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Research Article

COMPARISON OF POST-CONTRAST T1 SPACE, MPRAGE, TI TSE FS, AND T1 FLAIR FOR VESSEL WALL ENHANCEMENT IN CEREBROVASCULAR DISEASES.

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Abstract: ***Introduction*** Cerebrovascular diseases are major causes of morbidity and mortality worldwide. Conventional lumen-based imaging techniques such as CT angiography, MR angiography, and digital subtraction angiography often fail to detect early vessel wall pathology. Vessel Wall MRI (VW-MRI) provides direct visualization of intracranial arterial walls and has emerged as a valuable tool in the assessment of cerebrovascular diseases.**Aim :-**To compare post-contrast MRI vessel wall imaging sequences—T1 SPACE, MPRAGE, T1 TSE FS, and T1 FLAIR—for detection of vessel wall enhancement and to determine the most effective sequence in cerebrovascular diseases.**Materials and Methods :-**This prospective study was conducted in the Department of Radio-diagnosis and Imaging, Sher-i-Kashmir Institute of Medical Sciences, Srinagar. A total of 63 patients with suspected cerebrovascular disease were evaluated, of whom 10 patients with confirmed vessel wall enhancement and 10 control subjects were included. All patients underwent MRI on a 1.5T scanner using routine sequences followed by dedicated vessel wall imaging sequences: T1 SPACE, MPRAGE, T1 TSE FS, and T1 FLAIR after gadolinium administration.**Results :-**T1 SPACE demonstrated the highest diagnostic performance with a sensitivity of 90%, specificity of 100%, PPV of 100%, and NPV of 90.9%. T1 TSE FS showed good performance with 80% sensitivity and 100% specificity. MPRAGE and T1 FLAIR showed no diagnostic utility for vessel wall enhancement detection in this study. Image quality analysis revealed that MPRAGE had the highest image quality, followed by T1 SPACE. However, T1 SPACE showed the best overall diagnostic accuracy.**Conclusion :-**High-resolution vessel wall MRI is a valuable non-invasive imaging modality for evaluating intracranial vascular pathology. Among the evaluated sequences, T1 SPACE is the most sensitive and reliable for detecting vessel wall enhancement, followed by T1 TSE FS. These findings support the inclusion of dedicated vessel wall imaging in routine evaluation of cerebrovascular diseases for improved diagnostic accuracy and clinical decision-making.

Keywords: T1 FLAIR Vessel wall imaging Cerebrovascular diseases Contrast material Image quality

INTRODUCTION

Cerebrovascular diseases are among the leading causes of mortality and long-term disability worldwide. These disorders affect the blood vessels supplying the brain and commonly manifest as stroke due to arterial narrowing, occlusion, or rupture. The underlying pathology of many cerebrovascular diseases originates within the vessel wall, making early diagnosis difficult with conventional lumen-based imaging techniques such as CT angiography (CTA), MR angiography (MRA), and digital subtraction angiography (DSA). These traditional methods primarily visualize luminal abnormalities and may fail to detect early intracranial vascular pathology because intracranial arteries are small and possess thin vessel walls.

Magnetic Resonance Imaging (MRI) is a noninvasive imaging modality that provides excellent soft tissue contrast, high spatial resolution, and multiplanar imaging capabilities without ionizing radiation. The introduction of gadolinium-based contrast agents (GBCAs) has significantly improved MRI sensitivity by enhancing differentiation between normal and pathological tissues. MRI contrast agents are mainly classified into T1 and T2 agents, with T1-positive agents commonly preferred

because they produce more easily detectable enhancement patterns.

Vessel Wall MRI (VW-MRI) has emerged as an advanced imaging technique capable of directly visualizing intracranial arterial walls and assessing vessel wall pathology. Unlike conventional lumen-based imaging, VW-MRI allows detailed evaluation of wall thickening, plaque morphology, inflammatory changes, and contrast enhancement patterns. This technique has shown considerable clinical value in the diagnosis and differentiation of intracranial vasculopathies, including atherosclerosis, vasculitis, reversible cerebral vasoconstriction syndrome (RCVS), and intracranial aneurysms. VW-MRI is also useful in identifying causes of cryptogenic stroke and assessing aneurysm instability and rupture risk.

High-resolution VW-MRI requires specialized acquisition techniques, including black-blood imaging, cerebrospinal fluid suppression, isotropic 3D imaging, and high spatial resolution sequences. Commonly used sequences include T1-weighted, T2-weighted, proton density-weighted, and time-of-flight MR angiography sequences. Advanced black-blood techniques such as VISTA, SPACE, and CUBE improve visualization of intracranial vessel walls while minimizing flow-related artifacts.

Overall, VW-MRI represents a significant advancement in cerebrovascular imaging by providing direct assessment of intracranial vessel wall pathology. Its growing clinical utility improves diagnostic accuracy, risk stratification, and therapeutic decision-making in patients with cerebrovascular diseases.

Review of Literature – Summary :-

Several studies have demonstrated the growing importance of high-resolution Vessel Wall MRI (VW-MRI) in the evaluation of intracranial vascular diseases.

van der Kolk et al. (2011) developed a 3D turbo spin-echo sequence for intracranial vessel wall imaging at 7T MRI. Their study showed that intracranial vessel walls and pathological lesions could be visualized clearly with good contrast between vessel wall, blood, and cerebrospinal fluid. Many lesions identified did not produce luminal stenosis, highlighting the advantage of VW-MRI over conventional lumen-based imaging.

Nagahata et al. (2014) evaluated aneurysmal wall enhancement using 3D turbo spin-echo vessel wall imaging. Strong wall enhancement was observed predominantly in ruptured aneurysms, suggesting that aneurysmal wall enhancement may serve as an indicator of rupture risk and help in the management of subarachnoid hemorrhage patients.

Basha et al. (2015) investigated the role of multicontrast VW-MRI in differentiating intracranial vasculopathies such as intracranial atherosclerotic disease (ICAD), vasculitis, and reversible cerebral vasoconstriction syndrome (RCVS). Their findings demonstrated that ICAD lesions commonly showed eccentric wall thickening and T2 hyperintensity, whereas vasculitis and RCVS displayed different enhancement patterns. Combining T1- and T2-weighted imaging significantly improved diagnostic sensitivity.

Zhang et al. (2015) studied high-resolution 3D T1-weighted SPACE imaging at 3T MRI. Their work demonstrated that the technique provided excellent contrast between the vessel wall and cerebrospinal fluid with high spatial resolution and acceptable scan time. Importantly, several plaques detected on VW-MRI were not visible on conventional MR angiography, emphasizing the sensitivity of vessel wall imaging.

Xie et al. (2015) introduced the DANTE-SPACE technique to improve blood suppression during simultaneous carotid and intracranial vessel wall imaging. Compared with conventional SPACE imaging, DANTE-SPACE provided superior wall-to-blood contrast and reduced residual blood signal artifacts, enabling better visualization of vessel wall pathology and plaque components.

Larsen et al. (2018) correlated aneurysm wall enhancement on VW-MRI with histopathological findings. Strong wall enhancement was associated with inflammatory cell infiltration, neovascularization, and the presence of vasa vasorum, supporting the hypothesis that wall enhancement reflects aneurysm instability and increased rupture risk.

Tian et al. (2018) evaluated longitudinal changes in aneurysm wall enhancement using 3D T1-weighted SPACE imaging. Post-contrast images improved wall visibility significantly, and larger aneurysms demonstrated greater enhancement. The study concluded that VW-MRI can be used effectively for follow-up assessment of aneurysm wall changes over time.

Eiden et al. (2019) compared 2D and whole-brain 3D vessel wall imaging in patients with suspected cerebral vasculitis. The study showed that 3D VW-MRI provided better visualization of intracranial arterial segments, improved whole-brain coverage, and better depiction of parenchymal and leptomeningeal enhancement, making it more favorable for vasculitis assessment.

Zwarzany et al. (2021) studied small unruptured intracranial aneurysms using high-resolution VW-MRI. Aneurysm wall enhancement was associated with larger aneurysm size, irregular morphology, higher PHASES scores, and established risk factors for aneurysm rupture. The study concluded that aneurysm wall enhancement correlates with conventional predictors of aneurysm instability.

Overall, the reviewed literature demonstrates that VW-MRI is a valuable noninvasive imaging modality for detecting intracranial vessel wall pathology, differentiating cerebrovascular diseases, evaluating aneurysm instability, and improving risk stratification beyond conventional lumen-based imaging techniques.

AIMS AND OBJECTIVES:-

.To compare post-contrast T1 SPACE, MPRAGE,T1 TSE FS AND T1 FLAIR for vessel wall enhancement in cerebrovascular diseases.

.To identify which sequence is best for vessel wall enhancement in cerebrovascular diseases

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MATERIALS AND METHODS

Study Design

This prospective study was conducted in the Department of Radio-diagnosis and Imaging at Sher-i-Kashmir Institute of Medical Sciences to evaluate vessel wall enhancement in patients with suspected cerebrovascular diseases using MRI vessel wall imaging techniques.

Study Population

A total of 63 patients with suspected cerebrovascular diseases and possible vessel wall enhancement on MRI were included. Written informed consent was obtained from all participants. Both symptomatic and asymptomatic patients were enrolled. Kidney function tests (KFT) were performed before contrast administration.

Patients diagnosed with positive vessel wall enhancement after multidisciplinary image review were included in the study group. An equal number of control subjects underwent the same vessel wall imaging protocol. The control group consisted of patients undergoing contrast-enhanced MRI brain studies for non-cerebrovascular conditions such as metastasis, meningioma, meningitis, multiple myeloma, and encephalitis, with a low likelihood of vessel wall enhancement.

Inclusion Criteria

The study included patients with:
Stroke
Transient ischemic attack (TIA)
Intracranial aneurysm
Suspected reversible cerebral vasoconstriction syndrome (RCVS)
Suspected central nervous system (CNS) vasculitis

Exclusion Criteria

Patients were excluded if they had:
Ferromagnetic cardiac pacemakers
Aneurysmal clips in situ
First-trimester pregnancy
Surgical clips or magnetic foreign bodies
Cochlear implants
Claustrophobia

MRI Protocol

All MRI examinations were performed using a 1.5 Tesla MRI scanner (Magnetom Avanto, Siemens, Erlangen, Germany). Routine MRI sequences included:
Axial T1-weighted imaging
Axial T2-weighted imaging
FLAIR imaging
Diffusion-weighted imaging (DWI)
Susceptibility-weighted imaging (SWI)
Post-contrast imaging

Dedicated vessel wall imaging sequences included:
Post-contrast T1 SPACE
MPRAGE
T1 TSE Fat Suppression (FS)
T1 FLAIR

Imaging Parameters :-

T1 SPACE
Slice thickness: 1 mm
44 slices per slab
TR/TE: 700/19 ms
Field of view (FOV): 260 mm
Post-contrast imaging performed after gadolinium administration (0.2 mmol/kg)

MPRAGE Imaging Protocol :-

The MPRAGE sequence was acquired with 175 slices per slab and a slice thickness of 1 mm. The field of view (FOV) read was 256 mm with an FOV phase of 75%. Imaging parameters included a repetition time (TR) of 2200 ms and an echo time (TE) of 3.0 ms, with a base resolution of 256, phase resolution of 100%, and slice resolution of 80%. Post-contrast MPRAGE images were obtained using the same imaging parameters following gadolinium administration.

T1 TSE Fat-Suppressed (T1 TSE FS) Imaging Protocol :-

The T1 TSE FS sequence consisted of 19 slices with a slice thickness of 5 mm. The FOV read was 230 mm with an FOV phase of 90%. Imaging parameters included a TR of 692 ms and a TE of 10 ms, with a base resolution of 320 and phase resolution of 70%. Post-contrast T1 TSE FS images were acquired using identical parameters.

T1 FLAIR Imaging Protocol :-

The T1 FLAIR sequence included 19 slices with a slice thickness of 0.5 mm. The FOV read was 230 mm with an FOV phase of 87.5%. Imaging parameters included a TR of 500 ms and a TE of 11 ms, with a base resolution of 256 and phase resolution of 100%. Post-contrast T1 FLAIR images were obtained using the same acquisition parameters.

Slice thickness: 1 mm
175 slices per slab
TR/TE: 2200/3.0 ms
FOV: 256 mm

Post-contrast imaging acquired using identical parameters

T1 TSE FS :-
Slice thickness: 5 mm
19 slices
TR/TE: 692/10 ms
FOV: 230 mm

Post-contrast images obtained with the same settings
T1 FLAIR :-
Slice thickness: 0.5 mm
19 slices
TR/TE: 500/11 ms
FOV: 230 mm
Post-contrast imaging acquired similarly

Results

In our study, a total of 63 patients were enrolled who had a possibility of vessel wall elevation on MRI and were believed to have cerebrovascular disorders. Ten patients had their vessel wall enhancement determined to be positive following a multidisciplinary assessment of the images, and an equal number of controls were obtained and put through the same vessel wall imaging protocol as the study group.

Table.1. Distribution of study participants according to gender.

Gender	**No of patients(n=20)**	**Percentage**
Male	12	60.0%
Female	8	40.0%

In the present study, table 1 and chart 1.1 depicts that the male and female ratio that is 60% were male and 40% female included in this study.

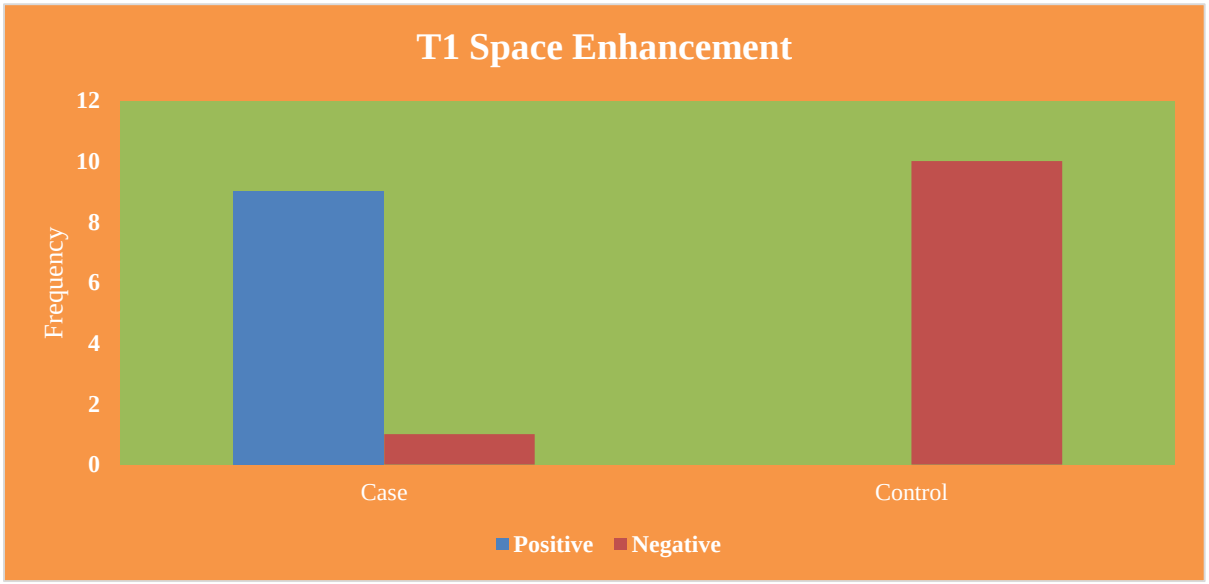
Table.2. Distribution of study participants according to age.

Age	**No of patients(n=20)**	**Percentage**
≤50	6	30.0%
>50	14	70.0%
Mean ± SD	55.05±12.18	

According to table 2 and chart 2.1 shows the distribution of age with 70% more than 50 years and remaining 30% under the category of equal and less than 50 years.

Table.3. Distribution of study participants according to T1 space enhancement :-

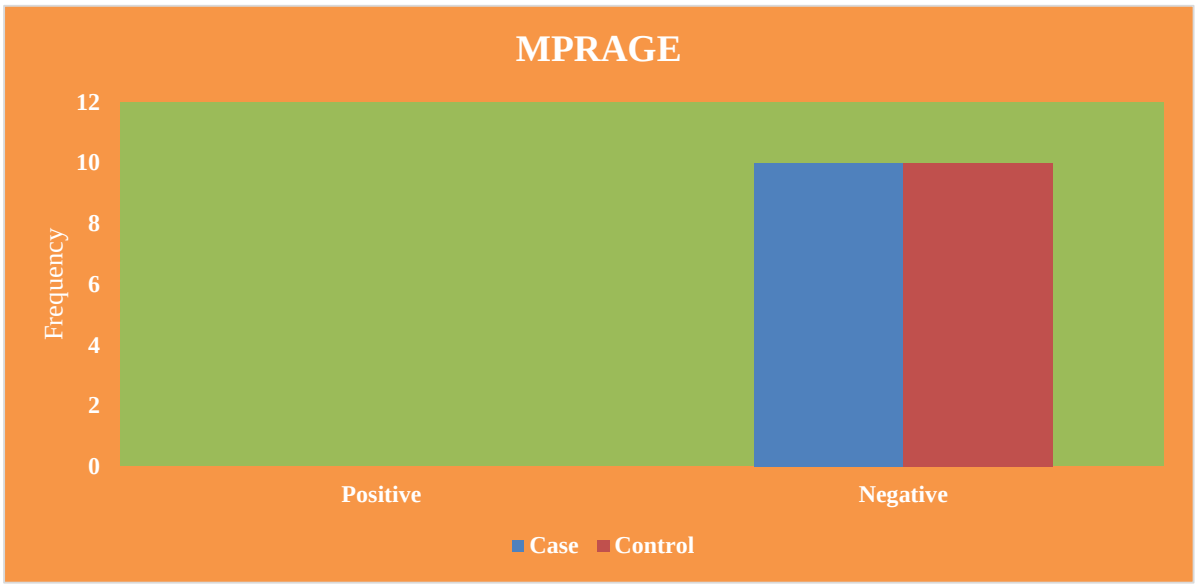
T1 Space Enhancement	**Positive**	**Negative**	**χ^2-value**	**p-value**
Case	9(90.0%)	1(10.0%)	12.93	0.0003**
Control	0(0.0%)	10(100.0%)		



In this present study, table 3 and figure 3.1 shows the distribution of participants according to T1 space enhancement. In the experimental group 90% had positive enhancement and 10% were negative. In normal study population, 100% were negative results of enhancement. Chi-square test was applied and the result was significant at 0.01 level of significance.

Table.4. Distribution of study participants according to MPRAGE enhancement :-

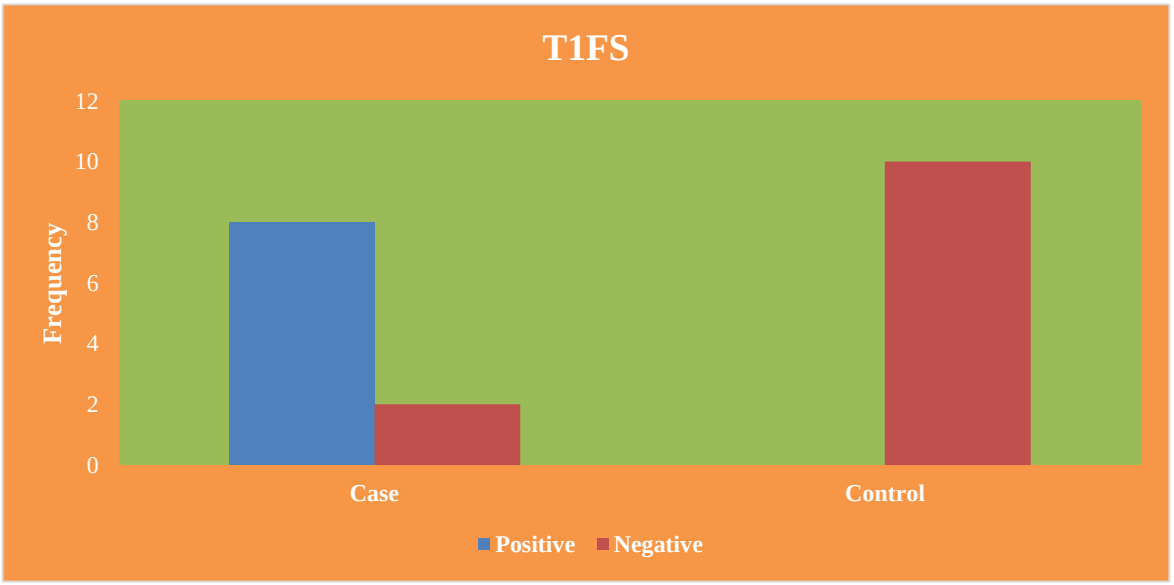
MPRAGE	Positive	Negative	χ^2-value	p-value
Case	0(0.0%)	10(100.0%)		
Control	0(0.0%)	10(100.0%)		



According to table 4 and figure 4.1 shows the distribution of participants according to MPRAGE. In the experimental group as well as in control group, all had 100% negative results of MPRAGE. Due to constant results Chi-square test and p-value was not estimated.

Table.5. Distribution of study participants according to T1FS enhancement :-

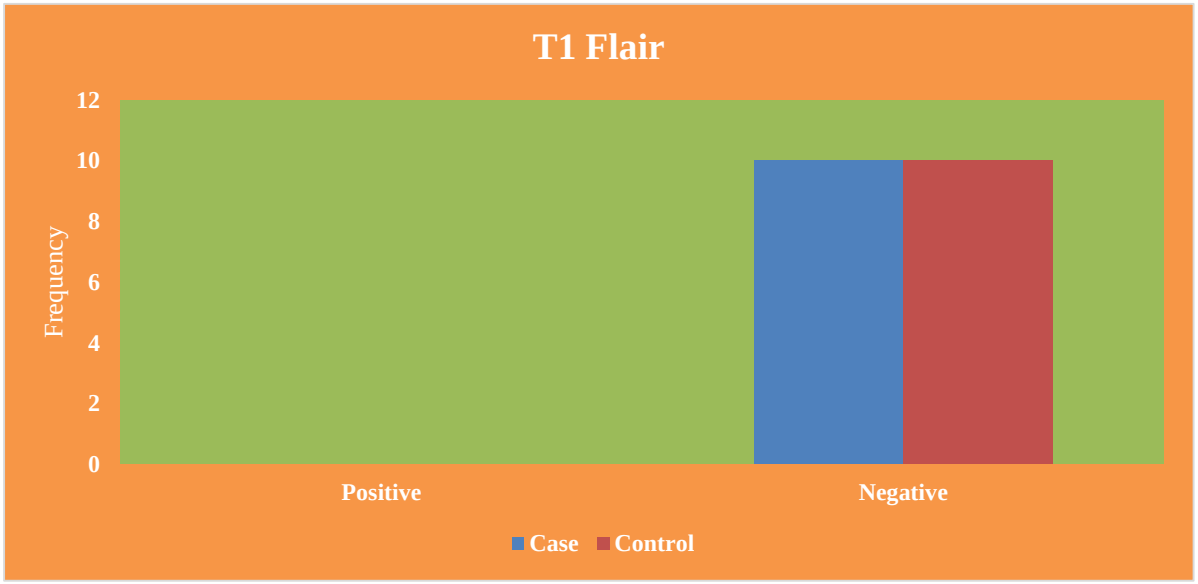
T1FS	Positive	Negative	χ^2-value	p-value
Case	8(80.0%)	2(20.0%)	10.21	0.001**
Control	0(0.0%)	10(100.0%)		



In our present study, table 5 and figure 5.1 shows the association between cases and control among T1FS enhancement and it was found that 80% cases had positive T1FS with 20% were having negative findings. In normal cases 100% are negative findings. Chi square test was applied and the results was significant at 0.01 level of significance.

Table.6. Distribution of study participants according to T1 flair enhancement :-

T1 Flair	**Positive**	**Negative**	**χ^2-value**	**p-value**
Case	0(0.0%)	10(100.0%)	-	-
Control	0(0.0%)	10(100.0%)		



According to table 6 and figure 6.1, it depicts the association of cases and control with T1 flair enhancement. The finding was found as in both the cases had 100% negative results. Due to constant results Chi-square test and p-value was not estimated.

TABLE 8:SHOWING ENHANCEMENT IN T1 SPACE AMD T1 TSE FS							
		B	S.E.	Wald	Df	Sig.	Exp(B)
Step 1[a]	T1SPACE	3.555	1.320	7.253	1	.007	35.000
	T1FS	-2.303	1.049	4.820	1	.028	.100

Odds ratio was not calculated for MPRAGE and T1 flair because al results were in single category i.e. all had not satisfactory results. For T1FS, the T1 Space enhancement was 35 times more accurate and result excellent then T1FS.

Pairwise comparison for experimental group :-

Group	**Group**	**z-value**	**p-value**
T1 Space Enhancement	MPRAGE	3.94	0.001**
T1 Space Enhancement	T1FS	2.37	0.018*
T1 Space Enhancement	T1 Flair	3.94	0.001**

In this study, pair wise comparison by T1 Space versus MPRAGE, the results was significant more than T1 Space versus T1FS. T1 Space versus T1 flair shows the significant difference it mean T1 space enhancement was more stable than others.

TABLE 10:Sensitivity, specificity, positive predictive value and negative predictive value of T1 SPACE.					
			Group		Total
			Case	Control	
T1Space	Positive	Count	9	0	9
		% within T1Space	100.0%	0.0%	100.0%

		% within Group	90.0%	0.0%	45.0%
	Negative	Count	1	10	11
		% within T1Space	9.1%	90.9%	100.0%
		% within Group	10.0%	100.0%	55.0%
Total		Count	10	10	20
		% within T1Space	50.0%	50.0%	100.0%
		% within Group	100.0%	100.0%	100.0%

Sensitivity was 90% PPV 100% and Specificity was 100% and NPV 90.9%

TABLE 11:Sensitivity, specificity, positive predictive value, negative predictive value of T1 MPRAGE.

			Group		Total
			Case	Control	
MPARAGE	Negative	Count	10	10	20
		% within MPARAGE	50.0%	50.0%	100.0%
		% within Group	100.0%	100.0%	100.0%
Total		Count	10	10	20
		% within MPARAGE	50.0%	50.0%	100.0%
		% within Group	100.0%	100.0%	100.0%

Sensitivity and PPV was 0 and Specificity was 100% with NPV 50%

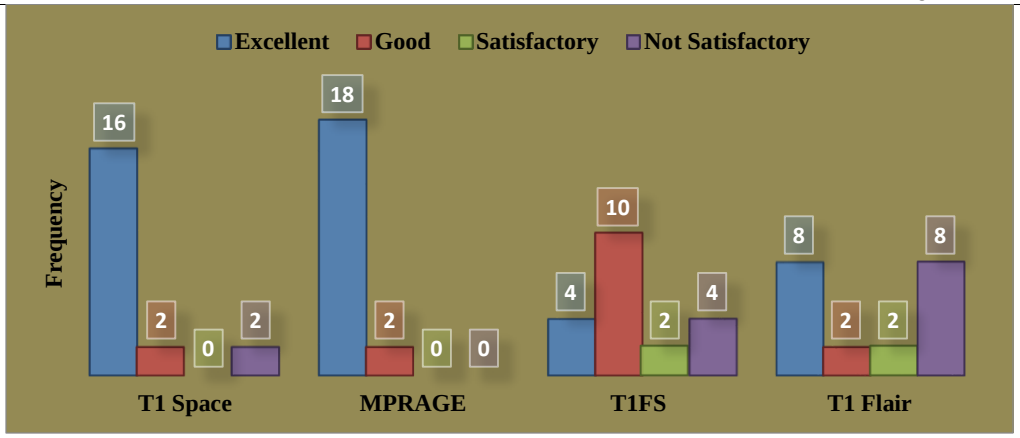
Table 12:Sensitivity, specificity. positive predictive value and negative predictive value of T1 TSE FS.

			Group		Total
			Case	Control	
T1FS	Positive	Count	8	0	8
		% within T1FS	100.0%	0.0%	100.0%
		% within Group	80.0%	0.0%	40.0%
	Negative	Count	2	10	12
		% within T1FS	16.7%	83.3%	100.0%
		% within Group	20.0%	100.0%	60.0%
Total		Count	10	10	20
		% within T1FS	50.0%	50.0%	100.0%
		% within Group	100.0%	100.0%	100.0%

Sensitivity was 80% with PPV 100% and Specificity was 100% with 83.3% NPV.
Sensitivity and PPV was 0 and Specificity was 100% with NPV 50%

Table.9. Distribution of image quality according to enhancement.

Enhancement	Image Quality				χ^2-value	p-value
	Excellent	Good	Satisfactory	Not Satisfactory		
T1 Space	16(80.0%)	2(10.0%)	0(0.0%)	0(0.0%)	33.46	0.001*
MPRAGE	18(90.0%)	2(10.0%)	0(0.0%)	2(10.0%)		
T1FS	4(20.0%)	10(50.0%)	2(10.0%)	4(20.0%)		
T1 Flair	8(40.0%)	2(10.0%)	2(10.0%)	8(40.0%)		



In this present study, table 9 depicts the image quality based on enhancement. It was observed that 90% image quality appear in MPARAGE with excellent results followed by T1 space and T1 Flair and the least excellency in T1FS with 20%. Chi-square test was applied and the results was significant at 0.01 level of significance.

Overall, the study utilized routine and dedicated high-resolution vessel wall MRI sequences to assess intracranial vessel wall enhancement in cerebrovascular diseases.

DISCUSSION

This prospective study conducted at the Department of Radio-diagnosis and Imaging, Sher-i-Kashmir Institute of Medical Sciences evaluated the diagnostic performance of different vessel wall MRI sequences in patients with suspected cerebrovascular diseases. A total of 63 patients with high suspicion of intracranial vessel wall pathology were assessed, out of which 10 patients demonstrated definite vessel wall enhancement on multidisciplinary image review. An equal number of control subjects (n = 10) with low likelihood of cerebrovascular disease and undergoing MRI for other indications were also included. The study population showed a slight male predominance (12 males, 8 females) with a mean age of 55.05 ± 12.08 years, indicating increased utility of vessel wall imaging in older patients, likely due to age-related vascular risk factors such as hypertension and diabetes mellitus.

Four dedicated vessel wall imaging sequences—T1 SPACE, MPRAGE, T1 TSE FS, and T1 FLAIR—were evaluated in addition to routine MRI sequences.

T1 SPACE

T1 SPACE demonstrated the highest diagnostic performance among all sequences, with a sensitivity of 90%, specificity of 100%, PPV of 100%, and NPV of 90.9%. Vessel wall enhancement was observed in 9 of 10 positive cases, while all control subjects showed no enhancement. The sequence provided excellent delineation of the vessel wall due to its high-resolution isotropic 3D acquisition and effective suppression of cerebrospinal fluid and flow-related artifacts. These findings are consistent with previous studies such as those by Eiden et al. and Zhang et al., which also reported superior vessel wall visualization and diagnostic utility of T1 SPACE in intracranial vasculopathies.

MPRAGE

MPRAGE showed limited utility for vessel wall enhancement assessment, with sensitivity and PPV of 0%, although specificity remained 100%. No enhancement was detected in either study or control groups. While MPRAGE is widely used for high-resolution T1-weighted imaging, post-contrast hyperintensity of the vessel lumen can obscure the vessel wall, limiting its role in direct vessel wall evaluation. However, literature suggests it may still be useful in plaque characterization when appropriately optimized.

T1 TSE FS

T1 TSE FS demonstrated good diagnostic performance, with a sensitivity of 80%, specificity of 100%, PPV of 100%, and NPV of 83.3%. Enhancement was seen in 8 of 10 positive patients, while controls remained negative. The findings support the role of fat-suppressed T1-weighted imaging in improving visualization of intracranial vessel wall pathology. This aligns with previous reports emphasizing the importance of fat suppression and high-resolution imaging in intracranial vessel wall assessment.

T1 FLAIR :-

T1 FLAIR showed no diagnostic value for vessel wall enhancement detection in this study, with sensitivity and PPV of 0% and specificity of 100%. Despite its known utility in detecting leptomeningeal and low-concentration gadolinium enhancement, its application for intracranial vessel wall evaluation appears limited, likely due to signal characteristics and CSF suppression mechanisms.

Image Quality Analysis:-

Image quality assessment demonstrated that T1 MPRAGE provided the highest overall image quality, followed by T1 SPACE. T1 TSE FS and T1 FLAIR showed comparatively lower image quality, with a higher proportion of cases falling into satisfactory or

suboptimal categories. Despite this, diagnostic accuracy was highest with T1 SPACE.

CONCLUSION

This study reinforces the value of high-resolution vessel wall MRI as a noninvasive imaging modality capable of directly evaluating intracranial arterial pathology beyond conventional lumen-based imaging techniques. Among the sequences evaluated, T1 SPACE emerged as the most sensitive and diagnostically reliable sequence for detecting vessel wall enhancement at 1.5T MRI, followed by T1 TSE FS. These findings support the incorporation of dedicated vessel wall imaging protocols in the routine assessment of suspected cerebrovascular diseases for improved diagnostic accuracy and risk stratification.

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