
Original Contributions

SUBARACHNOID HEMORRHAGE DIAGNOSIS BY COMPUTED TOMOGRAPHY AND LUMBAR PUNCTURE: ARE FIFTH GENERATION CT SCANNERS BETTER AT IDENTIFYING SUBARACHNOID HEMORRHAGE?

Brian M. Boesiger, MD* and Joseph R. Shiber, MD†

*Idaho Emergency Physicians, Boise, Idaho and †Departments of Internal and Emergency Medicine, East Carolina University, Greenville, North Carolina

Reprint Address: Joseph R. Shiber, MD, Departments of Internal and Emergency Medicine, East Carolina University, 600 Moye Blvd., Greenville, NC 27858

□ **Abstract**—This study sought to determine the sensitivity and specificity of modern computed tomography (CT) scans for the diagnosis of subarachnoid hemorrhage (SAH). No studies have been done recently with fifth generation CT scanners to look at the diagnosis of SAH. A retrospective chart review was done of Emergency Department (ED), laboratory, and hospital records at Pitt County Memorial Hospital in Greenville, North Carolina over 1 year from January 1, 2002 to December 31, 2002. Patients presented with headache and had a CT scan of the head with a fifth generation multi-detector CT scanner followed by a lumbar puncture (LP) to rule out SAH. There were 177 patients who presented to the ED with headache and went on to have a CT scan and an LP to rule out SAH. No patients who had a negative CT were found to have a subarachnoid hemorrhage. It is concluded that fifth generation CT scanners are probably more sensitive than earlier scanners at detecting SAH. © 2005 Elsevier Inc.

□ **Keywords**—subarachnoid hemorrhage; diagnosis; sensitivity; computed tomography; lumbar puncture

INTRODUCTION

The incidence of subarachnoid hemorrhage (SAH) is approximately 1 in 10,000 patients/year, affecting 28,000 people per year in the United States. About 1% of all patients presenting to the Emergency Department with

headache have SAH (1). Although most cases of SAH are traumatic in origin, about 80% of non-traumatic SAH are caused by aneurysm rupture in the area of the Circle of Willis. This condition, if undetected, has high morbidity and mortality and often strikes people who are otherwise healthy. Twenty to fifty percent of people with SAH experience a small leakage or sentinel bleed that does not lead immediately to neurologic disability but often advances to worse outcomes if not promptly diagnosed (1). Studies have shown that early detection leads to vastly improved outcomes if the initial diagnosis is correct (2). It is the goal of medical practitioners to diagnosis SAH at this point so the patient can be spared the disability and mortality of an intracranial bleed. Currently, most patients with a severe headache (HA) or acute onset of the worst headache of their life have a computed tomography (CT) scan of the head performed; if the CT scan is negative for SAH, patients have a lumbar puncture (LP) done. The current gold standard for diagnosing SAH is the LP, which can detect small amounts of blood and xanthochromia in the spinal fluid.

Recent advances in computed tomography technology have improved the accuracy of today's top-of-the-line CT scanners, yet we still practice medicine based on studies done in the 1980s and 1990s with third generation scanners. The most recent studies, also done with third generation scanners, quote the sensitivity of detect-

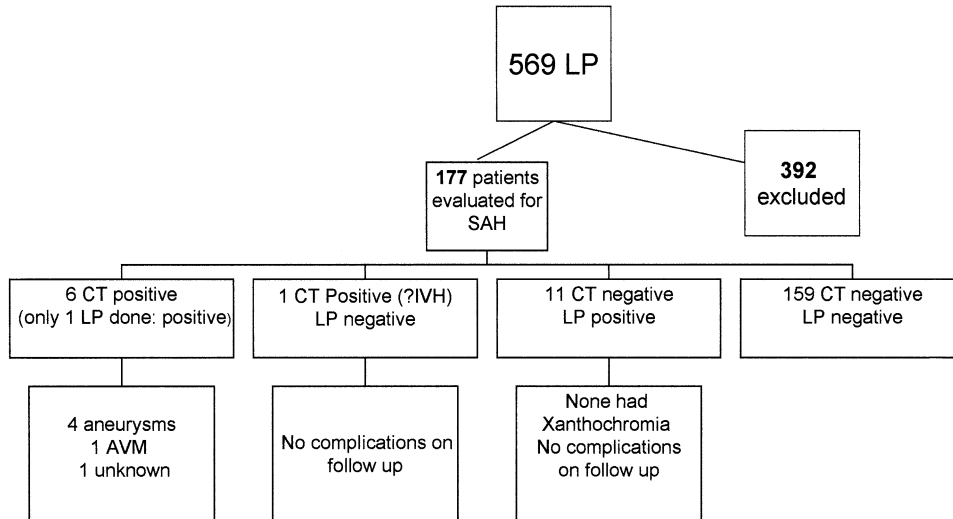


Figure 1. Identification of eligible patients who received a head CT (computed tomography) scan and LP (lumbar puncture) to rule out SAH (subarachnoid hemorrhage).

ing SAH at 92–98% (3,4). In the past 3 years, new “fifth generation” CT scanners have been installed at many hospitals. These multidetector CT scanners have advantages over previous models. They are much faster and able to take multiple images per rotation, which leads to thinner slices and less motion artifact and therefore better resolution. In a search of the medical literature as of March 15, 2003, there have been no studies looking at the sensitivity of these scanners in detecting subarachnoid hemorrhage. We undertook this study to evaluate the sensitivity of these fifth generation scanners for diagnosing SAH.

MATERIALS AND METHODS

This was an IRB-approved retrospective study conducted at Pitt County Memorial Hospital (PCMH) from January 1, 2002 to December 31, 2002. PCMH is an academic Level 1 Trauma Center located in a mostly rural region of Eastern North Carolina with an annual volume of 70,000 patient visits. A search of the Emergency Department (ED) and laboratory medical records for a 1-year period was done to identify adult patients presenting to the ED with a complaint of headache. If the patient went on to have a CT scan and LP to evaluate for SAH, they were included in the study. Patients excluded were those who: 1) had a history of trauma in the past 3 months; 2) were aged 17 years or less; 3) did not have rule-out SAH as the indication for LP documented in the physician records or LP consent form; or 4) had history of recent neurosurgery. Patients who presented with other chief complaints such as syncope, seizure, or mental status changes but also had a headache, were included in the

study. Figure 1 shows the schematic of how patients were identified for this study by searching laboratory records for all cerebrospinal fluid (CSF) samples, then reviewing medical and ED records for inclusion/exclusion criteria.

All patients in the study had a CT scan of the head done by a GE Lightspeed 2.× scanner (GE Medical Systems Waukesha, WI), which is a fifth generation CT scanner. The standard protocol involves 5-mm cuts through the cerebrum and 5-mm cuts through the posterior fossa. The scans were read by attending radiology staff, including both general radiologists and neuro-radiologists.

Patients with a negative CT scan of the head gave consent to have an LP done. Tubes 1 and 4 were sent to the laboratory for cell counts. Tube 2 was sent for protein and glucose and tube 3 was sent for Gram’s stain, culture and other indicated studies. The first and fourth tubes were centrifuged for 5 min and then inspected visually for the presence of xanthochromia. Patients were considered positive for SAH on LP if they had at least 400 red blood cells (RBC) in tube 1 (the visual threshold for detection of blood) and CSF that did not clear by at least 10-fold. Some of these patients had a CT angiogram (CTA) the same day to evaluate for aneurysm. Other patients who had elevated RBCs but did not have sufficient clearing were followed up by telephone and hospital records from 3 months to a year after the initial ED visit and were questioned about any other events or complications. Patients were also considered to be positive for SAH if there was evidence of xanthochromia. This hospital determined xanthochromia by visual analysis and not by spectrophotometry. The data were accu-

mulated in Microsoft Excel (Redmond, WA) for analysis.

RESULTS

A total of 177 patients were identified through the calendar year of 2002 who met the inclusion criteria of having a headache, getting a head CT scan, and having an LP done if the CT was negative. Six patients were found to have subarachnoid blood on their CT scan. Four of these patients had aneurysms found at cerebral angiography, and one had an arterial-venous malformation (AVM). The one remaining patient did not have a lesion identified, but had a positive LP and clinical course consistent with SAH. One patient had a CT scan positive for possible intraventricular blood, but on LP had only 405 and 22 RBCs in tubes 1 and 4, respectively. He did not have a further radiologic study done and did not have any further complications, so his CT scan result is considered to be a false positive.

A search of the ED database (Wellsoft Corporation Somerset, NJ) was also done to identify all cases of SAH. For the year 2002, 31 cases were identified with the admitting diagnosis of Subarachnoid Hemorrhage (Figure 2). The majority of these (77%) were traumatic SAH and all of these SAH were seen on CT scan. Of the non-traumatic cases, which numbered six, all of them had a positive CT scan for SAH, so only one went on to have an LP.

Forty-three patients had traumatic LPs with RBC counts >400 in tube 1. In none of these cases was xanthochromia noted by laboratory personnel using visual diagnosis. Two patients had CTA studies done. Neither of these studies was positive for aneurysm or AVM. On follow-up examination of these patients, one of them had no complications and the other had an ischemic stroke about 6 months after the initial event but did not have a SAH or hemorrhagic stroke.

Of the 170 patients who had a negative CT scan, none was found to have SAH by LP or patient follow-up. Patients with over 400 RBCs in tube 1 of their LP fluid and less than a 10-fold decrease in the number of red cells from tube 1 to tube 4 were identified. Eleven cases

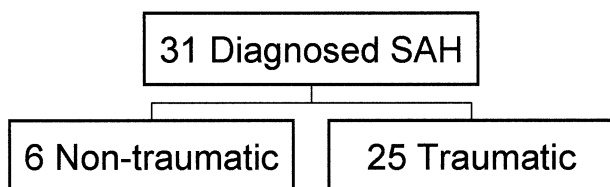


Figure 2. All identified SAH separated into traumatic and non-traumatic.

	SAH(+)	SAH (-)
CT(+)	6	1
CT(-)	0	170

Sensitivity of CT for SAH: 100% (95% CI: 61.0 - 100%)
 Specificity of CT for SAH: 99.4% (95% CI: 96.8 - 99.9%)
 Pretest Probability of having SAH: 3.4%

Figure 3. CT scan results for SAH and the confirmed outcomes (if SAH was actually present or not).

were identified and followed up by a search of the ED computer database for follow up or repeat visits and patients were also contacted by telephone to inquire about visits to other hospitals and any further complications. None of these patients had further complications related to their headaches and so their “positive” LP results were felt to be false positives. Figure 3 shows the determined sensitivity of CT scan for SAH to be 100% and the specificity to be 99.4%.

The most common ED diagnosis for patients undergoing CT and LP evaluation for SAH was Headache NOS (not otherwise specified), 92 (53%). The next most common diagnoses were; Migraine 16 (9%), Meningitis 14 (8%), Syncope 8 (5%), Mental Status Changes 8 (5%), Seizure 7 (4%), and Stroke 3 (2%). All of the other diagnoses composed 1% or less of the total diagnoses. All of the cases identified as meningitis had CSF cultures negative for a bacterial pathogen and were given the diagnosis of viral meningitis.

DISCUSSION

SAH is one of the critical diagnoses in Emergency Medicine. Yet this diagnosis continues to be missed in 23% to 53% of patients at their first encounter with a physician (5,6). Part of the problem is that this disease is neither common (migraine is 50× more common in the ED), nor rare (12% of patients presenting with acute severe headache have SAH) (1,7). The gold standard for diagnosing SAH remains the LP, although most SAH are diagnosed by CT scan. In Morgenstern’s study, 18/20, and in van der Wee’s study, 117/119 cases of SAH were diagnosed by CT scan using third generation scanners (2,8).

Physicians are commonly presented with the difficult decision of whether to perform an LP in a patient with a

headache and a negative CT scan in order to diagnose the small percentage of SAH missed by CT scan. Influencing this decision are considerations of pre-test probability, complication rate of the gold standard study, patient fear and anxiety, and sensitivity of the CT scan. It is this last issue that this study attempts to address. It is difficult to establish an acceptable miss rate when considering a potentially devastating disease such as SAH that has a high morbidity and mortality but offers an important opportunity to intervene if caught early.

Another important issue is the complication rate of LP. Lumbar puncture, although shown to be generally safe and with a low complication rate, is still not without risk. Post-dural puncture headaches occur in about 40% of all patients (9). The occurrence is even higher in patients with preceding headache (10). Low back pain also has been seen in up to 35% of patients having an LP in one study (11). Less common but real complications of LP include brainstem herniation, iatrogenic infection, cranial neuropathies, epidermoid tumor, subdural hematoma, and spinal hemorrhage leading to paraplegia (12). One must also take into account the extra time spent in the ED by the patient and the time it takes the physician to perform the procedure.

Although LPs are still felt to be the gold standard for diagnosis of SAH, their interpretation is not always straightforward. Traumatic LP occurs in 10–25% of diagnostic lumbar punctures (13). Traumatic lumbar puncture occurred in 25% of LPs done in this study, using a cutoff of 400 RBCs in tube 1. It has been shown that patients without SAH may have large numbers (10,000) of RBCs in the CSF and, conversely, patients with proven SAH may present with only hundreds of RBCs in the CSF (3,4). Spectrophotometry has been found to have a high false positive rate in previous studies. Most hospital laboratories do not use spectrophotometry; in fact, 99.7% analyze CSF for xanthochromia visually (14). Approximately 25% of hospitals do not check for xanthochromia by either method (13). Other studies suggested to help distinguish traumatic from non-traumatic LPs such as d-dimer, opening pressure, and clot formation are not always done or recorded and have not been found to be reliable (12). On the other hand, LP offers some benefits, as it allows us not only to exclude SAH with a high degree of certainty but also to help diagnose other conditions such as encephalitis, meningitis, and pseudotumor cerebri.

Although other studies have shown the prevalence of SAH in severe acute onset non-traumatic headache to be 12% this study showed a prevalence (pretest probability) of only 3.4% (6/178) (3,7). This is most likely a result of spectrum bias. Although patients in this study were required to have a headache, it did not have to be severe or acute in onset. Although other studies required patients

to present less than 12 h from the onset of the headache, this study included all patients (7). This was done for two reasons. First, studies have shown that many patients with SAH present after 12 h (3). Second, in clinical practice we must see patients at all time intervals from headache onset, not just those less than 12 h.

As stated above, headaches were not always severe. In several cases, other historical factors such as syncope, seizure, or a headache different than previous headaches moved SAH higher on the differential diagnosis. If clinicians included SAH on their differential diagnosis and felt confident enough about it to perform a CT scan and an LP, they were included in this study. If those who did not have severe headache were excluded, the percentage of those with SAH may have been higher.

There were some questionable cases of SAH vs. traumatic lumbar puncture. Although no studies showed xanthochromia, this hospital used visual diagnosis and not spectrophotometry to report xanthochromia. We attempted to ensure that none of these patients actually had SAH by searching hospital records and performing follow-up calls directly to patients to ensure that no sequelae had occurred by 3 months after the ictus. Most complications or cases of re-bleeding occur within 1 month of the initial headache (15). This study used the values of >400 RBCs in tube 1 and less than a 10-fold decrease in RBCs from tube 1 to tube 4 to define SAH. These criteria have not been validated and do not represent a standard. But as Shah and Edlow point out in their review, “Distinguishing Traumatic LP from true SAH,” there is no exact definition of traumatic tap (16). We tried to set the numbers artificially low in order not to miss any possible cases of SAH. Although there is no specific threshold of RBCs at which SAH is ruled out, patients with fewer than 400 RBCs have a very low risk for SAH. Median RBCs for SAH in Morgenstern’s study was 221,400 and no patients had less than 19,750 RBCs (2).

The results of this study suggest a sensitivity of 100% for fifth generation CT scanners evaluating for SAH, but the 95% confidence intervals are 61.0–100%. Due to the low pre-test probability, a much larger study would need to be conducted to increase the confidence intervals. Typically, as the sensitivity of a test increases, the specificity decreases, so that an “overly sensitive” test creates diagnostic errors. Here we found only one false positive, giving a specificity of 99.4% with 95% confidence intervals of 96.8–99.9%. This finding is extremely important, because missing a SAH could be devastating, but having a false positive CT for SAH and subjecting a patient to the risks of unnecessary angiography is also dangerous.

There are several limitations to this study. As a retrospective chart review, some of the cases may have been missed by our methods of identification. There were certainly some patients who had a CT scan performed to

evaluate for SAH, but whom either declined the LP or were not offered one. We do not have any data concerning these patients, but we know that the six patients with confirmed non-traumatic SAH had no prior ED visits during the 1-year study interval, so that it is unlikely that their CT scans were false negatives. With a small sample size of only 177 cases with a low pre-test probability and the acceptable level of false negative CT scans being very low, 1 or 2 missed cases over a year would have a serious impact on the implications of this study. There is certainly the need for a larger study conducted prospectively to help further clarify the questions asked in this study.

CONCLUSIONS

The results of this study suggest that the sensitivity of a fifth generation CT scan evaluating for SAH is 100%. This would need to be validated by further larger prospective studies in order for a change in clinical practice to take place. Not all hospitals have top-of-the-line fifth generation CT scanners. If the sensitivity were in fact 100% or even approached this number, the diagnostic algorithm or SAH would be changed. Another issue is informed consent. When obtaining consent from a patient to perform a lumbar puncture, the sensitivity should not be quoted as 85–90%; the actual sensitivity is probably closer to 99%. Given the possible complications of lumbar puncture, patients may decide more often that LP is not worth the risk. Avoiding complications of LP would be a benefit for patients and they would spend less time in the Emergency Department. Emergency physicians would be spared the time-consuming task of performing a lumbar puncture. Until further studies can validate the results presented in this study, the standard of care remains continuing to perform LP on patients after negative cranial CT scans if SAH is suspected. For

a disease as devastating as ruptured cerebral aneurysm, CT would have to be extremely sensitive to routinely forego LP.

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