this included temporo-parietal, temporo-occipital, frontotemporal, parieto-occipital, and temporo-parieto-occipital locations). Accordingly, the total number of counts exceeded the number of patients with EVD by 41.

^dDuration of episodes in individual subjects ranging from seconds to minutes. We noted reports of EVD lasting “several hours” in 8 patients from a single study.⁴⁷

^eA distinction between ni-EVD and i-EVD was possible only in part of the patients. Only these patients are reported in the ni-EVD and i-EVD columns, while all patients are considered in the “all” column.

prevalence) would not have been captured by our search, these numbers are probably plausible upper limits for the frequency of EVD in dizziness and in epilepsy. The higher prevalence of ni-EVD in the disease cohort makes intuitive sense (i.e., known seizure patients are more likely to have epileptic dizziness than patients evaluated for dizziness).

Second, i-EVD is probably rare in both dizziness (0.1%) and in epilepsy (0.4%). It is not surprising that i-EVD would be much less common than ni-EVD. Although this difference could be attributed to diagnostic ascertainment bias,²³ it seems plausible that i-EVD is, indeed, substantially less common in

both symptom and disease cohorts. Again, because our search strategy was skewed toward studies seeking EVD in dizziness, these estimates probably represent plausible upper bounds, although we cannot be sure that more rigorous diagnostic ascertainment would not have identified some missed cases.

Third, as suggested previously, EVD may be more common in children than in adults.²⁴ This claim is supported by our finding of a higher frequency of EVD in children relative to adults in our symptom cohort (ratio children:adults, 8.7:1), which suggests that EVD probably accounts for a greater fraction of vertigo/dizziness presentations in children than adults

Table 6 Accompanying seizure symptoms in EVD patients^{a,b}

Sensory phenomena	133
Cephalic sensations (pressure, heat, pain)	61
Visual hallucinations	32
Auditory hallucinations	23
Simple (tinnitus, sounds, dysacusis)	19
Complex (music, voices)	4
Somatosensory, excluding cephalic sensations	16
Olfactory hallucinations	1
Motor symptoms	120
Focal motor seizures	28
Generalized tonic-clonic seizures	25
Arrest (speech, activity)	22
Falls	14
Automatisms	12
Head deviation	8
Nystagmus	8
Verbal (screaming, vocalization)	3
Disturbances of consciousness	104
Transient loss of consciousness	45
Emotional (fear, anxiety, agitation)	16
Emergence of an idea	15
Loss of contact	11
Dysmnestic (e.g., déjà vu)	6
Conscious confusion	5
Aphasia	4
Disturbance of body image	2
Autonomic/visceral phenomena	57
Vomiting	18
Nausea	12
Malaise/weakness	8
Epigastric (rising sensation)	6
Pallor	5
Thermoregulatory	5
Cardiovascular	2
Pulmonary	1

Abbreviation: EVD = epileptic vertigo or dizziness; i-EVD = isolated epileptic vertigo or dizziness; ni-EVD = non-isolated epileptic vertigo or dizziness.

^a A total of 411 seizure symptoms were retrieved from 171 EVD patients (166 with ni-EVD and 5 with i-EVD, where nystagmus was the only sign besides the symptom of vertigo/dizziness); therefore some patients had more than one seizure symptom in one or several groups, leading to several counts.

^b Note that only symptoms accompanying vertigo/dizziness, i.e., occurring during the same episode, were considered and that in some studies information about symptoms was abstracted and therefore not available on the level of individual patients.

(or at least that EVD is a more frequent focus of diagnostic inquiry and publication in pediatric populations). For the disease cohort, EVD was diagnosed with roughly equal frequency (ratio children:adults, 1.1:1), indicating that seizures, when present, are

about equally likely to produce vertigo/dizziness in children and adults (although this finding must be viewed cautiously given the small number of children relative to adults in this cohort: 70 vs 2,162). These findings suggest that it is not a biological interaction with age (e.g., seizures in a young brain are more likely to produce dizziness), but an epidemiologic one. In other words, the proportion of dizziness cases due to EVD is probably higher in children than adults based on different population distributions of etiologies for dizziness in children vs adults. This could be because seizures are more common in children, other causes (e.g., benign paroxysmal positional vertigo, stroke) are more common in adults, or a combination of both.

Seizure location and lateralization. A critical role of temporal areas in self-motion perception has been previously proposed based on functional MRI studies during caloric irrigation,²⁵ case reports with focal lesions within the temporal gyrus,^{26,27} and transcranial magnetic stimulation over the superior temporal gyrus.²⁸ Illusory sensations of self-motion can be elicited by cortical electrical stimulation within a fairly large area including temporal and parietal lobes, but also, less frequently, occipital and frontal lobes,⁸ and may include sensations of rotation in different planes, translations, and indefinable body motion.⁹ The high frequency of temporal over parietal lobe seizure location in our review does not reflect the distribution noted in these electrical stimulation studies and current expert opinion. Potentially, this discrepancy is a result of the overall higher prevalence of temporal lobe seizures compared to parietal lobe seizures in epileptic patients²⁹ and as a result, EVD is more often associated with a temporal than a parietal location on epidemiologic rather than biological grounds.

Regardless, based on the distribution of seizure locations observed here, symptoms and signs of temporal lobe origin (e.g., rising epigastric sensations, auditory hallucinations, emotional/dysmnestic phenomena) should be sought in patients with suspected EVD. However, temporal lobe seizures may be difficult to diagnose clinically and by standard surface EEG,^{30,31} with invasive recordings offering improved spatial resolution and increased sensitivity.^{32,33} From our 580 EVD patients with EEG available, only a small fraction underwent intracranial EEG recordings. This probably suggests that, clinically, some patients with temporal lobe EVD remain undiagnosed because of a false-negative surface EEG.

Previously, a right-hemisphere dominance for EVD had been proposed,³⁴ which is a sensible hypothesis, given the right hemisphere's predominant role in spatial perception. In our dataset, however, no statistically significant differences were found. Left-hemisphere foci were slightly more common overall

in this sample. There was, however, some heterogeneity based on the focus of seizure activity: a slight left-sided predominance was noted for temporal lobe seizures, but a relatively large (and borderline statistically significant) right-sided predominance was noted in the subgroups with parietal and occipital lobe seizures.

Duration of EVD: From few seconds to several minutes.

Knowledge about the duration of vertigo/dizziness is important to narrow the differential diagnosis.³⁵ Traditionally, EVD has been considered to last a few seconds only,¹⁸ and consequently, the clinician may have dismissed a diagnosis of EVD if spells exceeded this duration. In this review, we found brief spells (≤ 1 minute) in 46.3% of cases. The remaining patients presented with spells lasting several minutes (a duration typically associated with vestibular migraine,³⁶ Meniere disease,³⁷ or episodic ataxia³⁸) or had spells of variable duration. Based on our data, dizzy spells exceeding a few seconds duration and lasting up to several minutes should still be considered as potentially epileptic. For the i-EVD cases, the dictum that epileptogenic vertigo/dizziness lasts a few seconds held true with a duration of ≤ 30 seconds in 69.6%, suggesting that the clinical presentation of seizures (isolated vertigo/dizziness vs with other seizure-like symptoms) may be linked to the duration of the dizzy spells. It is biologically plausible that short bursts of epileptic activity would be more likely to produce short-lived, isolated symptoms, while longer runs of epileptic activity would be more likely to be sustained and spread, causing longer, nonisolated episodes of EVD.

Interestingly, almost all cases with EVD localized to the temporal lobe (in which spell duration was provided) were in the range of few seconds to less than 1 minute, while the few EVD cases with nontemporal location lasted longer. This could indicate that EVD in temporal lobe seizures is associated with especially brief dizzy spells. Spontaneous spells lasting seconds are also typical in vestibular paroxysmia,³⁹ a condition known to be exquisitely carbamazepine-responsive,⁴⁰ so some such patients might readily be confused for i-EVD or vice versa, including in our series, where the quality of vestibular assessments was generally low. Whether a high frequency of attacks per day (as seen in some patients with vestibular paroxysmia)⁴⁰ excludes i-EVD is unknown; the reports we reviewed described patients with daily or more frequent spells in only 2 cases.^{10,41} Patients with suspected vestibular paroxysmia should probably be assessed by EEG to exclude the possibility of i-EVD as an alternative cause for brief paroxysms before treatment with carbamazepine.

High rate of AED treatment response. We found response rates to AED treatment in EVD of 90%. Some have suggested this be used as a diagnostic test to point to

an ictal etiology in responders.^{18,34} However, treatment response information was available in only 10% and, for example, successful treatment strategies for vestibular paroxysmia and vestibular migraine include AEDs such as carbamazepine, valproate, and topiramate.^{40,42} Thus, response to AED treatment in patients with episodic vertigo/dizziness does not prove an epileptic origin of the spells.

Quality of EEG and vestibular and imaging assessment. A thorough diagnostic workup (brain MRI plus complete vestibular testing plus ictal EEG) was rarely performed. In the disease cohort, only 9/34 case series placed emphasis on vestibular symptoms in study design,^{3,6,34,43–48} which may explain why vestibular testing was infrequent in this cohort. Likewise, in the symptom cohort, seizures were just one of many differential diagnostic considerations, explaining a low rate of obtaining EEG.

Incomplete workups in the disease cohort might have led to overdiagnosis of EVD (misattribution of dizziness from another cause to known epilepsy causing other symptoms); likewise, incomplete workups in the symptom cohort might have led to underdiagnosis of EVD. Of note, the lifetime prevalence of migraine headaches is about 2.4 times greater in patients with diagnosed epilepsy than in their relatives without epilepsy,⁴⁹ and the lifetime prevalence of migraine in the epileptic population is 8%–24%.^{49–51} Likewise, in migraine headache patients, the lifetime prevalence of epilepsy is 1%–17%,⁵⁰ which is clearly higher than that of epilepsy in the general population (0.6%–1.5%).⁵² This nonchance association may have led to diagnostic misclassification of vestibular migraine as EVD or vice versa.

Epileptic nystagmus. From all EVD patients identified, only 1% presented with both EVD and epileptic nystagmus. This rate may be falsely low as, in most EVD patients, seizures were not observed by a physician and eyewitness reports of nystagmus are usually not available. The cortical areas associated with seizure activity leading to epileptic nystagmus spread across temporal, parietal, and occipital lobes and are presumably related to the control of smooth-pursuit or saccadic eye movements.⁵³ These seizure locations partially overlap with the mostly temporal locations for EVD in our systematic review. However, reviews in the literature collecting cases of epileptic nystagmus report rates of associated episodic vertigo/dizziness of only 5%–7%.^{54–56} This dissociation suggests that the cortical areas eliciting epileptic nystagmus and EVD are activated at the same time by an epileptic attack in only a minority of cases. If the clinician therefore witnesses a seizure presenting with EVD, it is unlikely that he or she will detect nystagmus and vice versa.

EVD is primarily associated with temporal lobe seizures and we found ni-EVD is more common than

i-EVD; i-EVD appears to be rare. Consistent with clinical wisdom, i-EVD spells often last just seconds, although many patients experience longer spells. Epileptic nystagmus is an infrequent accompaniment, despite its apparent similarity. Prospective diagnostic studies in unselected symptom or disease cohorts would be required to confirm and refine these estimates further, which are based largely on retrospective case series data. In the meantime, clinicians should consider EVD when assessing patients with dizziness/vertigo, particularly children with very brief episodes or when other suspicious symptoms are present.

AUTHOR CONTRIBUTIONS

Dr. Tarnutzer conceived of the study, performed the literature search, reviewed identified manuscripts and selected matching inclusion criteria, performed the statistical analysis, drafted and critically reviewed the manuscript, and approved the final version of the manuscript. Dr. Lee reviewed identified manuscripts and selected matching inclusion criteria, critically reviewed and edited the manuscript, and approved the final version of the manuscript. Dr. Robinson performed the literature search, critically reviewed and edited the manuscript, and approved the final version of the manuscript. Dr. Kaplan reviewed identified EEG traces, critically reviewed and edited the manuscript, and approved the final version of the manuscript. Dr. Newman-Toker conceived of the study, critically reviewed and edited the manuscript, and approved the final version of the manuscript.

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