



Convexity subarachnoid haemorrhage: a practical guide

John Van Ly,^{1,2} Henry Ma,^{1,2} Singhal Shaloo,^{1,2} Benjamin Clissold,^{1,2} Thanh Phan^{1,2}

¹Department of Neurology, Monash Health, Clayton, Victoria, Australia

²Department of Medicine, Monash University, Clayton, Victoria, Australia

Correspondence to

Dr John Van Ly, Department of Neurology, Monash Health, Clayton, Victoria, 3168, Australia; john.ly@monashhealth.org

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ABSTRACT

Atraumatic convexity subarachnoid haemorrhage describes spontaneous bleeding into the convexities of the brain sulci without parenchymal involvement. Its many causes include reversible cerebral vasoconstriction syndrome, cerebral sinus venous thrombosis, posterior reversible encephalopathy syndrome and (in older people) cerebral amyloid angiopathy. We describe the clinical and radiological features of non-traumatic convexity subarachnoid haemorrhage with its various presentations, causes, treatments and prognoses, and use clinical vignettes to highlight important clinical points and pitfalls.

INTRODUCTION

Atraumatic non-aneurysmal convexity subarachnoid haemorrhage (cSAH) represents approximately 6% of SAH and is distinct from aneurysmal-related SAH.¹ Both are due to spontaneous haemorrhage into the subarachnoid space between the pia and arachnoid membranes. cSAH is confined to the cortical surfaces, without extending into the Sylvian or hemispheric fissure, basal cisterns, parenchyma or ventricles. By contrast, aneurysmal SAH tends to occur around the Circle of Willis, with subarachnoid bleeding and intracerebral haemorrhage (ICH) concentrated around the site of the aneurysm.²

The causes of cSAH in younger people include reversible cerebral vasoconstriction syndrome (RCVS), posterior reversible encephalopathy syndrome (PRES), cerebral sinus venous thrombosis and others.^{1 3} In people aged over 60 years, cerebral amyloid angiopathy (CAA) is a common cause.^{1 4} Although people with CAA-related cSAH generally recover well from the episode, they remain at increased risk of lobar haemorrhage (by 13% per year (95% CI 10% to 17%)), recurrent cSAH (by 11% per year (95% CI 8% to 15%)) and ischaemic stroke

(by 5% per year (95% CI 3% to 8%)).⁵

Furthermore, cSAH may also rarely accompany inflammatory CAA, a condition causing significant neurological disability if not recognised and treated early.⁷ People with Alzheimer's disease receiving aducanumab, a monoclonal antibody targeting amyloid- β (A β), also have imaging abnormalities resembling amyloid angiitis.⁸

CAA probably results from an imbalance between the production and clearance of A β , a breakdown product of A β precursor protein. Excessive A β accumulates in the small leptomeningeal and cortical blood vessels, which become brittle and fragile, allowing blood leakage into the subarachnoid space.⁹ The triggers for inflammatory CAA remain unknown, but there is probably an inappropriate perivascular immune response, with predominantly granulomatous inflammatory reactivity to vascular A β deposition within the meningeal and cortical vessels.^{10 11}

Clinical presentation

cSAH presents with a range of symptoms, depending on its cause and the patient's age. Common symptoms include headache, impaired level of consciousness, seizures, confusion, transient focal neurological episodes, persistent focal neurological deficits, visual abnormalities, nausea and vomiting (table 1).

Reversible cerebral vasoconstriction syndrome

cSAH presenting with thunderclap headache—typically in young people and especially women—is usually caused by RCVS. Occasionally there are associated focal neurological symptoms, but these may not be immediately apparent. It is important to look for potential triggers, including recent use of vasoconstrictive agents, including herbal medicines, illicit drugs and several prescribed medications.



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Table 1 Summary of symptoms, investigations findings and common causes of convexity SAH

Convexity SAH causes	RCVS	PRES	CVST	CAA
Clinical features				
Age	<60	<60	<60	≥60
Headache	Common	Common	Common	May occur
Confusion/impaired consciousness	May occur	Common	May occur	May occur
Seizures	May occur	Common	May occur	May occur
Transient focal neurological episode	May occur	Rare	May occur	Common
Persistent focal neurology	May occur	May occur	May occur	Rare
Nausea and vomiting	May occur	May occur	Rare	Rare
Visual symptoms	Common	Common	May occur	Rare
Investigation features				
CT/A/V	Beading	May have beading	Cortical vein thrombus	White matter changes, atrophy
MRI/A/V	Beading	Posterior parietal, subcortical brainstem. Often symmetrical	Venous ischaemic stroke or parenchymal haemorrhage	Superficial siderosis, microbleeds, previous lobar haemorrhages, leukoaraiosis. May have punctate DWI ischaemic lesions
EEG	Often normal	Often abnormal	Often normal	Often normal
CSF examination (besides xanthochromia)	Often normal	High protein. May have pleocytosis	Normal, unless infarct or haemorrhage	Often normal
A/V, angiography/venogram; CAA, cerebral amyloid angiopathy; CSF, cerebrospinal fluid; CVST, cerebral venous sinus thrombosis; DWI, diffusion-weighted imaging; EEG, electroencephalogram; PRES, posterior reversible encephalopathy syndrome; RCVS, reversible cerebral vasoconstriction syndrome; SAH, subarachnoid haemorrhage.				

Other relevant medical history includes migraine, which may be associated with RCVS.

Posterior reversible encephalopathy syndrome

While RCVS and PRES are considered distinct entities, they overlap in terms of triggers and clinical features. In suspected PRES, clinicians should identify specific triggers, including elevated blood pressure, pre-eclampsia/eclampsia, cytotoxic or immunosuppressive agents, renal failure and autoimmune disorders. Common presenting features of PRES include headache, cognitive impairment or altered conscious state, visual symptoms and seizures.¹²

Cerebral venous sinus thrombosis

Patients with cerebral venous sinus thrombosis may have worsening subacute headaches, often with focal neurological symptoms. It is important to identify thrombotic risk factors including pregnancy, dehydration and other thrombotic tendencies, with or without a family history.

Cerebral amyloid angiopathy-related convexity SAH

cSAH in CAA typically presents in elderly people with recurrent transient focal neurological episodes (also known as amyloid spells), manifesting as brief motor, somatosensory, visual or language disturbances.^{4 13 14} These may easily be misdiagnosed as recurrent transient ischaemic attacks and treated with antithrombotic medications, with potentially fatal complications. The episodes probably result from cortical spreading depolarisation with its stereotypical migratory spread; their

duration of several minutes rather than seconds also helps their clinical distinction from seizures.^{13–15} When in doubt, early electroencephalogram (EEG) may help. Although inflammatory CAA rarely presents with cSAH, this condition is important to consider early in elderly people with subacute onset of confusion and imaging features of CAA, especially if there are also confluent regions of vasogenic oedema. Delayed diagnosis may lead to significant neurological disability. Depending on the location, patients may have other focal clinical cortical features including dysphasia and neglect. Often, however, there are no focal motor deficits. Early EEG may also help in managing inflammatory CAA, as epileptic seizures are common.¹⁰

Investigations

While it is important to recognise that cSAH is distinct from aneurysmal SAH—so avoiding unnecessary digital subtraction angiography—it can be challenging to identify its cause. After careful clinical history and examination, several investigations may help with the diagnosis (table 1 and figure 1).

Radiological imaging

CT scan of head

The first-line investigation for all patients with suspected cSAH is a non-contrast CT scan of the head (figure 2A). This needs scrutinising carefully, as it is easy to overlook small amounts of subarachnoid blood. We find the coronal view especially helpful in identifying subtle bleeds. CT scanning has high sensitivity (98%) for detecting SAH within 6 hours of

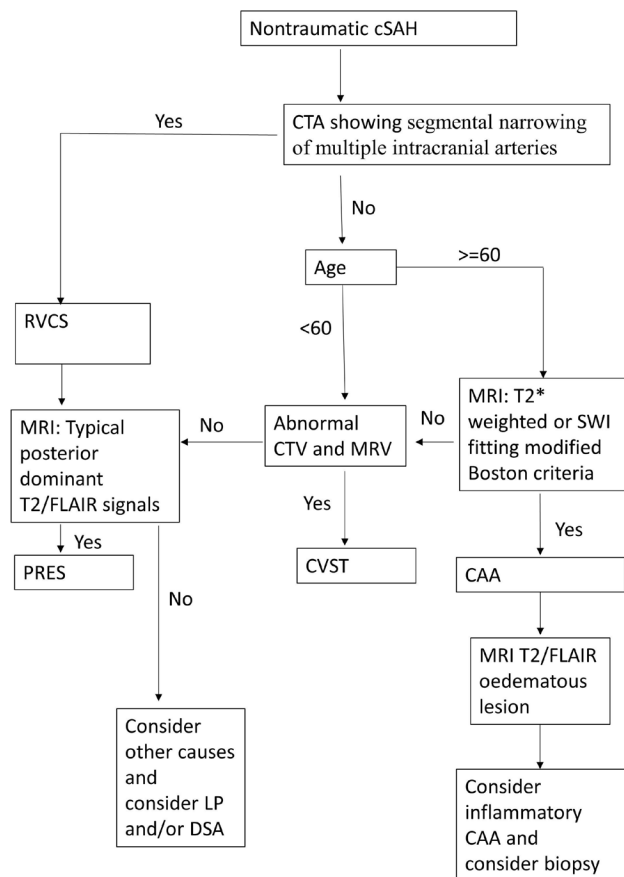


Figure 1 Suggested flow chart for investigating acute non-traumatic convexity SAH (cSAH). CAA, cerebral amyloid angiopathy; CTA, CT angiography; CTV, CT venogram; DSA, digital subtraction angiography; FLAIR, fluid-attenuated inversion recovery; LP, lumbar puncture; MRI, magnetic resonance imaging; PRES, posterior reversible encephalopathy syndrome; RVCS, reversible cerebral vasoconstriction syndrome; SWI, susceptibility-weighted imaging.

onset, though only about 90% after 6 hours.¹⁶ cSAH probably has a lower sensitivity, in view of the smaller blood volume.

In RCVS, a CT cerebral angiogram may identify segmental narrowing of multiple intracranial arteries, suggesting vasospasm, usually in multiple vascular territories. A CT cerebral venogram is appropriate if suspecting cerebral venous sinus thrombosis.

MRI/AV with SWI

In the acute phase of cSAH, an MR scan of the brain may show an increase in T2/FLAIR and T1 signals in the corresponding sulcus (figure 2B,C). However, very early after the presentation, the scan may be normal if there is only a small leptomeningeal protein leak.¹⁷ Susceptibility-weighted imaging (SWI) and gradient recalled echo (GRE) are MRI T2* sequences that detect paramagnetic material as a hypointense signal. This susceptibility effect may also not be apparent in the early phase of cSAH (figure 2D). As time passes

and blood products degenerate leaving haemosiderin deposits, the SWI and GRE phase becomes hypointense, giving the appearance of superficial siderosis. By this time, the T2/fluid-attenuated inversion recovery (FLAIR) and T1 hyperintense signal have typically resolved (figure 2F,G). Interestingly, these dynamic transient MRI sulcal T2/T1 and SWI abnormalities also occur in people with Alzheimer's disease treated with monoclonal anti-amyloid therapy: this is termed amyloid-related imaging abnormalities with haemosiderin deposits (ARIA H). Similar transient sulcal changes without superficial siderosis may also develop without haemorrhage, probably from proteinaceous fluid leaking into the leptomeningeal space (ARIA E).¹⁸

MR brain imaging and MR cerebral angiography can provide important clues to the underlying cause of cSAH. The Boston criteria are traditionally used to diagnose CAA but these require a biopsy or autopsy to confirm definite CAA. The recently revised Boston criteria (version 2.0) include updated clinical and MRI criteria, increasing the sensitivity of diagnosis.¹⁹ For example, probable CAA can now be diagnosed in those aged over 50 years presenting with spontaneous ICH. Also, transient focal neurological episodes or cognitive impairment can be diagnosed in those with MRI evidence of either two lobar haemorrhagic lesions (including either ICH, cerebral microbleeds, or superficial siderosis) or one lobar haemorrhagic lesion and another feature such as large perivascular spaces in the centrum semiovale region or multiple (>10) white matter hyperintensity lesions. Cerebral microbleeds are small collections of blood appearing as hypointense signal visible with T2* imaging. Although punctate DWI lesions may be associated with cSAH, they are not included in version 2.0 of the Boston criteria^{9 19} (figure 3G).

Vasogenic oedema in PRES is predominantly posterior parietal and occipital, although occasionally it involves the brainstem and frontal lobes.²⁰ Typically, vasogenic oedema appears as a hyperintense signal on FLAIR images and increased diffusion on apparent diffusion coefficient images. These changes resemble a 'finger glove' pattern as the oedema spreads along the white matter tracts. While these changes often develop in the subcortical white matter, they can extend to involve the grey matter. Patients with inflammatory CAA can have single or multiple confluent hyperintense lesions on FLAIR images, suggesting vasogenic oedema. There is often corresponding increased leptomeningeal enhancement on post-contrast T1 images²¹ (figure 4E).

In RCVS, CT or MR angiography shows diffuse and segmental narrowing or "beading" of multiple vessels. The improved resolution of these scans means that digital subtraction angiography is now rarely used for RCVS (figure 2E).

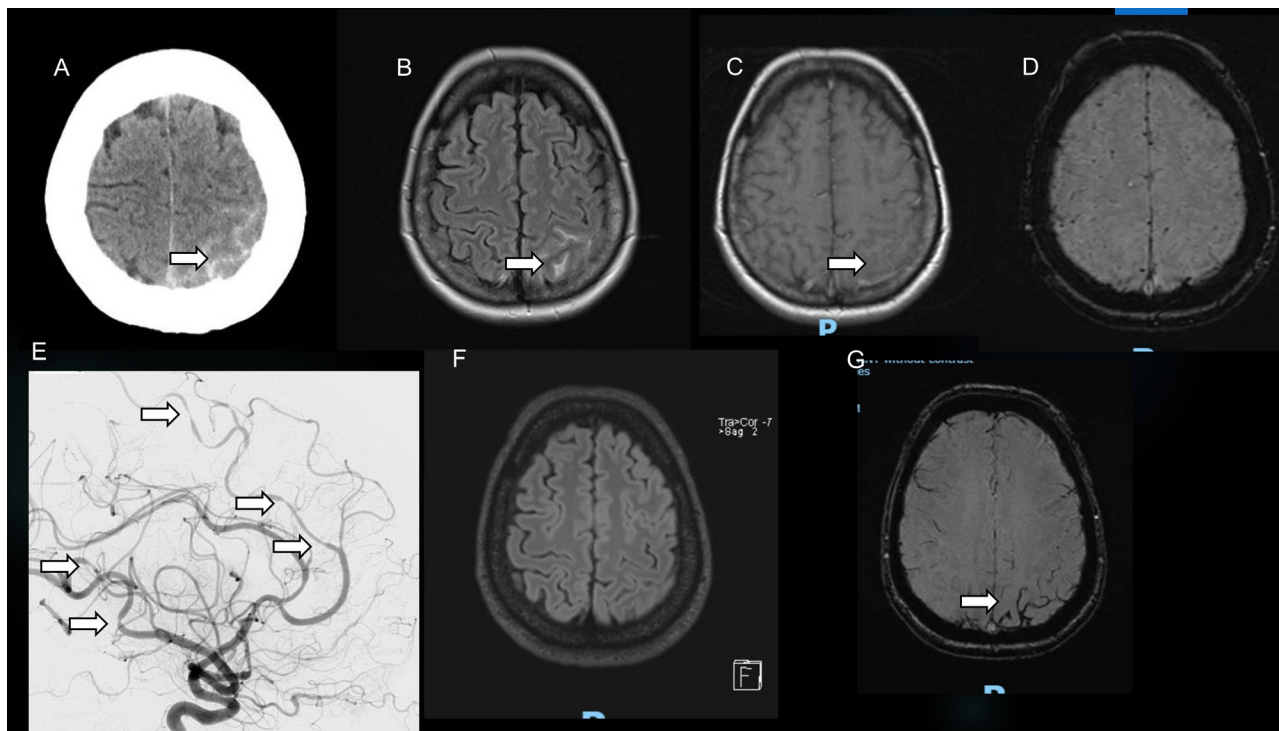


Figure 2 Case 1 RVCS: A 42-year-old woman developed a thunderclap headache while straining in the toilet. Her medical history includes hypertension, hysterectomy and regular marijuana use. (A) Convexity SAH on plain CT scan of the head (white arrow). (B) Corresponding MRI T2/FLAIR signal in the corresponding sulcus (white arrow) with (C) faint T1 hyperintensity in the acute phase (white arrow). (D) Normal SWI. (E) Digital subtraction angiogram showing multiple segmental beading “sausage” narrowing in the middle cerebral and anterior cerebral arteries (white arrows). (F) Resolution of convexity SAH on T2/FLAIR. (G) Residual superficial siderosis on SWI (white arrow). FLAIR, fluid-attenuated inversion recovery; SAH, subarachnoid haemorrhage; SWI, susceptibility-weighted imaging; RVCS, reversible cerebral vasoconstriction syndrome.

Positron emission tomography (PET) imaging

The gold standard of diagnosis for CAA requires pathological sampling.¹⁹ However, brain biopsy is invasive and rarely performed, unless there is suspicion of inflammatory CAA. While Pittsburgh compound B and other amyloid-specific ligands used in PET imaging show increased uptake in the cortical region in CAA,²² their use is currently limited to the research setting.

Lumbar puncture

Lumbar puncture is traditionally recommended for people with “thunderclap” headaches if the CT scan of the head showed no evidence of SAH and there is no contraindication, looking for red blood cells and xanthochromia. Red blood cells may be from a traumatic tap, but xanthochromia is more specific for haemorrhage, although its sensitivity relates to the timing of lumbar puncture after headache onset. Xanthochromia typically develops as early as 2 hours after onset, with maximum sensitivity around 12 hours after symptom onset.¹⁶ Lumbar puncture is not usually needed where imaging has established cSAH unless suspecting infection or other immune-inflammatory causes. In most other instances, cerebrospinal fluid (CSF) is normal but may show non-specific changes of increased protein concentration and pleocytosis.

Electroencephalogram (EEG)

EEG should be considered in patients with cSAH and focal seizures or altered mental states. While the altered mental states may be from parenchymal involvement, it is important to exclude non-convulsive status epilepticus. This is particularly pertinent in patients with suspected inflammatory CAA or in PRES with a fluctuating conscious state. EEG may show generalised or focal slowing or active epileptic discharges.

Serological and other tests

Patients with cSAH often undergo tests for metabolic derangement, electrolyte abnormalities, inflammatory and hypercoagulable conditions, vasculitic screen and urinary drug screen. These are usually normal, but when abnormal may provide clues as to the cause and prognosis. This is particularly important in patients with PRES, who may have deranged electrolytes including hypomagnesaemia, renal failure, elevated C reactive protein (associated with poor outcomes) and hypoalbuminaemia.

Brain biopsy

There are proposed clinical and radiological criteria incorporating T2/FLAIR asymmetrical lesions and the Boston criteria for the diagnosis of probable

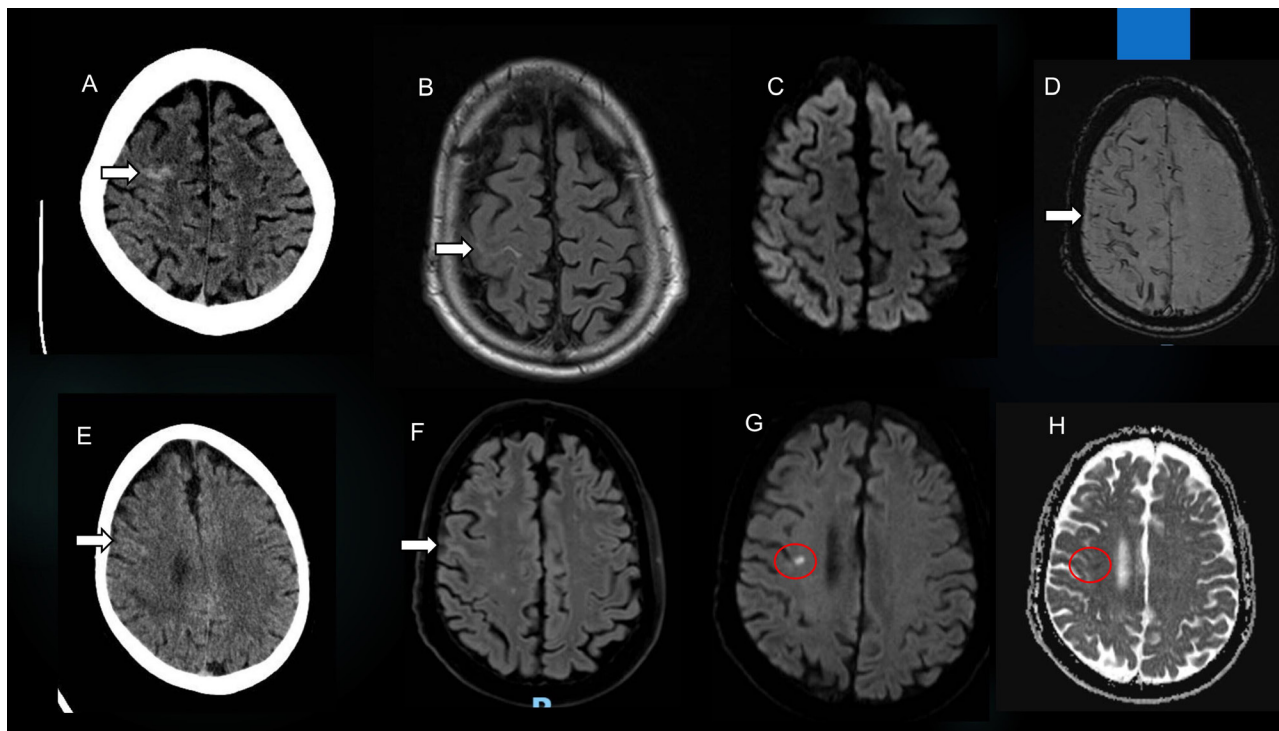


Figure 3 Case 2 CAA: A 79-year-old man developed transient left focal transient migratory paraesthesia. He took apixaban for paroxysmal atrial fibrillation, which was stopped. On review, he had ongoing recurrent stereotypical left focal paraesthesia. Repeat imaging showed new convexity SAH as well as new DWI restriction. A left appendage occluder device was inserted for stroke prevention. (A) Convexity SAH on plain CT scan of the head (white arrow). (B) Corresponding MR brain scan T2/FLAIR signal (white arrow). (C) DWI was normal. (D) SWI showed extensive superficial siderosis beyond the area of current convexity SAH (white arrow). (E) Repeat CT scan of the head showed new convexity SAH (white arrow) (F) with corresponding T2/FLAIR (white arrow). (G) DWI showed new punctate DWI lesion (red circle) (H) corresponding to ADC restriction indicative of acute ischaemia (red circle). ADC, apparent diffusion coefficient; CAA, cerebral amyloid angiopathy; DWI, diffusion-weighted imaging; FLAIR, fluid-attenuated inversion recovery; SAH, subarachnoid haemorrhage.

inflammatory CAA.²³ However, in patients with T2/FLAIR oedematous lesions—where other MR scan findings are inconclusive and other inflammatory or immune causes (including primary angiitis of the central nervous system) and malignancy cannot be ruled out with certainty—brain biopsy should be considered early. Immunosuppressive therapy should be started without delay, particularly if suspecting primary angiitis of the central nervous system (a particularly aggressive vasculitis that can be fatal if untreated). Corticosteroids probably have little effect on the diagnostic yield of the biopsy in the acute setting. The area of biopsy is often more helpful and should be targeted to the region of MRI T2/FLAIR oedematous abnormality, preferably in the cortex and leptomeninges.^{24 25}

Treatment

The management of cSAH includes treating complications, removing potential triggers, minimising the risk of haemorrhage extension and recurrence, and addressing underlying causes.

Patients with associated seizures need timely anti-seizure medication, especially in PRES or inflammatory CAA, which can mask non-convulsive status

epilepticus. Anyone with cSAH requires close monitoring and blood pressure control but particularly so in PRES. Selective use of antihypertensive medication depends on the cause of cSAH. In PRES, intravenous labetalol, magnesium and hydralazine are often used to manage hypertension. In RCVS, calcium blockers such as nimodipine are often used for their vasodilating as well as antihypertensive properties. It is important to avoid identified and other known triggers.

In people with CAA-related cSAH, there are no clear guidelines on antihypertensive medications to prevent ICH, and only observational evidence suggests a risk of haemorrhage expansion to ICH in the early phase.²⁶ Nevertheless, it seems reasonable to control blood pressure early, along similar lines to that recommended for acute ICH (ie, below 140 mm Hg systolic).¹⁴

Antithrombotic medication, particularly clopidogrel and anticoagulants, should be avoided in acute cSAH unless there is cerebral venous sinus thrombosis. Where there is a strong indication for their use, such as atrial fibrillation, it may be difficult to decide when to restart antithrombotic agents. This requires a careful risk–benefit discussion, taking account of individual circumstances. Note that CAA probably has the highest

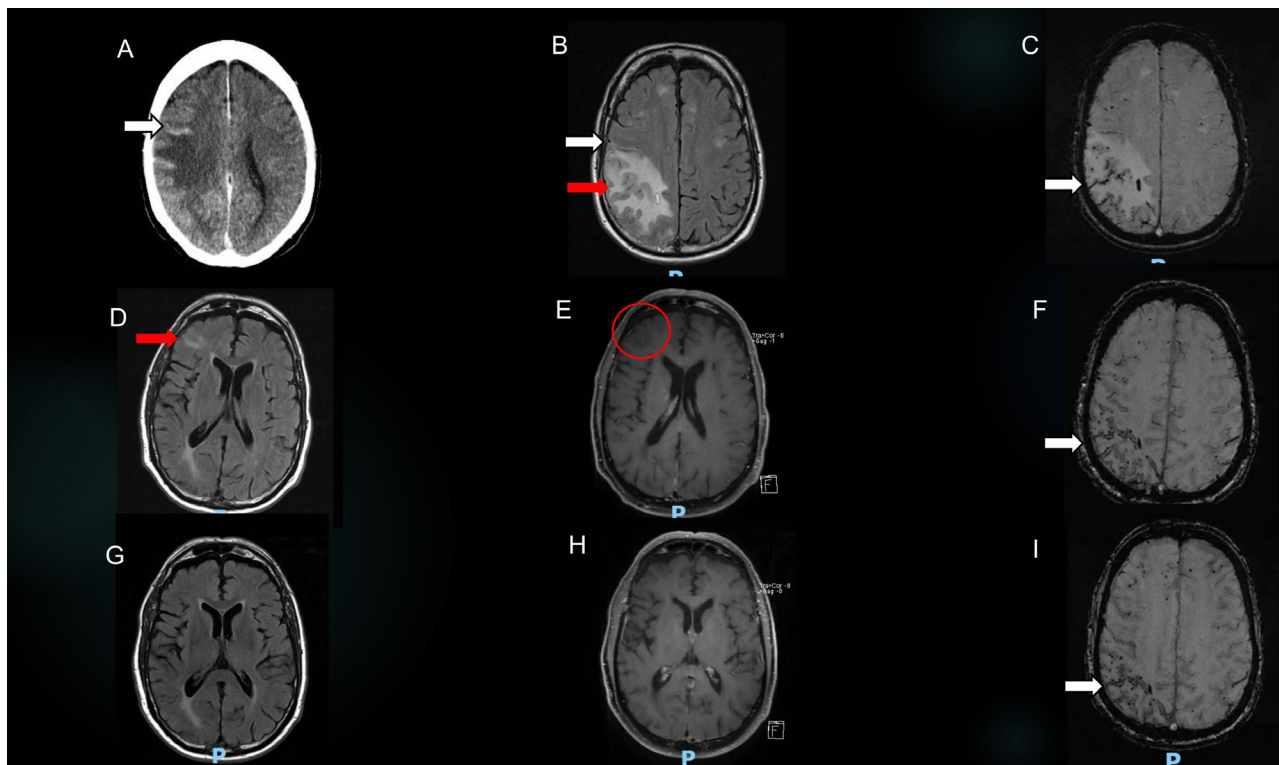


Figure 4 Case 3 inflammatory CAA: A 71-year-old man developed two episodes of left-sided paraesthesia and twitching, consistent with focal seizure. He had a background of subacute confusion. Based on the imaging findings, he underwent brain and leptomeningeal biopsies, showing scattered small-sized and medium-sized vessels with patent lumina and thickened walls. Congo red staining in these vessels showed positive staining with apple-green birefringence under polarised light, in keeping with inflammatory CAA. His symptoms responded well to levetiracetam and intravenous methylprednisolone but he relapsed 16 months later. Again, he responded well to 3 days of intravenous methylprednisolone and subsequently weaning dose of prednisolone. He has remained asymptomatic, but MR scanning with SWI sequence showed progression of superficial siderosis and microbleeds. (A) Convexity SAH with hypodensity parietal cortical and subcortical area on CT scan of the head (white arrow). (B) Corresponding MR brain scan T2/FLAIR convexity SAH (white arrow) and oedematous mass lesion (red arrow). (C) SWI superficial siderosis and microbleeds (white arrow). (D) Resolution of right parietal T2/FLAIR lesion but new right frontal T2/FLAIR (red arrow). (E) Corresponding T1 hypointensity with contrast enhancement (red circle). (F) Persisting superficial siderosis and microbleeds perhaps with some progression (white arrow). (G) Resolution of both the frontal and persisting resolution of right parietal oedematous T2/FLAIR lesion. (H) No further T1 contrast enhancement. (I) Progression of superficial siderosis and microbleeds (white arrow). CAA, cerebral amyloid angiopathy; SWI, susceptibility-weighted imaging; FLAIR, fluid-attenuated inversion recovery; SAH, subarachnoid haemorrhage.

risk of recurrent cSAH and an additional increased risk of ICH.⁶ However, recent meta-analyses have shown that in survivors of non-traumatic ICH, oral anticoagulation reduces thromboembolic events and all-cause mortality without significantly increasing the risk of recurrent ICH.^{27 28} There are several randomised controlled trials underway, such as ENRICH-AF,²⁹ to evaluate the safety of direct oral anticoagulants (DOACs) in survivors of ICH, including SAH with atrial fibrillation. Until these results are available, it is reasonable to restart DOACs at a lower dose sometime after the acute phase in patients at high risk of cardioembolic events, especially in people with a high CHA2DS2-VASc score.

Alternatively, if the risk of bleeding is considered to be too high even for a lower dose of DOAC—such as in patients with CAA-associated cSAH with previous lobar haemorrhages and extensive superficial siderosis—a possible option is left atrial appendage

occlusion, although patients may still need postprocedural antithrombotics in the short term.³⁰

The recurrent nature of CAA-related transient focal neurological episodes is probably due to cortical spreading depolarisation. Clinicians can reassure patients that such recurrent stereotypical symptoms in themselves do not necessarily reflect the recurrence of haemorrhage. Although some patients are treated with antiseizure medications, especially those with anti-migraine properties to reduce the frequency of transient focal neurological episodes, such treatment probably does not alter the natural history, as most episodes are self-limiting. It is even less certain whether suppressing cortical spreading depolarisation alters the risk of future bleeding.

In patients with cSAH related to cerebral venous sinus thrombosis, it is important to use therapeutic anticoagulation early, even in those with intraparenchymal haemorrhage or venous ischaemia.

For patients with inflammatory CAA, clinicians should consider intravenous corticosteroids early. In refractory cases with poor response to initial treatment, case series have shown possible benefits from maintenance oral prednisolone, either alone or with other immunosuppressants such as cyclophosphamide, with a possible higher chance of resolution of inflammation and reduction in relapses.^{31 32} Often such patients require ongoing maintenance of oral immunosuppressant therapy for some time.

It is important to advise patients regarding driving following cSAH. Any residual neurological deficit that may affect driving means the patient must notify their relevant driving licensing authority and may need to be cleared through an occupational therapy on-road driving assessment. Most jurisdictions also have clear driving guidelines regarding epileptic seizures. The more challenging task is how to advise patients who have recovered with no residual neurological deficit, as often occurs in patients with RCVS or CAA-associated transient focal neurological episodes. As an example, while the updated *Assessing Fitness to Drive 2022* edition in Australia briefly mentions cSAH associated with these two conditions, the only specific recommendation is that it depends on the 'presence of neurological impairments'.³³ Thus, the treating physician should check with their own local driving authority. In the absence of definite specific recommendations, it seems reasonable to advise asymptomatic patients also to notify their relevant driving authority and not to drive until they have further clarification from the authority.

Prognosis

The prognosis of cSAH very much depends on its underlying causes. RCVS generally has a favourable prognosis, with long-term outcomes predominantly determined by the presence of stroke. In most patients, headaches and vasospasm resolve within weeks and few have residual deficits from their stroke. In the absence of large stroke and uncontrolled brain oedema, RCVS mortality is less than 1%.³⁴ Recurrence occasionally occurs but is unlikely after triggers have been removed. Although PRES is traditionally considered as reversible and benign, recent case series have found up to 19% mortality, with functional impairments in up to 44%. Factors associated with poor outcome include severe encephalopathy, malignant hypertension, elevated C reactive protein, coagulopathy, low CSF glucose, underlying neoplasia, multiple comorbidities, corpus callosum involvement, extensive cerebral oedema and large haemorrhage or infarcts.³⁵ Patients with cerebral venous sinus thrombosis usually make a good recovery, unless there is a large infarct or haemorrhage. However, because recurrence is possible, it is important that they must continue oral anticoagulation, often for life.

People with CAA-related cSAH appear at increased risk of both ICH and ischaemic stroke.⁵ Antithrombotics are best avoided unless strongly indicated, as in atrial fibrillation and/or high cardioembolic risk. A recent meta-analysis showed that antithrombotics taken after either a transient focal neurological episode or after motor transient focal neurological episodes lead to a greater risk of developing intracerebral (including lobar) haemorrhage; the finding of superficial siderosis was associated with greater mortality.³⁶

Although early recognition and treatment of inflammatory CAA can give a good outcome, such patients need to be closely monitored, as recurrences can occur. A recent cohort study found that up to 38% of patients had at least one relapse at 2 years. Following initial clinical improvement, patients should be maintained on slow tapering oral corticosteroids, at least

Key points

- ▶ Non-traumatic convexity subarachnoid haemorrhage (cSAH) (comprising 6% of all SAHs) has causes that vary with age: in young people most are due to reversible cerebral vasoconstriction syndrome and often present with acute headache; in those aged over 60 years, clinicians should consider cerebral amyloid angiopathy-related pathology.
- ▶ Associated vasogenic oedema, especially in the posterior parietal and occipital areas, suggests posterior reversible encephalopathy syndrome.
- ▶ In young people with convexity SAH who present with headache and focal neurological symptoms, CT venogram or MR venogram should be considered to rule out cerebral venous sinus thrombosis.
- ▶ CAA-related convexity SAH in older people typically presents with transient neurological focal episodes (amyloid spells); there may also be associated punctate DWI lesions on MRI, easily mistaken for stroke or transient ischaemic attack, thus risking treatment (dangerously) with antithrombotic therapy.

Further reading

- ▶ Hostettler, I.C., *et al.*, Risk of intracranial haemorrhage and ischaemic stroke after convexity subarachnoid haemorrhage in cerebral amyloid angiopathy: international individual patient data pooled analysis. *J Neurol*, 2021.
- ▶ Charidimou, A., *et al.*, The Boston criteria version 2.0 for cerebral amyloid angiopathy: a multicentre, retrospective, MRI-neuropathology diagnostic accuracy study. *Lancet Neurol*, 2022. 21(8): p. 714–725.
- ▶ Antolini, L., *et al.*, Spontaneous ARIA-like Events in Cerebral Amyloid Angiopathy-Related Inflammation: A Multicenter Prospective Longitudinal Cohort Study. *Neurology*, 2021. 97(18): p. e1809-e1822.

until follow up MR imaging shows radiological resolution of inflammation. Following this, it is reasonable to follow up with MR scans at 3, 6, 12 months and then yearly intervals. If new attacks occur, patients may benefit from early repeat treatment with intravenous immunosuppressants.³⁷

Summary

Spontaneous non-traumatic cSAH is increasingly recognised. A careful history and examination with targeted investigations is important to help early recognition of the underlying cause. The causes of cSAH vary with age. In the young, while most are due to RCVS, finding posterior dominant T2/FLAIR oedematous lesions would suggest PRES. It is also important to rule out cerebral venous sinus thrombosis using CT or MR venogram. In the elderly, it is important to consider CAA-related conditions, as patients have an increased risk of future haemorrhage. A good understanding of investigation findings, in particular advanced imaging, can lead to an accurate diagnosis and avoid potentially dangerous differential misdiagnosis.

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REFERENCES

- 1 Khurram A, Kleinig T, Leyden J. Clinical associations and causes of convexity subarachnoid hemorrhage. *Stroke* 2014;45:1151–3.
- 2 Beitzke M, Gattringer T, Enzinger C, *et al.* Clinical presentation, etiology, and long-term prognosis in patients with nontraumatic convex subarachnoid hemorrhage. *Stroke* 2011;42:3055–60.
- 3 Kumar S, Goddeau RP Jr, Selim MH, *et al.* A traumatic convex subarachnoid hemorrhage: clinical presentation, imaging patterns, and etiologies. *Neurology* 2010;74:893–9.
- 4 Greenberg SM, Vonsattel JP, Stakes JW, *et al.* The clinical spectrum of cerebral amyloid angiopathy: presentations without lobar hemorrhage. *Neurology* 1993;43:2073–9.
- 5 Hostettler IC, Wilson D, Fiebelkorn CA, *et al.* Risk of intracranial haemorrhage and ischaemic stroke after convexity subarachnoid haemorrhage in cerebral amyloid angiopathy: international individual patient data pooled analysis. *J Neurol* 2022;269:1427–38.
- 6 Calviere L, Viguier A, Patsoura S, *et al.* Risk of intracerebral hemorrhage and mortality after convexity subarachnoid hemorrhage in cerebral amyloid angiopathy. *Stroke* 2019;50:2562–4.
- 7 Regenhardt RW, Thon JM, Das AS, *et al.* Association between immunosuppressive treatment and outcomes of cerebral amyloid angiopathy-related inflammation. *JAMA Neurol* 2020;77:1261–9.
- 8 Salloway S, Chalkias S, Barkhof F, *et al.* Amyloid-related imaging abnormalities in 2 phase 3 studies evaluating aducanumab in patients with early Alzheimer disease. *JAMA Neurol* 2022;79:13–21.
- 9 Gregoire SM, Charidimou A, Gadapa N, *et al.* Acute ischaemic brain lesions in intracerebral haemorrhage: multicentre cross-sectional magnetic resonance imaging study. *Brain* 2011;134:2376–86.
- 10 Corovic A, Kelly S, Markus HS. Cerebral amyloid angiopathy associated with inflammation: a systematic review of clinical and imaging features and outcome. *Int J Stroke* 2018;13:257–67.
- 11 Scolding NJ, Joseph F, Kirby PA, *et al.* Abeta-related angitis: primary angitis of the central nervous system associated with cerebral amyloid angiopathy. *Brain* 2005;128:500–15.
- 12 Kastrup O, Gerwig M, Frings M, *et al.* Posterior reversible encephalopathy syndrome (PRES): electroencephalographic findings and seizure patterns. *J Neurol* 2012;259:1383–9.
- 13 Ly JV, Singhal S, Rowe CC, *et al.* Convexity subarachnoid hemorrhage with PiB positive Pet scans: clinical features and prognosis. *J Neuroimaging* 2015;25:420–9.
- 14 Smith EE, Charidimou A, Ayata C, *et al.* Cerebral amyloid angiopathy-related transient focal neurologic episodes. *Neurology* 2021;97:231–8.
- 15 Roch JA, Nighoghossian N, Hermier M, *et al.* Transient neurologic symptoms related to cerebral amyloid angiopathy: usefulness of T2*-weighted imaging. *Cerebrovasc Dis* 2005;20:412–4.
- 16 Backes D, Rinkel GJE, Kemperman H, *et al.* Time-dependent test characteristics of head computed tomography in patients suspected of nontraumatic subarachnoid hemorrhage. *Stroke* 2012;43:2115–9.
- 17 Mitchell P, Wilkinson ID, Hoggard N, *et al.* Detection of subarachnoid haemorrhage with magnetic resonance imaging. *J Neurol Neurosurg Psychiatry* 2001;70:205–11.
- 18 Mintun MA, Lo AC, Duggan Evans C, *et al.* Donanemab in early Alzheimer's disease. *N Engl J Med* 2021;384:1691–704.
- 19 Charidimou A, Boulouis G, Frosch MR, *et al.* The boston criteria version 2.0 for cerebral amyloid angiopathy: a multicentre, retrospective, MRI-neuropathology diagnostic accuracy study. *Lancet Neurol* 2022;21:714–25.
- 20 Bartynski WS. Posterior reversible encephalopathy syndrome, Part 1: fundamental imaging and clinical features. *AJNR Am J Neuroradiol* 2008;29:1036–42.
- 21 Salvarani C, Hunder GG, Morris JM, *et al.* Abeta-related angitis: comparison with CAA without inflammation and primary CNS vasculitis. *Neurology* 2013;81:1596–603.
- 22 Ly JV, Donnan GA, Villemagne VL, *et al.* 11C-PIB binding is increased in patients with cerebral amyloid angiopathy-related hemorrhage. *Neurology* 2010;74:487–93.
- 23 Auriel E, Charidimou A, Gurol ME, *et al.* Validation of clinico-radiological criteria for the diagnosis of cerebral amyloid angiopathy-related inflammation. *JAMA Neurol* 2016;73:197.

- 24 Calabrese LH, Furlan AJ, Gragg LA, *et al.* Primary angitis of the central nervous system: diagnostic criteria and clinical approach. *Cleve Clin J Med* 1992;59:293–306.
- 25 Beuker C, Schmidt A, Strunk D, *et al.* Primary angitis of the central nervous system: diagnosis and treatment. *Ther Adv Neurol Disord* 2018;11:175628641878507.
- 26 Beitzke M, Enzinger C, Wünsch G, *et al.* Contribution of convexal subarachnoid hemorrhage to disease progression in cerebral amyloid angiopathy. *Stroke* 2015;46:1533–40.
- 27 Ivany E, Ritchie LA, Lip GYH, *et al.* Effectiveness and safety of antithrombotic medication in patients with atrial fibrillation and intracranial hemorrhage: systematic review and meta-analysis. *Stroke* 2022;53:3035–46.
- 28 Murthy SB, Gupta A, Merkler AE, *et al.* Restarting anticoagulant therapy after intracranial hemorrhage: a systematic review and meta-analysis. *Stroke* 2017;48:1594–600.
- 29 Population Health Research Institute. *Edoxaban for Intracranial Hemorrhage survivors with atrial fibrillation (ENRICH-AF)*. 2023.
- 30 Reddy VY, Doshi SK, Kar S, *et al.* 5-year outcomes after left atrial appendage closure: from the prevail and protect af trials. *J Am Coll Cardiol* 2017;70:2964–75.
- 31 Danve A, Grafe M, Deodhar A. Amyloid beta-related angitis--a case report and comprehensive review of literature of 94 cases. *Semin Arthritis Rheum* 2014;44:86–92.
- 32 Eng JA, Frosch MP, Choi K, *et al.* Clinical manifestations of cerebral amyloid angiopathy-related inflammation. *Ann Neurol* 2004;55:250–6.
- 33 Austroads. Assessing fitness to drive. 2022. Available: https://austroads.com.au/_data/assets/pdf_file/0037/498691/AP-G56-22_Assessing_Fitness_Drive.pdf
- 34 Singhal AB, Hajj-Ali RA, Topcuoglu MA, *et al.* Reversible cerebral vasoconstriction syndromes: analysis of 139 cases. *Arch Neurol* 2011;68:1005–12.
- 35 Hinduja A. Posterior reversible encephalopathy syndrome: clinical features and outcome. *Front Neurol* 2020;11:71.
- 36 Sanchez-Caro JM, de Lorenzo Martínez de Ubago I, de Celis Ruiz E, *et al.* Transient focal neurological events in cerebral amyloid angiopathy and the long-term risk of intracerebral hemorrhage and death: a systematic review and meta-analysis. *JAMA Neurol* 2022;79:38–47.
- 37 Antolini L, DiFrancesco JC, Zedde M, *et al.* Spontaneous ARIA-like events in cerebral amyloid angiopathy-related inflammation: a multicenter prospective longitudinal cohort study. *Neurology* 2021;97:e1809–22.