Missed Strokes Using Computed Tomography Imaging in Patients With Vertigo
Population-Based Cohort Study

Keerat Grewal, MD; Peter C. Austin, PhD; Moira K. Kapral, MD, MSc; Hong Lu, PhD; Clare L. Atzema, MD, MSc

Background and Purpose—The purpose of this study was to determine the proportion of emergency department (ED) patients with a diagnosis of peripheral vertigo who received computed tomography (CT) head imaging in the ED and to examine whether strokes were missed using CT imaging.

Methods—This population-based retrospective cohort study assessed patients who were discharged from an ED in Ontario, Canada, with a diagnosis of peripheral vertigo, April 2006 to March 2011. Patients who received CT imaging (exposed) were matched by propensity score methods to patients who did not (unexposed). If performed, CT imaging was presumed to be negative for stroke because brain stem/cerebellar stroke would result in hospitalization. We compared the incidence of stroke within 30, 90, and 365 days subsequent to ED discharge between groups, to determine whether the exposed group had a higher frequency of early strokes than the matched unexposed group.

Results—Among 41,794 qualifying patients, 8,596 (20.6%) received ED head CT imaging, and 99.8% of these patients were able to be matched to a control. Among exposed patients, 25 (0.29%) were hospitalized for stroke within 30 days when compared with 11 (0.13%) among matched nonexposed patients. The relative risk of a 30- and 90-day stroke among exposed versus unexposed patients was 2.27 (95% confidence interval, 1.12–4.62) and 1.94 (95% confidence interval, 1.10–3.43), respectively. There was no difference between groups at 1 year. Strokes occurred at a median of 32.0 days (interquartile range, 4.0–33.0 days) in exposed patients, compared with 105 days (interquartile range, 11.5–204.5) in unexposed patients.

Conclusions—One fifth of patients diagnosed with peripheral vertigo in Ontario received imaging that is not recommended in guidelines, and that imaging was associated with missed strokes. (Stroke. 2015;46:108-113. DOI: 10.1161/STROKEAHA.114.007087.)

Key Words: computed tomography, x-ray ▪ emergency service, hospital ▪ stroke ▪ vertigo

Dizziness is a common complaint in the emergency department (ED). It accounts for 2.5% of all ED visits in the United States, and the number of visits doubled between 1995 and 2009. Vertigo is a subcategory of dizziness that has both peripheral (inner ear) and central (brain) causes. Although most vertigo is peripheral and benign, ≈3% of patients who come to the ED for vertigo will be diagnosed with a stroke during that ED visit. Strokes that cause vertigo usually originate from the cerebellum and brain stem; these stroke types are associated with particularly high morbidity and mortality.

Identifying the small group of patients with serious illness among all vertiginous patients may be challenging because the signs and symptoms are similar in some cases of peripheral and central vertigo. Standard teaching in emergency medicine is that a thorough history and examination, which includes a neurological examination, can effectively rule out central causes of vertigo; the neurological literature substantiates this approach. If the neurological examination is abnormal, magnetic resonance imaging (MRI) with diffusion weighted imaging is the test of choice to visualize the posterior fossa. Even the initial MRI, however, is not 100% sensitive. Recently, the HINTS test (Head Impulse Nystagmus Test of Skew) has been proposed for the detection of cerebellum and brain stem strokes; however, it was derived in a patient group with a different pretest probability than those seen in the ED (72% had a stroke versus 3% in ED vertigo patients); testing was performed by a neuro-ophthalmologist, and it has not been externally validated. A third diagnostic test option is computed tomography (CT). Unlike MRI, CT imaging is easy to obtain in most EDs; however, noncontrast head CT has been shown to have low sensitivity for detecting ischemic strokes overall, and several small studies have suggested that the sensitivity is even worse in patients with...
posterior fossa strokes.\textsuperscript{15,16} For these reasons, CT is not recommended to rule out stroke in patients with vertigo.\textsuperscript{10,11,17}

Despite these recommendations, the use of CT imaging has increased tremendously for the dizzy patient in the ED: from 9.4\% to 37.4\% in the US between 1995 and 2009.\textsuperscript{2} Numbers in the other countries are unknown although CT imaging for other clinical indications is lower in Canada than in the US.\textsuperscript{18} In addition to increased radiation exposure, which is associated with increased risk for certain cancers,\textsuperscript{19} the use of a potentially insensitive, low-yield test could result in false reassurance for the managing physician, and paradoxically leave the patient with an undetected, untreated, central cause of vertigo. The purpose of this study was to determine how many patients discharged from a Canadian ED with a diagnosis of peripheral vertigo received head CT imaging during their evaluation, and to compare subsequent early strokes between patients who received CT imaging during their ED visit with matched patients who did not, to assess whether cerebellum and brain stem strokes were being missed.

Methods

Study Design

We conducted a retrospective cohort study using linked administrative databases from the province of Ontario, Canada. To reduce confounding due to measured covariates when estimating the effect of exposure to CT imaging, propensity score methods were used to match exposed patients (received ED CT imaging) to unexposed patients (did not). Research Ethics Board approval was obtained from the Sunnybrook Health Sciences Center.

Data Sources and Study Population

Patients were identified from the Canadian Institutes of Health Information (CIHI) National Ambulatory Care Reporting System, an administrative database that contains anonymized, abstracted data on all ED patient visits in Ontario. Ontario is Canada’s largest province, with an ethnically diverse population of 13 million.\textsuperscript{20} Patients in CIHI-National Ambulatory Care Reporting System were eligible if they had a valid Ontario Health Card number and were aged between 18 and 105 years when they had an ED visit with a primary diagnosis of peripheral vertigo (International Classification of Disease, 10th edition codes H81.1–81.3) between April 1, 2006, and March 31, 2011. We validated these International Classification of Disease, 10th edition codes in the CIHI-National Ambulatory Care Reporting System database using charts from 1 community and 1 tertiary hospital. Positive predictive value was 97.7\% (95\% confidence interval, 95.0–99.1).

Only index ED visits (first eligible visit per patient) were included. We excluded urgent care centers (not open 24 hours/d), patients from nursing homes, and patients who died in the ED. Patients admitted to the hospital from the ED were excluded, thereby excluding patients in whom a stroke was diagnosed during that ED visit (because individuals with a brain stem or cerebellar stroke are admitted to hospital), in addition to other serious diagnoses requiring admission. Therefore, it was assumed that CT imaging, if performed, was read as negative for brain stem or cerebellar stroke, in our cohort of discharged patients.

Patients in CIHI-National Ambulatory Care Reporting System were linked to other province-wide databases using unique, encoded identifiers (online-only Data Supplement). Ontario has universal healthcare coverage for all medically necessary care; therefore, these data sets contain the vast majority of all healthcare use in the province.

Outcome Measures

The primary outcome measure was hospitalized stroke within 30 days of ED discharge. Secondary outcomes included (1) hospitalized strokes within 90 and 365 days of ED discharge; (2) composite outcome of hospitalized stroke or all-cause mortality within 30, 90, and 365 days of ED discharge; and (3) the number of CT head scans performed in the year after ED discharge.

Data Analysis

The frequency of head CTs performed was described using percentages and 95\% confidence intervals. To reduce selection bias, we used propensity score matching to create a group of unexposed patients (did not receive ED CT imaging) who were similar to the exposed patients (received CT imaging). The propensity score is each patient’s probability of receiving CT imaging given their pre-CT baseline covariate values; thus matching on the propensity score aims to simulate a randomized trial using observational data.\textsuperscript{21,22}

Logistic regression was used to estimate the propensity score for the probability of receiving head CT imaging;\textsuperscript{23} 32 model covariates were selected via review of the literature for potential predictors of stroke and mortality (Table 1). Where available, validated algorithms were used to identify comorbidities in the linked databases, including myocardial infarction, hypertension, heart failure, diabetes mellitus, chronic obstructive lung disease, asthma, and HIV status.\textsuperscript{25–29} The Johns Hopkins Adjusted Clinical Group case-mix system is a measure of patient acuity/comorbidity.\textsuperscript{24} Its purpose in an ambulatory cohort is similar in principle to the Charlson Co-morbidity index in studies of hospitalized patients (online-only Data Supplement).

Outcomes were compared between exposed and unexposed patients in the matched samples using the proportion of patients who experienced the outcome of interest. Using these probabilities, the absolute risk difference and relative risk were calculated. To account for matching, McNemar test was used to test the differences in proportions.\textsuperscript{30} Among subjects who had a stroke after ED discharge, we examined the type of stroke in the CIHI-DAD, their presenting ED complaint, and we plotted the cumulative incidence of strokes in exposed and nonexposed patients over time, using a cumulative incidence function (which takes into account the competing risk of death). All analyses were done with SAS software (version 9.3; SAS Institute Inc, Cary, NC).

Results

Among 41,794 qualifying patients, 8596 (20.6\%) received head CT imaging in the ED. The large majority were without contrast (96.9\%). In the year after discharge from the ED, another 7256 (17.4\%) head CTs were performed on the 41,794 patients. The frequency with which patients were hospitalized for stroke within 30, 90, and 365 days after ED discharge in the 8596 patients who received ED CT imaging was 0.29\%, 0.41\%, and 0.60\%, respectively, when compared with 0.15\%, 0.20\%, and 0.36\% among the remaining 33,198 patients.

The online-only Data Supplement shows patient characteristics before matching (Table 1). Of the 8596 patients who received a head CT in the ED, 8582 (99.8\%) were successfully matched to a patient who was unexposed, resulting in a matched sample consisting of 17,164 patients (Table 1). Standardized differences were at most 0.01, indicating that the 2 groups were well matched. Median age in both was 63.0 years (interquartile range, 51.0–74.0 years) and 62\% were women. Just over half in both cohorts had a history of hypertension, 22\% had diabetes mellitus, 10\% had atrial fibrillation, 5.5\% had heart failure, and 1.4\% had a previous stroke.

By 1 year, there were 92 strokes in the 17,164 patients: in the exposed patients, these strokes occurred markedly earlier after ED discharge (median, 32 days; interquartile range, 4.0–133.0) than among unexposed patients (median, 105 days; interquartile range, 11.5–204.5; Figure). At 30 days, 25 (0.29\%) of the exposed patients had been hospitalized for stroke when compared with 11 (0.13\%) among matched
Table 1. Characteristics of Discharged ED Patients With a Diagnosis of Peripheral Vertigo, Matched on Receipt of Head CT

<table>
<thead>
<tr>
<th></th>
<th>Propensity Score Matched Cohort</th>
<th>Had CT During Index ED Visit</th>
<th>Standardized Difference of the Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes (n=8582)</td>
<td>No (n=8582)</td>
<td></td>
</tr>
<tr>
<td><strong>Demographics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean±SD</td>
<td>62.1±15.4</td>
<td>62.0±15.3</td>
<td>0</td>
</tr>
<tr>
<td>Median (IQR)</td>
<td>63.0 (51.0–74.0)</td>
<td>63.0 (51.0–74.0)</td>
<td>0</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td>5263 (61.3%)</td>
<td>5303 (61.8%)</td>
<td>0.01</td>
</tr>
<tr>
<td>Income quintile</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1715 (20.0%)</td>
<td>1722 (20.1%)</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1765 (20.6%)</td>
<td>1772 (20.6%)</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1693 (19.7%)</td>
<td>1696 (19.8%)</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>1788 (20.8%)</td>
<td>1804 (21.0%)</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>1621 (18.9%)</td>
<td>1588 (18.5%)</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Medical history</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroke</td>
<td>122 (1.4%)</td>
<td>123 (1.4%)</td>
<td>0</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>847 (9.9%)</td>
<td>840 (9.8%)</td>
<td>0</td>
</tr>
<tr>
<td>Acute myocardial infarction</td>
<td>321 (3.7%)</td>
<td>334 (3.9%)</td>
<td>0.01</td>
</tr>
<tr>
<td>Heart failure</td>
<td>470 (5.5%)</td>
<td>473 (5.5%)</td>
<td>0</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>1894 (22.1%)</td>
<td>1863 (21.7%)</td>
<td>0.01</td>
</tr>
<tr>
<td>COPD</td>
<td>1210 (14.1%)</td>
<td>1218 (14.2%)</td>
<td>0</td>
</tr>
<tr>
<td>Cancer</td>
<td>865 (10.1%)</td>
<td>858 (10.0%)</td>
<td>0</td>
</tr>
<tr>
<td>Hypertension</td>
<td>4666 (54.4%)</td>
<td>4657 (54.3%)</td>
<td>0</td>
</tr>
<tr>
<td>Asthma</td>
<td>678 (7.9%)</td>
<td>661 (7.7%)</td>
<td>0.01</td>
</tr>
<tr>
<td>HIV</td>
<td>7 (0.1%)</td>
<td>8 (0.1%)</td>
<td>0</td>
</tr>
<tr>
<td>Dementia</td>
<td>160 (1.9%)</td>
<td>166 (1.9%)</td>
<td>0.01</td>
</tr>
<tr>
<td>Sick sinus syndrome</td>
<td>796 (9.3%)</td>
<td>791 (9.2%)</td>
<td>0</td>
</tr>
<tr>
<td>Abnormal heart beat</td>
<td>2681 (31.2%)</td>
<td>2705 (31.5%)</td>
<td>0.01</td>
</tr>
<tr>
<td>Falls</td>
<td>1572 (18.3%)</td>
<td>1530 (17.8%)</td>
<td>0.01</td>
</tr>
<tr>
<td>Parkinson disease</td>
<td>71 (0.8%)</td>
<td>63 (0.7%)</td>
<td>0.01</td>
</tr>
<tr>
<td>Hypotension</td>
<td>111 (1.3%)</td>
<td>109 (1.3%)</td>
<td>0</td>
</tr>
<tr>
<td>Glaucoma</td>
<td>872 (10.2%)</td>
<td>864 (10.1%)</td>
<td>0</td>
</tr>
<tr>
<td>Renal failure</td>
<td>74 (0.9%)</td>
<td>75 (0.9%)</td>
<td>0</td>
</tr>
<tr>
<td>Fracture in the previous year</td>
<td>40 (0.5%)</td>
<td>47 (0.5%)</td>
<td>0.01</td>
</tr>
<tr>
<td>Gout</td>
<td>152 (1.8%)</td>
<td>150 (1.7%)</td>
<td>0</td>
</tr>
<tr>
<td>Inflammatory bowel disease</td>
<td>76 (0.9%)</td>
<td>66 (0.8%)</td>
<td>0.01</td>
</tr>
<tr>
<td>Rostered with a family doctor</td>
<td>6548 (76.3%)</td>
<td>6497 (75.7%)</td>
<td>0.01</td>
</tr>
<tr>
<td>Cardiologist care in previous 2 y</td>
<td>4136 (48.2%)</td>
<td>4124 (48.1%)</td>
<td>0</td>
</tr>
<tr>
<td>Hospitalizations in previous 2 y, mean±SD</td>
<td>0.57±1.14</td>
<td>0.56±1.19</td>
<td>0</td>
</tr>
<tr>
<td>Homecare visit in the previous 3 mo</td>
<td>434 (5.1%)</td>
<td>445 (5.2%)</td>
<td>0.01</td>
</tr>
<tr>
<td>ADG score, mean±SD</td>
<td>11.52±4.20</td>
<td>11.53±4.23</td>
<td>0</td>
</tr>
<tr>
<td><strong>Emergency visit characteristics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ambulance arrival</td>
<td>2821 (32.9%)</td>
<td>2849 (33.2%)</td>
<td>0.01</td>
</tr>
<tr>
<td>ED triage score (1=highest acuity)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 or 2</td>
<td>1806 (21.0%)</td>
<td>1795 (20.9%)</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>6138 (71.5%)</td>
<td>6150 (71.7%)</td>
<td>0</td>
</tr>
<tr>
<td>4 or 5</td>
<td>638 (7.4%)</td>
<td>637 (7.4%)</td>
<td>0</td>
</tr>
</tbody>
</table>

(Continued)
unexposed patients (Table 2). The relative risk of stroke at 30 days among exposed patients was twice (2.27; 95% confidence interval, 1.12–4.62) that of unexposed patients. The relative risk of stroke at 90 days remained higher in the exposed group (although the difference was lower than at 30 days), whereas it was no longer significant at 365 days.

The relative risk of the composite outcome of stroke or death at 30 days among exposed patients was twice as high as in the matched unexposed patients, whereas there was no difference between the groups at 90 days or at 1 year. Among the 52 exposed patients who returned with a stroke, the reason for the return ED visit was dizziness in 88.5% (95% confidence interval, 76.6–95.6), along with confusion/disorientation, headache, syncope/collapse, and head injury (Table II in the online-only Data Supplement).

Discussion

In this population-based study, we found that one fifth of discharged patients who were diagnosed with peripheral vertigo underwent head CT imaging during their ED visit (almost all noncontrast), and 17% had more CT imaging in the year subsequent. This is lower than American numbers during the same time period (22.8% in 2005 and 37.4% in 2009), consistent with a previous study that found that CT imaging in Canada was lower than in the US for patients with abdominal pain, headache, chest pain, or shortness of breath. These numbers are despite recommendations by several professional groups that CT imaging not be used for the diagnosis of brain stem or cerebellar strokes. Our results support this recommendation: patients who received CT imaging and were discharged from an ED in Ontario with a diagnosis of peripheral vertigo had a significantly higher frequency of early strokes than matched patients who did not receive CT imaging, suggesting a missed event in the ED.

The earlier occurrence of the strokes in the exposed group can be explained by the increased early risk of a recurrent event after a transient ischemic attack or stroke. In addition, missed cerebellar strokes result in 10% to 20% of patients deteriorating within several days after the event, consistent with the time to return to hospital with a stroke in exposed patients in this study (lower quartile of four days). Finally, the reasons for returning to the ED were symptoms that were consistent with a cerebellar or brain stem stroke. Taken together, these results point toward missed, high-risk strokes in patients who received a head CT.

Few studies have examined the sensitivity of CT imaging in ED patients with vertigo. A case series of 15 ED

![Figure](http://stroke.ahajournals.org) Cumulative incidence of stroke in the 365 days after discharge from an emergency department with a diagnosis of peripheral vertigo, in matched exposed (received computed tomography [CT] imaging) and unexposed patients. CIF indicates cumulative incidence function.
patients who had a misdiagnosed cerebellar infarction (half of whom came from malpractice cases) found that 9 had head CT imaging performed during the visit, all of which were initially read as no evidence of acute infarct or hemorrhage (one was subsequently reread as early cerebellar infarct). In the largest case series on the subject, CT images were examined among 67 patients in a database of patients with a documented posterior fossa stroke. Using diffusion imaging MRI as the gold standard, sensitivity of the initial noncontrast CT was 41.8%. However, the results are limited by the use of MRI as the gold standard, which is not 100% sensitive, and not all patients received an MRI (resulting in indication bias). These 2 studies were case series, beginning with patients already identified with posterior fossa strokes: this may result in capture of only the worst cases. In our population-based cohort study, we began with all discharged vignettes in EDs with peripheral vertigo had CT head imaging, despite published recommendations. We found that CT imaging was associated with twice the number of early brain stem or cerebellar strokes after discharge from the ED.

### Table 2. Outcomes at 30, 90, and 365 Days, in Matched Exposed (Received CT) and Unexposed Patients

<table>
<thead>
<tr>
<th>Had CT During Index ED Visit</th>
<th>Relative Risk (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Stroke, d</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>25 (0.29%)</td>
</tr>
<tr>
<td>90</td>
<td>35 (0.41%)</td>
</tr>
<tr>
<td>365</td>
<td>52 (0.61%)</td>
</tr>
<tr>
<td>Stroke or death, d</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>31 (0.36%)</td>
</tr>
<tr>
<td>90</td>
<td>62 (0.72%)</td>
</tr>
<tr>
<td>365</td>
<td>154 (1.8%)</td>
</tr>
</tbody>
</table>

* Indicates a statistically significant result.

This study has several limitations. Propensity scores cannot adjust for unmeasured covariates, such as patient preference. However, we successfully matched patients from an entire population on 32 variables, including adjusted diagnostic groups risk score, and the groups were extremely similar on the risk factors that a physician is likely to consider when pursuing a central cause of vertigo with imaging. The similar risk of stroke in the longer term suggests that these patients were well matched for risk of stroke after the initial, inciting event; the early period after a transient ischemic attack or stroke is when the risk of another thromboembolic event is highest. Our study was retrospective. A future prospective study that provides finer clinical details (such as neurological examination findings) is needed to confirm our findings. However, given the huge sample sizes that are required in the setting of extremely low event rates, a study enrolling this number of patients is not likely to be soon forthcoming.

We do not have CT reports to verify that patients who received CT imaging did not report a stroke at the time of the study. However, given the high risk of morbidity and mortality after a brain stem or cerebellar stroke, it would be extremely unlikely for a patient to be discharged from the ED with such a stroke. Administrative databases may have coding inaccuracies; however, we validated the peripheral vertigo codes and used validated algorithms for the determination of many comorbidities. How many MRIs were performed is unknown; future intervention studies that include the early use of MRI could assess the benefit of improvement in the management protocol with CT.

### Conclusions

Although lower than in US EDs, one fifth of patients discharged from an Ontario ED with peripheral vertigo had CT head imaging, despite published recommendations. We found that CT imaging was associated with twice the number of early brain stem or cerebellar strokes after discharge from the ED.

### Sources of Funding

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### Disclosures

None.

### References


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The online version of this article, along with updated information and services, is located on the
World Wide Web at:
http://stroke.ahajournals.org/content/46/1/108

Data Supplement (unedited) at:
http://stroke.ahajournals.org/content/suppl/2014/12/04/STROKEAHA.114.007087.DC1

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Supplemental Material.

Methods and Materials

Data Sources
The CIHI Discharge Abstract Database (CIHI-DAD) contains data on all hospitalizations in Ontario, the Registered Persons Database contains accurate mortality information for all Ontario residents (including out-of-hospital deaths),\(^1\) and the Homecare database contains all homecare visits by allied healthcare professionals. The Ontario Health Insurance Plan contains billings for all physician visits, in any setting,\(^2\) and includes billings for CT imaging: ICD 9 codes X400-405, X408, and X188, were used to identify head CT imaging.

Data Analysis
The Johns Hopkins Adjusted Clinical Group (ACG) case-mix system is a measure of patient acuity/comorbidity. It is based on diagnoses from ambulatory physician visits and hospital admissions. Diagnoses are assigned to one of 32 diagnostic clusters; patients with the greatest number of highest-risk clusters are the sickest and require the most health care resources.\(^3\)\(^-\)\(^4\) Where validated algorithms were not available, the patient was considered to have a past medical history of the disease in question if they had, within the five years prior to the ED visit, one diagnosis in the CIHI-DAD or two outpatient diagnoses in the Ontario Health Insurance Plan database (similar to many of the validated algorithms).

Patients were matched on the logit of the propensity score using a 1:1 without replacement approach and a caliper width of 0.2 of the standard deviation of the logit of the propensity score.\(^5\) Balance in baseline covariates was evaluated by calculating standardized differences (<0.1 was considered indicative of balance).\(^6\) Restricted cubic smoothing splines with 3 knots were used to model the relationship between the continuous covariate and the log-odds of exposure.

Supplemental References


4. Austin PC, van Walraven C, Wodchis WP, Newman A, Anderson GM. Using the Johns Hopkins Aggregated Diagnosis Groups (ADGs) to Predict Mortality in a General Adult
Population Cohort in Ontario, Canada. Med Care 2011.


Online Supplement.
Supplementary Table I. Characteristics of discharged ED patients with a diagnosis of peripheral vertigo, prior to propensity score matching, by receipt of head computed tomography (CT)

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Had CT during index ED visit</th>
<th>Original Cohort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Mean ± SD</td>
<td>62.1 ± 15.4</td>
</tr>
<tr>
<td></td>
<td>Median (IQR)</td>
<td>63.0 (51.0-74.0)</td>
</tr>
<tr>
<td>Sex</td>
<td>Female</td>
<td>5,269 (61.3)</td>
</tr>
<tr>
<td>Income quintile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1,716 (20.0%)</td>
<td>7,120 (21.5%)</td>
</tr>
<tr>
<td>2</td>
<td>1,770 (20.6%)</td>
<td>6,907 (20.8%)</td>
</tr>
<tr>
<td>3</td>
<td>1,696 (19.7%)</td>
<td>6,580 (19.8%)</td>
</tr>
<tr>
<td>4</td>
<td>1,792 (20.9%)</td>
<td>6,596 (19.9%)</td>
</tr>
<tr>
<td>5</td>
<td>1,622 (18.9%)</td>
<td>5,995 (18.1%)</td>
</tr>
<tr>
<td>Past Medical History</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroke</td>
<td>126 (1.5%)</td>
<td>236 (0.71%)</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>853 (9.9%)</td>
<td>2,090 (6.3%)</td>
</tr>
<tr>
<td>Acute myocardial infarction</td>
<td>321 (3.7%)</td>
<td>914 (2.8%)</td>
</tr>
<tr>
<td>Heart failure</td>
<td>472 (5.5%)</td>
<td>1,141 (3.4%)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>1,899 (22.1%)</td>
<td>5,192 (15.6%)</td>
</tr>
<tr>
<td>COPD</td>
<td>1,213 (14.1%)</td>
<td>3,860 (11.6%)</td>
</tr>
<tr>
<td>Cancer</td>
<td>872 (10.1%)</td>
<td>2,177 (6.6%)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>4,680 (54.4%)</td>
<td>13,586 (40.9%)</td>
</tr>
<tr>
<td>Asthma</td>
<td>681 (7.9%)</td>
<td>2,279 (6.9%)</td>
</tr>
<tr>
<td>Human Immunodeficiency Virus</td>
<td>7 (0.08%)</td>
<td>39 (0.12%)</td>
</tr>
<tr>
<td>Dementia</td>
<td>161 (1.9%)</td>
<td>310 (0.93%)</td>
</tr>
<tr>
<td>Sick sinus syndrome</td>
<td>801 (9.3%)</td>
<td>1,966 (5.9%)</td>
</tr>
<tr>
<td>Abnormal heart beat</td>
<td>2,689 (31.3%)</td>
<td>8,207 (24.7%)</td>
</tr>
<tr>
<td>Falls</td>
<td>1,575 (18.3%)</td>
<td>6,066 (18.3%)</td>
</tr>
<tr>
<td>Parkinson’s Disease</td>
<td>74 (0.86%)</td>
<td>131 (0.39%)</td>
</tr>
<tr>
<td>Hypotension</td>
<td>111 (1.3%)</td>
<td>350 (1.1%)</td>
</tr>
<tr>
<td>Glaucoma</td>
<td>876 (10.2%)</td>
<td>2,216 (6.7%)</td>
</tr>
<tr>
<td>Renal failure</td>
<td>74 (0.86%)</td>
<td>187 (0.56%)</td>
</tr>
<tr>
<td>Fracture in the previous year</td>
<td>41 (0.48%)</td>
<td>99 (0.30%)</td>
</tr>
<tr>
<td>Gout</td>
<td>152 (1.8%)</td>
<td>476 (1.4%)</td>
</tr>
<tr>
<td>Inflammatory bowel disease</td>
<td>76 (0.88%)</td>
<td>298 (0.90%)</td>
</tr>
<tr>
<td>Rostered with a family doctor</td>
<td>6,558 (76.3%)</td>
<td>24,773 (74.6%)</td>
</tr>
<tr>
<td>Cardiologist care in prior 2 years</td>
<td>4,148 (48.3%)</td>
<td>11,937 (36.0%)</td>
</tr>
<tr>
<td>Hospitalizations in prior 2 year</td>
<td>Mean ± SD</td>
<td>0.57 ± 1.13</td>
</tr>
<tr>
<td>Homecare visit in the prior 3 months</td>
<td>438 (5.1%)</td>
<td>1,015 (3.1%)</td>
</tr>
<tr>
<td>ADG score</td>
<td>Mean ± SD</td>
<td>11.5 ± 4.2</td>
</tr>
<tr>
<td>Emergency Visit Characteristics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Ambulance arrival</td>
<td>2,835 (33.0%)</td>
<td>6,787 (20.4%)</td>
</tr>
<tr>
<td>ED triage score</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1 = highest acuity)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 or 2</td>
<td>1,820 (21.2%)</td>
<td>3,485 (10.5%)</td>
</tr>
<tr>
<td>3</td>
<td>6,138 (71.4%)</td>
<td>21,246 (64.0%)</td>
</tr>
<tr>
<td>4 or 5</td>
<td>638 (7.4%)</td>
<td>8,467 (25.5%)</td>
</tr>
<tr>
<td>Hospital type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>34 (0.40%)</td>
<td>3,323 (10.0%)</td>
</tr>
<tr>
<td>Community</td>
<td>6,325 (73.6%)</td>
<td>23,409 (70.5%)</td>
</tr>
<tr>
<td>Teaching</td>
<td>2,237 (26.0%)</td>
<td>6,466 (19.5%)</td>
</tr>
</tbody>
</table>
Online Supplement
Supplementary Table II. Hospitalized strokes by 365 days, by presence or absence of ED head computed tomography imaging, in discharged ED patients with a diagnosis of peripheral vertigo

<table>
<thead>
<tr>
<th>Patients with stroke</th>
<th>ICD 10 code</th>
<th>Description</th>
<th>Had Head CT (n=52)</th>
<th>No Head CT (n=40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chief Complaint</td>
<td>R42</td>
<td>Dizziness / giddiness</td>
<td>46</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>R51</td>
<td>Headache</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>R53</td>
<td>Malaise / fatigue</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>R113</td>
<td>Nausea / Vomiting</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>R55</td>
<td>Syncope / collapse</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>R410</td>
<td>Disorientation, confusion NOS</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>R074</td>
<td>Chest pain, unspecified</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>S099</td>
<td>Unspecified injury of head</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>R111</td>
<td>Nausea</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>R112</td>
<td>Vomiting</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>S010</td>
<td>Open wound of scalp</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>H811</td>
<td>Benign Positional Vertigo</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Hospital Diagnosis</td>
<td>I605</td>
<td>SAH from vertebral artery</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>I609</td>
<td>SAH, unspecified</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>I611</td>
<td>ICH in hemisphere, cortical</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>I613</td>
<td>ICH in brain stem</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>I614</td>
<td>ICH in cerebellum</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>I615</td>
<td>ICH, intraventricular</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>I618</td>
<td>Other ICH</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>I619</td>
<td>ICH, unspecified</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>I632</td>
<td>Cerebral infarction due to unspecified occlusion or stenosis of precerebral</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>ICD</td>
<td>Description</td>
<td>Count</td>
<td>Expected</td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------</td>
<td>----------</td>
<td></td>
</tr>
<tr>
<td>I634</td>
<td>Cerebral infarction due to embolism of cerebral arteries</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>I635</td>
<td>Cerebral infarction due to unspecified occlusion or stenosis of cerebral arteries</td>
<td>5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>I638</td>
<td>Other cerebral infarction</td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>I639</td>
<td>Cerebral infarction, unspecified</td>
<td>17</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>I64</td>
<td>Stroke, not specified as haemorrhage or infarction (NOS)</td>
<td>15</td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>

ICD 10: international classification of diseases, 10th edition; CT: computed tomography; ED: emergency department; ICH: Intracerebral hemorrhage; NOS: Not otherwise specified
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Supplementary Table III. Top 15 reasons for hospital admission (most responsible diagnosis) among the 926 ED patients with a final ED diagnosis of peripheral vertigo who were admitted to hospital during the same time period that the 41,794 discharged patients were seen

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>patients</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Received a head CT (n=587)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Peripheral vertigo</td>
<td>265</td>
<td>45.1</td>
</tr>
<tr>
<td>2 Dizziness</td>
<td>113</td>
<td>19.3</td>
</tr>
<tr>
<td>3 Labyrinthitis</td>
<td>48</td>
<td>8.2</td>
</tr>
<tr>
<td>4 Stroke</td>
<td>42</td>
<td>7.2</td>
</tr>
<tr>
<td>5 Vertigo of central origin</td>
<td>10</td>
<td>1.7</td>
</tr>
<tr>
<td>6 Meniere’s Disease</td>
<td>10</td>
<td>1.7</td>
</tr>
<tr>
<td>7 TIA</td>
<td>9</td>
<td>1.5</td>
</tr>
<tr>
<td>8 Benign hypertension</td>
<td>9</td>
<td>1.5</td>
</tr>
<tr>
<td>9 Syncope / collapse</td>
<td>5</td>
<td>0.9</td>
</tr>
<tr>
<td>10 Traumatic brain injury</td>
<td>2</td>
<td>0.3</td>
</tr>
<tr>
<td>11 Zoster with neurological involvement</td>
<td>2</td>
<td>0.3</td>
</tr>
<tr>
<td>12 Acute Renal Failure</td>
<td>2</td>
<td>0.3</td>
</tr>
<tr>
<td>13 Atrial fibrillation</td>
<td>2</td>
<td>0.3</td>
</tr>
<tr>
<td>14 Orthostatic hypotension</td>
<td>2</td>
<td>0.3</td>
</tr>
<tr>
<td>15 Palliative care</td>
<td>2</td>
<td>0.3</td>
</tr>
<tr>
<td><strong>No ED head CT (n=339)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Peripheral vertigo</td>
<td>134</td>
<td>39.5</td>
</tr>
<tr>
<td>2 Dizziness</td>
<td>84</td>
<td>24.8</td>
</tr>
<tr>
<td>3 Labyrinthitis</td>
<td>25</td>
<td>7.4</td>
</tr>
<tr>
<td>4 Stroke</td>
<td>16</td>
<td>4.7</td>
</tr>
<tr>
<td>5 Meniere’s Disease</td>
<td>7</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>Description</td>
<td>Value</td>
</tr>
<tr>
<td>---</td>
<td>--------------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>6</td>
<td>Vertigo of central origin</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>Benign hypertension</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>Orthostatic hypotension</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>Unsteadiness on feet</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>Disorientation</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>Syncope / collapse</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>Acute myocardial infarction</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>Migraine</td>
<td>2</td>
</tr>
<tr>
<td>14</td>
<td>Viral infection NYD</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>Arrhythmia</td>
<td>2</td>
</tr>
</tbody>
</table>