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Case Report

Identification of penumbra in acute ischemic stroke using multimodal MR imaging analysis: A case report study ☆,☆☆,★

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ABSTRACT

Ischemic etiology of stroke is the most common health issue. Differentiating the ischemic core from the associated penumbra is tremendously important in tailoring an effective therapeutic strategy and potential intervention. Additionally, the degree of cell damage adjacent to the ischemic core may be either reversible or irreversible, which may also affect clinical outcomes. We describe a case of a 58-year-old female, who was diagnosed with global aphasia and fluctuating right-sided hypoesthesia. Multimodal MR imaging analysis was obtained, with cerebral blood flow and mean transit time , demonstrating an infarcted core with an even larger penumbra, suggesting potentially salvageable tissue. We concluded that quantified perfusion imaging data should be used in combination with other MR protocols to determine at-risk tissues. This case substantiates the role of multimodal imaging of the penumbra as a routine part of acute stroke workup and management.

Introduction

Stroke is defined as a sudden onset of a neurologic deficit caused by an acute focal injury to the central nervous system due to a vascular cause [1]. It is the second leading cause of mortality worldwide after coronary artery disorders [2]. Ischemic strokes are the most common form, accounting for 87% of all strokes [3]. In a stroke event, the penumbra is the area surrounding the ischemic core and it is defined as perfused brain tissue at a level within the thresholds of functional impairment and morphologic integrity, which has the

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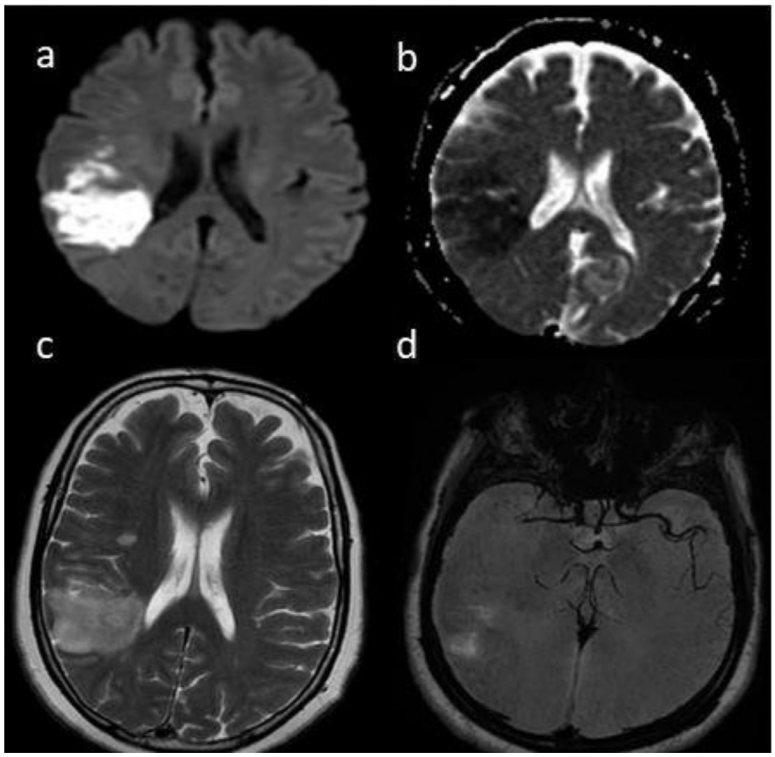

Fig. 1 – Some of the brain advanced sequences. (a) Diffusion-weighted imaging (DWI), (b) apparent diffusion coefficient (ADC) map, (c) T2 weight image, and (d) dark blood magnetic resonance angiography (MRA).

capacity to recover and be salvaged if perfusion is improved rapidly. This territory, where autoregulation is still preserved but cell survival is only permitted for a certain amount of time, surrounds the critically hypoperfused ischemic core with irreversible damage. Separating penumbra from the ischemic core is tremendously important in tailoring the therapeutic strategy and improving the clinical outcome. Eligible patients for blood flow recovery are selected, within a narrow temporal window, based on the relative size of these 2 regions. In the assessment of acute stroke syndrome, neuroimaging plays a critical role in improving clinical decisions regarding acute stroke treatment. Magnetic resonance imaging (MRI) has significantly higher sensitivity and specificity than computed tomography (CT) in the diagnosis of acute ischemic infarction in the first few hours after the onset.

This case report demonstrates how the differentiation of penumbra from the ischemic core may assist in the identification of patients who are most likely to benefit from thrombectomy or thrombolysis.

Case report

A 58-year-old female was presented to our institution with an 8-hour history of right-sided paresthesias, incomplete global aphasia, and difficulty speaking. Stroke was suspected, and the patient underwent whole-brain MRI on a 1.5 Tesla GE scanner.

Multiple sequences were obtained including T2-weighted fast spin echo (FSE), T2-weighted fluid attenuation inversion recovery (FLAIR), gradient recalled echo (GRE) T2*-weighted, GRE T1-weighted, T1-weighted FSE, diffusion-weighted imaging, apparent diffusion coefficient (DWI/ADC), dynamic susceptibility contrast perfusion-weighted imaging (DSC PWI), and dark blood magnetic resonance angiography (MRA) (Fig. 1).

DSC perfusion processing was performed using Olea Sphere (Olea Medical, La Ciotat, France) to display the relative cerebral blood volume (rCBV), cerebral blood fluid (CBF), and mean transient time (MTT) maps. Combined maps were also generated. Regions of interest (ROI) were identified and the corresponding perfusion graphs were assessed (Fig. 2).

Pathologic signal change is shown in the posterior part of the right temporoparietal junction. A significant mass effect is not detected. Sign of small intraparenchymal hemorrhages in GRE T2* and T1-weighted images are seen in this region (Fig. 3).

Increased signal intensity on the DWI sequence and decreased signal intensity in the ADC map are demonstrated within the right temporal and parietal lobes, and dark blood MRA showed a right distal of MCA (M1) occlusion (Fig. 1).

After contrast injection, gyral, and leptomeningeal type enhancement is seen in the involved regions which may be related to the disruption of the blood-brain barrier.

In perfusion images map, a decrease in relative cerebral blood volume (rCBV = 0.27) and cerebral blood flow (CBF = 3.39) is detected which is associated with an increase

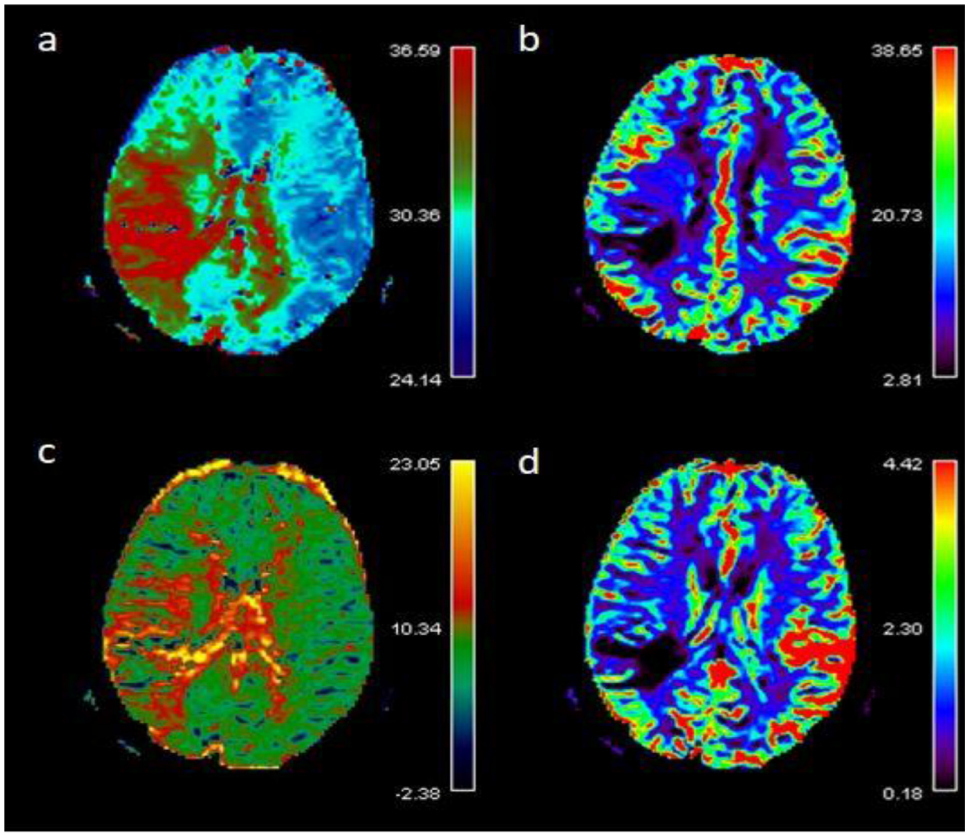

Fig. 2 – Perfusion imaging derived maps. (a) Time-to-peak (TTP), (b) relative cerebral blood volume (rCBV), (c) mean transient time (MTT), and (d) cerebral blood flow (CBF).

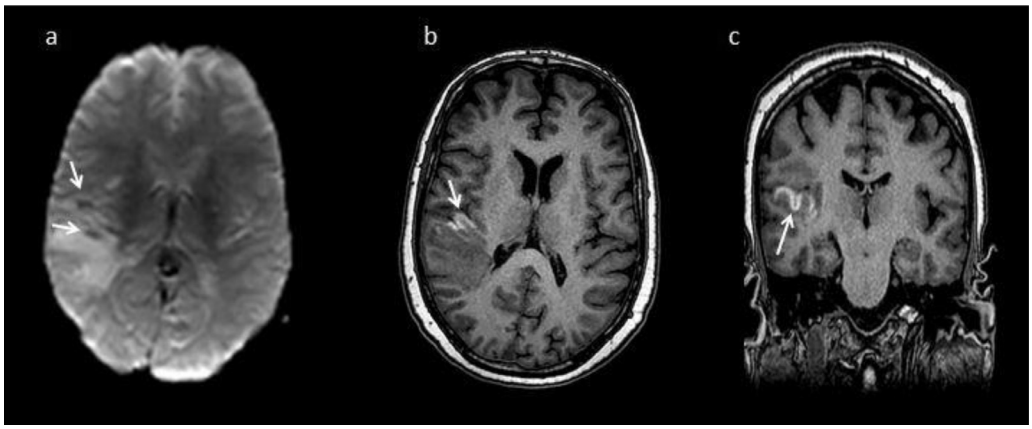

Fig. 3 – The signal changes in GRE T2* and T1-weighted image. (a) GRE T2*-weighed image, (b) axial GRE T1-weighted image, (c) coronal GRE T1-weighted image. The white arrows show small intraparenchymal hemorrhages.

in time to peak (TTP) and MTT (Fig. 4). rCBF and MTT map and combined maps including TTP/DWI map showed a large perfusion deficit (prolonged MTT). Small DWI lesion and large perfusion deficit (prolonged MTT and TTP) suggest the presence of large penumbral region which is larger than infarct core (DWI restricted area), indicating the presence of salvageable tissue. These findings are in favor of ischemic infarction (Fig. 5).

Discussion

Acute stroke causes an irreversibly damaged ischemic core and salvageable surrounding tissue. “Penumbra” is the reversibly injured brain tissue around the ischemic core which is the target for the treatment of acute stroke [4]. The earliest rescue of the penumbra is key for treating ischemic

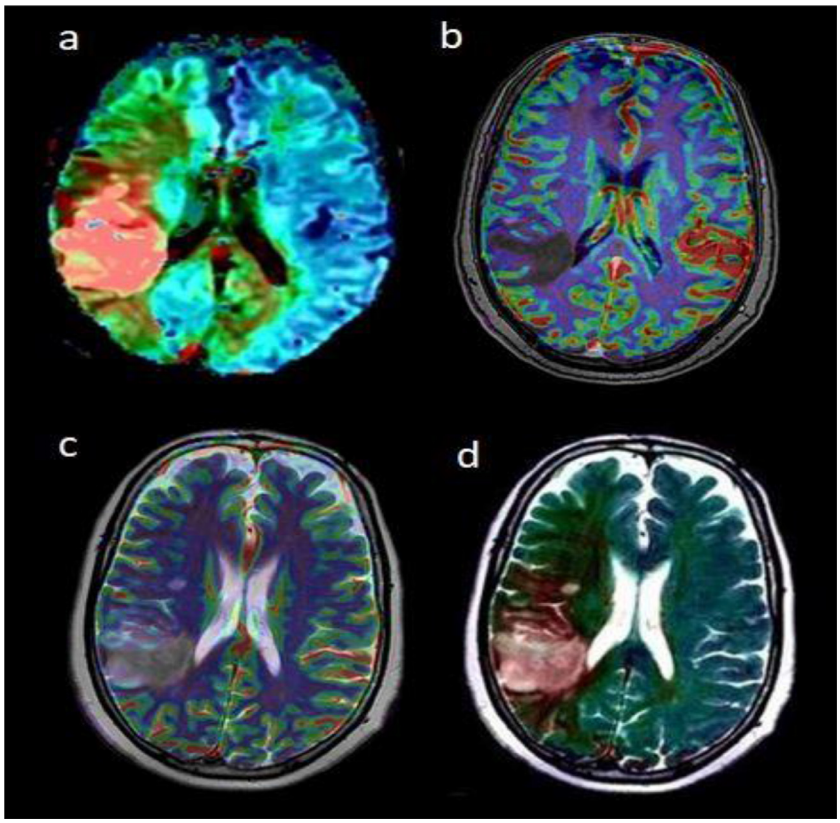

Fig. 4 – Advanced secondary maps. (a) TTP/DWI mismatch, (b) CBF/T1 mismatch, (c) rCBV/T2, (d) MTT/T2.

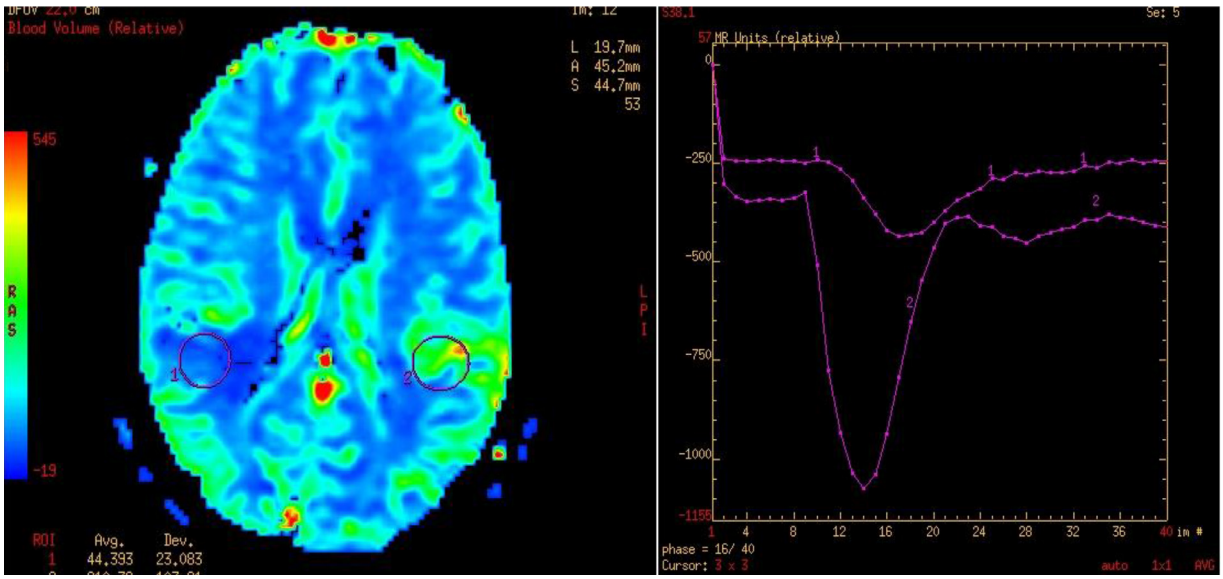

Fig. 5 – Signal intensity curve obtained from T2*DSC MR perfusion data. Yellow curve: reference ROI (normal tissue). Red curve: ROI within the lesion.

stroke. It has been shown that about half of all acute ischemic patients show penumbra on MR Images [5]. In acute ischemic stroke, the number of penumbra changes in response to regional cerebral blood flow, pathophysiological environment, and treatment protocols [6]. Penumbra can be detected using different Imaging scanners, such as MRI, PET/CT, and SPECT [7]. The emerging role of penumbral imaging in acute ischemic stroke has been a matter of controversy [8]. Despite that, there is widespread agreement on the importance of penumbra as a concept and the importance of recognizing the presence of

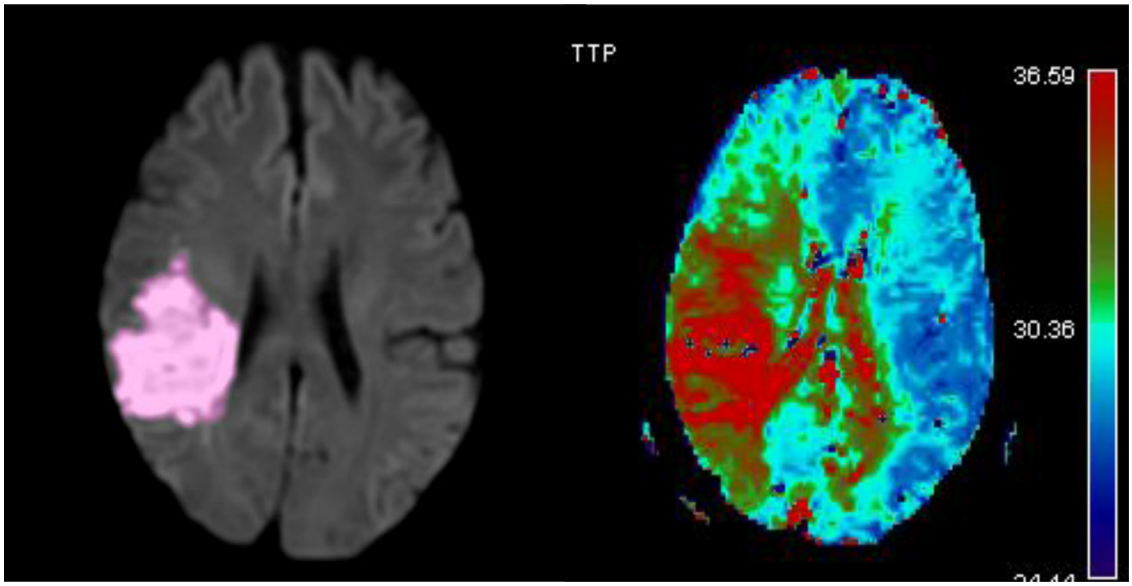

Fig. 6 – MRI perfusion-diffusion mismatch. The small lesion on diffusion-weighted imaging (DWI) represents the infarct core, while the much larger area in the time to peak map calculated from perfusion imaging (PWI) identifies the area of critically hypoperfused tissue (prolonged TTP).

a mismatch between the core infarction and the penumbra in selecting patients for the treatment of acute stroke.

In our study, we employed multimodal MRI including DWI, T2-weighted sequences (T2W)/FLAIR, PWI, and dark blood MRA. Our selected patient demonstrated imaging evidence of a salvageable penumbra that is more massive than the core infarction. There are various MR imaging modalities available for the evaluation of patients with stroke. PWI depicts areas of brain tissue with reduced cerebral blood flow that occur with the onset of an acute occlusion, whereas lesions on DWI have long been thought to represent severely injured tissue. DWI in combination with PWI has shown great promise for the identification of brain tissue in patients with acute ischemic stroke (Fig. 6) that is dysfunctional because of low blood flow but potentially salvageable on the restoration of blood flow [9]. The mismatch between DWI and PWI volumes represents the tissue at risk of an infraction and thus, the target tissue for reperfusion treatment.

Conclusion

We found that MR perfusion imaging offers the potential for measuring brain perfusion in acute stroke patient and diagnosis penumbra. In our patient, the DWI-PWI mismatch may estimate the extent of an ischemic penumbra, which has the potential to progress to tissue infarction if blood flow is not restored, and which may be saved with accurate therapeutic intervention. The proper identification of this ischemic penumbra probably depends on good quantification of the MR images rather than a qualitative assessment of Images. Consequently, it will help guide future ischemic stroke therapy and potentially aide in extending the time window for treatment. We can conclude that using quantified perfusion imaging data combined with other MR protocols in the determination of the at-risk tissues will substantiate the role of multimodal imaging of the penumbra as a routine part of acute stroke management.

Credit author statement

Forough Sodaei: data analysis/interpretation, writing draft.
Vahid Shahmaei: design of the study, data acquisition, data analysis/interpretation.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.radcr.2020.07.066.

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