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Authors

Meurer, William J
Walsh, Brian
Vilke, Gary M
et al.

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AAEM Position Paper

CLINICAL GUIDELINES FOR THE EMERGENCY DEPARTMENT EVALUATION OF SUBARACHNOID HEMORRHAGE

William J. Meurer, MD,* Brian Walsh, MD,† Gary M. Vilke, MD,‡ and Christopher J. Coyne, MD‡

*Department of Emergency Medicine, University of Michigan Health System, Ann Arbor, Michigan, †Department of Emergency Medicine, Morristown Medical Center, Morristown, New Jersey, and ‡Department of Emergency Medicine, University of California San Diego School of Medicine, San Diego, California

Reprint Address: Christopher J. Coyne, MD, Department of Medicine, University of California San Diego School of Medicine, 200 W. Arbor Drive #8676, San Diego, CA 92103

Abstract—Background: Subarachnoid hemorrhage (SAH) is frequently caused by the rupture of an intracranial aneurysmal vessel or arteriovenous malformation, leading to a cascade of events that can result in severe disability or death. When evaluating for this diagnosis, emergency physicians have classically performed a noncontrast computed tomography (NCCT) scan, followed by a lumbar puncture (LP). Recently, however, as CT technology has advanced, many studies have questioned the necessity of the LP in the SAH diagnostic algorithm and have instead advocated for noninvasive techniques, such as NCCT alone or NCCT with CT angiogram (CTA). **Objective:** The primary goal of this literature search was to determine the appropriate emergency department (ED) management of patients with suspected SAH. **Methods:** A MEDLINE literature search from October 2008 to June 2015 was performed using the keywords *computed tomography AND subarachnoid hemorrhage AND lumbar puncture*, while limiting the search to human studies written in the English language. General review articles and single case reports were omitted. Each of the selected articles then underwent a structured review. **Results:** Ninety-one articles were identified, with 31 papers being considered appropriate for analysis. These studies then underwent a rigorous review from which recommendations were developed. **Conclusions:** The literature search supports that NCCT followed by CTA is a reasonable

approach in the evaluation of ED patients with possible SAH. © 2016 Elsevier Inc.

Keywords—subarachnoid hemorrhage; headache; lumbar puncture; computed tomography; angiogram; CTA; NCCT

INTRODUCTION

Subarachnoid hemorrhage (SAH) is frequently associated with significant morbidity and mortality, especially when the diagnosis is missed (1,2). Unfortunately, initial presenting symptoms of this disease are frequently subtle and often overlap with more common and more benign headaches. Up to 2% of all emergency department (ED) visits are related to headache, while approximately 1%–3% of these headaches are caused by SAH (3). SAH is thought to present as a sudden headache, maximal at onset, and dissimilar to previous headaches. Other high-risk characteristics include age older than 40 years, neck pain, witnessed loss of consciousness, and onset with exertion (4,5). Clinical decision rules that include these high-risk findings have been proposed to help identify SAH patients (6,7). If the appropriate history and symptoms are present, the classic teaching is to perform a noncontrast computed tomography (NCCT) scan of the head, followed by a lumbar puncture (LP) if the NCCT does not show clear

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evidence of SAH (8–10). If the LP shows no signs of xanthochromia (visual or spectrophotometric) or elevated red blood cells, then one can safely exclude SAH as a diagnosis, with very few exceptions (11–13).

However, there are some barriers to obtaining a diagnostic LP. Providers often encounter difficulties with this procedure due to patient body habitus or previous lumbar procedures. Traumatic LP can obscure results and frequently lead to nondiagnostic studies (14). In addition, patient reluctance to go through a procedure that they perceive as invasive and painful can lead to a failure to perform the procedure. Given these patient and provider difficulties surrounding the LP when evaluating for SAH, other strategies have been presented that often forego these issues, including NCCT alone and NCCT combined with computed tomography angiogram (CTA) of the brain (15). The purpose of this paper is to review the available medical literature on these diagnostic modalities and to offer evidence-based recommendations for a safe approach for the diagnosis or ruling out of SAH.

METHODS

A structured literature review was performed using MEDLINE and was limited to studies that were published in the English language between October 2008 and June 2015. Search terms included *computed tomography AND subarachnoid hemorrhage AND lumbar puncture*. Two emergency physicians analyzed the abstract of each identified article to determine which ones should be pulled for more detailed review, based upon the suspected relevance to the topic of interest. If either physician felt the study had relevance, the full article was pulled for review. Studies included for the final, detailed review were limited to randomized controlled trials, prospective trials, retrospective cohort trials, and systematic reviews. General review articles and single case reports were not included for formal review.

Each of the selected articles underwent a Grade of Evidence Review. Two or more of the study authors performed a detailed review of each selected article. The level of the evidence was assigned a grade using the

definitions shown in Table 1 and were based on reference focus, specific research design, and methodology.

All selected articles were also assigned a Quality Ranking based on quality of the design and methodology. This includes Design Consideration (i.e., focus, model structure, presence of controls) and Methodology Consideration (actual methodology utilized). The definitions of the Quality Ranking scores are shown in Table 2.

RESULTS

Through this structured review, 91 abstracts were identified, 43 of which were thought to be relevant by the reviewers and were pulled for detailed formal review. Of these articles, 12 were commentary or single case reports and were therefore excluded from analysis. Among the final 31 articles, we identified 1 relevant clinical trial as well as 5 systematic reviews (Tables 3 and 4).

CT/LP

Performing a CT scan of the head, followed by an LP if the CT scan is negative, has historically been the most common diagnostic pathway in the ED for the evaluation of SAH. A large prospective cohort study reported this testing strategy to be 100% sensitive and to have a negative predictive value of 100% (35). Similarly, in a meta-analysis of >800 patients with negative CT/LP results who were followed for at least 1 year, none went on to develop an SAH (30). The inclusion of LP after a negative CT has been shown to identify clinically significant SAH, especially when presentation is delayed (17).

Its sensitivity notwithstanding, LP has some drawbacks, leading some providers to forego the procedure altogether (16,22,33). The procedure is somewhat painful, time consuming, and may be difficult, especially in patients who are overweight, uncooperative, or in those with a history of spine surgery (36). Patients may be reluctant to undergo the procedure because they view it as invasive. There are also potential risks to performing an LP, such as prolonged post-LP headaches and the rare severe complication of epidural hematomas.

Table 1. Definitions of the Grades of Evidence of the Articles

Grade	Definition
A	Randomized clinical trials or meta-analyses (multiple clinical trials) or randomized clinical trials (smaller trials), directly addressing the review issue
B	Randomized clinical trials or meta-analyses (multiple clinical trials) or randomized clinical trials (smaller trials), indirectly addressing the review issue
C	Prospective, controlled, nonrandomized, cohort studies
D	Retrospective, nonrandomized, cohort or case-control studies
E	Case series, animal/model scientific investigations, theoretical analyses, or case reports
F	Rational conjecture, extrapolations, unreferenced opinion in literature, or common practice

Table 2. The Definitions of the Quality Ranking Scores of the Articles

Ranking	Design Consideration Present	Methodology Consideration Present	Both Considerations Present
Outstanding	Appropriate	Appropriate	Yes, both present
Good	Appropriate	Appropriate	No, either present
Adequate	Adequate with Possible bias	Adequate	No, either present
Poor	Limited or biased	Limited	No, either present
Unsatisfactory	Questionable/none	Questionable/none	No, either present

The emergency medicine literature on the use of CT/LP for the diagnosis of SAH is robust and includes prospective cohort studies, retrospective reviews, and meta-analyses. The review of this literature suggests that a negative NCCT followed by a negative LP adequately rules out SAH. Traumatic LPs, however, have the potential to create false-positive results that lead to increased downstream testing. Clinicians may have difficulty interpreting equivocal results, given that there is no definitive way to distinguish blood in the cerebrospinal fluid from a traumatic tap vs. blood from an SAH (37,38). The specificity of LP is approximately 65% (35).

Recommendation: Patients presenting with headache symptoms concerning for SAH can be evaluated safely with NCCT, followed by LP (if CT is negative).

Level of Recommendation: B.

NCCT Alone

There have been significant advances in CT scanning. The introduction of 64-slice CT scanners and improvements in imaging software have improved the sensitivity of NCCT. If done within the first 6 h of headache onset, NCCT is reported to have a sensitivity of 100% (97.0%–100.0%), specificity of 100% (99.5%–100%), negative predictive value of 100% (99.5%–100%), and positive predictive value of 100% (96.9%–100%) (20,21,23,39). NCCT alone also may be a more cost-effective strategy in the diagnosis of SAH (25). However, a validation study regarding CT scan within 6 h of

Table 3. Grade and Quality of Literature

Article no.	First Author, Year	Grade	Quality	Design/Size
1	Phillips, 2011 (2)	C	Good	Prospective cohort (459 patients)
2	Perry, 2010 (4)	C	Good	Prospective cohort (1999 enrolled, 130 cases)
3	Mehrotra, 2010 (16)	C	Adequate	Prospective cohort (128 patients)
4	Matloob, 2013 (6)	D	Adequate	Case control (112 patients, 4 cases)
5	Chalouhi, 2013 (17)	D	Adequate	Case control (35 patients, 16 cases)
6	Czuczman, 2013 (14)	E	Adequate	Case series (280 patients)
7	Khan, 2013 (18)	E	Adequate	Case series (50 patients)
8	Mark, 2013 (19)	D	Good	Case control (223 patients, 55 cases)
9	Backes, 2012 (20)	D	Adequate	Prospective cohort (250 patients)
10	Gee, 2012 (21)	E	Poor	Case series (134 patients)
11	Muhammed, 2010 (22)	E	Adequate	Case series (100 patients)
12	Eggers, 2011 (11)	E	Adequate	Cases series (220 patients)
13	Cortnum, 2010 (23)	E	Adequate	Cases series (296 patients)
14	Dupont, 2008 (12)	D	Good	Retrospective cohort (152 patients)
15	Bø, 2008 (5)	D	Unsatisfactory	Prospective cohort (163 patients)
16	Lourenco, 2009 (24)	E	Adequate	Case series (61 cases)
17	Farzad, 2013 (15)	F	Unsatisfactory	Unstructured literature review
18	Ward, 2012 (25)	E	Adequate	Theoretical modeling
19	Jehle, 2012 (26)	E	Unsatisfactory	Case series (7 cases)
20	Horstman, 2012 (27)	E	Poor	Case series (30 cases)
21	Brown, 2011 (8)	E	Adequate	Expert opinion
22	Perry, 2009 (7)	F	Poor	Cross-sectional survey (1149 respondents)
23	Vivancos, 2014 (28)	E	Poor	Literature review
24	McCormack, 2010 (29)	E	Adequate	Systematic review
25	Edlow, 2010 (10)	E	Adequate	Systematic review
26	Savitz, 2009 (30)	B	Good	Meta-analysis (7 studies)
27	Eldow, 2008 (31)	E	Adequate	Systematic review
28	Rana, 2013 (32)	E	Adequate	Case series (9 cases)
29	Rogers, 2014 (33)	F	Poor	Cross-sectional survey (878 respondents)
29	Rogers, 2014 (33)	F	Poor	Cross-Sectional Survey (878 respondents)
30	Gangloff, 2015 (34)	D	Good	Retrospective cohort (706 patients)
31	Chu, 2014 (13)	E	Adequate	Systematic review

Table 4. Supportive Evidence*

Quality	Grade					
	A	B	C	D	E	F
Outstanding						
Good		26	1, 2	8, 14, 30		
Adequate			3	4, 5, 9	6, 7, 12, 13, 16, 18, 21, 24, 25, 27, 28, 31	
Poor					10, 11, 20, 23	22, 29
Unsatisfactory				15	19	17

* Article numbers from Table 3.

headache onset found that NCCT alone missed approximately 20% of SAHs (19). Furthermore, NCCT sensitivity decreases as the time from the onset of the headache increases (27,40). It is estimated that current NCCT is >90% sensitive for diagnosing SAH in the first 24–48 h, with some studies reporting sensitivities around 97% if the study is done in the first 12 h after the onset of headache (24,41,42). Many of these studies, however, relied on experienced neuroradiologist interpretations, where most CTs are actually read by general radiologists, emergency physicians, or neurologists (43). Additionally, many of these studies are limited by spectrum bias, whereas the pretest probability of SAH may be higher than the average population of awake and alert patients being evaluated (31,44,45).

Recommendation: There is insufficient evidence at this time to support the use of NCCT alone in the evaluation of SAH, even if the NCCT is performed within the first 6 h.

CT/CTA

CTA is very sensitive and specific for the detection of aneurysms in the setting of SAH. A recent study showed 64-slice CTA to be 98% sensitive and 100% specific for detecting aneurysms >3 mm (46). Approximately 85% of all nontraumatic SAHs are caused by arteriovenous malformations (AVMs) or aneurysms. Detection and treatment of these aneurysms within 24 h of rupture is associated with a significant decrease in morbidity (47). SAH from other causes tends to have a better prognosis and repeat angiography is generally unwarranted (18). A recent analysis of the utility of CTA in the workup of possible SAH determined that, if the pretest probability of SAH is $\leq 15\%$ (acute-onset headache, nonfocal neurologic examination), then a negative NCCT and negative CTA would correlate to a <1% chance of SAH due to AVM or aneurysm (29). These authors stated that in patients with a higher pretest probability (e.g., those with classic presentation, abnormal neurologic examination, or risk factors), a strategy incorporating NCCT, CTA, and LP may be appropriate. In the setting of a negative CTA, there is likely no added benefit to further

evaluation with classic angiography to evaluate for aneurysmal bleed, even in the setting of a positive LP (32). CTA can also be beneficial in the workup of acute-onset headache through the diagnosis of symptomatic aneurysms, allowing for treatment before rupture. These abnormalities would go undetected if the classic CT/LP approach were employed (26).

A major drawback to vascular imaging is the discovery of aneurysms that are not the cause of the headache, with the consequent exposure of the patient to the risks of additional testing and potentially unnecessary procedures (31). CTA also exposes the patient to approximately 2–4 mSv of radiation, as well as possible harm from the administration of intravenous contrast (nephrotoxicity, allergic reactions) (48). In addition, CTA is an expensive study and can require significant time to perform and interpret.

The literature on the use of CTA to diagnose cerebral aneurysms includes several prospective cohort studies, retrospective reviews, and case series (46,47,49,50). There are no comparative studies that specifically evaluate CT/LP vs. CTA in the diagnosis of aneurysmal SAH.

Recommendation: CTA is a reasonable strategy to consider for excluding aneurysmal SAH in select patients (in hospitals where CTA is available). It may be an appropriate alternative in those patients at higher risk for SAH after a negative NCCT and in those situations where a diagnostic LP is either refused by the patient or the results of the LP are equivocal.

Level of Recommendation: B.

DISCUSSION

This review of the available medical literature focused on the ED diagnosis of SAH. Although the body of literature on this disease continues to grow, there remains no ideal strategy for attempting to diagnose SAH in the ED. The classic CT/LP approach is known to have a high sensitivity and high negative predictive value. Inclusion of the LP after a negative NCCT has been shown to identify SAH that would have been missed by NCCT alone (34). However, LPs are frequently complicated by needle

trauma and often leave clinicians with equivocal results. As CT technology continues to improve, NCCT alone (especially within the first 6 h of headache) may prove sensitive enough to make the LP obsolete. Unfortunately, the literature remains sparse and more prospective trials are needed before this diagnostic strategy can be safely employed. NCCT followed by CTA has been shown to be highly sensitive and specific for aneurysmal SAH. The body of evidence suggests that this is a reasonable strategy in the workup of SAH in the ED. Clinicians must, however, consider the possibility of incidental aneurysms on CTA and should have candid discussions with their patients regarding the potential for false-positive results before ordering these studies.

Limitations

The review of the clinical question addressed in this article is limited by the quantity and quality of publications on the topic. Also, the structure and search parameters of this literature review may have resulted in omitted information. We did not evaluate magnetic resonance imaging/magnetic resonance angiography in this review, given the relative lack of timely availability in many institutions.

CONCLUSIONS

The available literature on SAH suggests that the CT/LP and NCCT/CTA approaches are both reasonable diagnostic strategies in the evaluation of this disease. At this time, there is a lack of evidence to support the use of NCCT alone, even if performed within 6 h of headache onset.

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