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KEY MRI FEATURES IN ACUTE STROKE: INSIGHTS FROM AN MRI-FIRST APPROACH AT A TERTIARY CARE CENTRE

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ABSTRACT:

Magnetic Resonance Imaging (MRI) has emerged as a crucial tool in acute stroke management, offering superior sensitivity and specificity in detecting early ischemic changes. This review explores key MRI features in acute stroke based on insights from an MRI-first approach implemented at Universiti Putra Malaysia's tertiary care center. The Putra Acute Stroke Protocol, an optimized 8-minute MRI protocol, has demonstrated the feasibility of prioritizing MRI in hyperacute stroke settings. This approach has led to high rates of accurate ischemic stroke identification (72.5%) and thrombolysis (17.1%). The manuscript discusses essential MRI sequences, including Diffusion-Weighted Imaging (DWI), Fluid-Attenuated Inversion Recovery (FLAIR), and Susceptibility-Weighted Imaging (SWI). It highlights the diagnostic and prognostic significance of specific imaging markers such as the FLAIR Vascular Hyperintensity Sign (FVHS), Susceptibility Vessel Sign (SVS), and Prominent Vein Sign (PVS). These features provide crucial information about infarct core, penumbra, collateral circulation, and thrombus composition, guiding treatment decisions and improving patient outcomes. The review also addresses the challenges and benefits of implementing an MRI-first policy, including concerns about delays and costs, while emphasizing its value in personalizing stroke management. The manuscript underscores the particular relevance of advanced MRI techniques in Southeast Asian populations, where intracranial atherosclerosis and small vessel disease are prevalent. By leveraging MRI's capabilities, clinicians can make more informed decisions about reperfusion therapies, potentially extending treatment windows for suitable candidates and improving overall stroke care.

Keywords:
Magnetic Resonance Imaging, Stroke, Brain Ischemia, Thrombectomy

INTRODUCTION:

Stroke remains one of the leading causes of mortality and long-term disability worldwide, with ischemic strokes comprising nearly 87% of cases [1]. Rapid and accurate differentiation of ischemic stroke from other conditions, such as hemorrhagic stroke or stroke mimics, is essential for appropriate management. Magnetic Resonance Imaging (MRI) has established itself as a gold-standard diagnostic tool due to its superior sensitivity to early ischemic changes and its ability to provide detailed physiological and anatomical insights. At Universiti Putra Malaysia (UPM) teaching hospital, the implementation of an MRI-first protocol has further showcased the importance of advanced MRI features in acute stroke care [2,3].

UPM's adoption of an MRI-first protocol prioritizes MRI as the primary imaging modality for all acute stroke cases classified as Code Red (onset within 6 hours) or Code Yellow (onset between 6 and 24 hours). Using Putra Acute Stroke Protocol [3] which gives an optimized 8-minute to decision, MRI protocol for hyperacute stroke evaluation, followed by added advance sequences when necessary.

In 2023, Mohd Fandi et. al [2] reported that this approach successfully identified 72.5% ischemic strokes, 8.9% hemorrhagic stroke with high thrombolysis rate of 17.1%, likely due to the confidence of accurate ischemic stroke diagnosis. This protocol has demonstrated the feasibility and effectiveness of MRI as the primary imaging modality in the hyperacute stroke setting, providing rapid and accurate diagnoses that inform timely therapeutic decisions.

MRI offers unparalleled sensitivity and specificity in detecting acute ischemic changes and differentiating stroke subtypes. Key sequences such as Diffusion-Weighted Imaging (DWI) and Susceptibility-Weighted Imaging (SWI) provide crucial diagnostic insights:

- Early Ischemic Changes: DWI detects cytotoxic edema within minutes of onset, outperforming CT in identifying early infarcts.
- Hemorrhagic Transformation: MRI, particularly SWI, is superior in detecting microbleeds and subtle hemorrhagic transformations that may contraindicate thrombolysis.
- Stroke Mimics: By identifying conditions such as seizures, migraines, and functional disorders, MRI minimizes unnecessary interventions like thrombolysis, which are associated with significant risks.

In UPM’s experience, the MRI-first policy avoided unnecessary thrombolysis or thrombectomy, reducing the risk of adverse events and improving resource allocation. This review explores key MRI findings such as the FLAIR Vascular Hyperintensity Sign (FVHS), Susceptibility Vessel Sign (SVS), Prominent Vein Sign (PVS), Clot Signs and other advanced sequences, highlighting their diagnostic and prognostic relevance. In UPM, Putra Acute Stroke Protocol was adopted [3].

MRI SEQUENCE IN ACUTE STROKE:

Diffusion-Weighted Imaging (DWI)

DWI remains the cornerstone of acute stroke MRI protocols. Hyperintense lesions on DWI with corresponding hypointense regions on Apparent Diffusion Coefficient (ADC) maps indicate cytotoxic edema, making DWI essential for identifying the infarct core. DWI can detect changes within minutes of ischemic onset, thus facilitating early diagnosis and intervention [4,5]. DWI with ADC also able to detect haemorrhagic infarct.

Fluid-Attenuated Inversion Recovery (FLAIR)

FLAIR suppresses cerebrospinal fluid signals to enhance the visibility of parenchymal abnormalities. Hyperintense lesions on FLAIR can indicate the age of the infarct, aiding in estimating stroke onset time. The presence of FVHS on FLAIR imaging is particularly significant as it correlates with larger infarct volumes [6].

FLAIR Vascular Hyperintensity Sign (FVHS)

An important MRI feature observed in acute stroke is FVHS, characterized by hyperintense signals within cerebral vessels on FLAIR imaging. FVHS is indicative of slow or stagnant blood flow, often associated with arterial occlusion or severe hypoperfusion [6,7]. Its presence correlates with larger infarct volumes and can inform prognosis and therapeutic strategies. Recent studies have suggested that FVHS may serve as a predictor of collateral circulation status, which is critical for assessing potential recovery outcomes following reperfusion therapies [8].

Susceptibility-Weighted Imaging (SWI)

SWI is sensitive to paramagnetic substances and detects microbleeds and hemorrhagic transformations, providing critical information for treatment planning. This sequence enhances visualization of venous structures and can reveal signs of venous congestion or thrombosis that may complicate acute stroke management [9,10].

Susceptibility Vessel Sign (SVS)

Kang et al., (2017) defined SVS as hypointense signal inside vessel lumen detected on SWI regardless of its size. SVS is particularly valuable because it provides early visualization of clot composition, length, diameter, and burden and size, information that is crucial for guiding therapeutic decisions [11].

Prominent Vein Sign (PVS)

The sign (PVS), observed on susceptibility-weighted imaging (SWI), reflects increased oxygen extraction in hypoperfused tissue during acute ischemic stroke. It appears as asymmetrically dilated cortical or medullary veins in the affected hemisphere [12]. Its visibility is attributed to the increased ratio of deoxygenated to oxygenated hemoglobin in the draining veins of ischemic regions, providing valuable insights into tissue viability and potential treatment strategies [13].

Perfusion-Weighted Imaging (PWI)

PWI evaluates cerebral hemodynamics by measuring parameters such as cerebral blood flow (CBF) and cerebral blood volume (CBV) [14]. PWI is instrumental in identifying the ischemic penumbra. The mismatch between PWI and DWI findings delineates salvageable brain tissue, which is crucial for determining treatment eligibility.

DISCUSSION:

MRI has established itself as a critical tool in evaluating and managing acute ischemic strokes, offering detailed insights that inform treatment decisions and prognostication. The experience at Universiti Putra Malaysia demonstrates the feasibility and benefits of an MRI-first approach, contributing to improved patient outcomes. Ongoing research and adaptation of MRI protocols continue to enhance its applicability across diverse clinical settings.

In Southeast Asia, where intracranial atherosclerosis and small vessel disease are prevalent, advanced MRI techniques are particularly beneficial. Research from Malaysia confirms that FVHS correlates with better collateral circulation, emphasizing its value in predicting treatment success [15,16].

SWI Features in ICAS studies highlight the utility of PVS and SVS in identifying hypoperfusion and thrombogenic vessels in ICAS-related strokes [17].

MRI enables a more precise evaluation of ischemic core and penumbra through DWI which is critical for guiding reperfusion therapies. MRI allows treatment decisions to be based on tissue viability rather than elapsed time alone. This is particularly relevant in cases of "wake-up strokes" or patients presenting beyond the traditional therapeutic window. Features like the Susceptibility Vessel Sign (SVS) and Prominent Vein Sign (PVS) on SWI provide information about thrombus composition and collateral status, aiding in the selection of candidates likely to benefit from thrombectomy.

FLAIR Vascular Hyperintensity Sign (FVHS) correlates with the quality of collateral circulation, which predicts better outcomes after reperfusion therapies.

Despite its advantages, critics of the MRI-first policy often cite delays, cost, and accessibility as barriers to widespread adoption. Concerns about delays are valid but overstated. UPM's 8-minute MRI protocol demonstrates that optimized workflows can achieve early enough decision time with acceptable door-to-needle times (~49 minutes on average), comparable to CT-based workflows in many settings [2,3]

While MRI is more expensive than CT upfront, the avoidance of unnecessary treatments (e.g., thrombolysis in stroke mimics) and better long-term outcomes can offset these costs. In addition, increased utilization of MRI slots reduces per-scan costs. Implementation of MRI-first policies should focus on centers with existing MRI infrastructure, high stroke volumes, and specialized stroke care teams, ensuring cost-efficiency without compromising access.

The MRI-first policy aligns with emerging evidence that stroke progression is highly individualized, encapsulated in the concept that "time is brain, but every patient has their own time." By leveraging advanced imaging to personalize treatment, MRI-based evaluation minimizes biases associated with rigid time windows, ensuring that late-presenting patients with viable penumbra are not excluded from life-saving therapies. Routine MRI use provides rich datasets that can drive research into stroke pathophysiology, biomarkers, and therapeutic strategies, particularly in diverse populations like those in Southeast Asia.

Regional studies have highlighted the prevalence of intracranial atherosclerosis (ICAS) and small vessel disease in Southeast Asian populations, in which sequences such as SWI and FLAIR are more sensitive than CT in identifying small infarcts and microvascular changes [18]. Vessel Wall Imaging (VWI) and Black Blood Imaging improve the detection of ICAS-related occlusions, aiding in targeted treatment planning. UPM's local data and the broader Southeast Asian context underscore the value of MRI in addressing unique regional challenges, further justifying the MRI-first approach in this population.

CONCLUSION:

MRI is an indispensable tool in acute stroke imaging, offering a comprehensive view of ischemic changes and vascular status. Features like FVHS, SVS, and PVS have significantly improved diagnostic accuracy, treatment decision-making, and prognostication. UPM's MRI-first policy exemplifies the benefits of leveraging advanced imaging techniques to enhance acute stroke care, particularly in resource-rich centres. Ongoing research and adaptation of protocols will further solidify MRI's role in stroke management globally and regionally.

DATA AVAILABILITY:

Further information regarding the data used for this work can be obtained from the corresponding author upon reasonable request.

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CONFLICT OF INTEREST:

The author have no conflicts of interest to declare and is in agreement with the contents of the manuscript.

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FIGURE LEGEND:

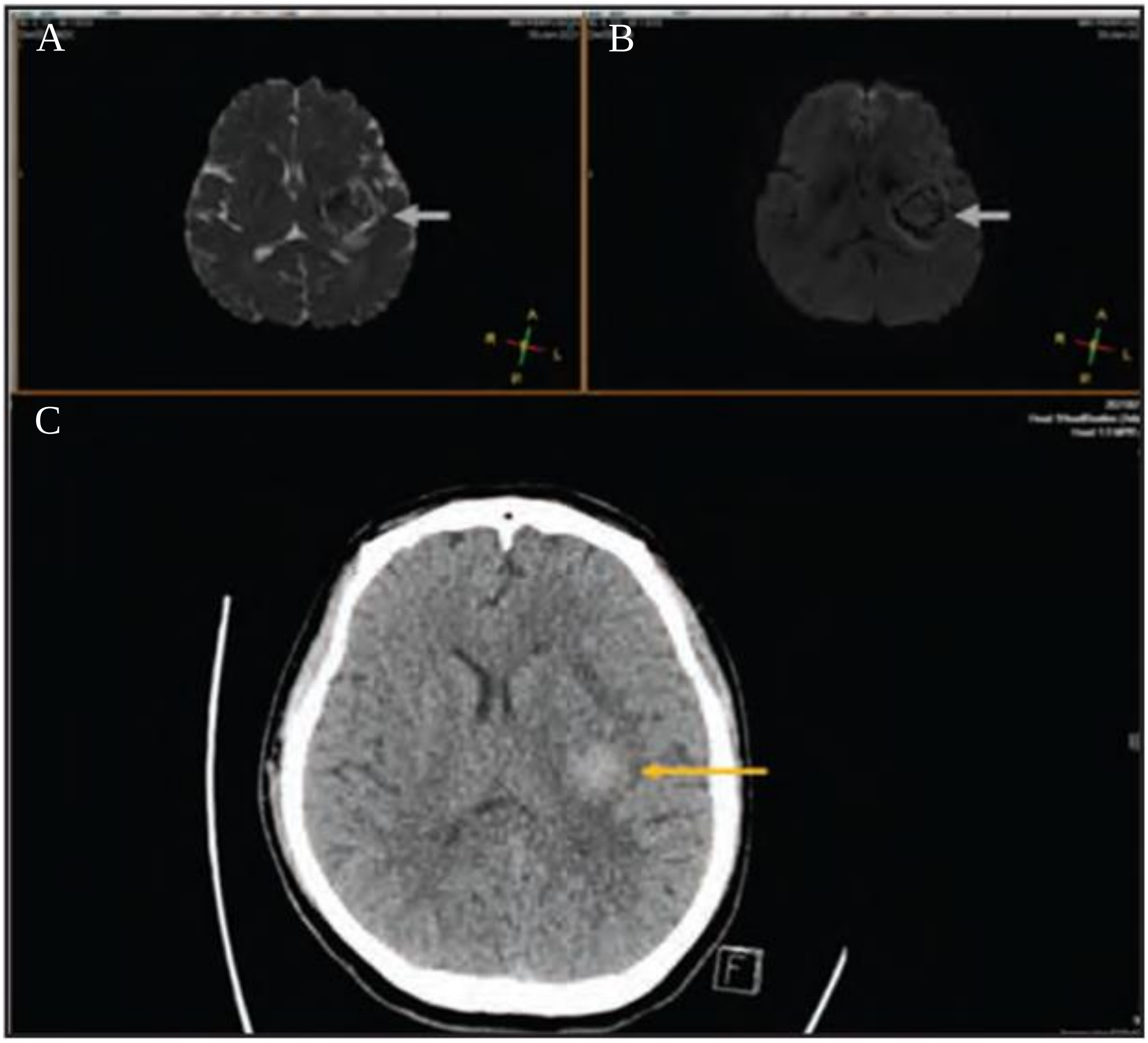

Figure 1: DWI shows central hyperintensity with surrounding hypointensity rim with the outer hyperintense rim in b1000 and ADC, representing oedema (arrows, A). Comparison to SWI (B) and CT (C) of the same patient. Adapted from Kamis et al. (2023).

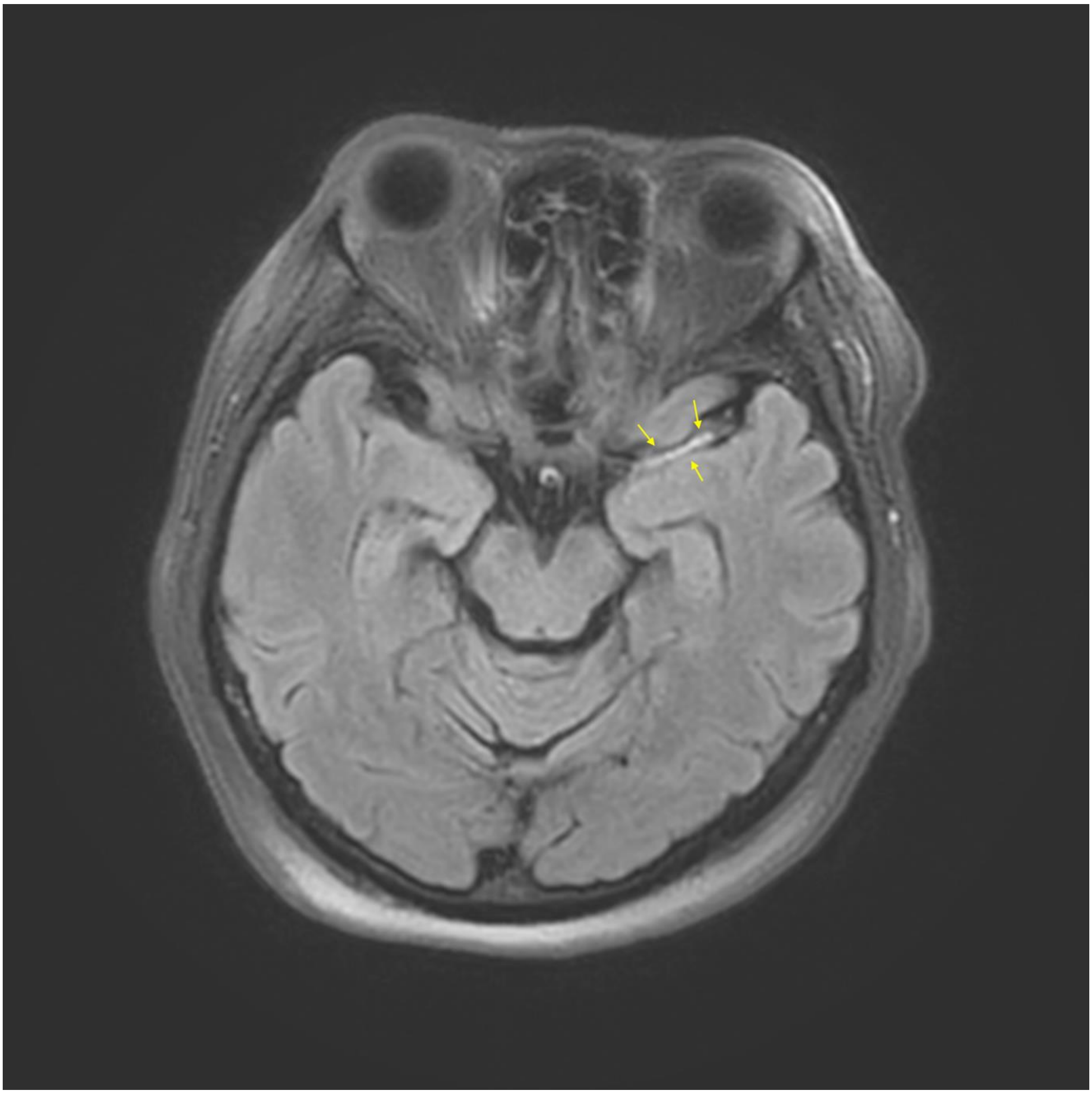

Figure 2: 56 years old acute stroke with LVO, shows FHVS involving Left M1 segment (arrows).

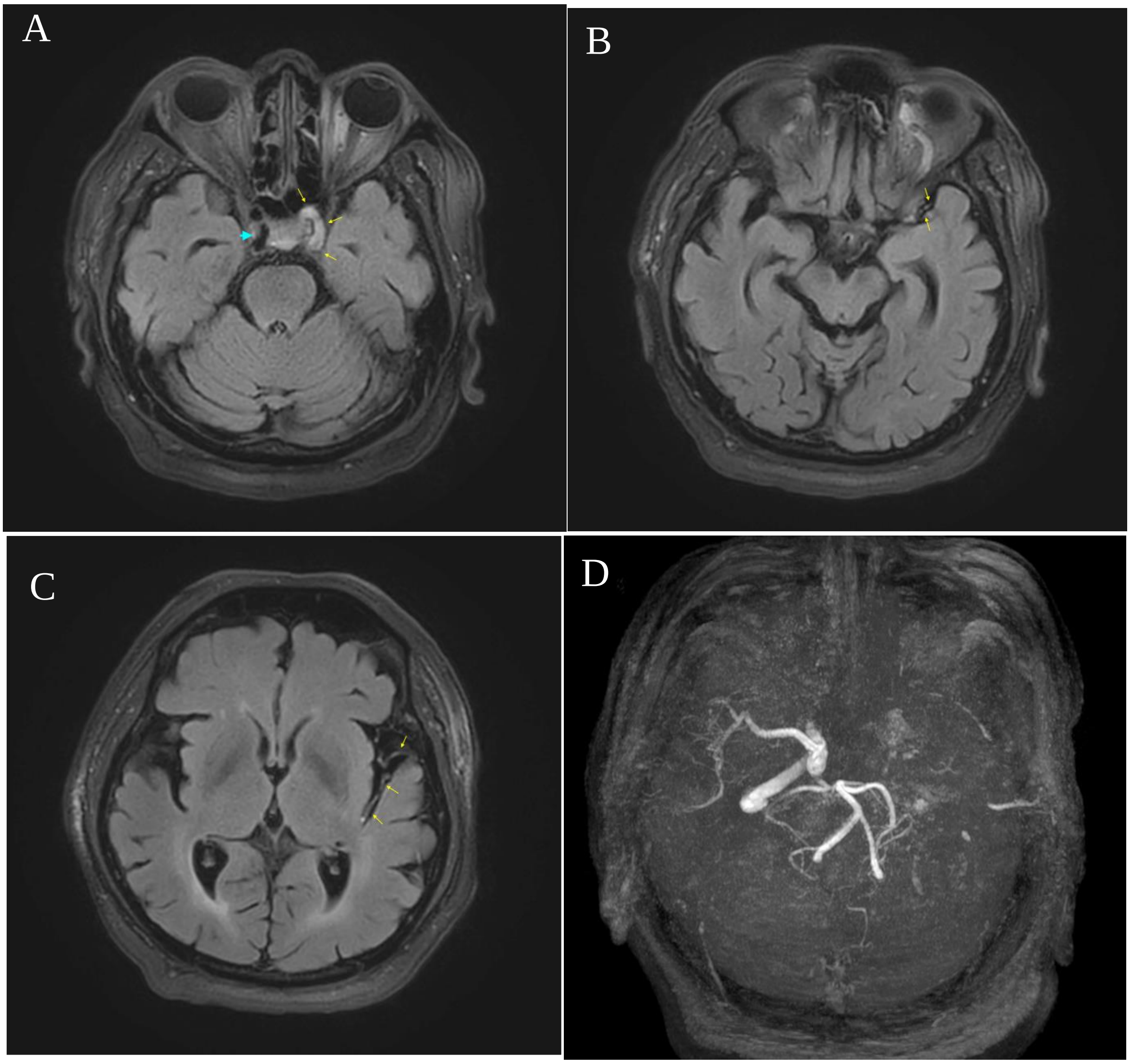

Figure 3: A 69-year-old acute stroke with LVO, shows FHVS involving Left ICA and MCA. Features of FVHS involving the intracranial segment of Left ICA (yellow arrow, A) with corresponding normal flow void Right ICA (blue arrowhead, A). The FVHS also noted within M1 (B) and M2 (C) segment of Left MCA. The MRA of the same patient showing the Left ICA and MCA LVO (D).

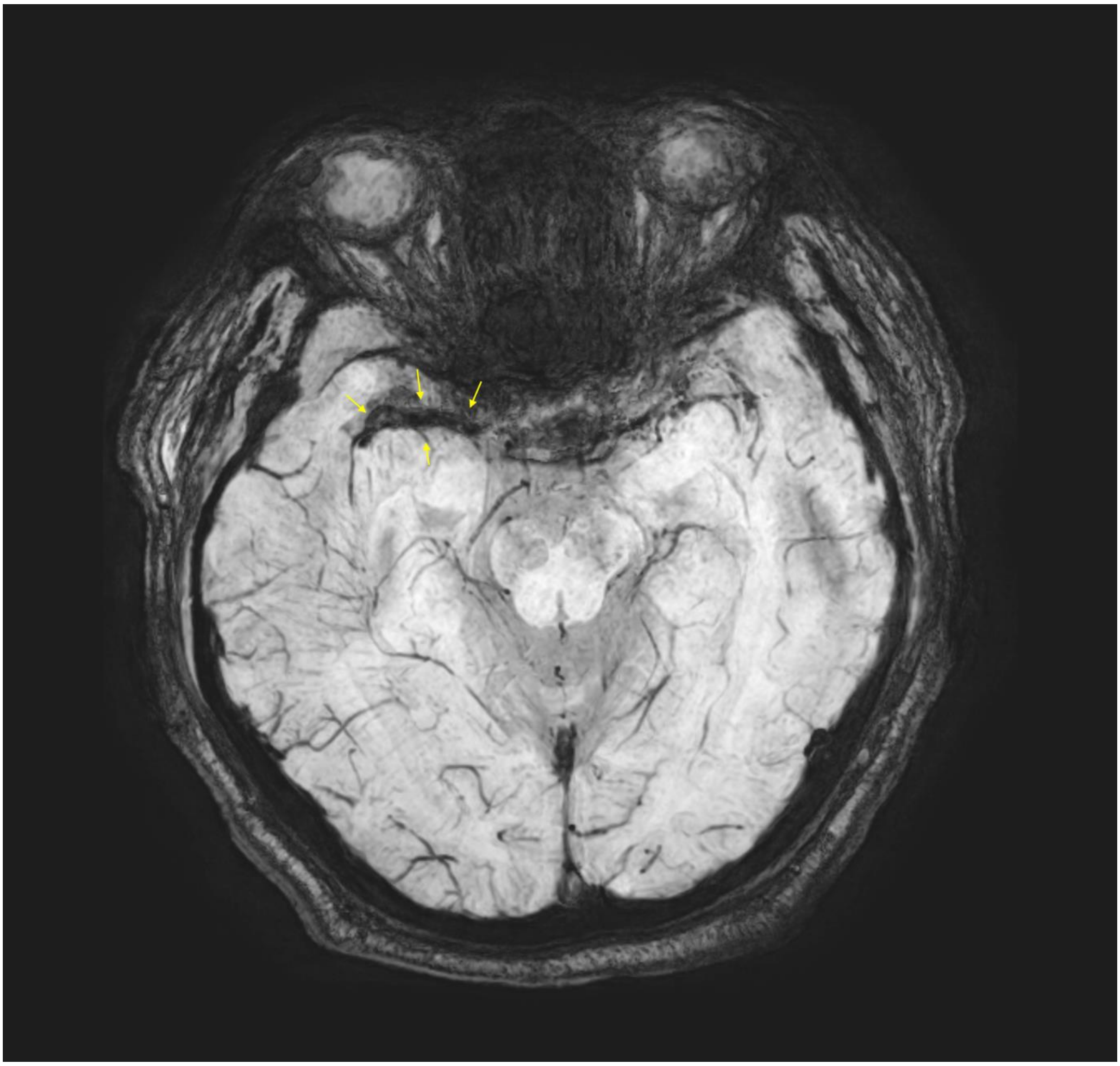

Figure 4: SWI shows blooming feature within M1 segment of Left MCA in an acute stroke patient with LVO (arrows).

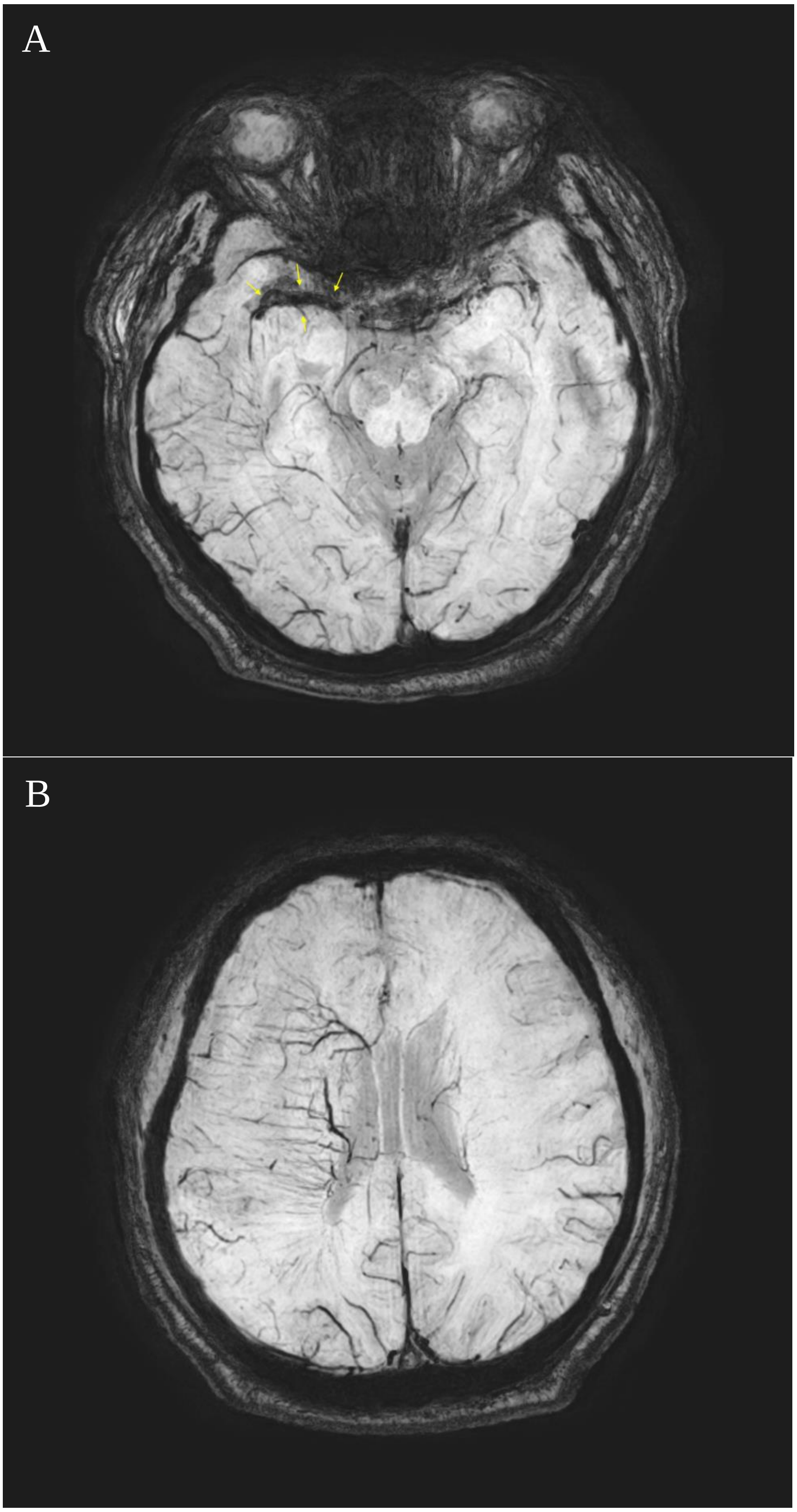

Figure 5: A 47 year-old-male acute stroke patient with LVO, shows hypointense signal M1 segment of Right has exceed the normal diameter of MCA in keeping with SVS (arrows, A). The same patient shows prominent and enlarged diameter of the right medullary and septal veins compared to the contralateral veins (B).