Missed Diagnosis of Subarachnoid Hemorrhage in the Emergency Department

Marian J. Vermeulen, MHSc; Michael J. Schull, MD, MSc, FRCPC

Background and Purpose—Subarachnoid hemorrhage (SAH) can be devastating, yet its initial presentation may be limited to common symptoms and subtle signs, potentially leading to misdiagnosis. Little is known about population rates of misdiagnosis of SAH, or hospital factors that may contribute to it. We estimated the population-based rate of missed SAH among emergency department (ED) patients and examined its relationship with hospital characteristics.

Methods—We studied persons admitted with a nontraumatic SAH to all Ontario hospitals over 3 years (April 2002 to March 2005). SAH was defined as missed if the patient had an ED visit related to the SAH (based on a prespecified definition) in the 14 days before admission. We examined the association between hospital teaching status and missed SAH and explored whether annual ED volume of SAH or CT availability explained this association.

Results—Of 1507 patients diagnosed with SAH, 5.4% (95% CI, 4.3 to 6.6) had a missed diagnosis. The risk was significantly higher among patients triaged as low acuity (odds ratio 2.65; 95% CI, 1.46 to 4.80), as well as in nonteaching hospitals (adjusted odds ratio 2.12; 95% CI, 1.02, 4.44). Neither ED SAH volume nor on-site CT availability explained the effect of teaching status.

Conclusions—About 1 in 20 SAH patients are missed during an ED visit. Lower acuity patients are at higher risk of misdiagnosis, suggesting the need for heightened suspicion among patients with minimal clinical findings. The risk is also greater in nonteaching hospitals, but this is not explained by the annual volume of SAHs seen in the ED or access to CT. (Stroke. 2007;38:1216-1221.)

Key Words: diagnosis ■ health services research ■ subarachnoid hemorrhage

Subarachnoid hemorrhage (SAH) is a serious condition that frequently leads to neurological impairment and death.1–3 The diagnosis can be challenging because headache is the predominant symptom and often the only manifestation of the condition,4 yet it is also a common benign complaint.5,6 Delays in diagnosis and treatment of SAH are associated with a higher risk of rebleeding and related mortality.7–9

The rate of missed or delayed diagnosis has been reported to vary from 12% to 51%.8–16 This wide range of misdiagnosis rates reflects a variety of study methods and definitions. In addition, important risk factors for misdiagnosis, such as patient acuity, physician experience and access to diagnostic resources vary between different clinical settings.

Hospital factors such as patient volume, teaching status and access to diagnostic resources have been found to be associated with misdiagnosis in emergency department (ED) patients with acute myocardial infarction,17 yet little is known about how system factors might contribute to the risk of missed SAH. We sought to ascertain population-based rates of missed SAH among patients presenting to an ED, and certain hospital system factors associated with it. Specifically, we examined whether hospital teaching status, which reflects a number of system-related differences in health care, such as access to specific diagnostic technology and specialists, was associated with missed SAH and, if so, whether this relationship could be explained by the annual volume of SAHs seen in the ED and CT availability.

Methods

The study setting was Ontario, Canada’s largest province with a population of 12.5 million. We included all Ontario residents aged 18 years and older with a valid health insurance number who were admitted to any hospital through an ED from April 1, 2002, to March 31, 2005, with a most responsible diagnosis (responsible for the majority of the hospital length of stay) of nontraumatic SAH (International Classification of Disease [ICD]-10-CA codes I60.0 to I60.9). Patient records were identified from the Discharge Abstract Database (DAD) and the National Ambulatory Care Reporting System (NACRS), administrative health databases containing all hospital admissions and ED visits in Ontario, respectively. We selected the earliest SAH admission in the study period and excluded patients admitted for an SAH or cerebral aneurysm in the previous...
The hospital admission records of SAH patients were linked to their ED visit(s) by an anonymous unique identifier. We identified all visits to any ED in the 14 days before hospital admission, excluding the admitting ED visit (ie, the index visit). This time frame was chosen to ensure that the prior ED visit was actually related to the index SAH admission; in one recent study of missed SAH that identified previous patient visits to the ED, 96% of missed cases occurred within 14 days10 (Mayer SA, unpublished data, 2004). Among patients transferred from one ED to another before admission, the visit to the first ED was considered the index visit. A missed SAH on a prior visit was defined a priori by the presence of an alternative ED main discharge diagnosis, including migraine/headache (ICD-10-CA F454, G430-9, G440-2, G448, R51), neck pain (ICD-10-CA M436, M4642, M4782, M4792, M4802, M501-9, M530, M531, M542, S1340-2, S1348, S136, S168), hypertension (ICD-10-CA I100-1), sinusitis (ICD-10-CA J010-9, J320-9), stroke/transient ischemic attack (ICD-10-CA G450, G459, I64, I674), meningitis (ICD-10-CA A870-9, G000-9, G01, G020-8, G030-9, G042), syncope and collapse (ICD-10-CA R55), or giant cell arteritis (ICD-10-CA I100-1), meningitis (ICD-10-CA A870-9, G000-9, G01, G020-8, G030-9, G042), syncope and collapse (ICD-10-CA R55), or giant cell arteritis (ICD-10-CA M315-6), provided that the patient was not admitted to hospital during the ED visit. These conditions have been described as initial misdiagnoses among ED and other patients with missed SAH10,11,13,18 (Kowalski RG, Mayer SA, unpublished data, 2004).

Teaching and nonteaching (community or small) hospital status was determined according to Ontario Hospital Association definitions.10,12 The data were linked with the Ontario Registered Persons Database, which documents mortality statistics for the province, to obtain 30-day and 1-year mortality. CT availability was obtained from a survey of all Ontario EDs mailed in March 2005, in which respondents were asked whether CT scanning was available onsite or offsite.

Statistical Analysis
We used logistic regression to estimate the odds ratio (OR) and 95% CI to characterize the relationship between hospital teaching status and missed SAH. Multivariate models controlled for patient age, sex, socioeconomic status (ie, neighborhood income quintile), day of week, time of day, and Canadian Triage and Acuity Scale. Triage scores were grouped as high (resuscitation and emergent categories), medium (urgent), and low acuity (less urgent and nonurgent). Because patients at the same ED may have correlated outcomes, we adjusted for clustering of patients within EDs using generalized estimating equations.21,22 As a secondary analysis, we separately added 2 ED-level variables to the model to determine whether these factors explained the relationship between hospital type and missed SAH, in accordance with previous methods23: (1) the logarithm of the annual ED volume of both diagnosed and missed SAH, and (2) CT scan availability. These variables were deemed influential if they attenuated the OR for hospital type by at least 20% or caused the OR to become no longer statistically significant.17,23 We also conducted a sensitivity analysis to determine whether the rate of missed SAH changed if the period of observation before the index admission was extended from 14 to 28 days. \( \chi^2 \) tests were used to compare proportions. \( P \) values were 2-sided, at a significance level of 0.05. Statistical analyses were performed using SAS 9.0 (SAS Inst). The study was approved by the Ethics Review Board of Sunnybrook Health Sciences Centre.

Results
Over 3 years there were 1603 patients hospitalized with a diagnosis of nontraumatic SAH; 1507 (94.0%) of these were admitted through the ED. Of the 176 EDs in the province, 147 (83.5%) admitted at least 1 patient with SAH, ranging from 1 to 49 per ED. Of these, 38 (25.9%) were in small hospitals, 93 (63.3%) in community hospitals, and 16 (10.9%) in teaching hospitals. Patient characteristics according to missed SAH are shown in Table 1. With the exception of age, triage level, and hospital type, persons with missed SAH did not differ from those initially diagnosed with SAH.

A total of 150 (10.0%; 95% CI, 8.5 to 11.6) patients had an ED visit in the 14 days preceding their SAH admission. SAH was missed on a prior ED visit in 81 (5.4%; 95% CI, 4.3 to

<table>
<thead>
<tr>
<th>Time to registration in ED, n (%)</th>
<th>Total</th>
<th>Missed SAH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day</td>
<td>636</td>
<td>36 (4.9)</td>
</tr>
<tr>
<td>Evening</td>
<td>608</td>
<td>37 (4.7)</td>
</tr>
<tr>
<td>Night</td>
<td>182</td>
<td>8 (9.9)</td>
</tr>
<tr>
<td>Day of registration in ED, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekday</td>
<td>1017</td>
<td>51 (6.0)</td>
</tr>
<tr>
<td>Weekend</td>
<td>409</td>
<td>30 (7.0)</td>
</tr>
<tr>
<td>Hospital type, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Community</td>
<td>1037</td>
<td>66 (6.1)</td>
</tr>
<tr>
<td>Small</td>
<td>64</td>
<td>5 (6.2)</td>
</tr>
<tr>
<td>Teaching</td>
<td>325</td>
<td>10 (12.3)</td>
</tr>
<tr>
<td>Mortality, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-day*</td>
<td>484</td>
<td>5 (6.2)</td>
</tr>
<tr>
<td>1-year*</td>
<td>524</td>
<td>6 (6.2)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ED discharge diagnosis at prior ED visit, n (%)</th>
<th>Total</th>
<th>Missed SAH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Migraine/headache</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neck pain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sinusitis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroke/TIA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Syncope/collapse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meningitis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time to diagnosis, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;1 day</td>
<td></td>
<td>≥5 (3.7)</td>
</tr>
<tr>
<td>1 day</td>
<td>33(40.7)</td>
<td></td>
</tr>
<tr>
<td>2 days</td>
<td>16 (19.8)</td>
<td></td>
</tr>
<tr>
<td>≥3 days</td>
<td>29 (35.8)</td>
<td></td>
</tr>
</tbody>
</table>

*\( P < 0.05 \)
†Unknown for 42 persons (2.8%).
6.6) cases. The rate of misdiagnosis varied from 0% to 100% across the 147 EDs which saw at least one SAH; 59 EDs (40.1%) missed at least one SAH over the study period. The mean (SD) delay in diagnosis was 2.7 (2.8) days. In 37% of missed cases, the admitting hospital was different from the ED in which the patient was seen on the earlier visit. The majority of missed cases were diagnosed with “migraine” or “headache” at the prior related visit (Table 1). Acuity of presentation based on triage score was worse at the second ED visit (24.7% triaged as high acuity) as compared with the first (17.3% high acuity) among patients with missed SAH; however, the proportion of patients with a high acuity presentation at the admitting visit was even greater among patients who were not missed (57.5% high acuity).

Patients who were seen at EDs in nonteaching hospitals were similar to those in teaching hospitals with respect to age, sex, SES, acuity, and mortality (Table 2). The mean [SD] delay to diagnosis was also similar among patients in teaching and nonteaching hospitals (3.5 [4.1] versus 3.2 [4.1] days, respectively).

The rate of misdiagnosis among patients seen initially in nonteaching hospitals was 6.1%, versus 3.0% in teaching hospitals. The rate also varied with the acuity level at the initial ED visit, with 20 (19.8%) low acuity patients being misdiagnosed, 47 (8.2%) medium acuity patients, and 14 (1.7%) high acuity patients. In multivariable analyses, the adjusted risk of a missed diagnosis of SAH was more than twice as high in nonteaching compared with teaching hospitals (OR 2.12; 95% CI, 1.02 to 4.44; Figure), and the odds of misdiagnosis were 2.65 (95% CI, 1.46 to 4.80) among those triaged as low acuity and 0.18 (95% CI, 0.09 to 0.35) among those triaged as high acuity, relative to medium acuity patients.

When annual SAH volume was added to the multivariate model, the association between nonteaching hospital status did not change meaningfully. Information on CT availability was obtained from the 138 of 147 EDs (93.9%) in our cohort who responded to our survey. All 14 teaching hospitals had on-site access to CT, compared with 46.8% (58) of nonteaching hospitals; among patients with a missed SAH, 12 (16.0%) attended an ED where CT was only available off-site, compared with 166 (11.9%) who were not missed (P=0.29). Adding CT availability to the model among EDs surveyed had a negligible impact on the effect estimate for nonteaching hospitals. Neither SAH volume nor CT availability were independent predictors of missed SAH.

Missed SAH patients had a significantly lower crude 30-day mortality rate (6.2%) compared with other patients (33.9%), though the lack of detailed information on clinical status, such as Hunt&Hess grade, did not permit us to control for SAH severity. When the definition of missed SAH was broadened to include ED visits up to 28 days before the index admission, the misdiagnosis rate remained virtually unchanged at 5.6% (95% CI, 4.5 to 6.9).

### TABLE 2. Characteristics of SAH Patients According to Hospital Type

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Nonteaching (n=1172)</th>
<th>Teaching (n=335)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (SD) SAH ED visits per year*</td>
<td>4.7 (3.6)</td>
<td>8.2 (3.6)</td>
</tr>
<tr>
<td>No. of EDs</td>
<td>131</td>
<td>16</td>
</tr>
<tr>
<td>Age, years, mean (SD)</td>
<td>57.8 (15.6)</td>
<td>57.9 (15.7)</td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>440 (37.5)</td>
<td>140 (41.8)</td>
</tr>
<tr>
<td>Income quintile†, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q1 (lowest)</td>
<td>240 (21.0)</td>
<td>70 (21.7)</td>
</tr>
<tr>
<td>Q2</td>
<td>253 (22.2)</td>
<td>75 (23.2)</td>
</tr>
<tr>
<td>Q3</td>
<td>229 (20.1)</td>
<td>46 (14.2)</td>
</tr>
<tr>
<td>Q4</td>
<td>219 (19.2)</td>
<td>59 (18.3)</td>
</tr>
<tr>
<td>Q5 (highest)</td>
<td>201 (17.6)</td>
<td>73 (22.6)</td>
</tr>
<tr>
<td>Triage acuity (CTAS), n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resuscitation</td>
<td>204 (17.4)</td>
<td>55 (16.4)</td>
</tr>
<tr>
<td>Emergent</td>
<td>461 (39.3)</td>
<td>114 (34.0)</td>
</tr>
<tr>
<td>Urgent</td>
<td>426 (36.3)</td>
<td>146 (43.6)</td>
</tr>
<tr>
<td>Less urgent</td>
<td>70 (6.0)</td>
<td>16 (4.8)</td>
</tr>
<tr>
<td>Nonurgent</td>
<td>11 (0.9)</td>
<td>≤5 (1.2)</td>
</tr>
<tr>
<td>Time of registration in ED, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day</td>
<td>524 (44.7)</td>
<td>148 (44.2)</td>
</tr>
<tr>
<td>Evening</td>
<td>503 (42.9)</td>
<td>142 (42.4)</td>
</tr>
<tr>
<td>Night</td>
<td>145 (12.4)</td>
<td>45 (13.4)</td>
</tr>
<tr>
<td>Day of registration in ED, n (%)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekday</td>
<td>808 (68.9)</td>
<td>260 (77.6)</td>
</tr>
<tr>
<td>Weekend</td>
<td>364 (31.1)</td>
<td>75 (22.4)</td>
</tr>
<tr>
<td>Mortality, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-day</td>
<td>390 (33.3)</td>
<td>99 (29.6)</td>
</tr>
<tr>
<td>1-year</td>
<td>418 (35.7)</td>
<td>111 (33.1)</td>
</tr>
</tbody>
</table>

*P<0.05.
†Unknown for 42 persons (2.8%).
Discussion

Among all nontraumatic SAH patients admitted to an Ontario hospital over 3 years, we found that 5.4% had been misdiagnosed on a prior visit to an ED. Patients who attended nonteaching hospitals were more than twice as likely to have a missed SAH as those at teaching sites, and those with low acuity presentations had a 2.7-fold increase in the risk of misdiagnosis. Annual volume of SAHs seen in the ED and on-site presence of a CT scanner did not account for the effect of hospital teaching status.

We found a lower rate of missed SAH compared with other published estimates, which range from 12% to as high as 51%. However, most were conducted in single referral centers, which may have restricted the study population to those who were more likely to be missed, and included visits to multiple outpatient settings such as physicians’ offices, where misdiagnosis rates may be higher. The definitions of missed diagnosis varied, sometimes relying on patient recall to ascertain prior symptoms or contact with the healthcare system, increasing the likelihood of misclassification, or included patients with very lengthy delays in diagnosis, raising questions as to the specificity of the diagnosis. A number of studies were conducted using earlier generations of CT technology, possibly resulting in higher misdiagnosis rates. Our study was population-based and included all SAH patients admitted to any hospital (even those who might not have survived long enough or been appropriate for transfer to referral centers) and was focused on patients seen in EDs over a relatively narrow time frame before SAH admission to increase the specificity of our definition of missed diagnosis.

SAH has a clinical presentation that varies from a simple headache to obvious neurological deficits. In addition, it is a rare condition which many emergency and primary care physicians may encounter infrequently even over many years of practice. Indeed, the number of cases of SAH seen at each ED varied from 1 to 49 over 3 years, and 29 EDs saw no patients who were diagnosed with a SAH over the entire study period. However, in the model adjusting for the volume of SAHs seen in each ED, the risk of missed diagnosis associated with nonteaching hospital status was unchanged, suggesting that SAH volume did not explain the higher rate of missed SAH in nonteaching hospitals. Whereas hospital volume has not been found to be a predictor of medical errors in general, ED misdiagnosis rates for AMI have been shown to be higher in low-volume ED settings, and one study of pediatric appendicitis found that the risk of misdiagnosis was inversely related to the number of appendectomies performed. Although volume-related experience at the physician level is likely to influence diagnostic accuracy, SAH volume was uniformly low across participating sites. The opportunity for individual emergency physicians to gain diagnostic experience is limited by the rarity of SAH (the highest volume center saw only 49 patients over a 3-year period, an average of 1.4 per month) and the fact that ED physicians may never become aware of the misdiagnosis (nearly 4 of 10 missed cases present to a different ED the second time). This reinforces the importance of shared learning between physicians by discussing the diagnosis of rare and serious conditions cases informally or formally, as well as sharing information between hospitals by ensuring that the ED where a case was missed is informed once the diagnosis is ultimately made.

Despite improvements in diagnostic imaging, CT may be less sensitive in SAH patients presenting with so-called “minor leaks” or normal neurological status. Failure to obtain a CT has been described as a common cause of delayed diagnosis of SAH, and recommendations to carry out a lumbar puncture after a negative CT may not always be carried out. Less than half of nonteaching hospitals had on-site access to CT scanners, which may have led to increased reluctance to transfer a patient for a scan in borderline cases, or may have increased the likelihood of patients refusing a transfer for the test. However, the relationship between nonteaching hospital status and missed SAH was not explained by CT availability. Systematic differences in diagnostic approaches between teaching and nonteaching institutions that are unrelated to CT scan availability might explain the variation in misdiagnosis rates, such as higher thresholds for initiating any investigations in headache patients, variation in quality of CT interpretation between sites, and differences in rates of lumbar puncture after negative CTs. Our results suggest that simply having CT technology on site may not necessarily reduce misdiagnosis rates in nonteaching hospitals.

Adverse events attributable to negligence have been found to be significantly lower in teaching hospitals, although the reasons for this are generally not well understood. Before these differences can be addressed, other explanatory factors at the hospital and physician level need to be explored. Whereas clinical judgment is likely to play an important role in the accurate diagnosis of SAH in the ED, standardization of the diagnostic approach to potential SAH patients may not fully address the problem. Current efforts to derive a clinical decision rule to rule out SAH in headache patients have been carried out among patients attending teaching hospital sites, and the effectiveness of rules could be limited if their implementation or interpretation varies between community and teaching hospitals.

We found that the crude mortality rate was lower among patients with a missed SAH, but this analysis should be interpreted with caution because we were unable to control for differences in SAH severity, and cannot account for patients who were misdiagnosed but subsequently died at home without being admitted for SAH. Our results are similar to another study which found the crude mortality rate to be lower among misdiagnosed patients, but higher once SAH severity was accounted for. Although triage levels among missed SAH patients in our study worsened between the prior and subsequent ED visit, they were still less acutely ill on their admitting visit than those diagnosed at their initial ED visit. Rebleeding, the most serious complication, typically occurs within days of an initial SAH, but there may have been less time for this and other SAH-related complications to develop compared with other studies because the majority returned within a few days.

We identified SAH patients retrospectively through administrative health databases; therefore, our data provided limited detail regarding clinical characteristics. Despite the limita-
tions of this data, SAH has been found to be coded with a reasonably high degree of accuracy in validation studies of hospital discharge data. At the same time, it was not feasible to derive population-based rates of missed SAH using a more detailed collection method, such as chart review, or to undertake a prospective study at such a large number of hospitals over so many years. This method has been previously used to identify misdiagnoses using administrative data; however, our definition of prior related visits for SAH patients has not been validated, which could lead to some misclassification. Previous studies have used a variety of methods and definitions to identify missed SAH, given the absence of a standard method to identify misdiagnoses, and none have been externally validated. Any misclassification should not affect our analysis of predictors of missed SAH so long as it is nondifferential. Although we were only able to include Ontario residents with valid health cards, out-of-province patients comprised <1% of the original study population, and we expect the number of persons without a health card in a publicly funded universal healthcare insurance system to be small. We could not ascertain prior related visits among missed SAH patients who attended the ED but died without re-admission. Hence, both the numbers of missed SAH and the associated mortality rates herein may be underestimated. In addition, we defined the prior related ED visits according to conditions described as misdiagnosed SAH. It is possible that some of these earlier diagnoses were not related to the subsequent presentation with SAH, but the narrow time frame of 14 days makes this less likely to be so. We extended the time period for misdiagnosis to 28 days and the rate remained virtually unchanged, similar to another study that found that the delay to SAH diagnosis among ED patients did not exceed 19 days (Mayer SA, unpublished data, 2004). Moreover, we have no reason to believe this would systematically occur more often in nonteaching than in teaching hospitals, and any misclassification would bias the results toward a null finding. The mechanisms that led patients to return to hospital after misdiagnosis were also unknown; they may have returned for lack of improvement of symptoms, worsening clinical condition, or may have been called back given abnormal results. In any case, however, the repeat visits would be captured in our databases and would still be appropriately identified as a missed SAH. Finally, we were unable to obtain data regarding other factors that may have explained the high rates of missed SAH in nonteaching hospitals, such as availability or routine use of CT angiography, MRI/angiography or neuroradiology consultants at each ED. These and other potential explanatory mechanisms require further study.

Our findings suggest that rates of missed SAH varied considerably across individual EDs, regardless of hospital type, but overall are lower than previously reported. Administrative data could be a valuable tool for identifying differences in misdiagnosis rates, as has been done previously for complications targeting interventions to reduce these rates, and monitoring the impact of interventions.

Summary

About 1 in 20 persons with SAH are missed on their first presentation to an ED, and the risk is greater in patients with low acuity presentations. The risk is also greater in nonteaching hospitals, but this could not be attributed to annual ED SAH volume or CT availability. Other contextual factors, such as physician training and experience, availability of consultants and other resources such as diagnostic technologies, or differences in diagnostic protocols will need to be evaluated before effective interventions to reduce missed SAH rates can be developed.

Sources of Funding

This study was supported by a grant from the Peter Lougheed Medical Research Foundation. Dr Schull has a Career Award from The Canadian Institutes of Health Research.

Disclosures

None.

References


