Pictorial Essay: Diagnostic Importance of Contrast-Enhanced FLAIR MRI in Various Intracranial Pathology`

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- Intracranial pathology may show contrast enhancement through various mechanisms associated with the disease process.
- The preferred MRI sequence in post-contrast imaging is T1WI.
- FLAIR sequence is a T2WI with dark CSF. However, it also shows mild T1W contrast that is responsible for contrast enhancement.
- CE-FLAIR imaging can be incorporated as a routine sequence for contrast-enhanced brain imaging to detect pathology.

What is FLAIR?

- Fluid-attenuated inversion recovery (FLAIR)
- A special inversion recovery pulse sequence with :
- long repetition time (TR)
- long echo time (TE)
- an inversion time (TI) that effectively nulls signals from CSF
- Has mild T1 effect that is produced by long TI

Lesions that show enhancement on CE-T1WI also show enhancement in CE-FLAIR images

CE-FLAIR offers more information than CE-T1WI alone

Mechanism of Gadolinium Enhancement

- Gadolinium (Gd) **shortens T1 and T2 relaxation time** of tissues in which it accumulates
- Contrast enhancement is **predominantly by T1-shortening effect** at clinical doses

- Contrast enhancement in CNS results from 3 processes:

1. Intra-axial lesion: disruption of blood-brain barrier (BBB) for Gd to enter extracellular space
2. Extra-axial lesion: lesion with relatively high vascularity
3. Leptomeningeal: contrast leakage from vessels into CSF

Advantages of CE-FLAIR over CE-T1W1

1. Faintly enhancing lesions on CE-T1WI might be depicted more clearly on CE-FLAIR images

- due to signal reducing T2 effects obscure signal-enhancing T1 effects

2. CE-FLAIR images do not show contrast enhancement in normal vascular structures & normal meninges

- highly effective in detection of sulcal/meningeal infection, inflammation, metastases that abut border of CSF

Drawback: observed hyperintensity may be due to T2 lengthening / T1 shortening

Therefore, should perform pre- and post-contrast FLAIR sequence

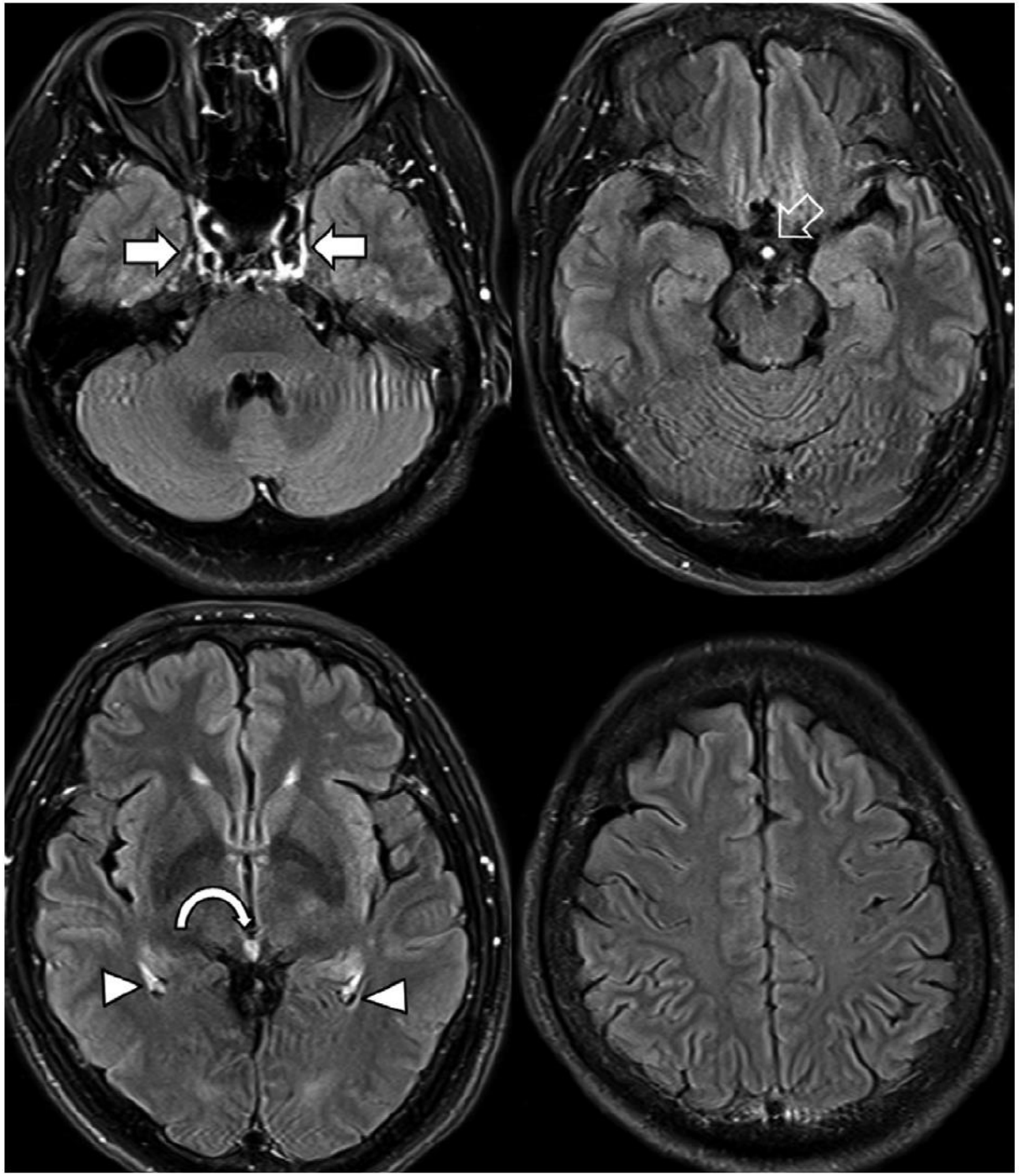
Normal enhancement in CE-FLAIR Imaging

Intense enhancement

- Choroid plexus
- Pituitary infundibulum
- Cavernous sinus

Mild enhancement

- Pituitary gland
- Pineal gland
- Nasal mucosa/turbinate



1. Parenchymal lesions

Mechanism of enhancement: disruption of BBB for Gd to enter extracellular space

Advantages of CE-FLAIR:

- Suppression of CSF signal
- No/minimal enhancement of normal blood vessels
- Reduced phase-shift artifact from enhanced blood vessels/dural sinus
- Better detection of peritumoral edema

Potential pitfall:

- difficult to differentiate lesion enhancement vs hyperintense lesion with long T2
- Large Gd accumulated lesion may not demonstrated enhancement (signal reducing T2 effect obscured signal enhancing T1 effect)
- Easier to detect enhancing lesion with surrounding hypointense edematous area in CE-T1WI

CE-T1W1 can be superior to CE-FLAIR for detection of intraparenchymal tumours

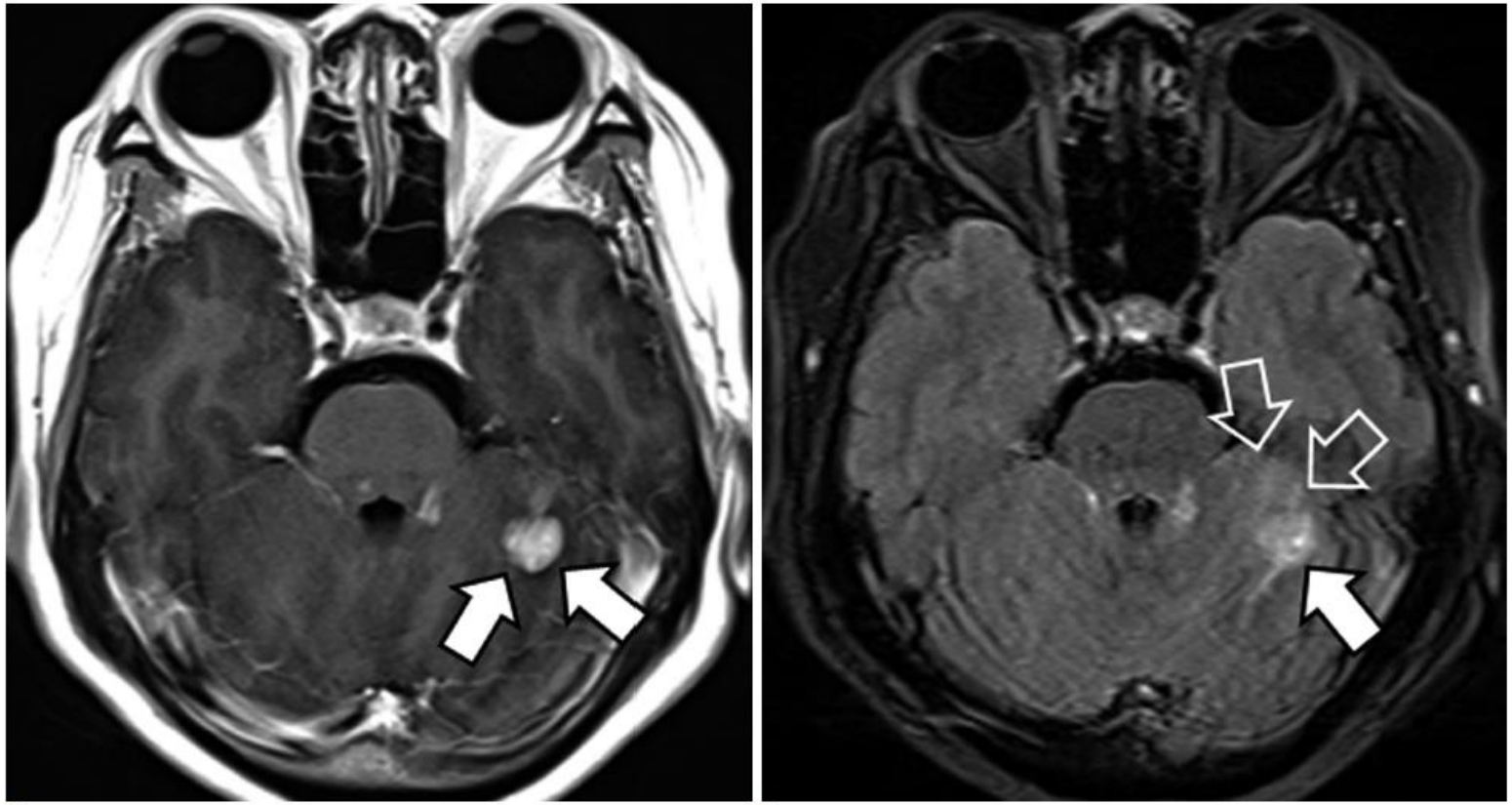


Fig. 3. Parenchymal metastasis from breast cancer.

(A) CE-T1WI depicts enhancing lesion in left cerebellar hemisphere more clearly because surrounding oedema is hypointense.
(B) CE-FLAIR depicts oedema as hyperintense, reducing lesion-to-background contrast.

2. Leptomeningeal lesions - Infection

- Infection meningitis commonest CNS infection
- MRI can be used for imaging diagnosis as well as monitor complications

Advantage of CE-FLAIR:

- Do not demonstrate enhancement in normal vascular structures / normal meninges
- More sensitive to lower Gd concentration (extreme sensitive to minimal modification of CSF composition)

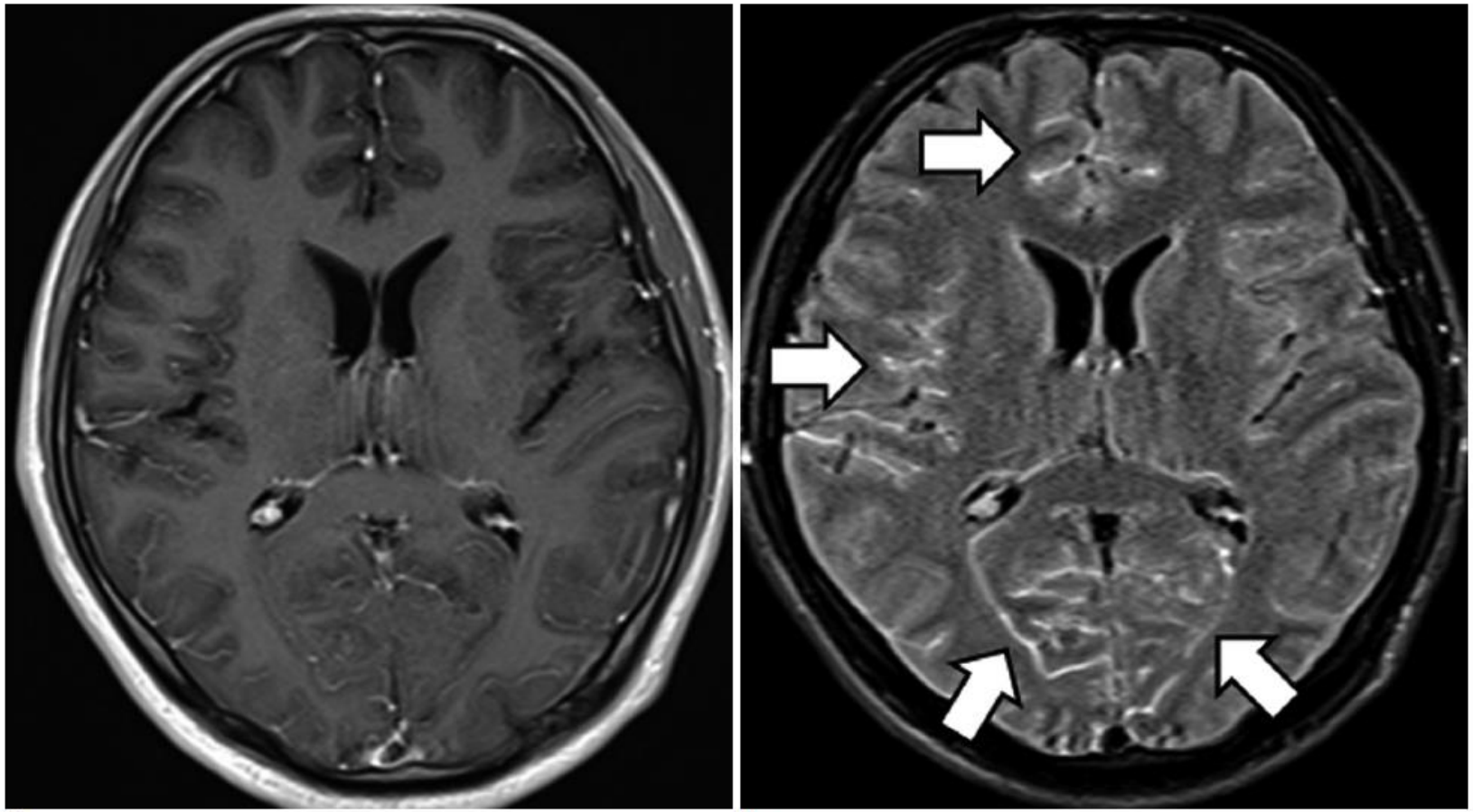


Fig. 4. Viral meningoencephalitis.

(A) CE-T1WI depicts subtle leptomeningeal enhancement. Difficult to discriminate vessels and leptomeningeal lesions.
(B) CE-FLAIR depicts leptomeningeal enhancement more definitely.

2. Leptomeningeal lesions – Neoplastic spread into subarachnoid space

- CE-T1WI is a reliable technique for confirming diagnosis, access extension and response to therapy in leptomeningeal carcinomatosis
- CE-FLAIR images show superiority for detection of leptomeningeal disease

combination of unenhanced FLAIR & CE-FLAIR images can be useful adjunct to CE-T1WI for evaluation of leptomeningeal carcinomatosis

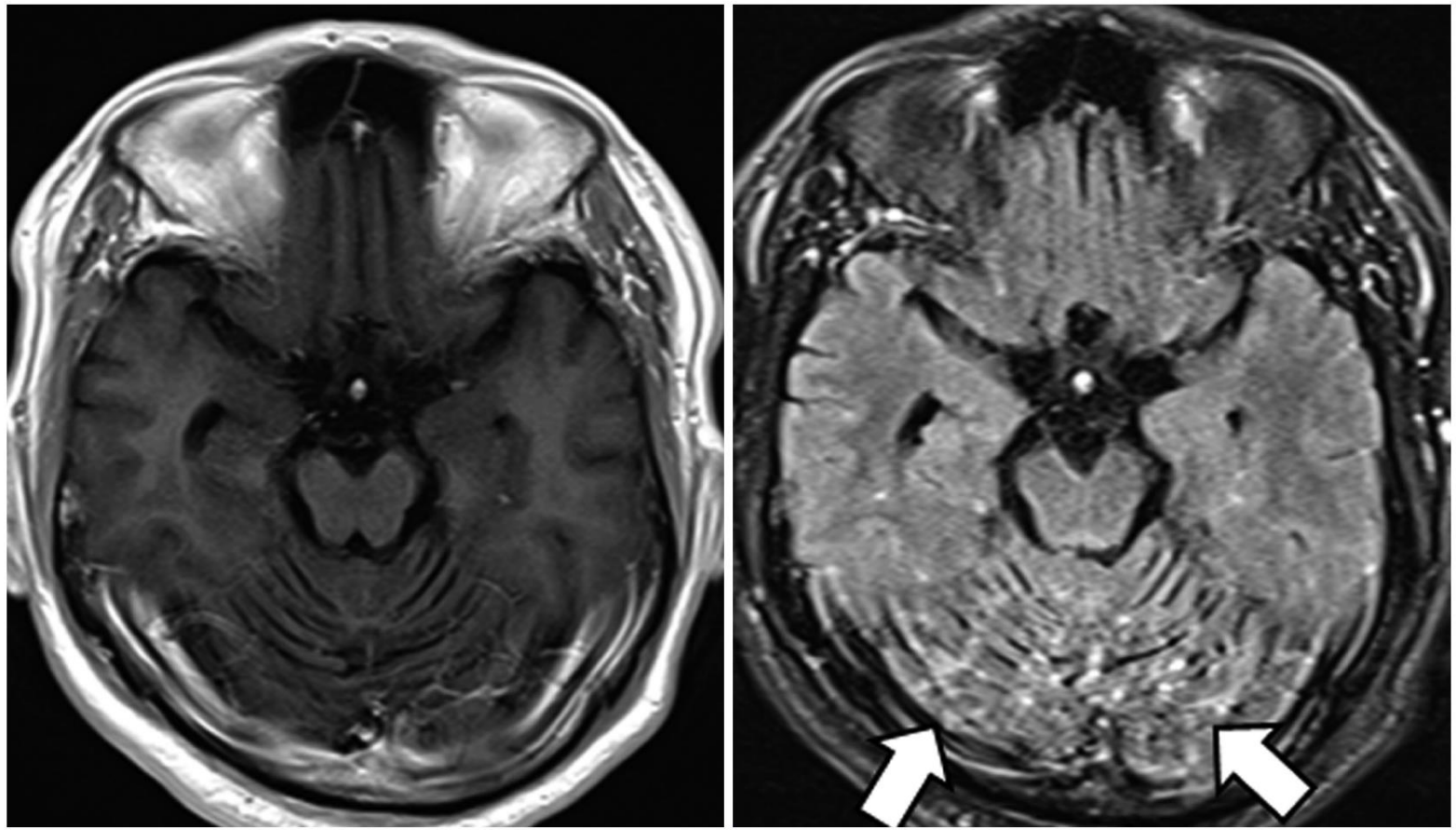


Fig. 5. Leptomeningeal metastasis from lung cancer.

(A) CE-T1WI depicts subtle leptomeningeal enhancement.
(B) CE-FLAIR depicts leptomeningeal enhancement more definitely.

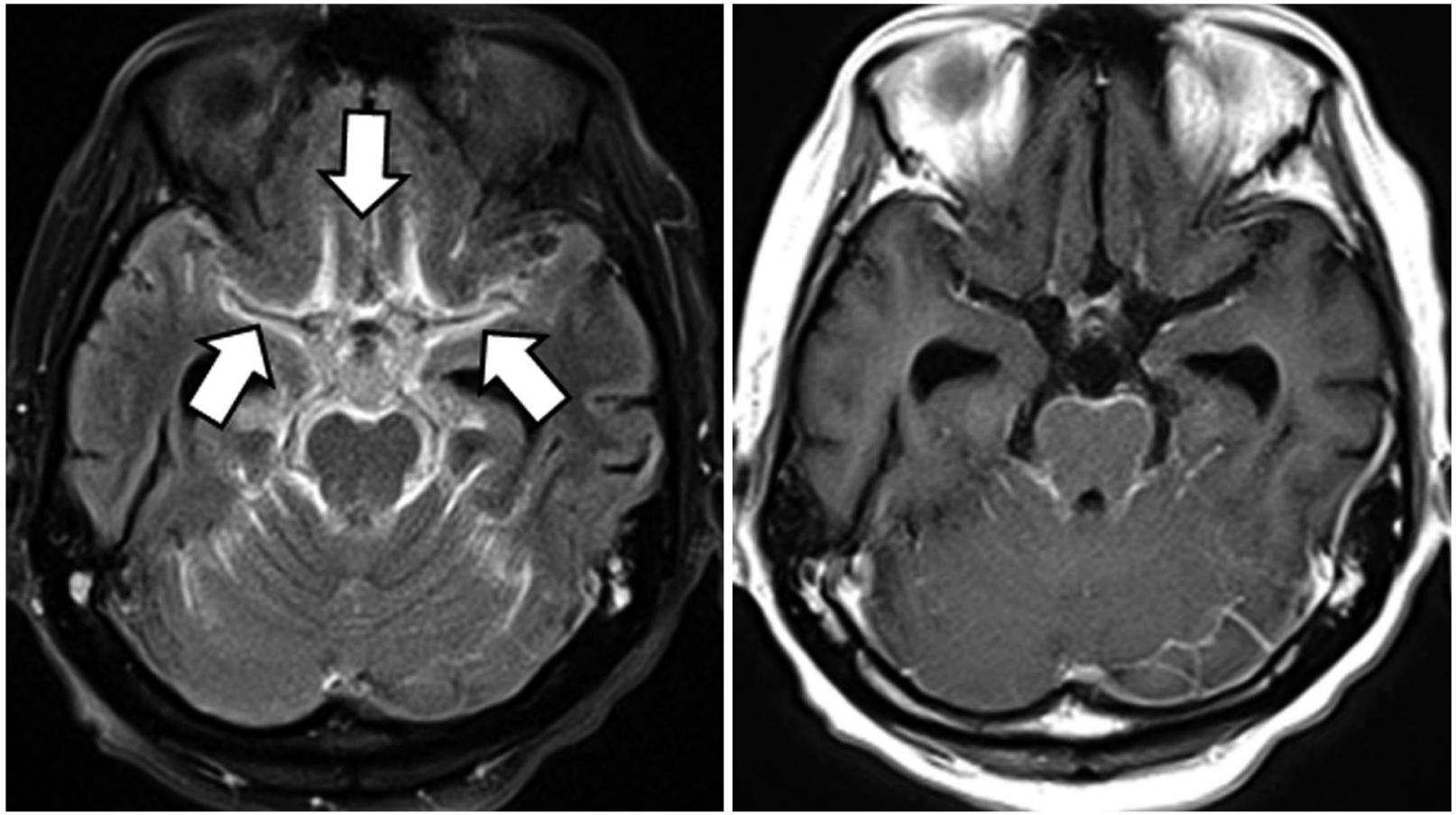


Fig. 6. Bithalamic glioblastoma with extensive CSF dissemination.

CE-FLAIR (A) depicts more definite leptomeningeal enhancement than CE-T1W1 (B).

2. Leptomeningeal lesions – Sturge-Weber Syndrome

- CE-FLAIR imaging helpful in depicting leptomeningeal angiomatosis

Advantage of CE-FLAIR:

- Lack of enhancement in normal vascular structures
- Better visualization of lesion with more extensive leptomeningeal enhancement
- Helpful in detecting mild / bilateral disease

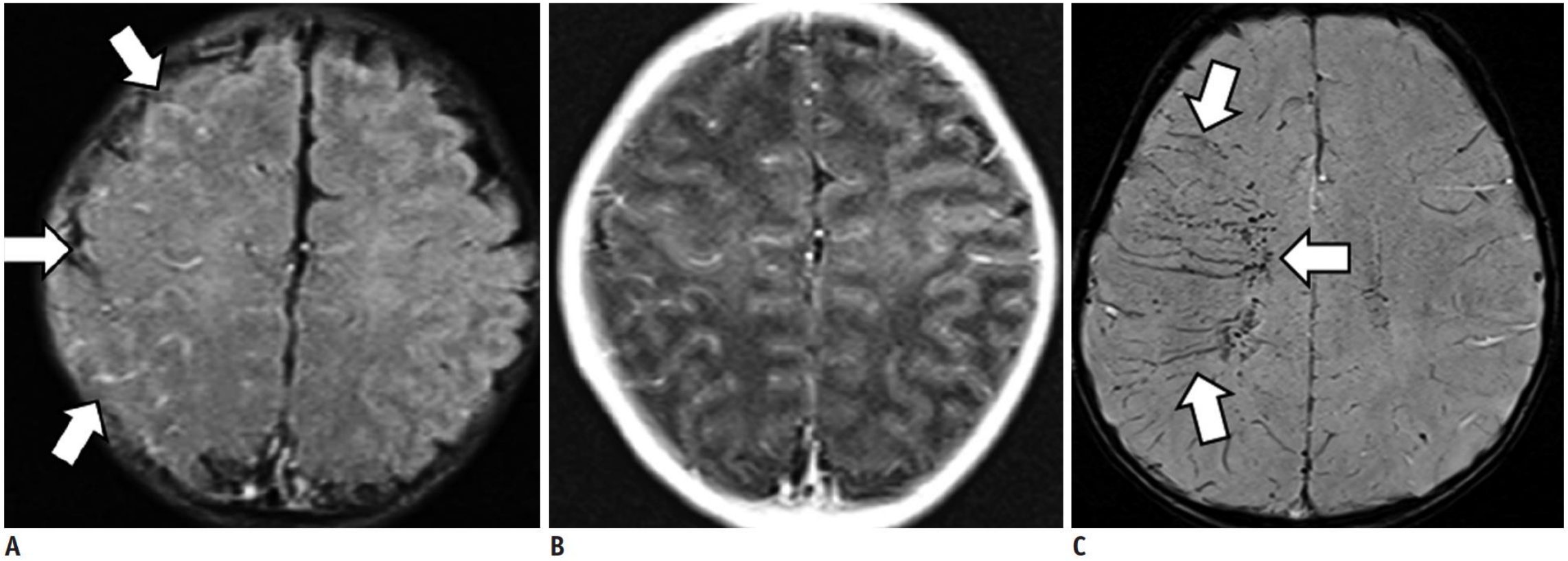


Fig. 7. 14-day-old male with clinically right-sided Sturge-Weber syndrome.

CE-FLAIR images (A) shows more definite leptomeningeal enhancement along right cerebral surface than CE-T1WI (B). Follow up SWI imaging 2 years later (C) shows enlarged, tortuous medullary veins draining into subependymal veins.

2. Leptomeningeal lesions
– Rheumatoid arthritis-associated leptomeningeal disease

- Rheumatoid leptomeningitis is rare but serious complication of rheumatoid arthritis
- Characteristic MRI findings:
- high signal intensity lesion in subarachnoid spaces on FLAIR or DWI images
- Meningeal thickening with enhancement (usually focal)

Advantage of CE-FLAIR:

- Aid in early diagnosis (more prominent enhancement than CE-T1WI)

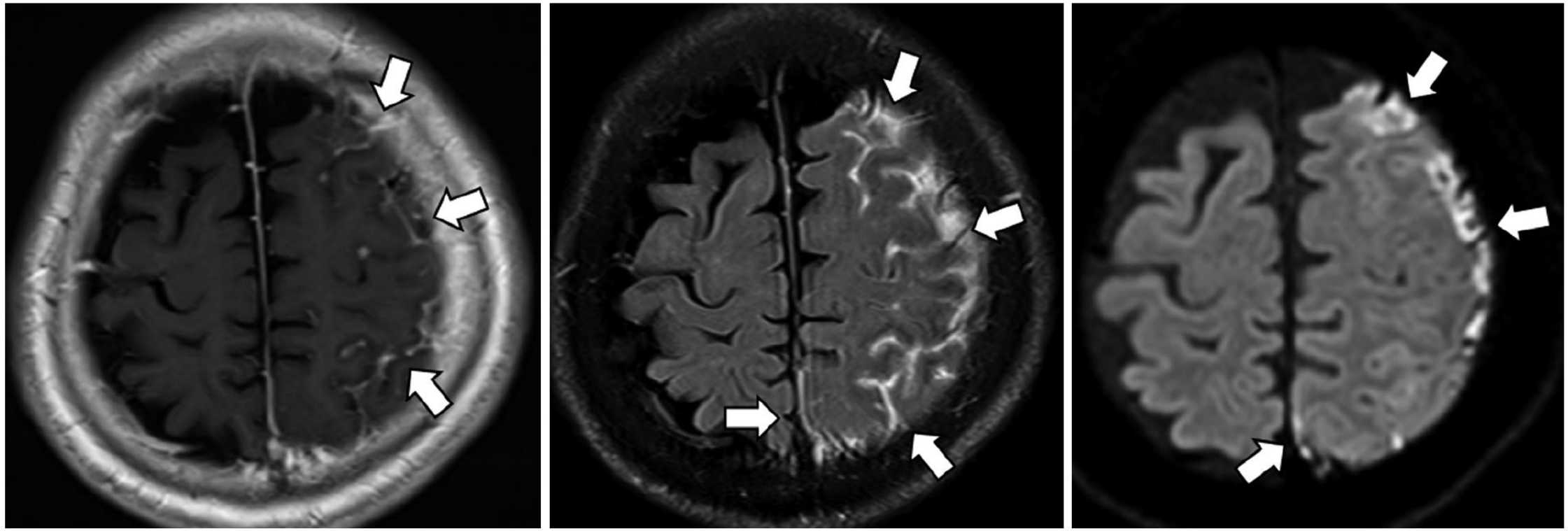


Fig. 8. Rheumatoid arthritis-associated leptomeningeal disease.

(A) CE-T1WI shows leptomeningeal enhancement along left high cerebral hemisphere.
(B) CE-FLAIR images shows more diffuse leptomeningeal enhancement along left high cerebral hemisphere with high signal on DWI (C).

3. Pachymeningeal lesions – Post-operative changes

- Post-operative dural enhancement can be seen as soon as 9 hours post intracranial surgery
- Usually smooth and linear
- Moderate or marked dural enhancement noted in all patients within 3 months after surgery
- Approximately 50% decrease in enhancement in 1-2 years thereafter

Advantage of CE-FLAIR:

- Demonstrate more extensive and persistent dural enhancement than CE-T1WI

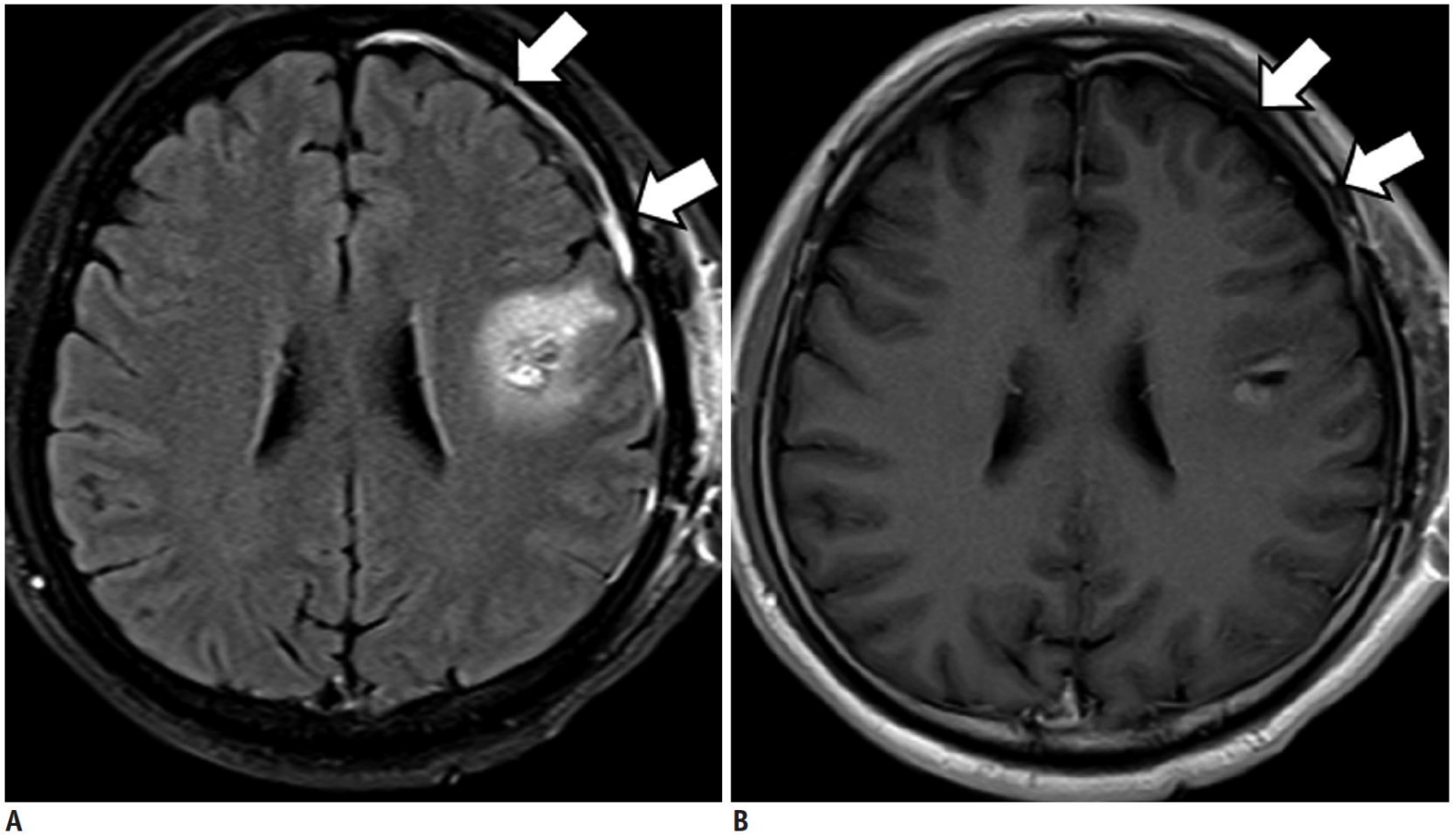


Fig. 9. Postoperative dural enhancement after surgery of cavernous hemangioma.

CE-FLAIR imaging performed 2 days after surgery (A) shows more definite dural enhancement along left craniotomy site than CE-T1WI (B).

3. Pachymeningeal lesions – Trauma

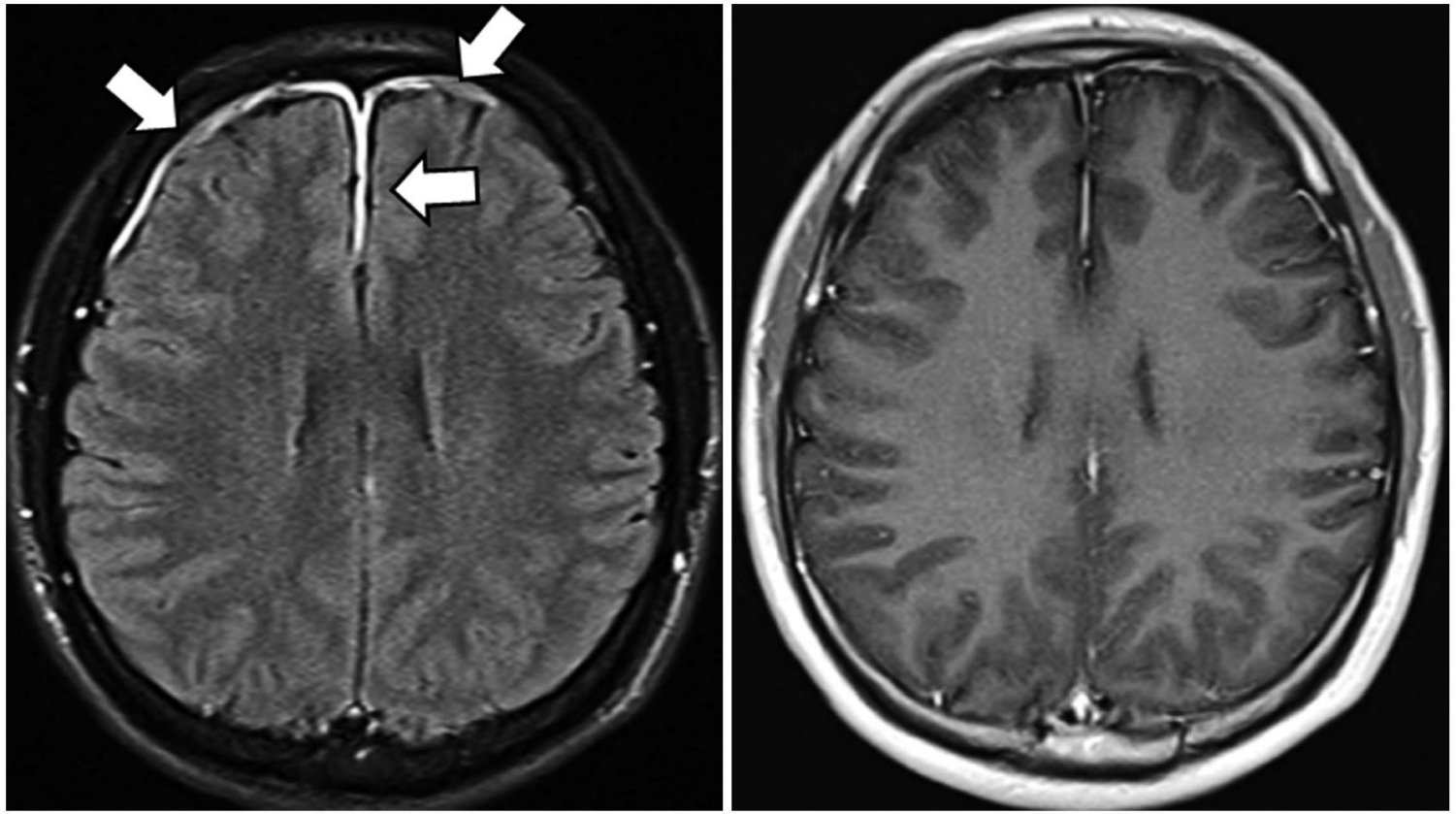
- Post-trauma dural enhancement implies considerable head injury (despite no other brain lesion on routine sequences)

Advantage of CE-FLAIR:

- Highly effective to detect dural enhancement in patients with acute/chronic head injury

→ Minor lacerations that cause bleeding into CSF spaces sufficient to induce contrast enhancement

In case of abnormal dural enhancement, look for other traumatic brain lesions e.g. small SDH or SAH → especially in case of suspected child abuse



A B

Fig. 10. Abnormal dural enhancement related to trauma.

CE-FLAIR imaging (A) shows more definite dural enhancement along both frontal surface and anterior falx cerebri than CE-T1WI (B).

3. Pachymeningeal lesions – Dural metastatic lesions

- Cancers associated with dural metastases are breast cancer, lung cancer, prostate cancer and lymphoma
- Usually occur as extension of tumour to dura from adjacent calvarial metastases
- Isolated dural metastases are relatively rare
- MRI findings: focal nodular/diffuse enhancing dural masses

CE-FLAIR has diagnostic potential equivalent to that of conventional CE-T1WI

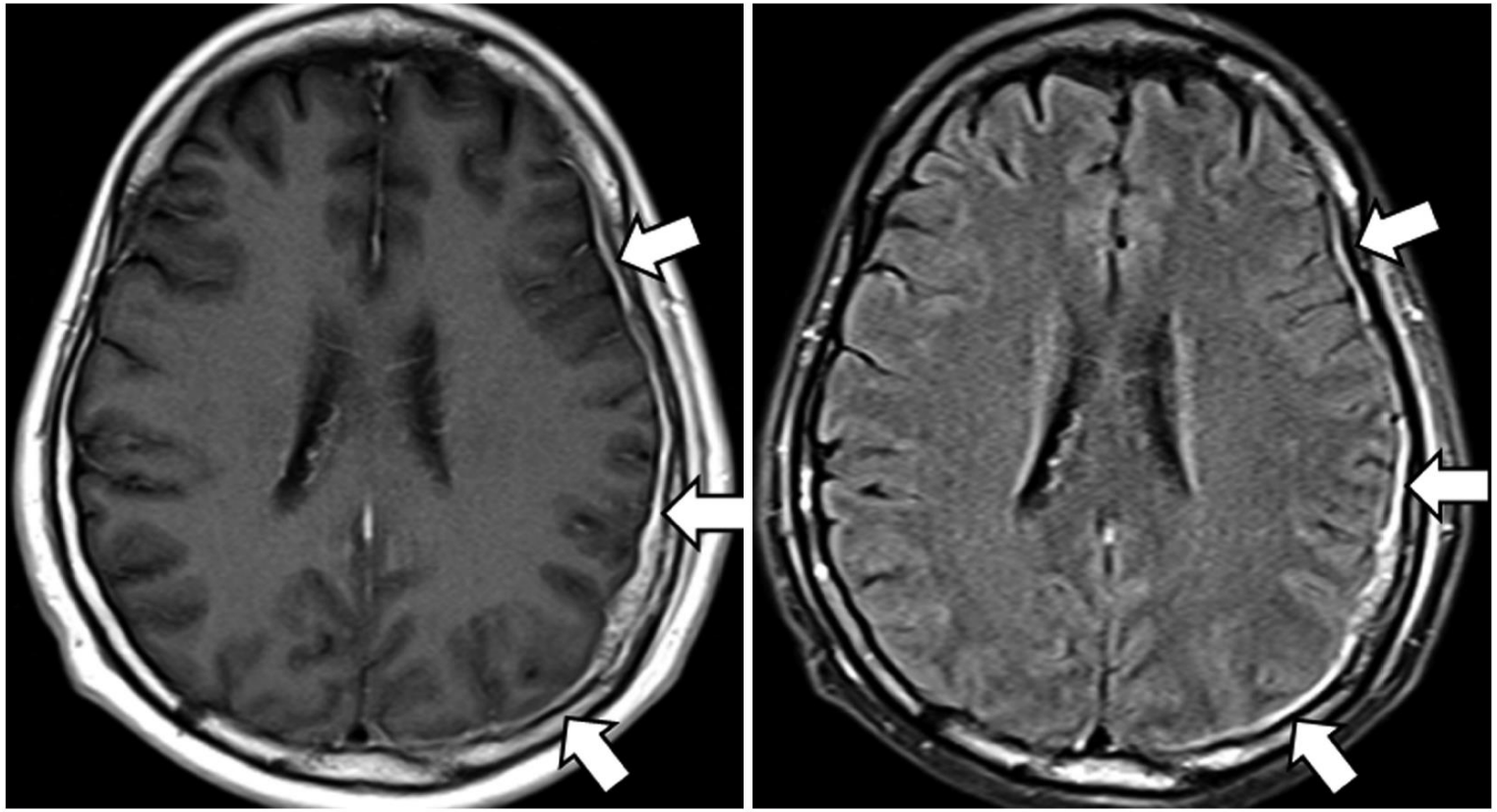


Fig. 11. Dural metastasis from breast cancer.

Diffuse uneven dural enhancement along left cerebral surface on both CE-T1WI (A) and CE-FLAIR imaging (B). Dural metastatic lesions demonstrates approximately equal contrast enhancement with both sequences.

3. Pachymeningeal lesions – Meningioma

- Commonest extra-axial tumour
- In CE-FLAIR, meningioma shows **typical peripheral enhancement pattern** → related to dual vascular supply of tumour that is more commonly seen in larger meningioma (> 2cm in diameter)
- Highly vascular central part of tumour, supplied by meningeal arteries, enhanced strongly on CE-T1WI. However, high concentration of Gd in the central of lesion induces signal loss on CE-FLAIR
- The less vascular capsule, supplied by pial artery. Lower concentration of Gd at periphery, resulting in peripheral enhancement on CE-FLAIR

Pitfall:

- Tumour less than 2cm in diameter, only homogeneous enhancement seen in CE-FLAIR

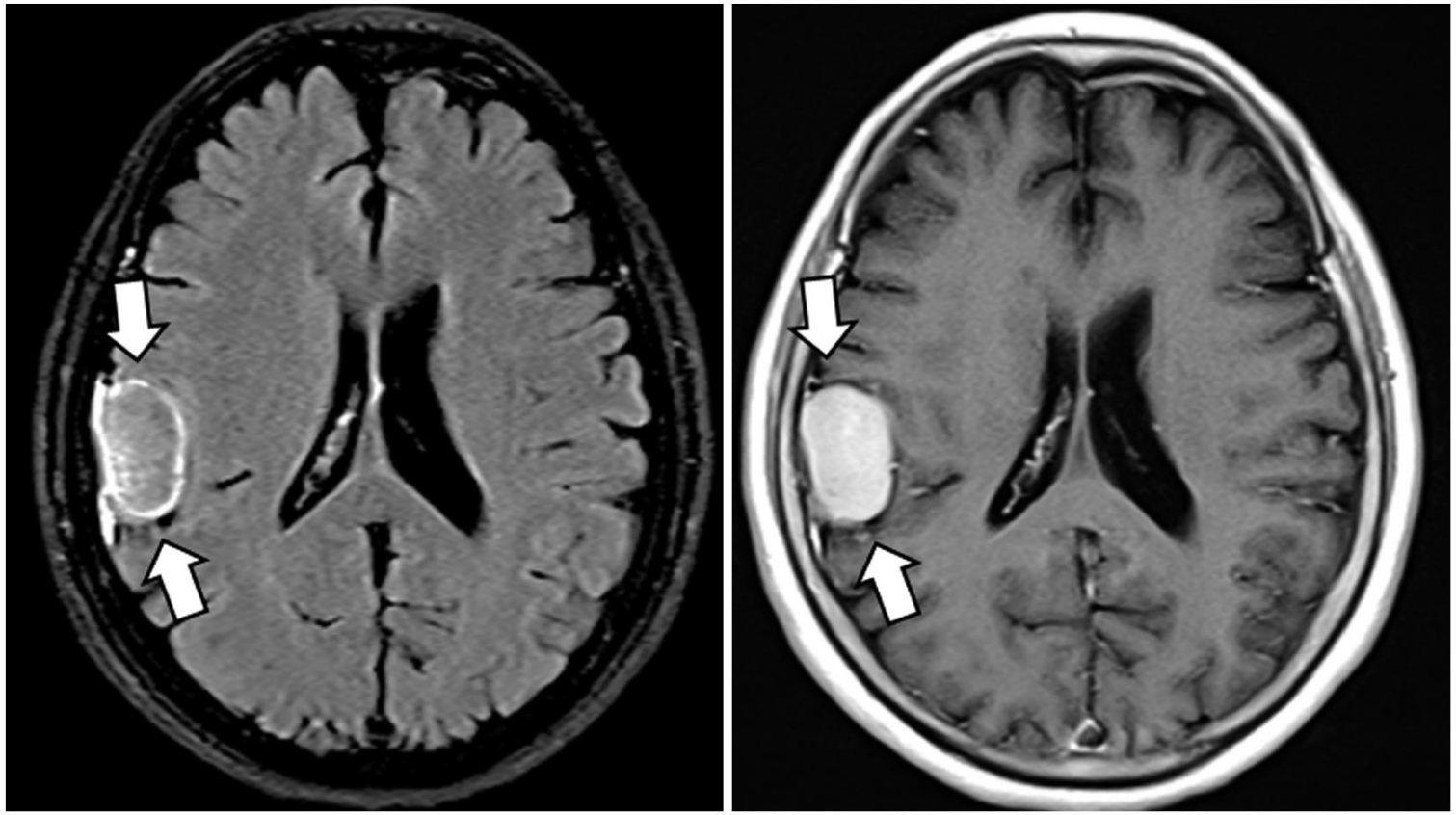


Fig. 12. Meningioma of fibroblastic type, WHO grade 1.

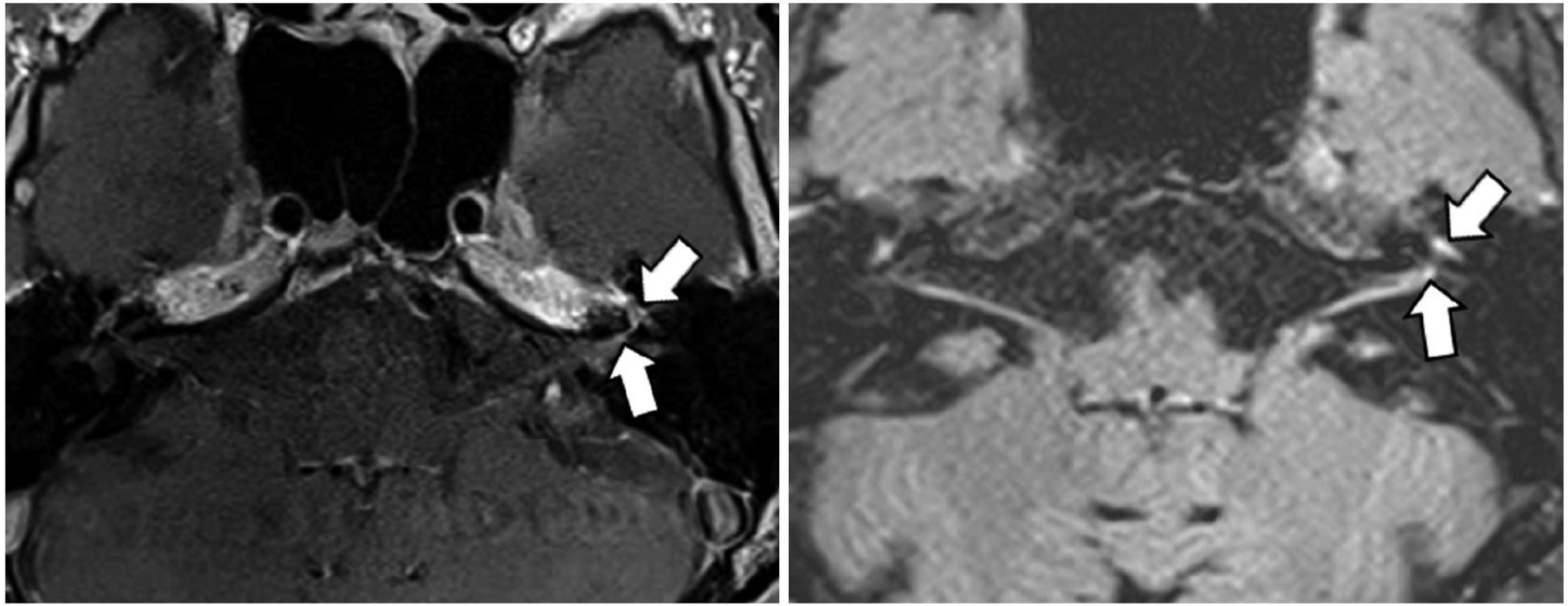
Peripheral rim enhancement in right parietal extra-axial mass in CE-FLAIR imaging (A).
Homogeneous enhancement pattern seen on CE-T1WI imaging (B).

4. Cranial Nerve Lesions – Diagnosis of facial neuritis

- CE-T1WI has limited role due to prominent normal facial nerve enhancement
- Normal geniculate ganglion, greater superficial petrosal nerve, as well as proximal tympanic and mastoid segments of normal facial nerve can enhanced due to flux of contrast in arteriovenous plexus (AVP) along facial nerve
- Thus, evaluation of pathological enhancement from breakdown of BBB can be inhibited

Advantages of CE-FLAIR:

- Prominent AVP surrounding normal facial nerve is no longer visible due to flow-related signal loss and high Gd concentration
- Enhancement in canalicular and anterior genu segments are significantly correlated with presence of facial palsy



A B

Fig. 13. Left facial neuritis.

CE-T1WI shows blurred abnormal enhancement in canalicular, labyrinthine and anterior segment of facial nerve (A).

CE-FLAIR shows more definite abnormal enhancement of left facial nerve (B).

5. Hyperintense Acute Reperfusion Marker (HARM)

- Imaging phenomenon of enhancement of subarachnoid CSF space (no enhancement of parenchymal) on FLAIR imaging, caused by leakage of Gd through disrupted BBB
- Seen in various clinical condition:

1. Acute ischaemic stroke (30-40% of patients with acute ischaemic stroke, 20% with TIA without DWI lesions)

- Associated with age, reperfusion, thrombolysis, endovascular procedure, higher Gd dose, reduced kidney function
- Possible increased risk of hemorrhagic transformation

2. After carotid stent insertion for severe carotid artery stenosis (60% of patients)

- Possible changes in BBB integrity due to sudden hemodynamic changes / reperfusion injury
- Majority are transient, not associated with neurological symptoms

3. Cardiac surgery (50% of patients, where 75% have acute lesion on DWI)

- BBB disruption due to ischaemia secondary to hypoperfusion, activation of inflammatory cascade and proteolytic enzymes
- Higher incidence in patients who received Gd during first 24 hours post-surgery

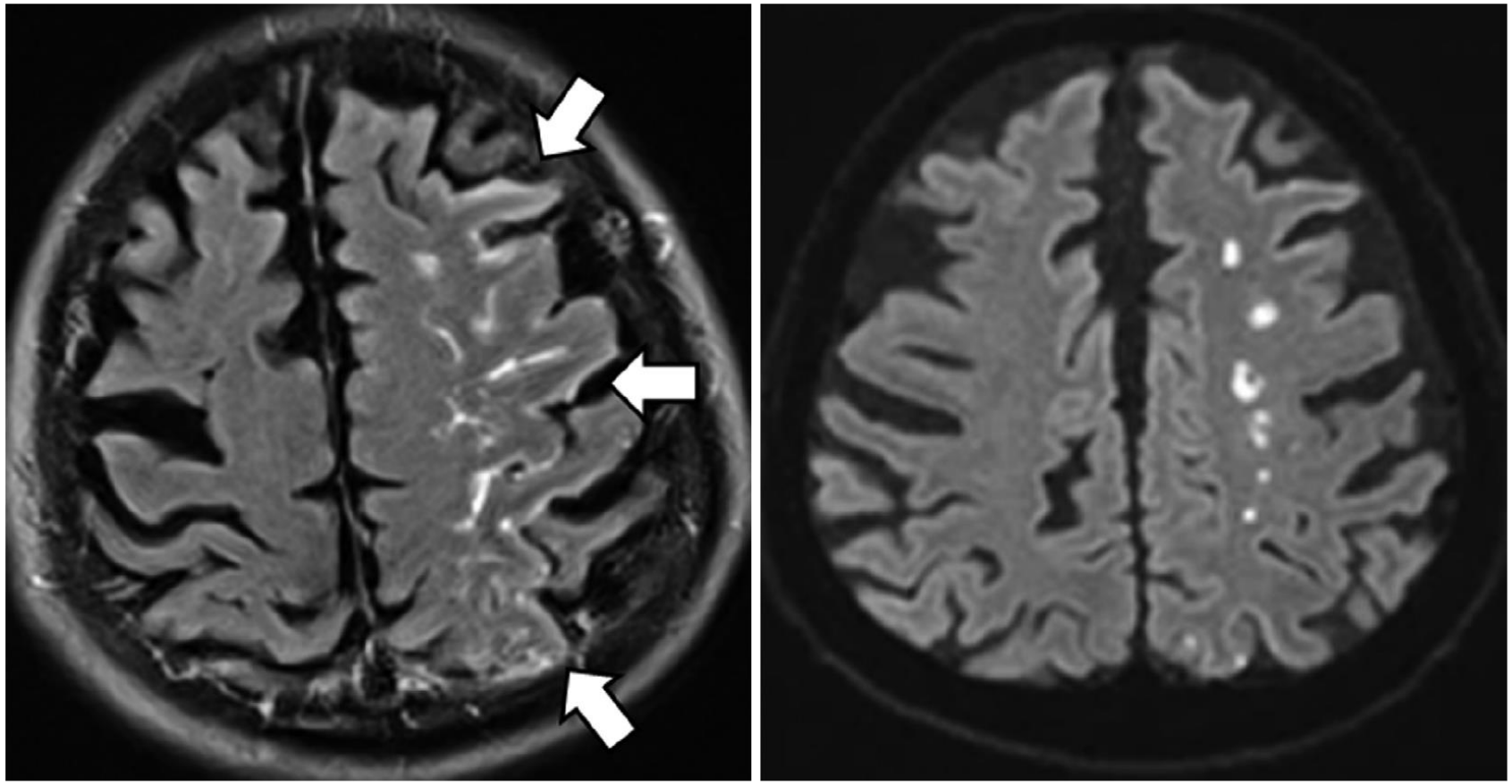


Fig. 14. Extensive HARM sign related to acute ischemic stroke.

CE-FLAIR (A) shows extensive positive HARM sign adjacent to acute infarcted lesions of left centrum semiovale on DWI (B).

6. Diabetic Retinopathy

- CE-FLAIR demonstrates ocular enhancement in diabetic patient
- Due to leaky, swollen blood vessels in retina, presumably inducing contrast enhancement
- Might correspond to development of diabetic retinopathy

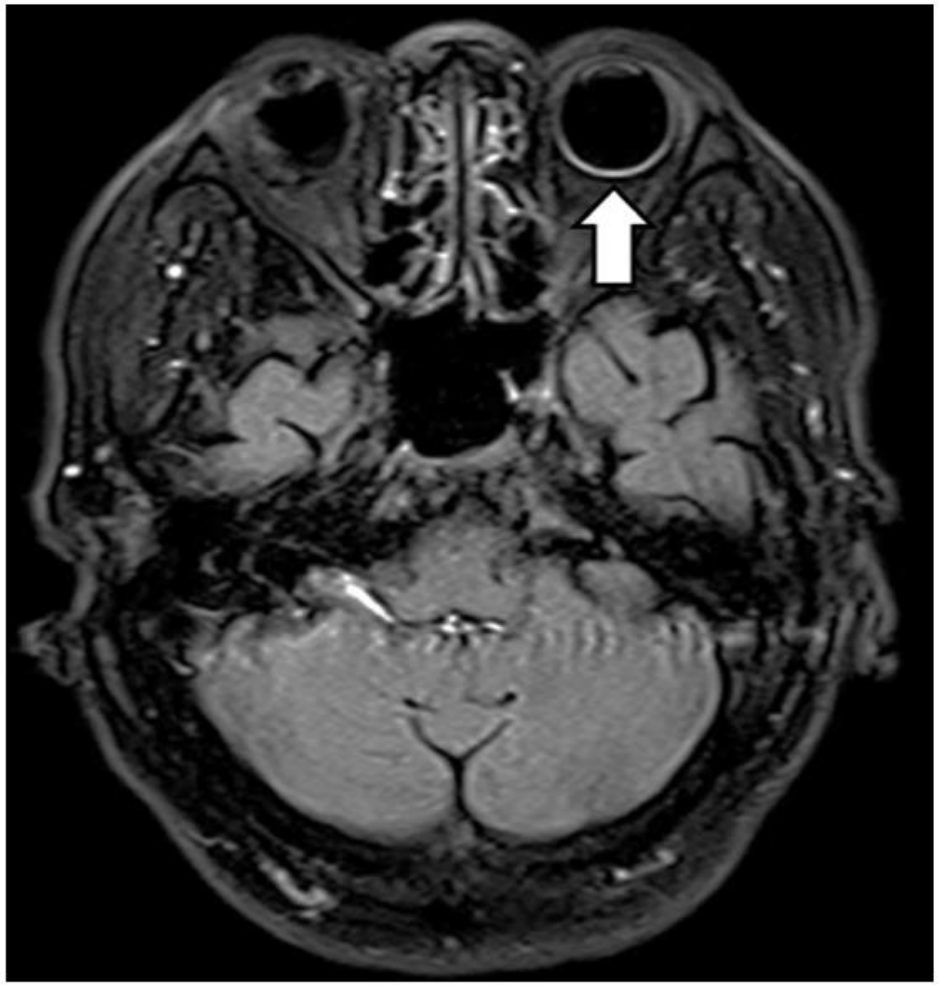


Fig. 16. Diabetic retinopathy. CE-FLAIR imaging depicts obvious left ocular enhancement (arrow) with no significant visual symptom.

7. Hyperglycemia-induced Seizures

- Patient with seizures in non-ketotic hyperglycemia may have transient MRI abnormality:
- subcortical T2 hypointensity with overlying cortical / leptomeningeal enhancement
- cortical swelling
- Leptomeningeal enhancement occurs due to seizure-induced dilatation of leptomeningeal vasculatures
- Cortical enhancement occurs due to seizure-induced hypoxia and acidosis with alternation of vascularity and breakdown of BBB

CE-FLAIR is superior to CE-T1WI for detection of focal cortical / leptomeningeal enhancement

(CE-FLAIR images do not show enhancement in normal vascular structures and normal meninges)

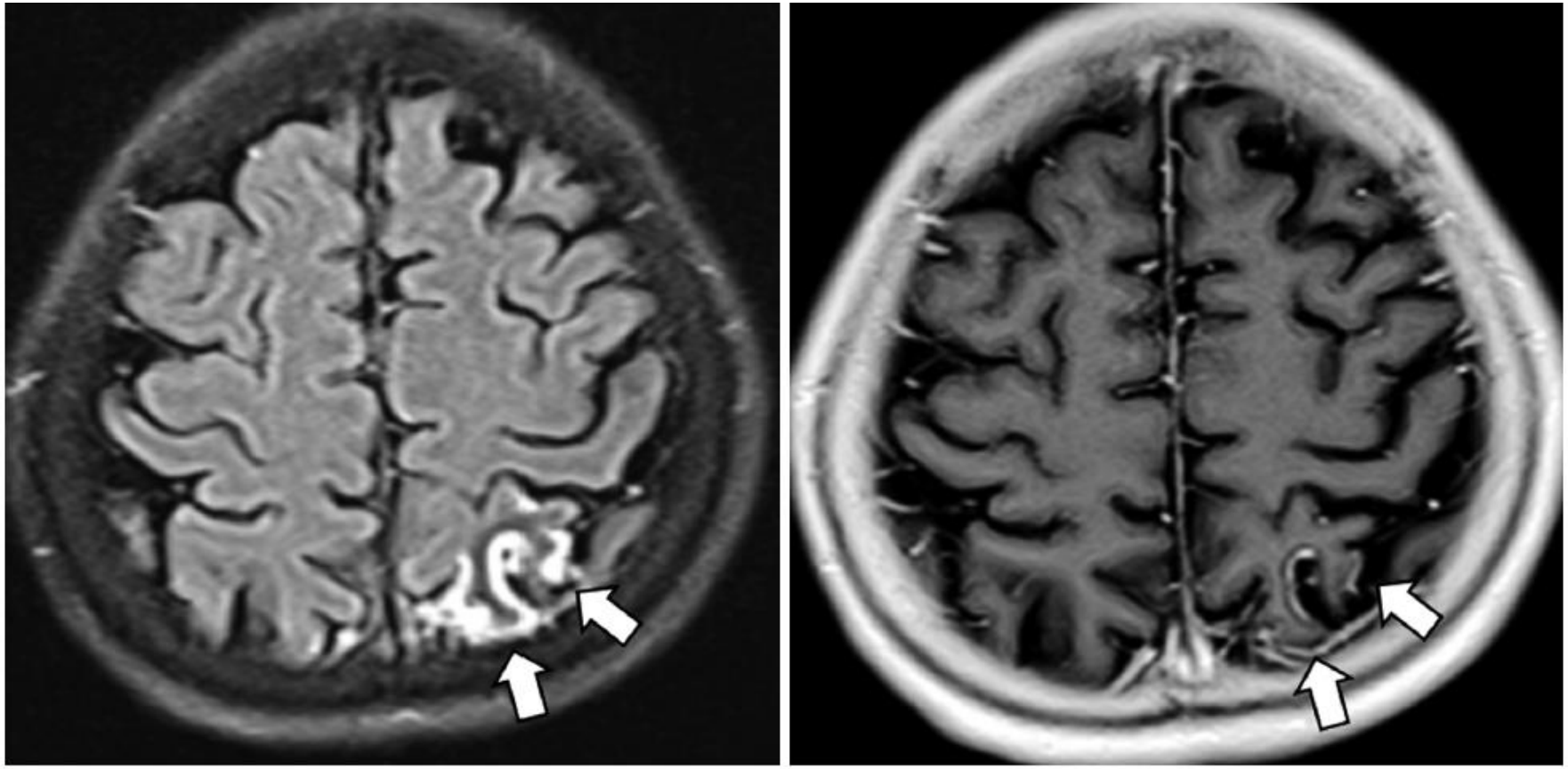


Fig. 17. Seizures associated with nonketotic hyperglycemia. CE-FLAIR imaging **(A)** depicts focal subcortical hypointensity with overlying prominent cortical and leptomeningeal enhancement (arrows) in left parietal area. CE-T1WI **(B)** shows inferior enhancement (arrows) to CE-FLAIR imaging. Follow-up CE-FLAIR images 6 weeks later show remarkable resolution of subcortical hypointense lesion and abnormal enhancement (not shown). CE = contrast-enhanced, FLAIR = fluid-attenuated inversion recovery, T1WI = T1-weighted imaging

Conclusion

- CE-FLAIR has many advantages for intracranial disease manifestations.
- It can be used as primary or adjunct sequences to CE-T1WI in equivocal cases to increase diagnostic confidence and improve patient care.


THANK YOU