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EXPERIMENTAL RESEARCH - VASCULAR

Spontaneous subarachnoid hemorrhage and negative initial vascular imaging—should further investigation depend upon the pattern of hemorrhage on the presenting CT?

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Abstract
Background Multiple investigations are usually performed in patients with spontaneous SAH who have negative initial angiography. This study aimed to evaluate the most appropriate use of additional imaging studies and how this may be influenced by the findings of the initial CT.
Methods A retrospective analysis was performed on a prospectively collected cohort of patients referred with spontaneous SAH and negative initial angiography. The patients were divided into four categories based upon the distribution of blood on the initial CT: perimesencephalic (pSAH), diffuse (dSAH), sulcal (sSAH) and CT negative (CSF positive for xanthochromia) (nCT-pLP). The number and nature of the subsequent imaging investigations were reviewed, and the results were correlated with the findings of the presenting CT.
Results One hundred fourteen patients were included in the study. Repeat imaging found five relevant abnormalities. Three cases of vasculitis were diagnosed on the first DSA following a negative CTA. A case of dissecting aneurysm was revealed on the third neurovascular study. A hemorrhagic spinal tumor presented with xanthochromia. No subsequent abnormality was found on the third DSA or MRI head. No case of pSAH had a subsequent positive finding if the initial CTA was negative.
Conclusions Certain patterns of SAH are associated with a low yield of abnormalities on repeat imaging if the initial angiography is normal. The authors believe that the pattern of hemorrhage on the presenting CT should be used to guide the most appropriate use of further imaging modalities and present a diagnostic algorithm for this purpose.

Keywords Subarachnoid hemorrhage · Perimesencephalic · Diffuse · Sulcal · Angiography

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Introduction

While the source of hemorrhage is not found in 15–20 % of patients with spontaneous SAH [9, 27], previous studies have documented a small number of missed vascular abnormalities on initial neurovascular imaging [1, 11, 34]. Multiple repeat investigations are usually performed in this group of patients who have negative initial angiography in order to improve the detection of potentially treatable pathologies. There is however little consensus on the best use of additional imaging studies and the necessity for multiple imaging modalities in determining the cause of spontaneous SAH. This study aimed to evaluate the most appropriate use of additional imaging studies and how this may be influenced by the findings of the initial diagnostic CT.

Materials and methods

A retrospective analysis was performed on a prospectively collected cohort of patients who presented to our neuroscience center over a 6-year period, with spontaneous SAH (confirmed by either CT or CSF xanthochromia) and the initial angiography (CTA or DSA) failed to reveal the source of hemorrhage. Patients with a history of trauma and those with equivocal lumbar punctures were excluded. The number and nature of the repeat imaging investigations were reviewed, and the results were correlated with the findings of the presenting CT.

The patients were divided into four categories based on the initial CT finding: perimesencephalic SAH (pSAH), diffuse SAH (dSAH), sulcal SAH (sSAH) or CT negative but CSF positive for xanthochromia (nCT-pLP). A patient was considered to have experienced perimesencephalic SAH if blood was confined to the cisterns around the midbrain, possibly with some extension to the suprasellar cistern but not to the anterior interhemispheric fissure, lateral Sylvian fissure or cerebral ventricles [31]. Sulcal SAH was defined as the presence of blood exclusively within the peripheral cerebral sulci. Any other distribution of blood visible on the presenting CT was considered to constitute a diffuse SAH.

Results

Between January 2007 and April 2013, a total of 114 patients presented to our center with definite CT or LP-positive spontaneous SAH, and the initial neurovascular studies were negative. This included 41 cases of pSAH, 6 cases of sSAH, 50 cases of dSAH and 17 cases with nCTpLP.

Imaging modalities (see Table 1)

Among those with pSAH, 39 underwent CTA, of which 35 proceeded to DSA. Two patients had DSA as the initial vascular imaging; three patients with pSAH had repeat DSA. Two of the 17 patients with nCTpLP underwent DSA directly, and 2 had further repeat DSA. Five patients in the sulcal group had CTA followed by DSA; none had a repeat DSA. Among the 50 patients with diffuse SAH, 46 had CTA, of which 39 proceeded to DSA. Four patients with dSAH had DSA without prior CTA and a total of 17 had repeat DSA; 3 patients had a third DSA. Many patients also had MRI head and some had spinal MRI, either cervical or complete.

Additional imaging findings

Relevant additional abnormalities were found in five cases. This included three cases of vasculitis, one case of ICA dissection and one spinal tumor. The three cases of vasculitis were diagnosed on the first DSA following a negative CTA and had presented with either sulcal SAH or a normal CT. The dissecting ICA aneurysm presented with diffuse SAH and was only revealed on the third neurovascular study (after normal CTA and DSA). There was also a case of hemorrhagic spinal ependymoma that presented with xanthochromia. No subsequent abnormality was found on a third DSA or MRI head. None of the patients presenting with perimesencephalic SAH had a positive finding if the initial CTA was negative.

Case illustrations

Case 1: A 54-year-old female presented with WFNS grade 1 spontaneous SAH. The initial CT demonstrated blood confined to the sulci of the right cerebral convexity. CTA performed within 24 h was normal. DSA on day 3 demonstrated several abnormalities of peripheral vessel caliber, most marked along the right and left inferior temporal branches of the middle cerebral arteries. MRA at day 10 showed further segmental irregularities. The radiological differential diagnosis included cerebral vasoconstriction syndrome, but a diagnosis of intracranial vasculitis was made on clinical grounds (Fig. 1).

Case 2: A 33-year-old female presented initially with a 10-day history of headache, neck stiffness and vomiting. The initial CT head was normal but CSF was positive for xanthochromia. CTA performed on the same day and subsequent catheter angiography were normal. A MRI head performed around 5 months was also normal. The patient represented 12 months later with a 5-day history of headache. The presenting CT head was normal but CSF was positive for xanthochromia. CTA within 48 h of ictus showed no source of hemorrhage. DSA was not performed on this occasion but she underwent whole-spine MRI, which showed a filum terminale ependymoma that was subsequently resected (Fig. 2).

Case 3: A 40-year-old female presented with sudden onset of headache, neck stiffness and right eye pain. The initial CT head demonstrated a diffuse pattern of subarachnoid hemorrhage. CTA performed on the same day was reported as normal; DSA performed the next day was also reported as negative. Repeat CT head on day 8 showed evidence of rebleeding and further DSA performed on day 10 revealed a bilobed broad-necked aneurysm arising from the superior surface of the right supraclinoid ICA. Three-dimensional angiography revealed narrowing of the parent vessel immediately proximal to this rapidly evolving abnormality, which was felt to represent a dissecting intradural aneurysm. In hindsight there was subtle irregularity of the dorsal wall of the ICA on the initial DSA (Fig. 3).

Discussion

Our findings are similar to a recently published retrospective study of 55 patients that subtyped patients into three categories based on the presenting CT (pSAH, dSAH and sSAH)

Table 1 Pattern of SAH on initial CT, diagnostic pathway and subsequent imaging findings in patients with negative initial angiography (CTA or DSA)

Total cases for each subtype		pSAH 41	sSAH 6	dSAH 50	nCT-pLP 17
CTA (1st vascular-imaging)	Cases	39	5	46	15
DSA (1st vascular imaging)	Cases	2	1	4	2
DSA (following negative CTA)	Cases	35	5	39	12
	Findings	0	2 Vasculitis	0	1 Vasculitis
2nd DSA	Cases	3	0	17	2
	Findings	0	0	1 ICA dissection	0
3rd DSA	Cases	0	0	3	0
	Findings	0	0	0	0
MRI head	Cases	24	5	27	7
	Findings	0	0	0	0
MRI spine	Cases	6	1	14	5
	Findings	0	0	0	1 Spinal tumor

SAH subarachnoid hemorrhage; *pSAH* perimesencephalic subarachnoid hemorrhage; *dSAH* diffuse subarachnoid hemorrhage; *sSAH* sulcal subarachnoid hemorrhage; *nCT-pLP* CT negative (CSF positive for xanthochromia); *ICA* internal carotid artery; *DSA* digital subtraction angiography; *CTA* computed tomography angiography

[11]. As observed in our cohort, the majority of patients presented with diffuse SAH (60 %). The authors found five vascular abnormalities on DSA following an initial negative CTA, and four of these had diffuse SAH, but no subsequent abnormality was found in patients with perimesencephalic SAH. A second DSA examination was required to demonstrate an anterior communicating artery aneurysm in one patient with diffuse SAH. No causative vascular lesion was found in patients with perimesencephalic or peripheral sulcal SAH on repeat DSA examination. A third DSA examination was performed in five patients (9 %); none was positive (Table 2).

In 2010, Agid described 193 patients subtyped into four groups (pSAH, dSAH, sSAH and nCTpLP) [1]. The majority presented with a perimensencephalic pattern of hemorrhage, all of whom had negative findings on DSA following normal initial CTA. DSA was felt to confirm a diagnosis of vasculitis in 1 patient with no blood on the presenting CT, and 6 out of the 18 patients with peripheral sulcal hemorrhage had vasculitis on the first DSA. A diagnosis of vasculitis was suspected on the basis of CTA for some of these cases, but DSA was performed for confirmation. This is somewhat different from our methodology in that only patients with a negative first investigation (almost invariably CTA) were included, and we therefore excluded patients suspected of either vasculitis or cerebral vasoconstriction on the basis of the initial CTA. Repeat delayed DSA in 28 patients found small aneurysms in 4 patients (Table 2).

Perimesencephalic SAH

On the basis of the findings from this study and other reported series [8, 9, 21, 34, 35], we conclude that a perimesencephalic pattern of SAH is associated with a low yield of abnormalities on subsequent imaging if the initial vascular study is normal. It is now our practice not to perform repeat neurovascular

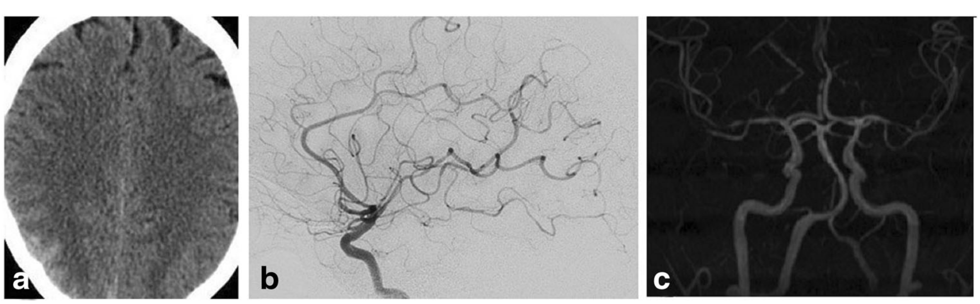

Fig. 1 Case 1: A 54-year-old female with WFNS grade 1 SAH. **a** Unenhanced CT head at presentation shows a sulcal pattern of hemorrhage. **b** CTA reported as normal, but DSA on day 3 shows multifocal changes in vessel caliber. **c** MRA at day 10 shows more extensive caliber changes involving a greater number of vessels

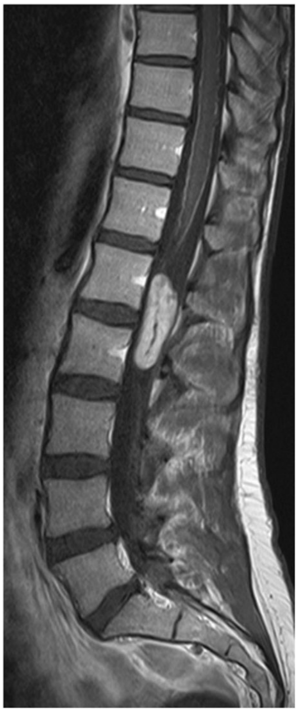

Fig. 2 Case 2: A 33-year-old female with two episodes of SAH. Normal CT head on both occasions but xanthochromia on lumbar puncture. Sagittal T1 post-gadolinium lumbar spine shows a filum terminale ependymoma

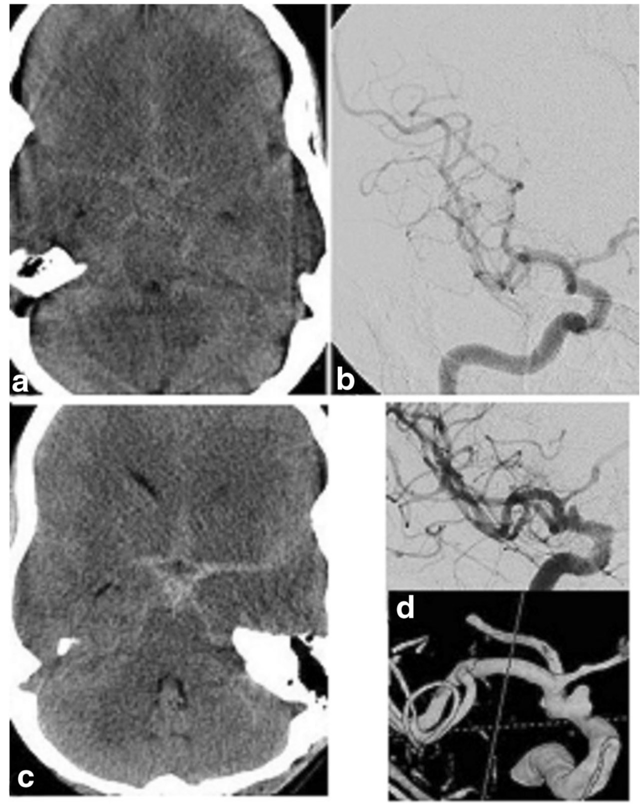

Fig. 3 Case 3: A 40-year-old female with headache, neck stiffness and right eye pain. **a** Unenhanced CT head at presentation showing a diffuse pattern of hemorrhage. **b** DSA on day 2 shows no definite vascular abnormality. **c** Unenhanced CT head on day 8 post SAH shows further hemorrhage. **d** Repeat DSA and 3D model at day 10 post SAH shows a dissecting aneurysm of the supraclinoid ICA

imaging in patients presenting with a perimesencephalic pattern of SAH if the clinical presentation is consistent with this diagnosis and the blood distribution falls within Van Gijn's definition [31] of pSAH on a scan performed within 48 h of the ictus. We require the CTA technique and bolus dynamics to be fully optimized and reported by at least two experienced neuroradiologists. DSA is performed if there is any clinical or radiological uncertainty of the diagnosis.

Multislice CTA has a high accuracy for diagnosis of vertebrobasilar aneurysms and of intracranial aneurysms in general [10, 23, 30, 32–34]. With the development of the matched mask bone elimination/bone subtraction technique [29] and more recently the dual-source CT scanner, improved visualization of the infraclinoid segments of ICA can also be achieved [36]. The preliminary data obtained from a study that compared dual-energy CTA with 3D rotational DSA have shown that contrast-enhanced dual-energy CTA had diagnostic image quality at a lower radiation dose than digital subtraction CTA and high diagnostic accuracy compared with 3D rotational angiography in the detection of intracranial aneurysm, even aneurysms smaller than 3 mm [36].

Diffuse SAH

There is a general consensus that other patterns of SAH warrant continued investigation, sometimes with multiple repeat tests and different imaging modalities. This is because patients presenting with dSAH, sSAH or LP proven SAH are far more likely to harbour a structural abnormality that is likely to require intervention than patients presenting with pSAH [4, 9, 21, 34, 35, 37]. Certain lesions, such as blisters, dissecting or "micro" aneurysms, must be identified because of their high risk of early rebleeding [6, 12, 15, 18], and despite the advances in the CTA technique it is still common for those lesions to be missed or absent on initial noninvasive neurovascular imaging. Furthermore, shunting vascular abnormalities, such as dural fistulas and small arteriovenous malformations, are usually easier to diagnose with DSA because of the combination of excellent spatial and temporal resolution. It is therefore our policy to perform at least two DSAs for patients presenting with diffuse SAH, which we consider to represent aneurysmal SAH until proven otherwise. Three-dimensional acquisitions of each vessel are routinely performed if there is thought to be a high risk of aneurysmal bleeding on clinical and/or radiological grounds (i.e., presenting CT). Reported case series have continued to demonstrate small numbers of aneurysms that have only been detected by repeat DSA, sometimes because of factors such as incomplete

Table 2 Comparison of this current study with previously published similar reports

Hallamshire cohort (114 cases)		DSA following negative CTA		DSA 2		DSA 3	
		Cases	Yield	Cases	Yield	Cases	Yield
pSAH	41	35	0	3	0	0	0
dSAH	50	39	0	17	1/17 (6 %) dissecting ICA aneurysm	3	0
sSAH	6	5	2/5 (40 %) vasculitis	0	0	0	0
nCT-pLP	17	12	1/12 (8 %) vasculitis	2	0	0	0
Almandoz 2013 (55 cases)		DSA following negative CTA		DSA 2		DSA 3	
		Cases	Yield	Cases	Yield	Cases	Yield
pSAH	11	11	0	7	0	0	0
dSAH	33	33	4/33 (12 %) 2AVF 1 AVM, 1 ICA blister	23	1/23 (4 %) ACOM aneurysm	5	0
sSAH	11	11	1/11 (9 %) RCVS	2	0	0	0
Agid 2010 (193 cases)		DSA following negative CTA		DSA 2			
		Cases	Yield	Cases	Yield		
pSAH	93	93	0	28	0		
dSAH	50	50	1/50 (2 %) ophthalmic aneurysm	28	4/28 (14 %) PICA, ACOM, M1-MCA, Basilar-tip, aneurysm		
sSAH	18	18	6/18 (30 %) vasculitis	5	0		
nCT-pLP	32	32	1/32 (3 %) vasculitis				

AVF arteriovenous fistula; *AVM* arteriovenous malformation; *ACOM* anterior communicating artery; *RCVS* reversible cerebral vasoconstriction syndrome; *ICA* internal carotid artery; *PICA* posterior inferior cerebellar artery; *M1-MCA* M1 (proximal) segment of middle cerebral artery

or poor technique, vasospasm and initially thrombosed aneurysms that subsequently recanalized [1, 11, 16, 21]. It is also easy to overlook certain subtle bleeding sources such as blisters and dissecting aneurysms that often evolve rapidly over days [6, 13, 15].

The timing of repeat DSA remains controversial [1, 11, 16, 21]. Some advocate repeat angiography within 10–14 days of the first DSA, while others argue in favor of delayed repeat angiography after 4–6 weeks of initial SAH to improved diagnostic yield following the recovery of vasospasm and resolution of potential thrombus within aneurysm. It has become our usual practice to perform the second DSA before the patient is discharged, the rationale being that the greatest risk to the patient is likely to be rebleeding from a missed aneurysm, which is greatest within the first 2 weeks of ictus.

CT-negative, LP-positive SAH

Unenhanced CT is universally performed in patients presenting with suspected SAH, but its sensitivity rapidly decreases with time from ictus and therefore lumbar puncture is generally considered mandatory for such patients if the CT is negative. Modern CSF analysis should include sphectrophotometric analysis for the breakdown products of SAH, and diagnostic guidelines exist for the positive identification of bilirubin and oxyhemoglobin [7]. Not all patients with CSF xanthochromia have a ruptured aneurysm, but the existing literature does not describe a systematic evaluation of a specific diagnostic algorithm for these patients [26]. The most appropriate diagnostic pathway for CT-negative, LP-positive SAH remains contentious, and since there is no information regarding the distribution of blood (and therefore the likely pathology) in these cases, we continue to perform at least one DSA and consider a second DSA if there is persisting clinical concern (such as an excellent clinical history of explosive headache with CT performed several days after the ictus).

On the basis of our 17 patients it is impossible for us to construct firm diagnostic guidelines for the investigation of CT-negative, LP-positive patients; however two significant abnormalities were found in this subgroup (one vasculitis, one spinal tumor). Several other studies have described similar small subsets of these patients, usually within the context of a broader group of patients, and have failed to demonstrate significant missed pathologies such that their authors have doubted the value of repeated investigations [1, 19, 20, 22, 34].

Sulcal SAH

There are several potential causes of spontaneous SAH with blood located exclusively in the cerebral sulci, and these are partly dependent upon the patient's age and clinical scenario. For example, sulcal SAH is increasingly identified in the context of aging patients with acute neurological events associated with amyloid angiopathy [3, 5], while conditions such as cerebral vasoconstriction syndrome typically present in a younger demographic with a different constellation of symptoms [2, 17, 28]. It therefore seems most appropriate to tailor the imaging of patients with sulcal SAH to the most likely clinical diagnosis and not apply a restrictive algorithm to all cases. Although CTA is not always the most appropriate initial imaging examination in all cases of sSAH, it is still regularly used in clinical practice. The need to perform further brain arterial imaging with DSA should be guided by the perceived risk of finding certain pathologies such as intracranial vasculitis, cerebral vasoconstriction, mycotic aneurysms or a shunting vascular malformation, whereas MR imaging is more indicated as the next step in patients with amyloid SAH, possible peripheral cavernoma or venous thrombosis. It is also accepted, however, that many patients with suspected primarily vessel abnormalities, such as vasculitis and vasoconstriction, will also require MR imaging as an adjunct to diagnosis and/or management. We do not therefore apply a rigid algorithm to investigation of these patients, but do carefully consider the need for DSA if the CTA is considered to be entirely normal.

MR imaging

Sixty-three out of 114 of our patients underwent MRI head ± MRA, but none demonstrated a bleeding source that had not been previously identified. It is accepted that MRI can detect lesions such as pituitary apoplexy and superficial cavernomas that are hard to demonstrate on other modalities, but the yield of this additional imaging also appears to be very low in most published series [24, 25]. Spinal MR imaging is routinely performed in some centers with a view to demonstrating an intraspinal vascular malformation or hemorrhagic intradural tumor. Despite the identification of a single spinal tumor in our series, we prefer to reserve spinal imaging for patients with a second clinical episode. A study of 75 cases of nonaneurysmal, nonperimesencephalic SAH reported by Germans [14] found 3 abnormalities within the spinal axis, namely one lumbar ependymoma and two cervical cavernous malformations. The authors do not recommend imaging of the entire spinal axis for all patients at first presentation, but suggest imaging is targeted at a subgroup, possibly those patients presenting at a younger age. We would agree with this diagnostic approach and also perform whole-spine MRI for patients presenting with focal back pain, associated neurological deficits and/or a second episode of hemorrhage. Therefore, while the current data do not support the routine use of brain and spinal MRI in all patients after initial negative vascular imaging for SAH, we believe that it should be considered in certain clinical situations where there is a high index of suspicion for conditions such as vasculitis, cerebral vasoconstriction, amyloid angiopathy, spinal pathology, dural sinus or cortical vein thrombosis.

Limitations

In common with other studies referenced in this report, we have described our experience of the investigation of patients with various patterns of SAH, but we have not systematically evaluated the performance a specific diagnostic algorithm for each distribution of blood on the presenting CT head. Our data were collected prospectively, and all the imaging was reviewed again for the purpose of this study, but it remains possible that not all cases were captured during the study period and for certain imaging subsets (sulcal SAH, CT negative, LP positive) the numbers are small. Mindful of the limited numbers in our study, and those previously reported, we have developed a diagnostic algorithm based upon the experience of our neuroscience center and reports in the literature. In the absence of an universal consensus statement we believe our diagnostic algorithm is an acceptable tool for guiding investigation of spontaneous SAH and suggest that individual centers may wish to consider modifications on the basis of their own experience and expertise.

Conclusion

Certain patterns of spontaneous intracranial bleeding, such as perimesencephalic SAH, are associated with a low yield of abnormalities on repeat imaging if the initial vascular study is normal and patients do not require multiple repeat examinations. Other patterns of bleeding, however, such as diffuse SAH, are associated with a greater likelihood of an important underlying abnormality that requires a specific, often life-saving, intervention. We believe that the distribution of blood on the presenting CT head scan is an important reference point from which to make the most efficient use of further imaging modalities in patients with negative first-line vascular imaging. Based upon our experience and review of the neurovascular literature, we propose a diagnostic algorithm (Fig. 4) to facilitate the prompt identification of critically important pathologies presenting with spontaneous SAH.

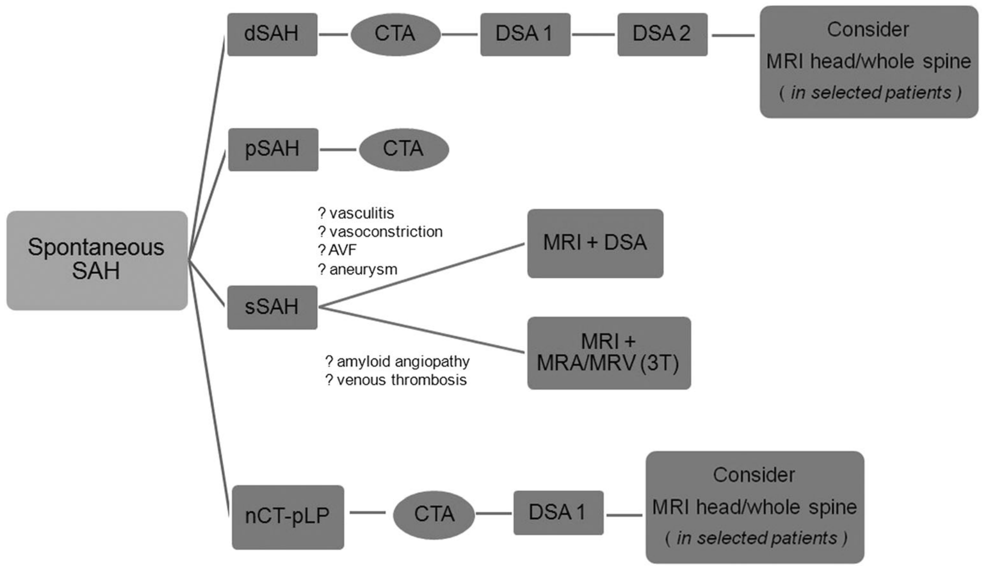

Fig. 4 Proposed investigation algorithm for patients with spontaneous SAH but negative initial neurovascular imaging

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