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Retrospective analysis of Routine T2 weighted brain MRI for detecting cervical internal carotid artery steno-occlusive disease

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Abstract

Objective: To determine accuracy of signal alteration replacing normal flow voids in routine T2WI MRI brain for identifying cervical carotid steno-occlusive disease. *Methods:* Neuroimaging data on patients with ischemic stroke was collected, only patients with both MRI brain T2WI and CT angiography of neck vessels (CTA) were included and the information was analyzed retrospectively. Flow void signals on routine axial T2 WI were analyzed by a neuroradiologist blinded to CTA of neck vessels and compared with CTA of neck vessels as gold standard to determine accuracy of altered flow void signals in identifying carotid steno-occlusive disease. *Results:* Total of 278 patients, 34 patients with both T2WI and CTA were included. 15/34(44.1%) showed altered flow voids in cavernous ICA on axial T2WI while 19/34(55.8%) with normal flow voids were considered intra cohort controls.18/19(94.7%) showed normal patency of ICA on both T2WI and CTA of neck vessels. All 15 patients with altered flow void on T2WI showed changes on cervical CTA conferring high specificity of 100%. Homogenously altered signal corresponded to occlusion in 100% (4/4) while heterogenous signals indicated significant stenosis in 88.8 % (8/9). Further, 100 % specificity of normal flow voids on T2WI to exclude significant steno-occlusive disease in cervical ICA was noted.
Conclusions: Loss of normal flow void signal on T2WI is highly specific indicator of significant steno-occlusive carotid disease and its absence vice versa of normal vessels.

Keywords: Carotid steno-occlusive disease, CTA of neck vessels, MRI brain T2WI

INTRODUCTION

Though the incidence and mortality from stroke is steadily decreasing in developed countries the statistics remain dismal in low-middle income countries like India.[1,2] The proportion of ischemic stroke caused by large vessel steno-occlusive diseases is more in Indians (41%) compared to rest of the world (15%).[1] The localization of stenosis or occlusion is a key step in initial evaluation of etiological mechanisms of acute ischemic stroke in patients who present late for optimizing management and secondary prevention.[3] This is especially true in the Indian population where median time to arrival in casualty is estimated to be 7.6 hours.[1]

It is recommended that all patients of ischemic stroke undergo neuroimaging like magnetic resonance imaging (MRI) or computed tomography (CT) of brain to identify infarction followed by vascular imaging like CT angiography (CTA), MR angiography (MRA), transcranial Doppler or carotid Doppler ultrasound, Digital subtraction angiography (DSA).[3,4] Routine MRI Brain is not only sensitive to detect infarction on DWI but can also evaluate patency of intracranial vessels by showing presence or absence of "flow void effect" on T1 weighted images (TIWI) and T2 weighted images (T2WI).[5-7] Capability of predicting cervical carotid stenosis or occlusion by recognition of altered flow void effect in intracranial carotid arteries has been studied only in few reports and validation is still ambiguous.[8-12] Therefore, the main aim of this study is to determine the accuracy of altered signals replacing flow voids to identify significant cervical carotid steno-occlusive disease on routine MRI T2WI.

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METHODS

Patients

The informed consent was taken from patient or their relatives for the inclusion in the study. Retrospective analysis of neuroimaging data of patients presenting with anterior circulation ischemic stroke or transient ischemic attack (TIA). The ethics committee approval was taken. Only patients who underwent both, conventional MRI with T2WI in 3.0 Tesla (T) MRI scanner and CTA of neck vessels with automated reconstruction within 7 days of acute ischemic stroke were included.

Conventional MRI and CT angiography

MRI studies were obtained on a 3.0-T Philips Ingenia (Netherlands) scanner using an identical protocol in all patients. The protocols and typical parameters were as follows: Transverse T2WI (Repetition time/Echo delay time: 2500 ms / 80 ms); slice thickness / gap for Transverse T2WI (5/1 mm) with a 256×256 acquisition matrix. All studies were performed with cardiac gating without using gradient-moment nulling technique.

CTA of neck vessels was performed on Philips Ingenity (Netherlands) scanner with an identical protocol in all patients. The protocols and typical parameters were as follows: 128 slices; slice thickness/gap = 0.9 mm/0.45mm; Pitch rotation time: 0.5 sec. A 70-90 ml of non-ionic contrast (Iohexol 300 mg/100 ml) mixed with 30 ml of normal saline was injected at 4.3-4.5 ml/sec. Reconstruction and bony subtraction was done automatically with workstation software developed by Philips.

Image analysis

MR images were assessed retrospectively by a neuroradiologist independently who looked for flow void signals in bilateral internal carotid arteries (ICA) on axial T2W images while being blind to CTA. Specifically, the segments in cavernous portion of ICA perpendicular to axial plane of acquisition were scrutinized. In addition, high signal in the same artery on at least two consecutive slices in the perpendicular plane was used to define altered flow void. Evaluation of the ICAs included: (1) Assessment for normal or altered flow void (abnormal configuration of intraluminal signals on T2W MRI); (2) Differentiating various configurations of intraluminal signals when normal flow void was altered (Partial flow void, homogenous hyperintense signal, heterogenous hyperintense signals and isointense signal caliber on T2WI MRI of cervical ICA) and (3) To look for symmetry in the size of the ICAs.

CT angiography images of cervical carotids were assessed for carotid stenosis. ICAs were categorized as artery without stenosis, mild (<50%), moderate (50-69%) or severe (70-99%) stenosis and artery with occlusion. The exact degree of stenosis was measured by comparing the minimal residual lumen at the site of stenosis (A) with the diameter of the more distal ICA where walls of artery first become parallel (B) using the following formula: Stenosis = (1-A/B) × 100 %.

Accuracy of identifying significant stenosis and occlusion in carotid artery by altered flow void effect on conventional T2WI

CTA results served as the standard to determine carotid artery significant stenosis and occlusion. If alteration of flow void signal on T2WI was verified by occlusion or stenosis above 50% on CTA, it was considered to be a true positive. Otherwise, it was considered a false positive.

Finally, the specificity of non-visualised or altered flow void signal on T2WI as an indicator of significant artery stenosis and occlusion was calculated.

Abnormal configurations of Intraluminal signals and their relationship with status of carotids on CTA

We also differentiated various abnormal signals (Table 3) which replace normal hypointense intraluminal flow void effect according to schema elaborated in detail by Lane *et al*[9], and compared them with level of stenosis or occlusion in cervical ICA on CTA in an attempt to determine whether some specific configuration can predict a particular level of stenosis or occlusion of cervical ICA. Keeping CTA interpretation as the gold standard, the specificity of detecting carotid artery stenosis and occlusion by altered flow void signal or asymmetry on axial T2WI was determined (Table 2).

RESULTS

Evaluation of flow void effect on axial T2WI

Neuroimaging data of a total of 278 consecutive patients with anterior circulation ischemic stroke or TIA were reviewed out of which 34 patients (5 female and 29 male) who had both, routine MRI brain with T2WI and CTA were included in this study. Fifteen out of 34 patients showed an altered flow void appearance or asymmetry in cavernous segments of ICA on axial MR T2WI and remaining 19 showed normal flow void and were considered as intra-cohort controls. Clinical data of those with altered flow void on MR T2WI are detailed in Table 1.

Specificity of axial T2WI to predict significant carotid artery stenosis and occlusion

All intra-cohort patients (normal flow void cavernous segments of ICA on axial MR T2WI) showed normal patency of internal carotids on CTA except one patient. This one patient was a 38-year-old male with left MCA infarct; he had mild cervical ICA stenosis (30-50%) with normal distal flow in CTA and normal flow void signals on T2WI. All 15 patients with altered intensity of flow void signals on T2WI showed changes in CTA of cervical ICA. Thus, specificity of normal flow void to exclude significant stenosis or occlusion in cervical ICA turns out to be 100% (Table 2).

Correlation of abnormal configuration of intraluminal signals on MRI T2WI with status of cervical ICA on CTA (Table 3)

All 15 patients with altered intensity of flow void signals on T2WI showed changes in CTA of cervical ICA. Partial loss of flow void (Figure 1) consisting of increased intensity at the periphery of persistent central flow void was identified in six patients out of which 5 patients showed significant stenosis (3 moderate and 2 severe) and one patient showed occlusion of proximal cervical ICA just distal to its origin on CTA.

Intraluminal signal was isointense (Figure 2) with brain in one patient who showed complete occlusion of cervical ICA on CTA. This pattern was not identified in any other case of significant stenosis on CTA.

Hyperintense intraluminal signals had

Table 1: Demographic and neuroimaging details of patients with altered flow void on T2W MRI

Patient Number	Sex/Age (years)	Infarction Territory	Configuration of altered flow void on T2W MRI	Severity of stenosis of ICA in CTA (%)
1.	M/29	Right MCA	Partial Flow Void	Moderate Stenosis (50-69)
2.	M/55	Right Borderzone	Partial Flow Void	Moderate Stenosis (50-69)
3.	M/70	Right Borderzone	Heterogeneous Hyperintense (Central hyperintense with peripheral Isointense)	Severe Stenosis (70-99)
4.	M/40	Left Borderzone	Homogenous Hyperintense	Occlusion
5.	M/40	Left MCA	Reduced Caliber	Moderate Stenosis (50-69)
6.	M/55	Left MCA	Partial Flow Void	Severe Stenosis (70-99)
7.	M/30	Right MCA	Homogenous Hyperintense	Occlusion
8.	M/83	Left MCA	Partial Flow Void	Severe Stenosis (70-99)
9.	M/68	Right MCA	Homogenous Hyperintense	Occlusion
10.	M/47	Left MCA	Heterogeneous Hyperintense (Hyperintense peripherally with centre Isointense)	Severe Stenosis (70-99)
11.	M/68	Right Borderzone	Partial Flow Void	Occlusion
12.	F/28	Right MCA	Heterogeneous Hyperintense (Central hyperintense with peripheral Isointense)	Severe Stenosis (70-99)
13.	M/40	Right MCA	Isointense	Occlusion
14.	M/50	Right MCA	Reduced Caliber	Moderate Stenosis (50-69)
15.	M/62	Left MCA	Partial Flow Void	Moderate Stenosis (50-69)

T2W MRI=T2 weighted magnetic resonance imaging; ICA= Internal Carotid Artery; CTA=computed tomography angiogram; M=Male; F=Female; MCA=Middle cerebral Artery.

Table 2: The specificity of axial T2W MRI to detect significant carotid steno-occlusive disease of internal carotid artery

T2W MRI Analysis	CTA Interpretation				Specificity (%)
Total cavernous ICA signals	No stenosis	Insignificant stenosis (<50%)	Significant stenosis (≥50%)	Occlusion	
Altered Flow Void signals (n=15)	0	0	10	05	100
Normal Flow Voids (n=19)	18	01	00	00	

T2W MRI=T2 weighted Magnetic resonance imaging; CTA=Carotid tomography angiogram

variable configurations on MRI T2W images; homogenous hyperintense signal (Figure 3) was observed in three patients and all had occlusion of cervical ICA, while heterogeneous patterns of hyperintensity (Figure 4) was observed in three patients and CTA of all three patients showed severe stenosis of cervical ICA. Homogenously altered signal corresponded to occlusion in 100% (4/4) while heterogenous signals indicated significant stenosis in 88.8 % (8/9).

DISCUSSION

In the evaluation of a patient with ischemic cerebrovascular disease, assessment of patency of major intracranial vessels in addition to parenchymal abnormalities is important. Rapidly flowing blood normally gives a characteristic signal loss known as “The flow void effect” which is produced by a combination of ‘time of flight effects and turbulence.[7] This flow void effect is replaced by varying degree of increased intraluminal signals which can provide information about the lumen of cerebral arteries on traditional brain T1WI and T2WI, which are designed mainly to detect cerebral parenchymal lesions.[6,9]

On T1WI, it is relatively difficult to differentiate flow void signals of arteries from the signal of surrounding cerebrospinal fluid (CSF). It is also vulnerable to flow related enhancement which increases the signal intensities of rapidly flowing blood and CSF both, this renders T1W imaging not so useful in detecting absence of flow void signals caused by cerebral artery stenosis or occlusion.[14]

On T2WI, partial volume effect can increase signals mimicking altered flow void if imaging planes parallel to artery are used for evaluation. So, imaging planes perpendicular to the artery should be used.[10,12] To decrease the partial volume effect, petrous segment of ICA was avoided and cavernous portion, specifically the immediate subclinoid segment was evaluated to define altered flow void signal as this segment is more consistently visualized.[15]

CTA of neck vessels was used as standard for comparison with T2WI. DSA is the gold standard technique for imaging the cerebral vasculature,[3,4] however it is not widely available, and is invasive and expensive to CTA. Moreover, there are recommendations which shows that CTA is a safe and accurate technique for imaging most

Table 3: Correlation of abnormal configuration of intraluminal signals on T2W MRI with status of cervical ICA on CTA

Abnormal configuration	CTA interpretation	
	Significant stenosis	Occlusion
Partial flow void(n=6)	5	1
Homogeneous hyperintense (n=3)	0	3
Heterogeneous hyperintense (n=3)	3	0
Isointense (n=1)	0	1
Reduced caliber (n=2)	2	0

T2W MRI=T2 weighted Magnetic resonance imaging; ICA= Internal 1arotid artery; CTA=Computed tomography angiogram

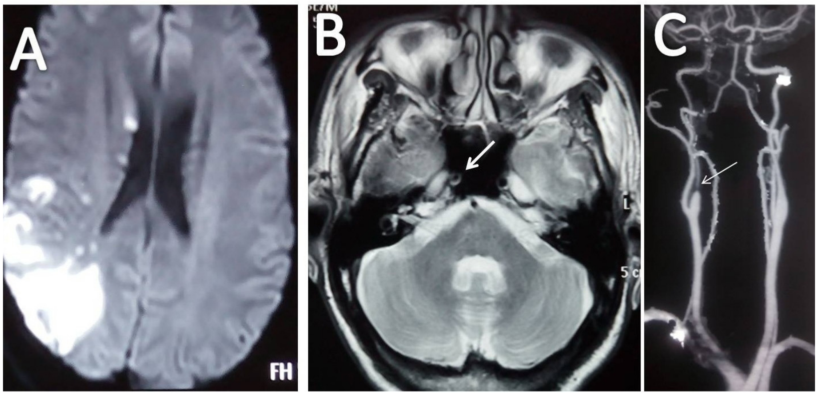

Figure 1. Partial flow void. Diffusion weighted-MRI (A) shows acute infarct in right middle cerebral artery territory; T2 Weighted-MRI (B) shows partial flow void signal in right ICA (arrow) and CT Angiography of neck vessels shows severe stenosis of the cervical portion of right ICA (arrow).

extracranial and intracranial vessels for stenosis and occlusion and its accuracy approaches that of DSA.[3,4] Also, to minimize risk of contrast induced nephropathy, only non-ionic contrast material was used in this study after confirming normal renal function test in each patient. The practical utility of T2WI MRI flow voids is that we can predict stenosis on vascular imaging in advance.

In comparison with any specific vascular imaging, the major disadvantage of T2WI in predicting carotid artery stenosis and occlusion is its low sensitivity, especially given the thick slices routinely employed at most centres.[12] We detected carotid artery stenosis or occlusion was by altered flow voids on T2WI in 44.1% (15 of 34). In a Chinese study 18.2% has carotid artery stenosis or occlusion was by altered flow voids on T2WI[12], which might be due to usage of thinner slices (5mm in present study vs. 6 mm used in Chinese study). Our study demonstrated high specificity (100%) of axial T2WI in detecting significant steno-occlusive disease of internal carotid arteries by identifying altered intraluminal flow void signals or reduced caliber of artery.

Lane *et al*. correlated abnormal configuration of flow voids with the status of cervical ICA and concluded that the isointense intraluminal signal was specific for carotid occlusion while a partial flow void though not specific was a reliable indicator of proximal severe stenosis.[9] Variable hyperintense intraluminal signals were also not specific and could be seen with occlusion or severe stenosis or both.[9] Our study also showed similar results, we have further simplified the interpretation, homogenous signal change (isointense or hyperintense) specifies occlusion, while, heterogeneous signal change (partial flow void and variable hyperintense signal) reliably

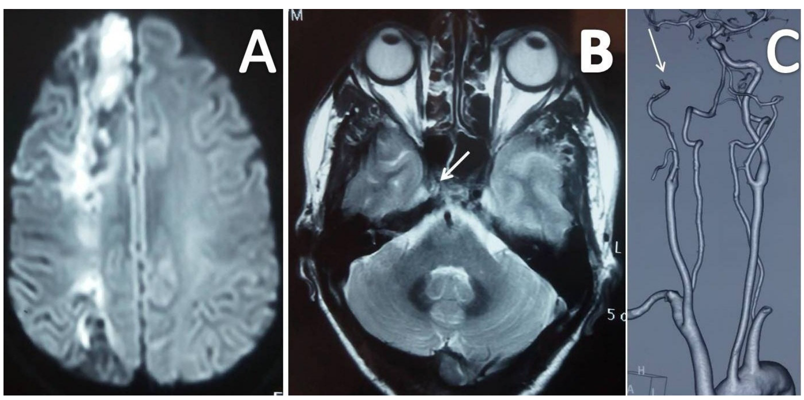

Figure 2. Isointense intraluminal signal. Diffusion weighted-MRI (A) shows acute border zone infarct between right middle cerebral and anterior cerebral artery territory. T2 Weighted-MRI (B) shows isointense intraluminal signal in right RICA (arrow) and CT Angiography of neck vessels (C) shows complete occlusion of cervical right ICA just near to its origin (arrow).

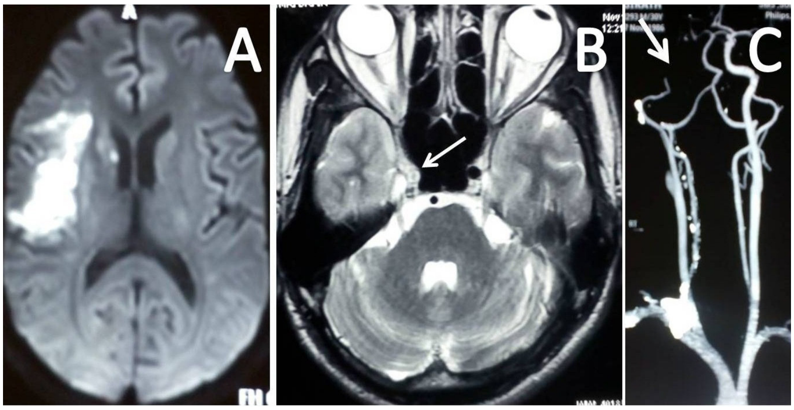

Figure 3. Homogenous Hyperintense intraluminal signal. Diffusion weighted-MRI (A) shows acute infarct in right middle cerebral artery territory. T2 Weighted-MRI (B) shows Homogenous hyperintense intraluminal signal in right ICA (arrow). CT Angiography of neck vessels (C) shows complete occlusion of right cervical ICA at the origin (arrow).

indicate significant stenosis of cervical ICA.

The results of our attempt to detect significant stenosis or occlusion on basis of configuration of abnormal flow void signals seems to be reassuring as homogenous signal changes either in form of isointensity or hyperintensity allied with complete occlusion of cervical ICA in all four cases while heterogeneous signal changes in form of partial flow void (increased signal peripherally with hypointense center) and heterogeneous hyperintensity (hyperintensity mixed with isointensity) correlated well with significant stenosis in 8 out of nine patients.

Our study showed 100 % specificity of normal flow voids on T2WI to exclude significant stenosis or occlusion in cervical ICA. Only one patient who had normal flow void on MRI T2 WI showed insignificant carotid stenosis (<50%) on CTA. This is in contrast to earlier studies[9], which concluded that normal flow void does not exclude significant extracranial carotid abnormality. This could be attributable to the difference in inclusion criteria, which involved only abnormal angiogram or abnormal flow void on MRI, difference in sample size and use of low-resolution MRI scanners.

The limitation of our study is relatively small sample size. Another limitation of the study is that MRI T2W images, planes perpendicular to artery cannot be assessed. Another weakness of using T2 flow voids is that only one location within the carotid artery is evaluated. Other parts of the intracranial vasculature are not evaluated using this methodology.

In conclusion, we surmise that alteration in flow

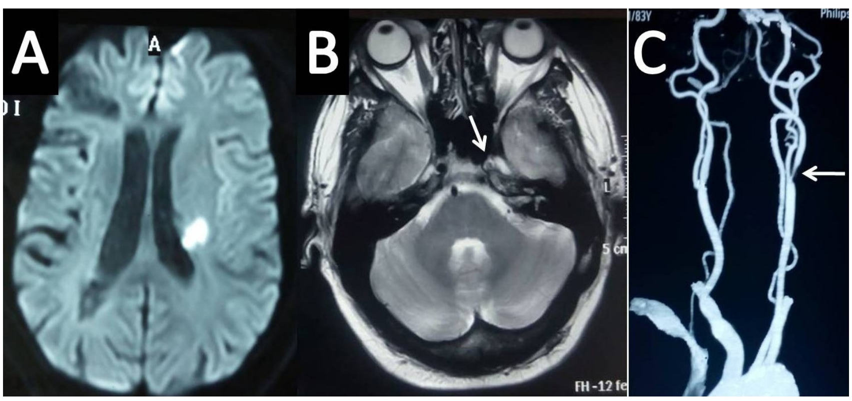

Figure 4. Heterogeneous hyperintense intraluminal signal. Diffusion Weighted- MRI (A) shows acute infarct in Left Periventricular region. T2 Weighted-MRI (B) shows Heterogeneous Hyperintense (hyperintense rim with Isointense centre) intraluminal signal in left ICA (arrow). CT Angiography of neck vessels (C) shows severe stenosis at origin of the cervical portion of left ICA (arrow).

void signals of cerebral arteries on axial brain T2W MRI is a specific indicator of significant stenosis or occlusion in cervical ICA. Employing routine T2WI sequences of MRI Brain one can exclude significant steno-occlusive disease of extracranial carotid arteries.

DISCLOSURE

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Conflicts of interest: None

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