CT in SAH
Do we still need LP?

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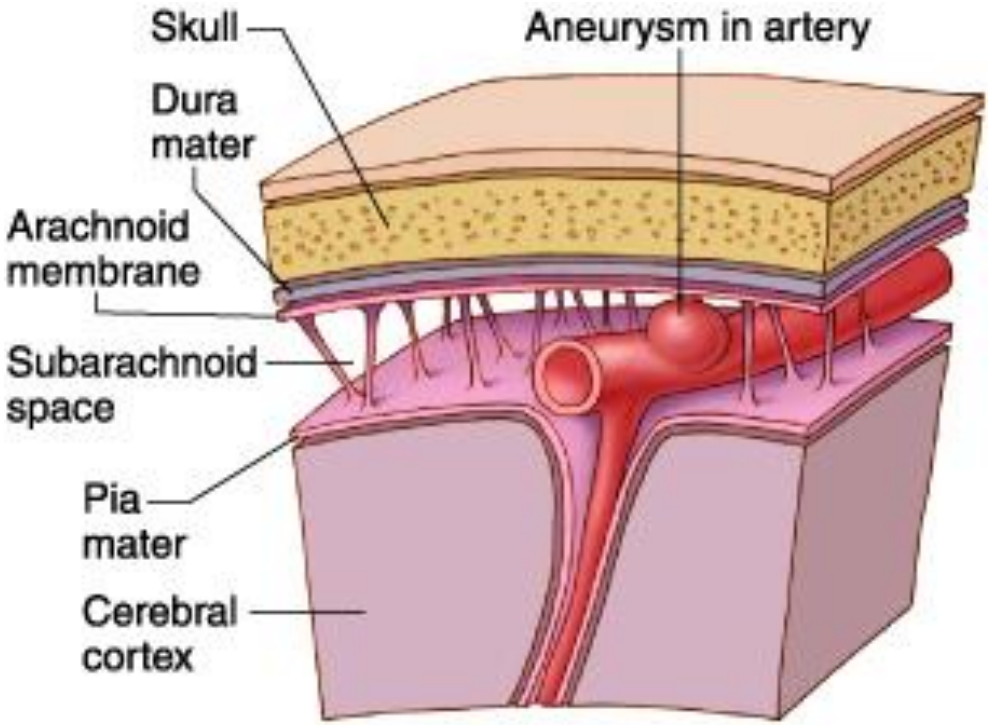
2016

PRESENTATION PLAN

1. **Definitions**
2. **New strategies for diagnosis**
3. **Brief summary**



BRIEF REPORT

February 18, 2004, Vol 291, No. 7

JAMA The Journal of the American Medical Association

JAMA. 2004 Feb 18;291(7):866-9.

Initial misdiagnosis and outcome after subarachnoid hemorrhage.

Kowalski RG[1], Claassen J, Kreiter KT, Bates JE, Ostapkovich ND, Connolly ES, Mayer SA.

⊕ Author information

Abstract

CONTEXT: Mortality and morbidity can be reduced if aneurysmal subarachnoid hemorrhage (SAH) is treated urgently.

OBJECTIVE: To determine the association of initial misdiagnosis and outcome after SAH.

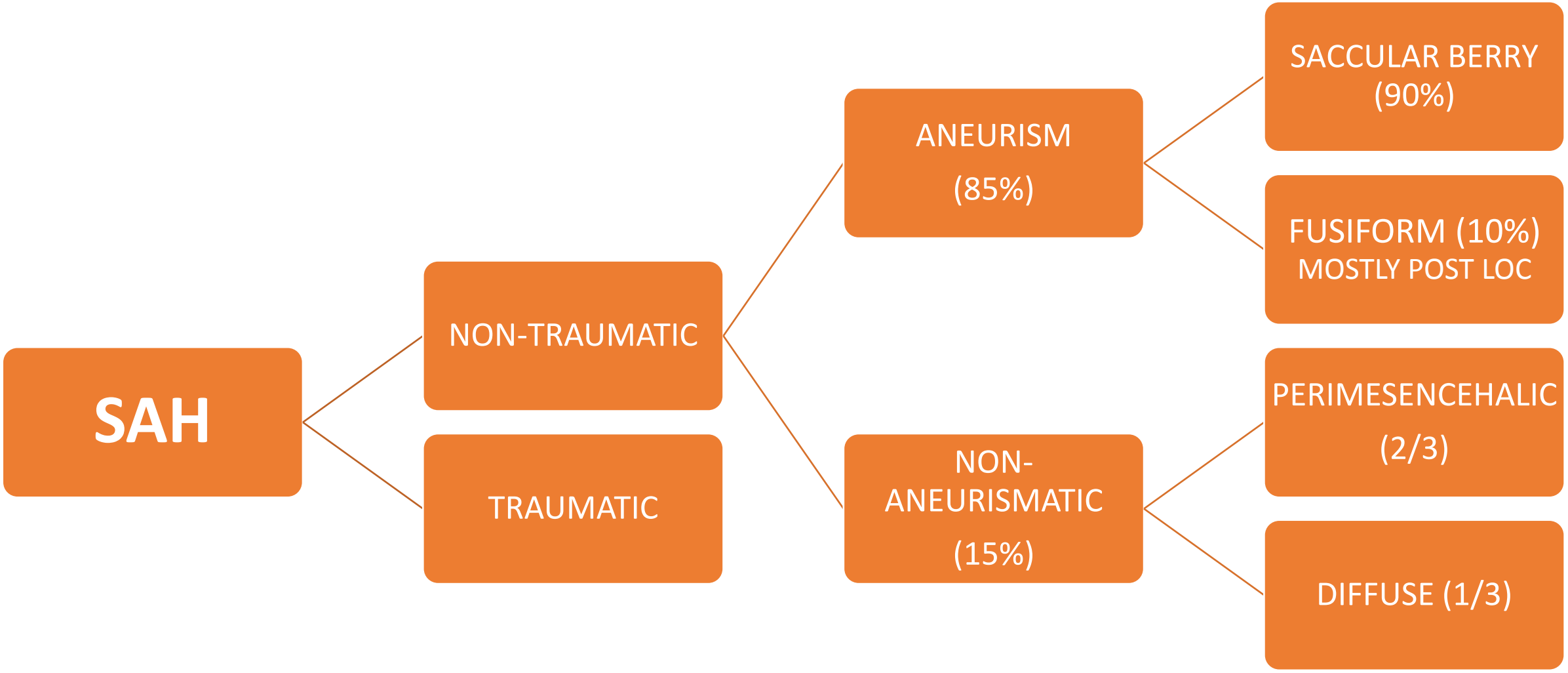
DESIGN, SETTING, AND PARTICIPANTS: Inception cohort of 482 SAH patients admitted to a tertiary care urban hospital between August 1996 and August 2001.

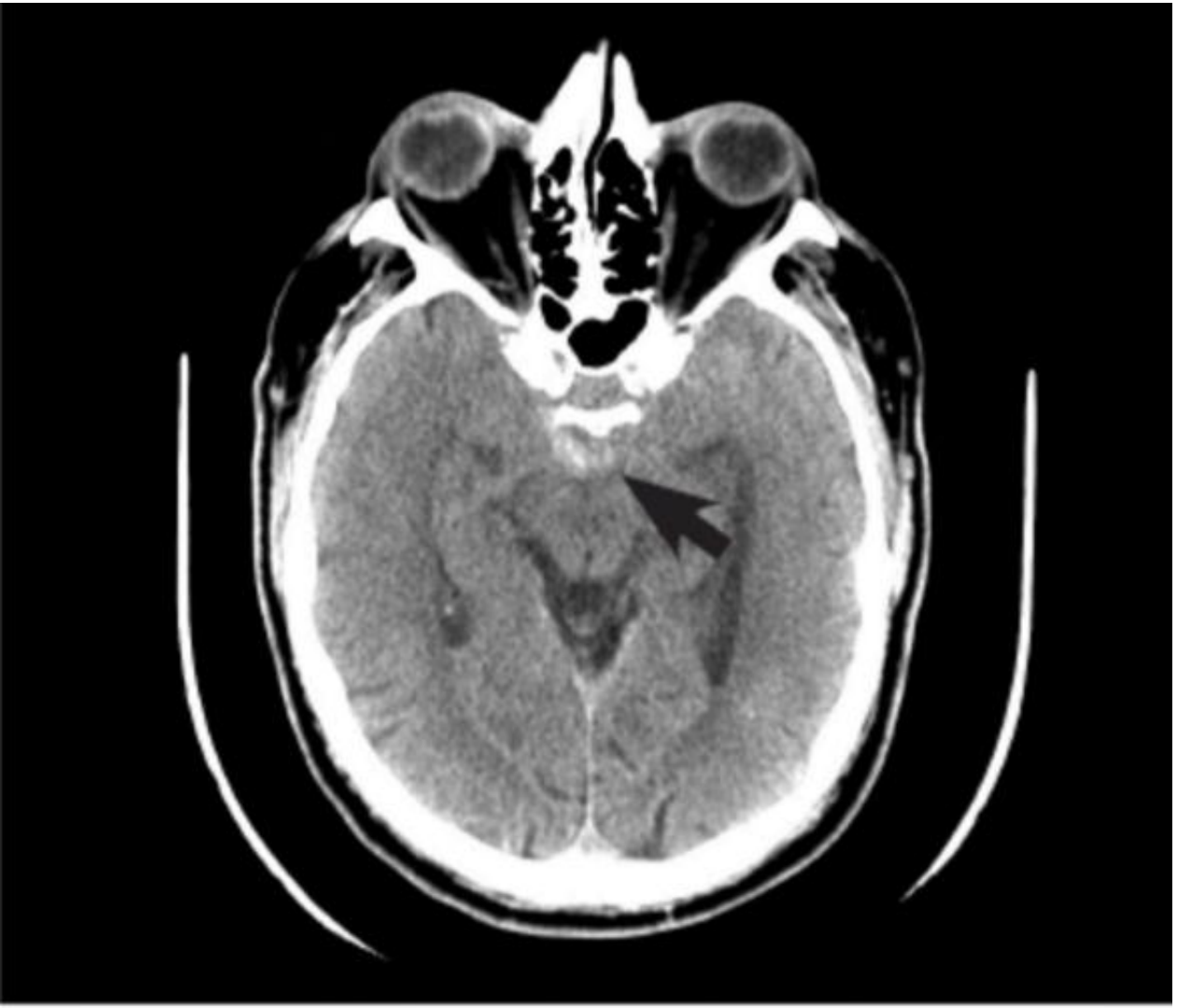
MAIN OUTCOME MEASURES: Misdiagnosis was defined as failure to correctly diagnose SAH at a patient's initial contact with a medical professional. Functional outcome was assessed at 3 and 12 months with the modified Rankin Scale; quality of life (QOL), with the Sickness Impact Profile.

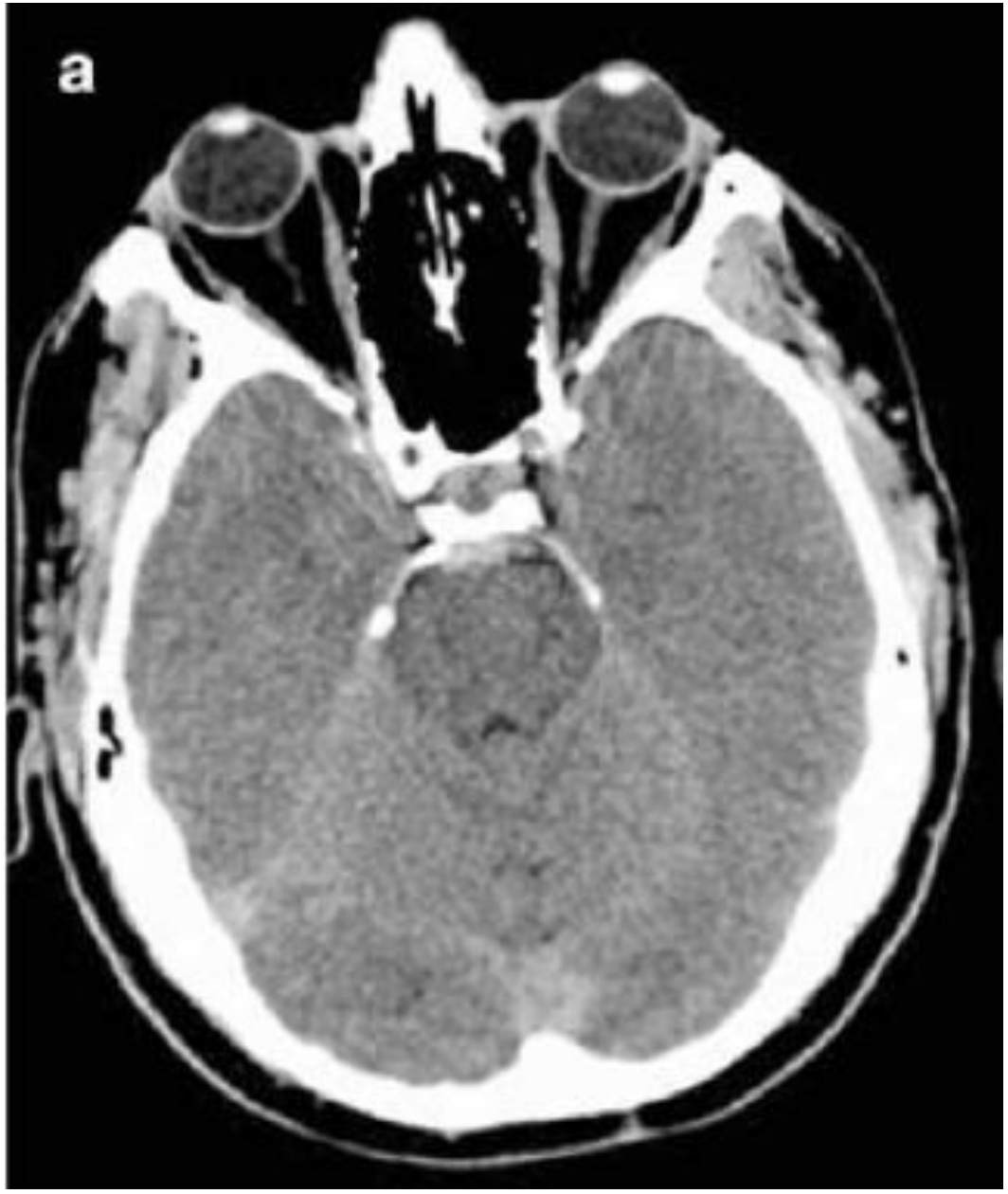
RESULTS: Fifty-six patients (12%) were initially misdiagnosed, including 42 of 221 (19%) of those with normal mental status at first contact. Migraine or tension headache (36%) was the most common incorrect diagnosis, and failure to obtain a computed tomography (CT) scan was the most common diagnostic error (73%). Neurologic complications occurred in 22 patients (39%) before they were correctly diagnosed, including 12 patients (21%) who experienced rebleeding. Normal mental status, small SAH volume, and right-sided aneurysm location were independently associated with misdiagnosis. Among patients with normal mental status at first contact, misdiagnosis was associated with worse QOL at 3 months and an increased risk of death or severe disability at 12 months.

CONCLUSIONS: In this study, misdiagnosis of SAH occurred in 12% of patients and was associated with a smaller hemorrhage and normal mental status. Among individuals who initially present in good condition, misdiagnosis is associated with increased mortality and morbidity. A low threshold for CT scanning of patients with mild symptoms that are suggestive of SAH may reduce the frequency of misdiagnosis.

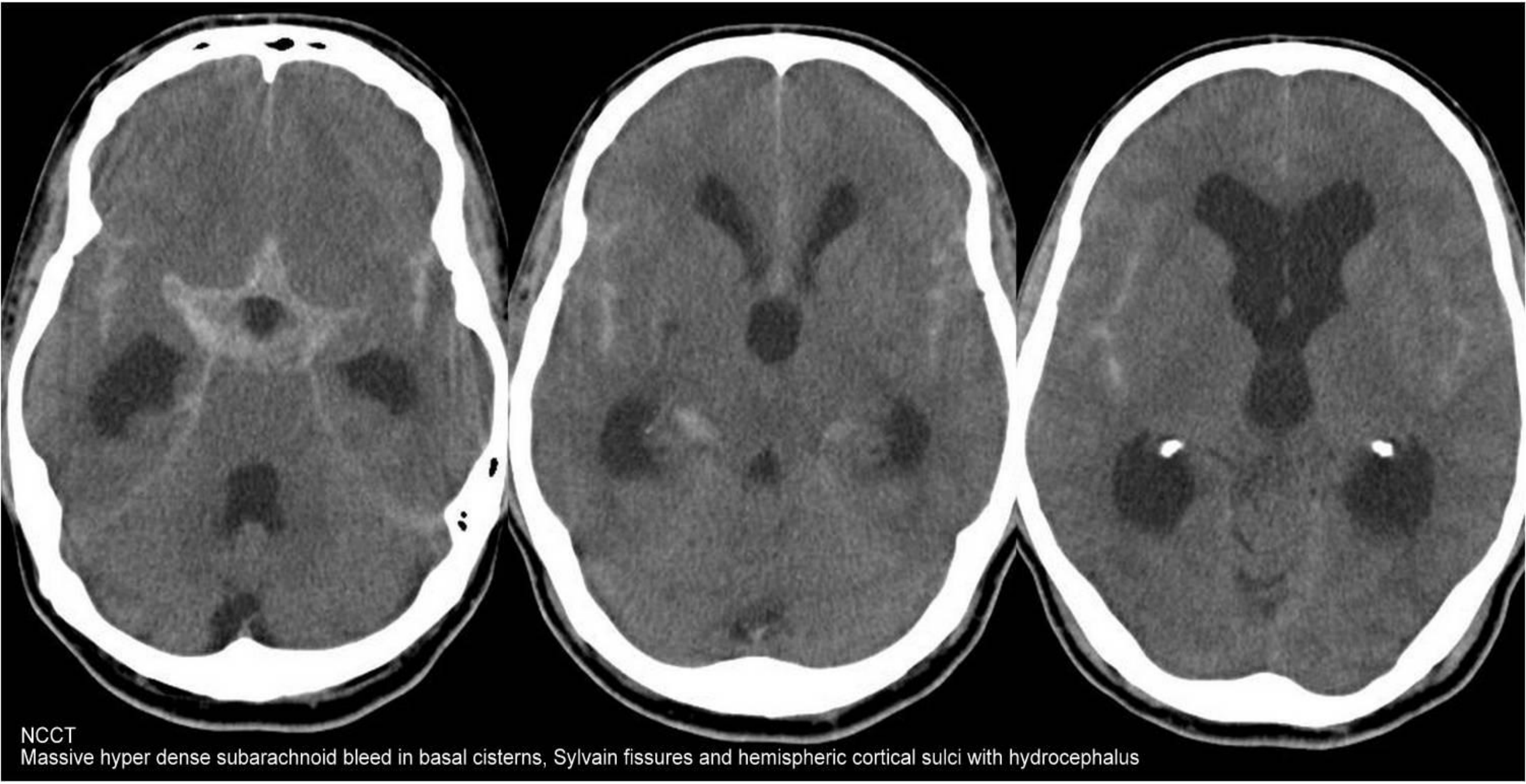
PMID: 14970066 [PubMed - indexed for MEDLINE]


SAH
NON-TRAUMATIC
TRAUMATIC
ANEURISM
(85%)
NON-
ANEURISMATIC
(15%)
SACCULAR BERRY
(90%)
FUSIFORM (10%)
MOSTLY POST LOC
PERIMESENCEHALIC
(2/3)
DIFFUSE (1/3)





A characteristic pattern of hyperdense blood anterior to the midbrain is seen. No aneurysm was found on follow-up angiogram. (Reprinted with permission from Lisa Thomas, MD.)



NCCT
Massive hyper dense subarachnoid bleed in basal cisterns, Sylvain fissures and hemispheric cortical sulci with hydrocephalus

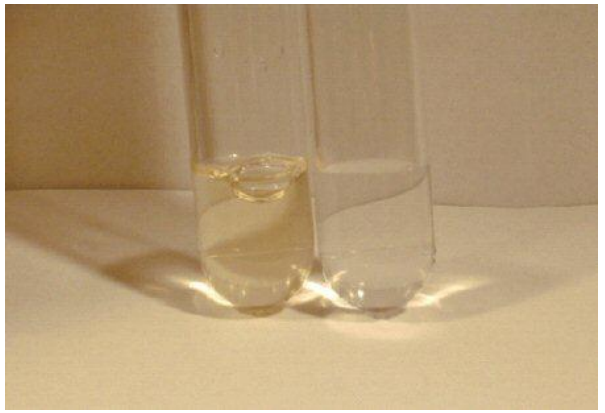
CURRENT PRACTICE GUIDELINES FOR Dx SAH

- Begin with NCCT
- If NCCT Negative or Non-Dx → LP (Both North America and UK Guidelines)
- Based on studies done in the 1980s and 1990s
- Older studies reported the sensitivity of CT scanning to be between 93-95%
- Sensitivity declines to 85% after 3 days and to as low as 50% after a week

LP PROS

- Gold-standart Dx test
- **Spectrophotometry**
- Sensitivity 99-100%

LP CONS



- Painful, difficult
- Limitations in diagnosing unruptured aneurysm, arterial dissection, cerebral venous sinus thrombosis
- Xanthocromia
- Traumatic LP (15%)
- Post LP headache (%4-16)
- Compl. like epidural hematoma

Alternatives for NCCT + LP for Dx of SAH

1) NCCT Alone
2) NCCT + CTA
3) MRI + MRA
4) Blood Biomarkers

1) NCCT ALONE

Selected Studies Reporting Sensitivity of CT for SAH

Study	YEAR	Data	Sensitivity, % (95% CI)	Comments
Lourenco et al.[27]	2009	61 SAH: 60 CT, 1 LP	97 (84–100)	Did not factor time to CT, retrospective, allowed abnormal mental status and exam
Byyny et al.[26]	2008	149 SAH: HA, normal exam 139 CT, 10 LP	93 (88–97) HA, normal neuro exam 91 (82–97)	Did not factor time to CT, retrospective, subgroup of HA with normal neuro exam
Boesiger et al.[20]	2005	177pts/6 SAH: 6 CT, 0 LP	100 (64–100)	Did not factor time to CT, wide CI, retrospective
Sidman et al.[24]	1996	140 patients 80/80 CT <12 hours 49/60 CT >12 hours	Overall 92 100 82	Retrospective, 100% prevalence, allowed abnormal mental status/exam
Sames et al.[25]	1996	114 < 24 hours HA 37 > 24 hours HA	93 84	Retrospective, 100% prevalence, allowed abnormal mental status/exam
Van der Waal et al.[23]	1995	175patients 119 SAH: 117 CT, 2 LP	98	CT <12 hours, high prevalence (69%) of disease

CT = computed tomography; HA = headache; LP = lumbar puncture; SAH = subarachnoid hemorrhage.

ACADEMIC EMERGENCY MEDICINE 2010; 17:444–451

The Journal of Emergency Medicine, Vol. 50, No. 4, pp. 696–701, 2016

Clinical Practice Paper

CrossMark

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‡

NCCT Alone

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.

CRITICAL CARE

REVIEW

Aneurysmal subarachnoid haemorrhage from a neuroimaging perspective

In conclusion, negative NCCT might be enough to rule out SAH in patients presenting within 6 hours of headache onset. Patients presenting beyond the 6-hour mark require additional diagnostic testing if NCCT is negative [3,4].

Neurology. 2015 May 12;84(19):1927-32. doi: 10.1212/WNL.0000000000001562. Epub 2015 Apr 10.

CT within 6 hours of headache onset to rule out subarachnoid hemorrhage in nonacademic hospitals.

Blok KM[1], Rinkel GJ[1], Majoie CB[1], Hendrikse J[1], Braaksma M[1], Tijssen CC[1], Wong YY[1], Hofmeijer J[1], Extercatte J[1], Kerklaan B[1], Schreuder TH[1], ten Holter S[1], Verheul F[1], Harlaar L[1], Pruissen DM[1], Kwa VI[1], Brouwers PJ[1], Remmers MJ[1], Schonewille WJ[1], Kruyt ND[1], Vergouwen MD[2].

⊕ Author information

Abstract

OBJECTIVE: To investigate whether staff radiologists working in nonacademic hospitals can adequately rule out subarachnoid hemorrhage (SAH) on head CT <6 hours after headache onset.

METHODS: In a multicenter, retrospective study, we studied a consecutive series of patients presenting with acute headache to 11 nonacademic hospitals. Inclusion criteria were (1) normal level of consciousness without focal deficits, (2) head CT <6 hours after headache onset and reported negative for the presence of SAH by a staff radiologist, and (3) subsequent CSF spectrophotometry. Two neuroradiologists and one stroke neurologist from 2 academic tertiary care centers independently reviewed admission CTs of patients with CSF results that were considered positive for presence of bilirubin according to local criteria. We investigated the negative predictive value for detection of SAH by staff radiologists in nonacademic hospitals on head CT in patients scanned <6 hours after onset of acute headache.

RESULTS: Of 760 included patients, CSF analysis was considered positive for bilirubin in 52 patients (7%). Independent review of these patients' CTs identified one patient (1/52; 2%) with a perimesencephalic nonaneurysmal SAH. Negative predictive value for detection of subarachnoid blood by staff radiologists working in a nonacademic hospital was 99.9% (95% confidence interval 99.3%-100.0%).

CONCLUSIONS: Our results support a change of practice wherein a lumbar puncture can be withheld in patients with a head CT scan performed <6 hours after headache onset and reported negative for the presence of SAH by a staff radiologist in the described nonacademic setting.

Stroke. 2016 Mar;47(3):750-5. doi: 10.1161/STROKEAHA.115.011386. Epub 2016 Jan 21.

Sensitivity of Early Brain Computed Tomography to Exclude Aneurysmal Subarachnoid Hemorrhage: A Systematic Review and Meta-Analysis.

Dubosh NM[1], Bellolio MF[2], Rabinstein AA[2], Edlow JA[2].

⊕ Author information

Abstract

BACKGROUND AND PURPOSE: Emerging evidence demonstrating the high sensitivity of early brain computed tomography (CT) brings into question the necessity of always performing lumbar puncture after a negative CT in the diagnosis of spontaneous subarachnoid hemorrhage (SAH). Our objective was to determine the sensitivity of brain CT using modern scanners (16-slice technology or greater) when performed within 6 hours of headache onset to exclude SAH in neurologically intact patients.

METHODS: After conducting a comprehensive literature search using Ovid MEDLINE, Ovid EMBASE, Web of Science, and Scopus, we conducted a meta-analysis. We included original research studies of adults presenting with a history concerning for spontaneous SAH and who had noncontrast brain CT scan using a modern generation multidetector CT scanner within 6 hours of symptom onset. Our study adheres to the preferred reporting items for systematic reviews and meta-analyses (PRISMA).

RESULTS: A total of 882 titles were reviewed and 5 articles met inclusion criteria, including an estimated 8907 patients. Thirteen had a missed SAH (incidence 1.46 per 1000) on brain CTs within 6 hours. Overall sensitivity of the CT was 0.987 (95% confidence intervals, 0.971-0.994) and specificity was 0.999 (95% confidence intervals, 0.993-1.0). The pooled likelihood ratio of a negative CT was 0.010 (95% confidence intervals, 0.003-0.034).

CONCLUSIONS: In patients presenting with thunderclap headache and normal neurological examination, normal brain CT within 6 hours of headache is extremely sensitive in ruling out aneurysmal SAH.

NCCT PROS

- Available in EDs
- Fast
- Cheap

NCCT CONS

- Inter-rater and intra-rater reliability
- 2% of cancers attributed to CT
  → Use CT for older patients

Acad Emerg Med. 2016 May;23(5):591-8. doi: 10.1111/acem.12941. Epub 2016 Apr 17.

False-negative Interpretations of Cranial Computed Tomography in Aneurysmal Subarachnoid Hemorrhage.

Mark DG[1], Sonne DC[2], Jun P[3], Schwartz DT[4], Kene MV[5], Vinson DR[6], Ballard DW[7].

⊕ Author information

Abstract

OBJECTIVES: Prior studies examining the sensitivity of cranial computed tomography (CT) for the detection of subarachnoid hemorrhage (SAH) have used the final radiology report as the reference standard. However, optimal sensitivity may have been underestimated due to misinterpretation of reportedly normal cranial CTs. This study aims to estimate the incidence of missed CT evidence of SAH among a cohort of patients with aneurysmal SAH (aSAH).

METHODS: We performed a retrospective chart review of emergency department (ED) encounters within an integrated health delivery system between January 2007 and June 2013 to identify patients diagnosed with aSAH. All initial noncontrast CTs from aSAH cases diagnosed by lumbar puncture (LP) and angiography following a reportedly normal noncontrast cranial CT (CT-negative aSAH) were then reviewed in a blinded, independent fashion by two board-certified neuroradiologists to assess for missed evidence of SAH. Reviewers rated the CT studies as having definite evidence of SAH, probable evidence of SAH, or no evidence of SAH. Control patients who underwent a negative evaluation for aSAH based on cranial CT and LP results were also included at random in the imaging review cohort.

RESULTS: A total of 452 cases of aSAH were identified; 18 (4%) were cases of CT-negative aSAH. Of these, seven (39%) underwent cranial CT within 6 hours of headache onset, and two (11%) had their initial CTs formally interpreted by board-certified neuroradiologists. Blinded independent CT review revealed concordant agreement for either definite or probable evidence of SAH in nine of 18 (50%) cases overall and in five of the seven (71%) CTs performed within 6 hours of headache onset. Inter-rater agreement was 83% for definite SAH and 72% for either probable or definite SAH.

CONCLUSIONS: CT evidence of SAH was frequently present but unrecognized according to the final radiology report in cases of presumed CT-negative aSAH. This finding may help explain some of the discordance between prior studies examining the sensitivity of cranial CT for SAH.

2) NCCT + CTA

The Journal of Emergency Medicine, Vol. 50, No. 4, pp. 696–701, 2016

Clinical Practice Paper

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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‡

CT + CTA

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.

Selected Studies Reporting Sensitivity of Multidetector CTA for Cerebral Aneurysm

Study	YEAR	Data	Sensitivity, %	Specificity, %	Comments
Kokkinis et al.[32]	2008	198 patients SAH: 179 w/ AN, 15 AVM	97.9	100	Single detector, found all AVMs
El Khaldi et al.[31]	2007	104 patients, 84 w/ AN, 0 AVM	98.8	100	16-detector CT
Yoon et al.[30]	2007	85 patients SAH 71 w/ AN, 0 AVM	100 for leaking AN 92.5 all AN	100 93.3	16-detector, caught 100% of culprit AN
Agid et al.[28]	2006	65 patients w/SAH, 47 w/ AN, 0 AVM	97.9 for AN (95% CI = 88.9%–99.9%)	100	64-detector CT

AN = cerebral aneurysm; AVM = arterial venous malformation; CT = computed tomography; CTA = computed tomography angiography; LP = lumbar puncture; SAH = subarachnoid hemorrhage.

ACADEMIC EMERGENCY MEDICINE 2010; 17:444–451

Can Computed Tomography Angiography of

Abstract

Objectives: The primary goal of evaluation for acute-onset headache is to exclude aneurysmal subarachnoid hemorrhage (SAH). Noncontrast cranial computed tomography (CT), followed by lumbar puncture (LP) if the CT is negative, is the current standard of care. Computed tomography angiography (CTA) of the brain has become more available and more sensitive for the detection of cerebral aneurysms. This study addresses the role of CT/CTA versus CT/LP in the diagnostic workup of acute-onset headache.

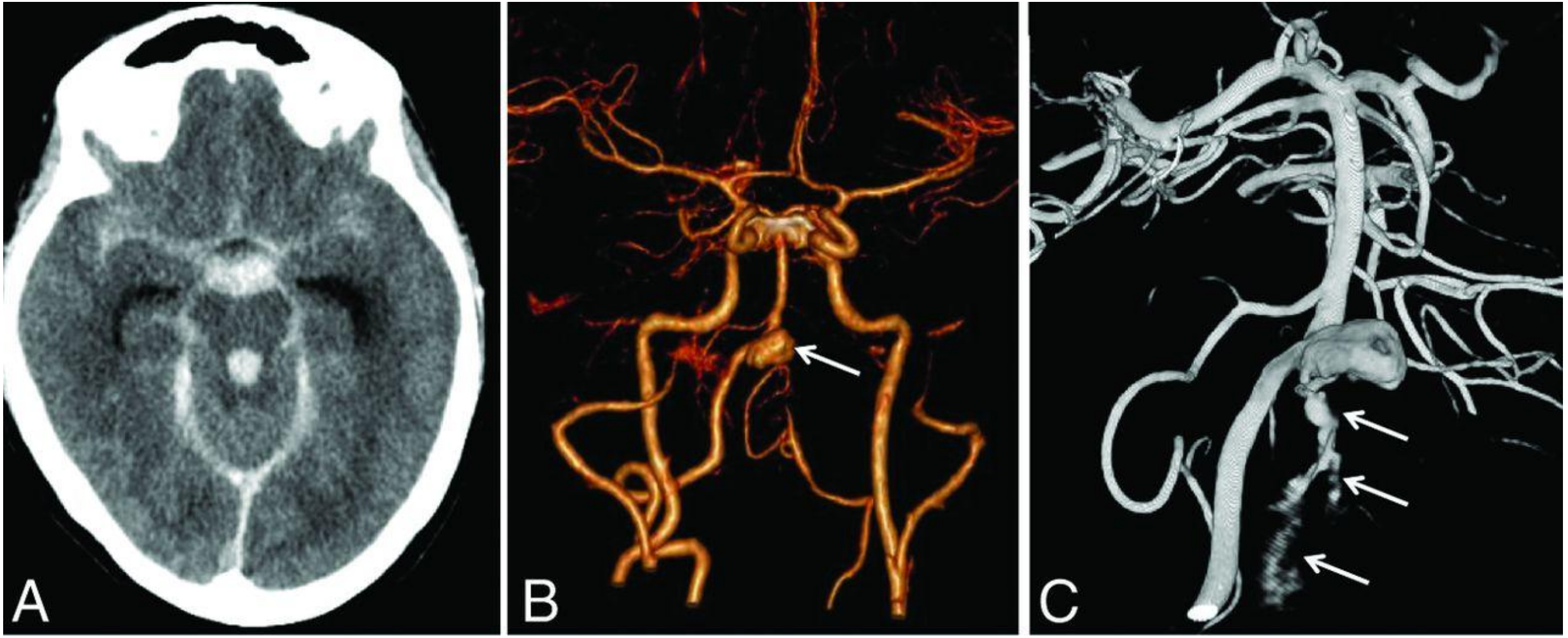
Methods: This article reviews the recent literature for the prevalence of SAH in emergency department (ED) headache patients, the sensitivity of CT for diagnosing acute SAH, and the sensitivity and specificity of CTA for cerebral aneurysms. An equivalence study comparing CT/LP and CT/CTA would require 3,000 + subjects. As an alternative, the authors constructed a mathematical probability model to determine the posttest probability of excluding aneurysmal or arterial venous malformation (AVM) SAH with a CT/CTA strategy.

Results: SAH prevalence in ED headache patients was conservatively estimated at 15%. Representative studies reported CT sensitivity for SAH to be 91% (95% confidence interval [CI] = 82% to 97%) and sensitivity of CTA for aneurysm to be 97.9% (95% CI = 88.9% to 99.9%). Based on these data, the posttest probability of excluding aneurysmal SAH after a negative CT/CTA was 99.43% (95% CI = 98.86% to 99.81%).

Conclusions: CT followed by CTA can exclude SAH with a greater than 99% posttest probability. In ED patients complaining of acute-onset headache without significant SAH risk factors, CT/CTA may offer a less invasive and more specific diagnostic paradigm. If one chooses to offer LP after CT/CTA, informed consent for LP should put the pretest risk of a missed aneurysmal SAH at less than 1%.

ACADEMIC EMERGENCY MEDICINE 2010; 17:444–451 © 2010 by the Society for Academic Emergency Medicine

NCCT + CTA



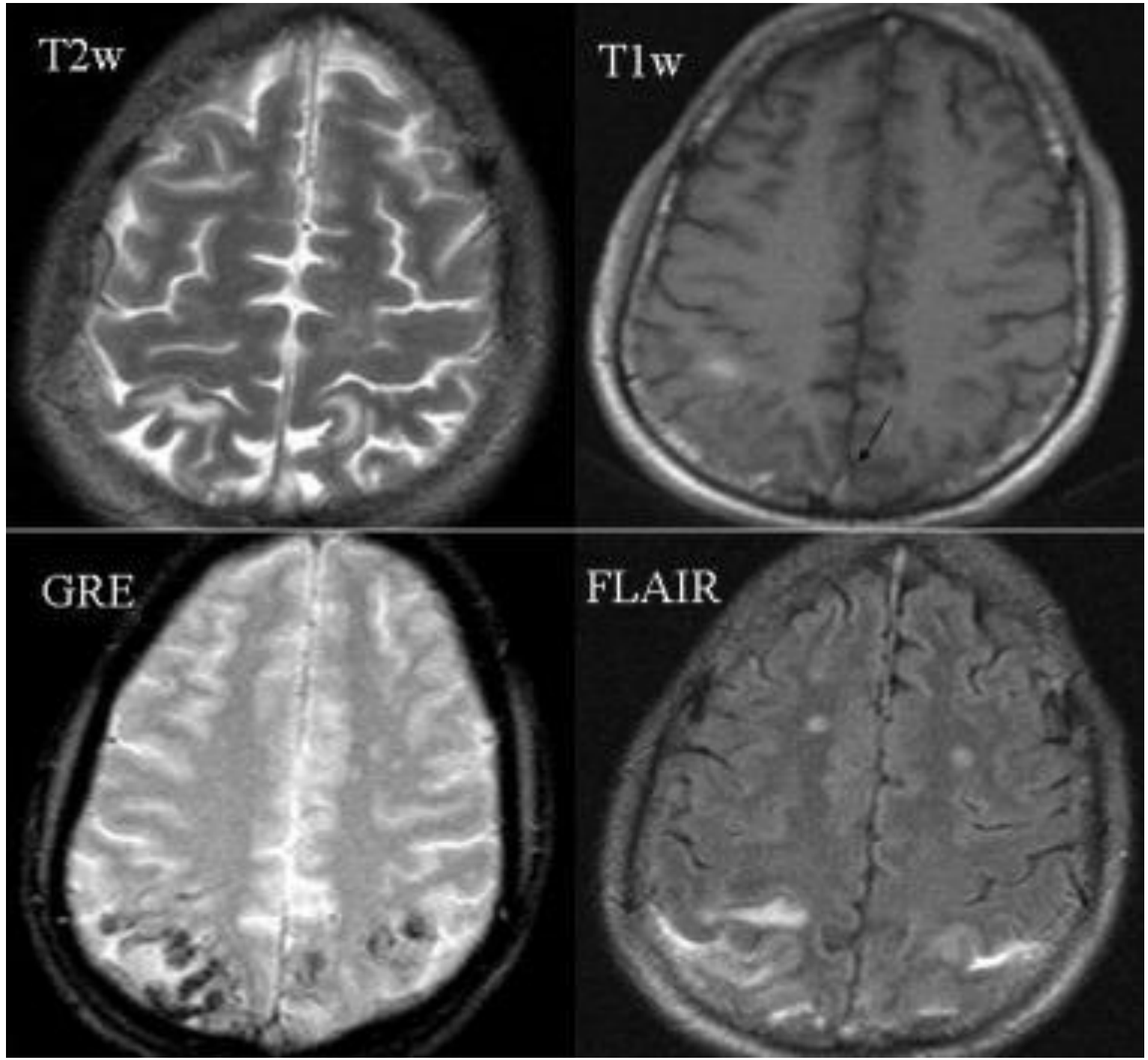
3) MRI + MRA

MRI

- MRI more sensitive than CT for detecting SAH
- T1 : anatomy
- T2 : pathology, liquids do shine

- **FLAIR** (T2): CSF shining is repressed

- **T2 gradient echo (T2 star)**: blood seen black


T2w
T1w
GRE
FLAIR

Summary Statistics Comparing FLAIR Sequences, T2 Gradient Echo, and NCCT for Assessment of Acute and Late Presentations of the SAH

First Author, Year	No. of Patients with MRI	FLAIR Sensitivity (%)	T2 Gradient Echo Sensitivity (%)	CT Sensitivity (%)	Criterion Standard (Comments)
Mitchell, 2001 (12)	16 acute	81	94	95	CT or LP for positive cases, CT and LP for negative cases
	15 late	89	100	75	
Yaun, 2004	11 acute	100	91	91	LP/surgery (three with trauma)
	11 late	33	100	46	
Mohamed, 2004 (61)	12, timing not reported	17	Not tested	†	LP positive, CT negative (missed cases all with <35,000 RBCs on LP)
da Rocha, 2006 (11)	32 acute	100	38	72	CT or MRI finding SAH (included 25 trauma patients)
	10 late	100	30	50	

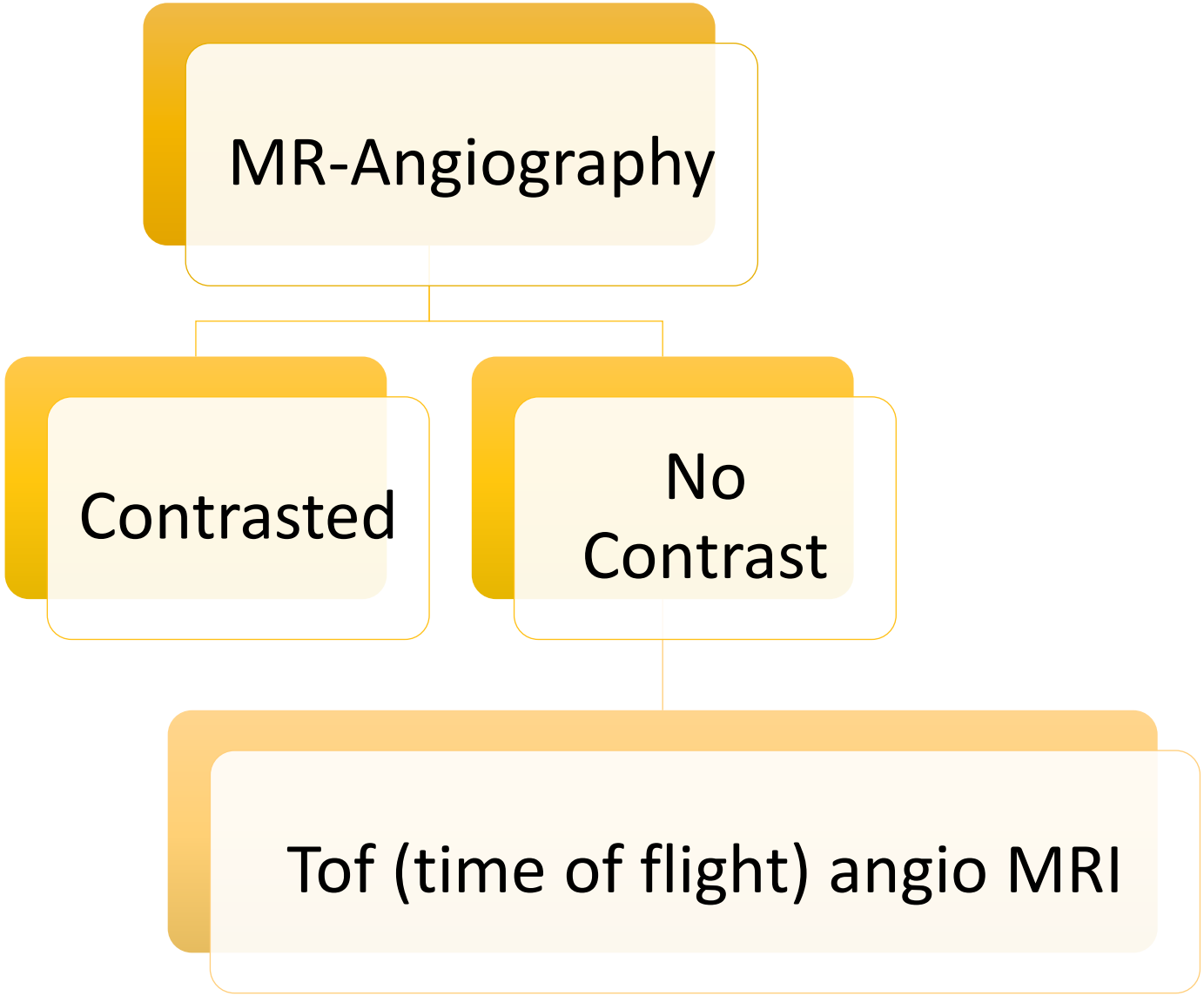
CT = computed tomography; FLAIR = fluid attenuation inversion recovery; LP = lumbar puncture; MRI = magnetic resonance imaging; RBCs = red blood cells; SAH = subarachnoid hemorrhage.

* Acute is defined as <4 or 5 days after onset. Late is defined as >4 or 5 days after onset (studies used cut points of 4 or 5 days).

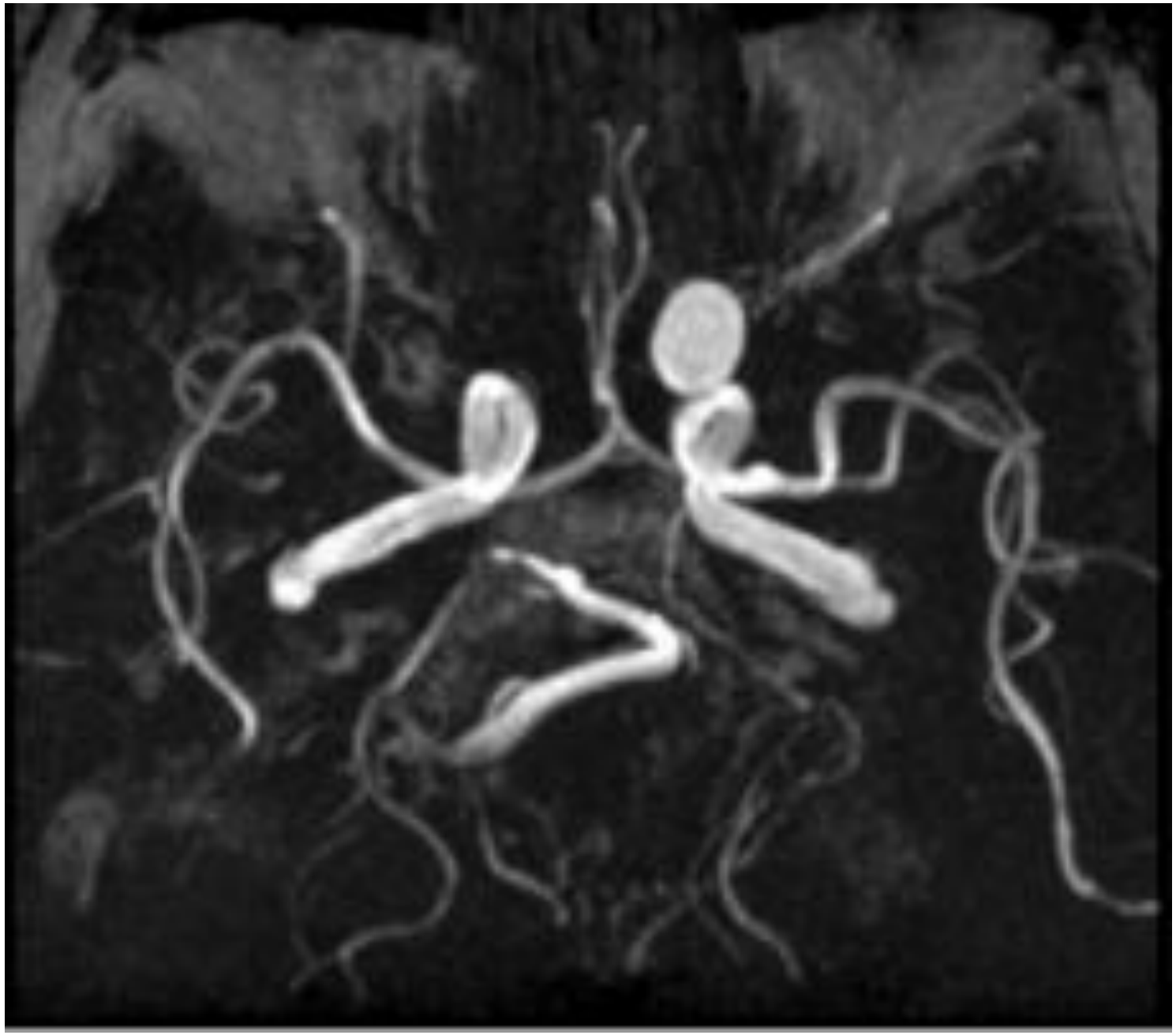
† This study included only cases missed by CT.

EMERGENCY DIAGNOSIS OF SUBARACHNOID HEMORRHAGE: AN EVIDENCE-BASED DEBATE

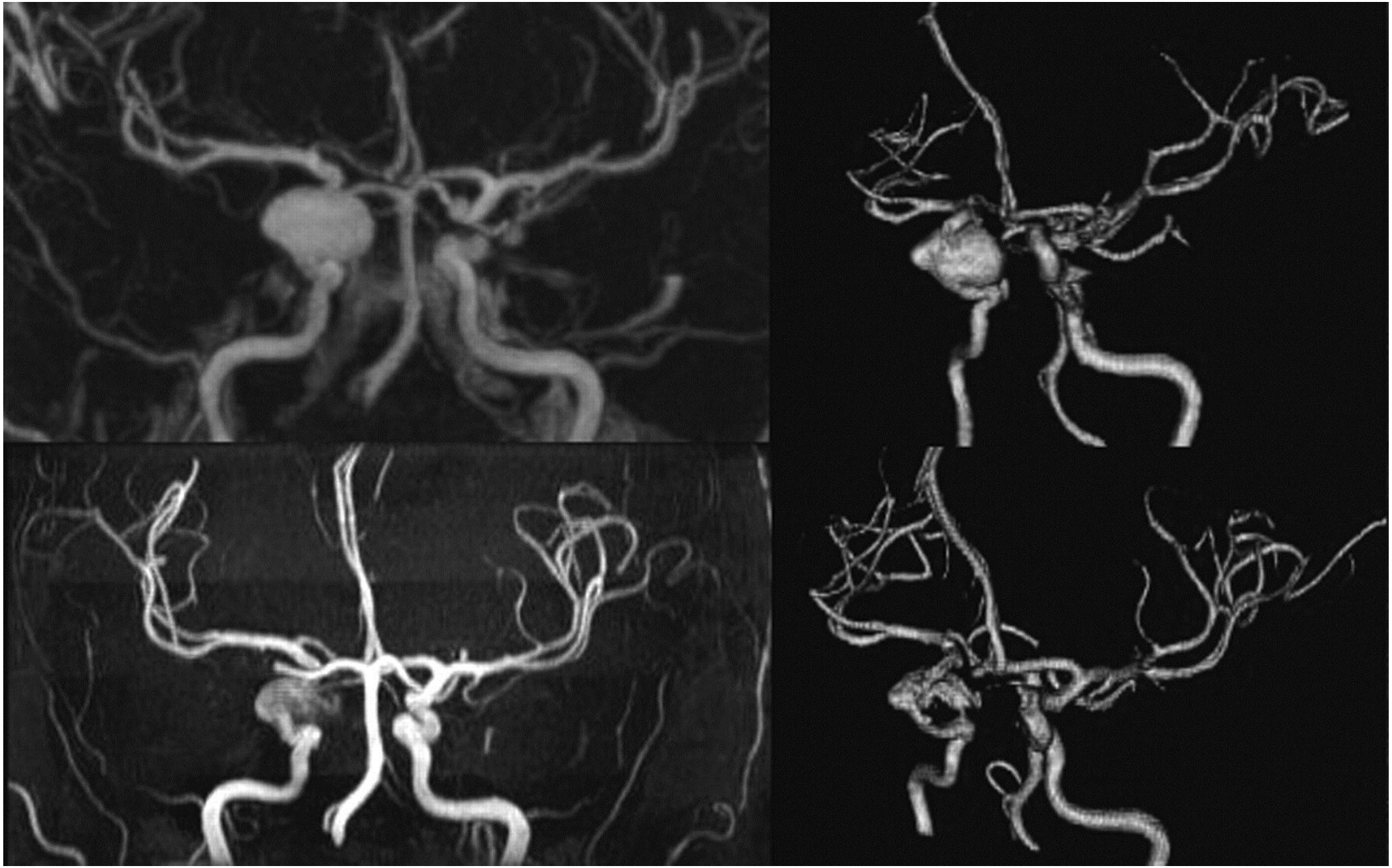
The Journal of Emergency Medicine, Vol. 44, No. 5, pp. 1045–1053, 2013


MR-Angiography
Contrasted
No Contrast
Tof (time of flight) angio MRI

TOF
MRA



CONTRASTED MRA



MRI PROS

- Not exposed to radiation
- Inflamatory signs of meningitis and encephalitis discernible

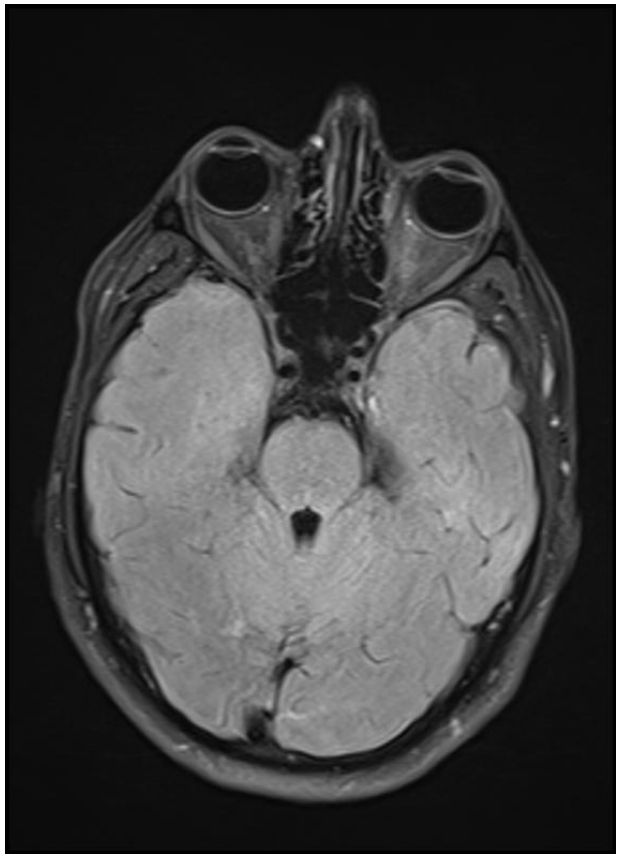
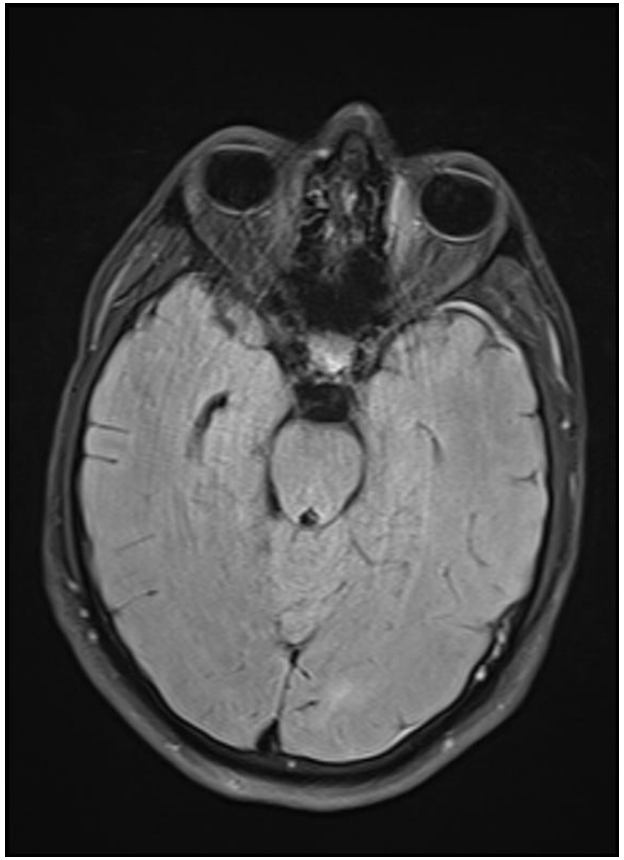
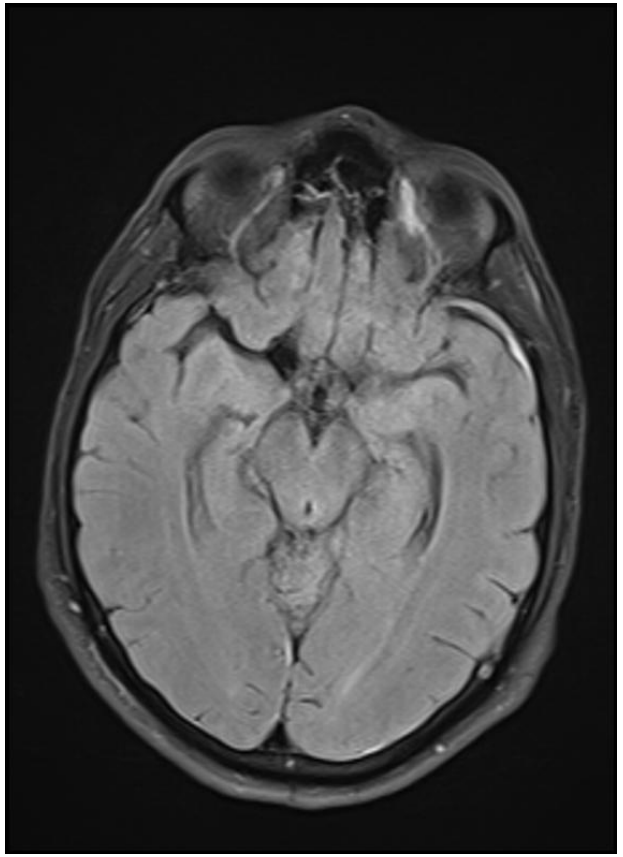
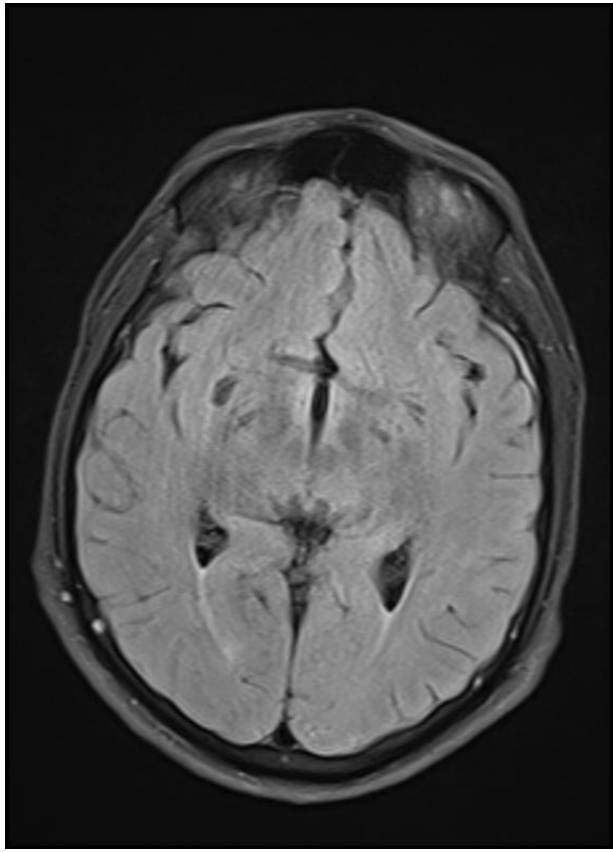
MRI CONS

- Unavailable in EDs
- Needs more time to conduct compared to CT
- Need for specialty radiologist
- No access 7/24
- Metal devices

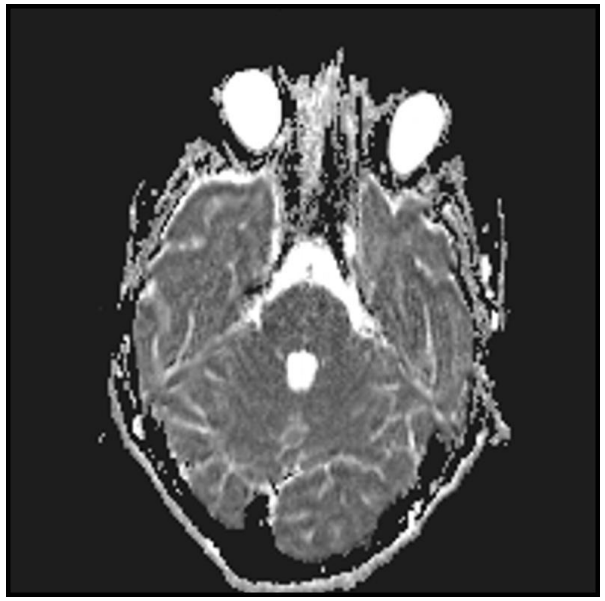
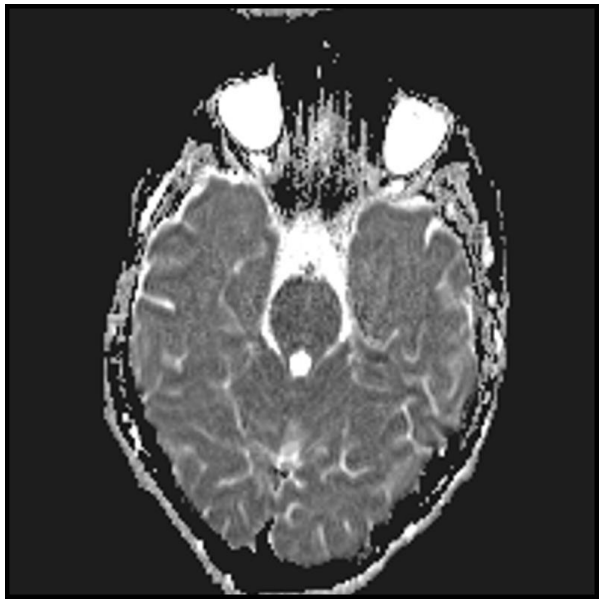
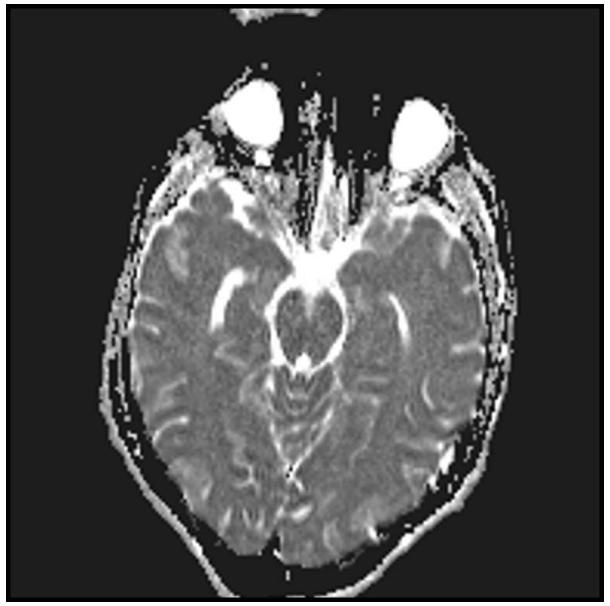
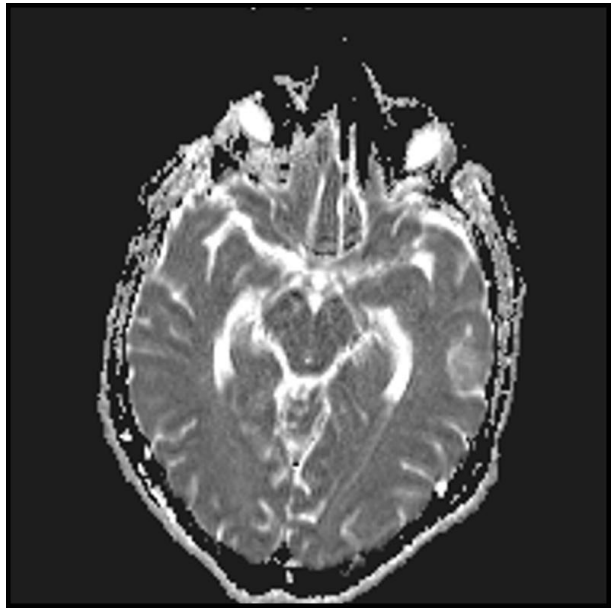
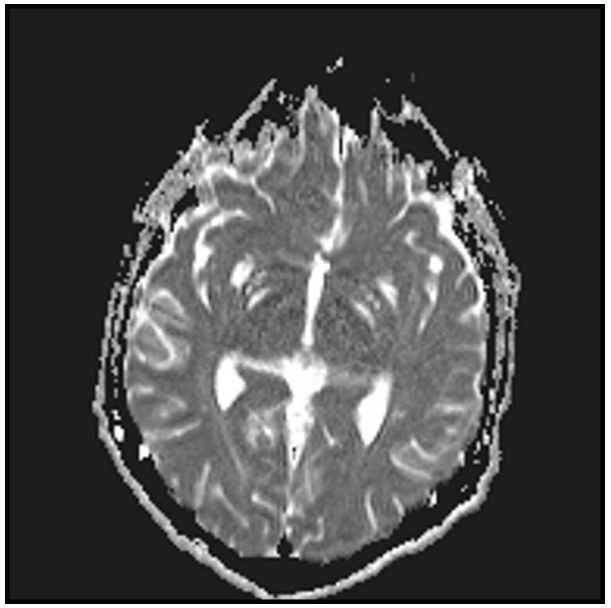
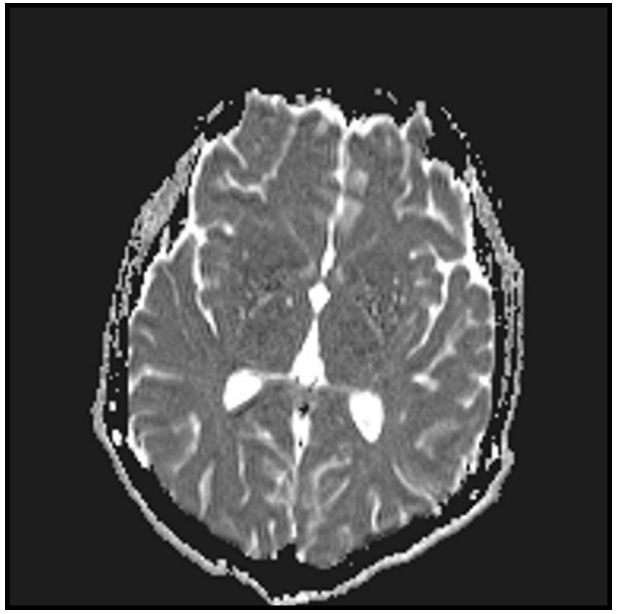




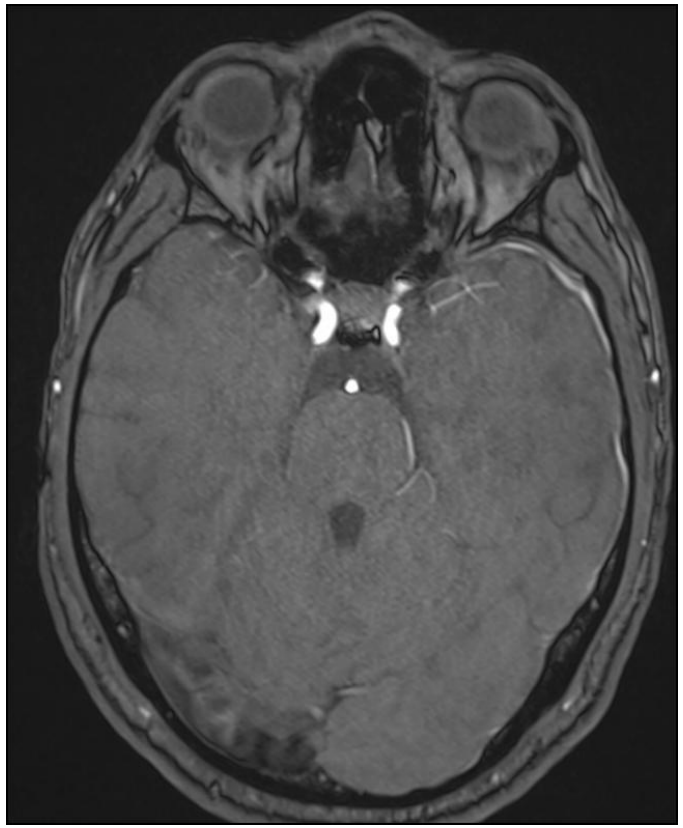

T2 MRI

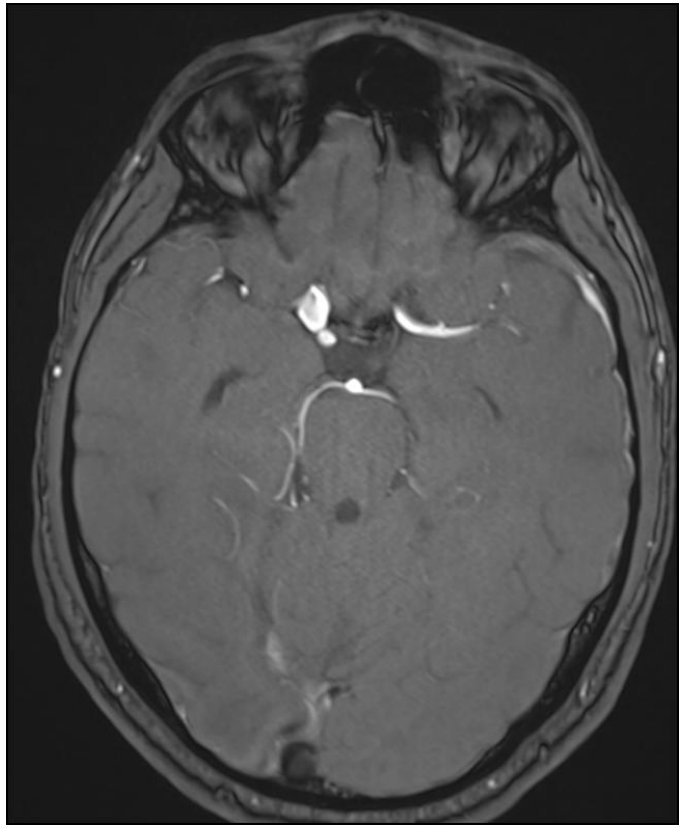





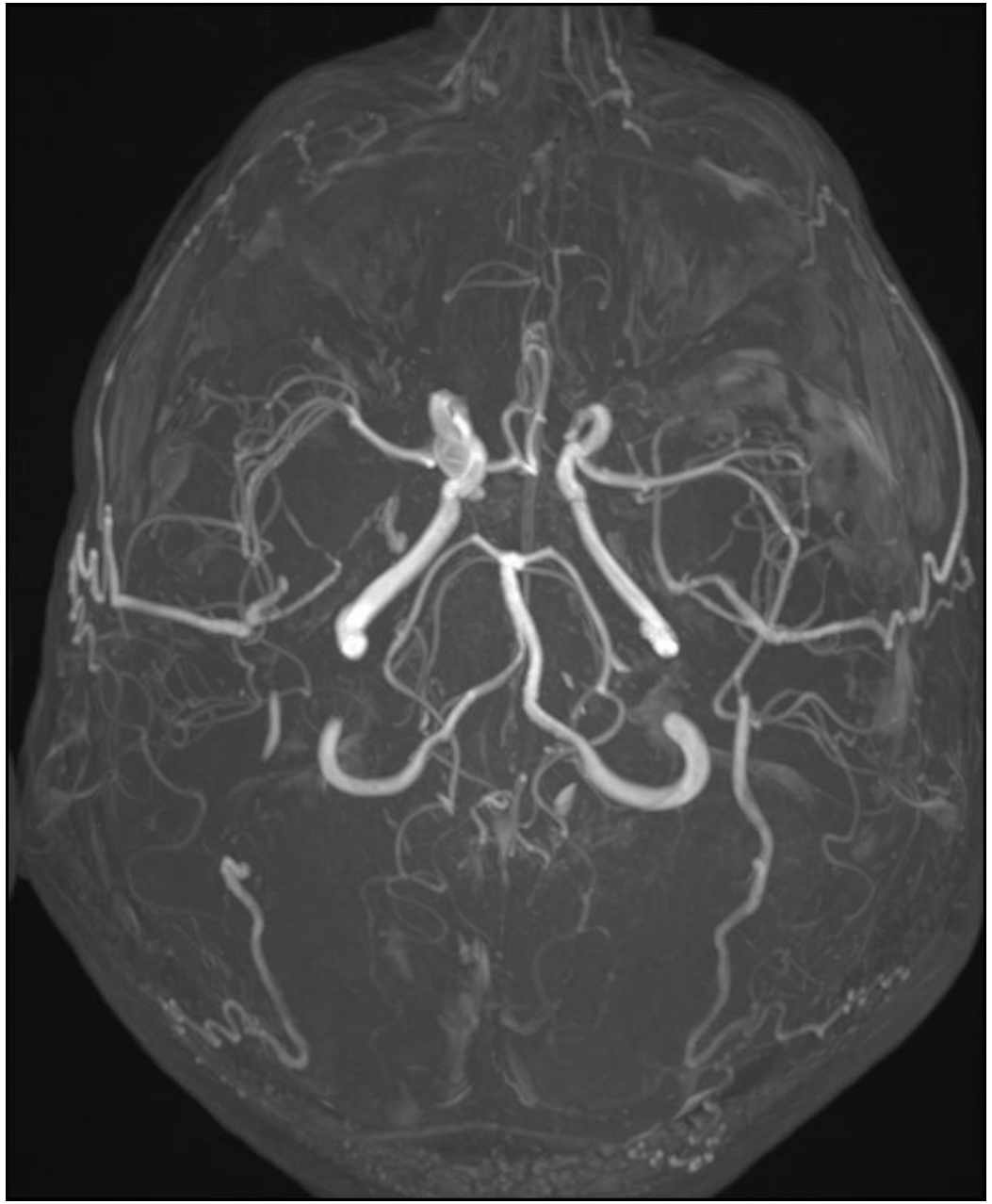
Apparent diffusion coefficient (ADC) Diffusion-weighted Imaging (DWI)

TOF MRA







4) Blood Biomarkers

Se s:

Table 2. Blood and Cerebrospinal Fluid (CSF) Biomarkers in Ruptured Aneurysms (RAs)

Author and Year	Number of Patients (Diagnosis)	Mean Age (SD)/(Range)	CSF Biomarkers	Blood Biomarkers
Wiesmann et al., 1997 (41)	Number = 71 (RA); control = 120 (healthy)	54.5 (12.2)/(30—77); control: 40.1 (13.6)/(18—65)		S-100 protein levels were increased in RA and correlated with outcomes.
Polin et al., 1998 (32)	Number = 17 (RA); control = 16 (no acutely ruptured aneurysms)	46.2 (23—84); control: 54.6 (28—86)	E-selectin, ICAM-1, VCAM-1 were all elevated in RA. No significant difference in L-selectin levels.	
Mack et al., 2002 (20)	Number = 101 (RA); control = 6 (no clinical or radiographic evidence of SAH; 4 UA and 2 with herniated disks)	52 (17—89); control: 56 (20—72)		ICAM-1 was increased after rupture and correlated with outcomes.
Mangieri et al., 2003 (21)	Number = 35 (RA; 9 grade I, 14 grade II, and 12 grade III SAH on Hunt and Hess scale)	51.9 (13.3)		Cortisol levels were higher than normal in all patients. Mean levels of prolactin, FSH, LH, TSH, T3, and T4 were within normal range.
Casulari et al., 2004 (5)	Number = 30 (RA); control = 25 (lumbar disk hernia or stable spinal trauma)	41.7 (11.4); control: 41.3 (14.2)		T3 and free T4 levels were lower in RA group. No significant difference in levels of T4 and TSH.
Tanriverdi et al., 2005 (39)	Number = 12 (RA); control = 8 (hydrocephalus without any other known central nervous system disease)	46.9 (17—71); control: 44.6 (14—81)	E-selectin was elevated in RA group.	E-selectin was elevated in RA group.
Petzold et al., 2006 (30)	Number = 149 (SAH); control = 416 (lumbar CSF from neurologic patients undergoing routine lumbar puncture)	54 (35—72)	NfHSM135 elevated in SAH group and correlated with outcomes.	
Witkowska et al., 2008 (42)	Number = 27 (RA); control = 17	56 (33—77); control: 55 (38—71)		TNF-α low after rupture, but did not correlate with Fisher score. ICAM-1 levels positively correlated with severity of bleeding on Fisher scale and negatively correlated with patient's scoring in the Glasgow outcome score.
Jia et al., 2011 (14)	Number = 9 (RA); control = 5 (intracranial tumors)	Median 42 (18—59)		E-selectin found in wall of aneurysm tissue, but rarely in controls.

SD, standard deviation; ICAM, intercellular adhesion molecule; VCAM, vascular cell adhesion molecule; SAH, subarachnoid hemorrhage; UA, unruptured aneurysm; FSH, follicle-stimulating hormone; LH, luteinizing hormone; TSH, thyroid-stimulating hormone; NfHSM135, neurofilament heavy chain SM135; TNF, tumor necrosis factor.

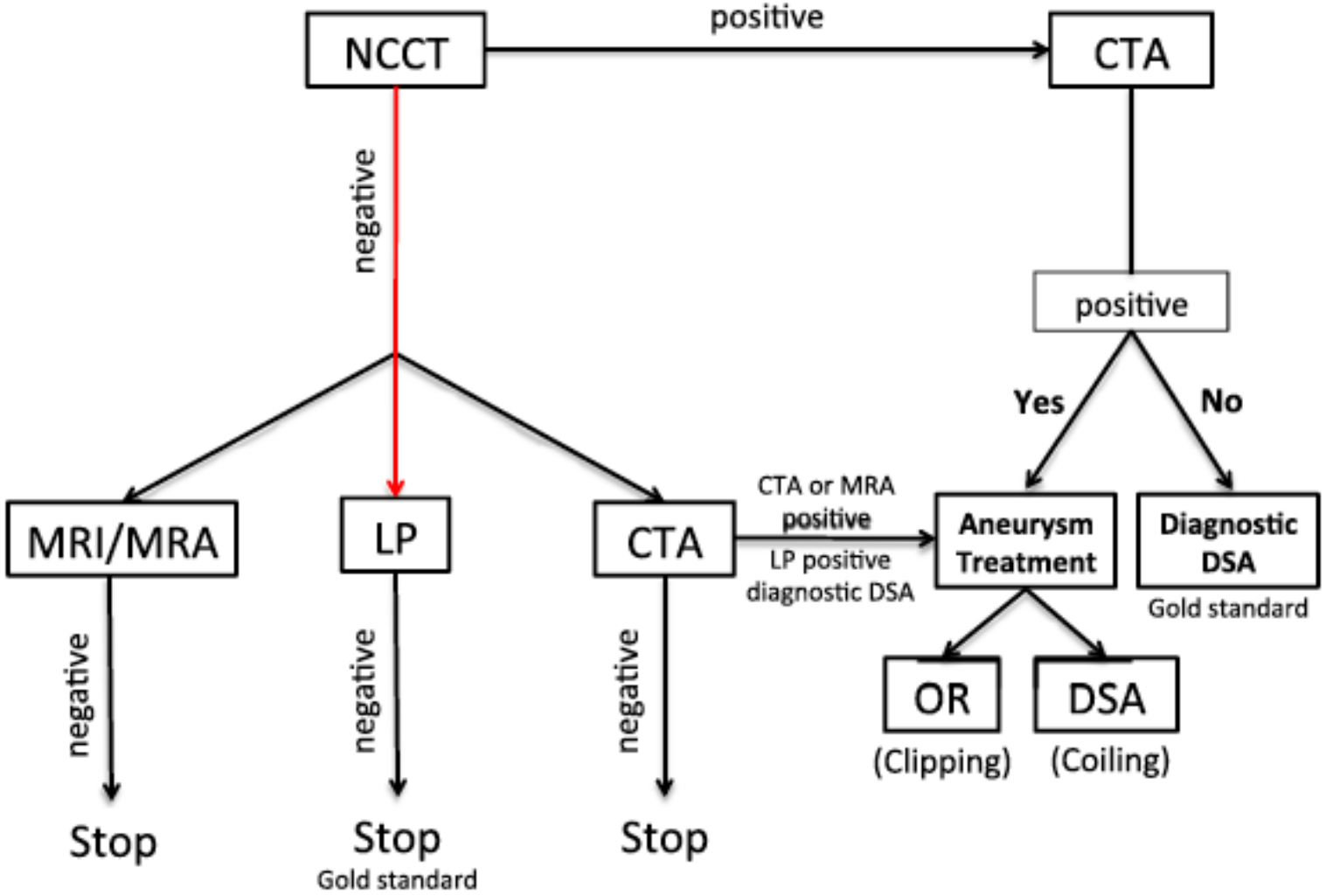


Figure 1 Diagnostic approach for subarachnoid haemorrhage in patients presenting with more than 6 hours of headache onset. CTA, computed tomography angiography; DSA, digital subtraction angiography; LP, lumbar puncture; MRA, magnetic resonance angiography; MRI, magnetic resonance imaging; NCCT, noncontrast computed tomography; OR, operating room.

Aneurysmal subarachnoid haemorrhage from a neuroimaging perspective. de Oliveira Manoel et al. Critical Care 2014, 18:557

Take Home Points

1) More recent studies suggesting NCCT alone within 6 hours
2) Give the decision of LP with your patient and use spectrophotometry
3) CT/CTA and MR/MRA other options for NCCT+LP
4) For MRI → “Flair” and “T2 gradient echo” should be used
5) No biomarkers yet : Hyponatremia, serum T3 and fT4 lower, cortisol elevated

Thank you