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Comparative analysis of functional outcome for CT-based versus MRI-based evaluation in acute ischemic stroke prior to mechanical thrombectomy

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Abstract

Background: This study aims to compare functional outcome for Computed tomography (CT)-based versus Magnetic resonance imaging (MRI)-based evaluation in acute ischemic stroke patients prior to Mechanical thrombectomy (MT) in less than 6-h window period in anterior circulation stroke. Participants were patients admitted from September 2, 2018 to September 2, 2020 with an acute ischemic stroke who underwent mechanical thrombectomy treatment. Total duration of MRI stroke protocol and CT scan with Computed tomography angiography (CTA) was 12 min 57 s, and 9 min 23 s, respectively. Follow-up for periodic Modified Rankin Scale (MRS) was performed at 3 months.

Results: Number of patients included in the study were 152 with mean age of 54.6 (range 22–80) years with male predominance ($n=102$). Mean GCS on admission was 12 (4–15) and 13(4–14) in CT and MRI group, respectively. National Institute of Health stroke scale (NIHSS) on admission was 17 (4–30) and 16(4–30) and at discharge was 7 (2–23) and 6(2–22) in CT-based group and MRI-based group, respectively. In the MRI group 65.5% had good outcome with mRS (0–2) at 3-month follow-up compared to 35.51% in CT group.

Conclusion: The current standard neuroimaging in acute ischemic stroke patients is CT and CTA brain. Using MRI over CT scan for acute ischemic stroke may improve clinical outcomes for the subgroup of patients who have an unclear diagnosis and who have higher risk of complications with MT. Even though MRI and MRA take longer period to acquire, patient's clinical outcome was better in MRI group in comparison to CT group and was comparable to that of the five major endovascular trials.

Keywords: MRI brain, CT brain, Acute stroke, Mechanical thrombectomy

Background

Stroke is a major cause of mortality and morbidity worldwide. Ischemic stroke is the most common subtype of stroke accounting for around 80% of all stroke cases [1]. Ischemic stroke treatment includes recanalization using either intravenous/intra-arterial thrombolysis, mechanical thrombectomy or sometime both. According to recent trials Mechanical thrombectomy has been proved to be effective treatment for ischemic stroke up to 24 h of onset of stroke [2].

In clinical practice, imaging has a big role in distinguishing between ischemia and intracerebral hemorrhage. Computed Tomography Scan (CT scan) and Magnetic Resonance Imaging (MRI) are the two imaging options for stroke cases. MRI has several

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advantages over CT Scan to examine the brain parenchyma in patients with acute ischemic stroke, such as detecting symptomatic ischemic lesions within few minutes of stroke onset, excluding stroke mimics, detecting ischemic lesions in the brain stem, distinguishing newly symptomatic from chronic ischemic lesions and establishing prognosis. This is true especially for the large "malignant" perfusion patterns at early timepoints, for which the risks of treatment may outweigh the benefits [1]. However, MRI has disadvantages, such as more acquisition time, contraindications with certain cardiac pacemaker, patients with severe claustrophobia and difficulty in monitoring of patients inside the MRI suite. The main reason many centers do not use MRI for routine stroke protocol is the time required to perform a complete examination, which can exceed 30 min. This fact has limited the use of MRI as routine imaging protocol to screen for acute ischemic stroke patients for mechanical thrombectomy [3].

The most important MRI technique for selecting acute ischemic stroke patients for reperfusion therapy is Diffusion-weighted MR imaging (DWI). DWI has emerged as the most sensitive (88 to 100%) and specific (95 to 100%) imaging technique for acute infarct even at very early timepoints after symptom onset [4]. DWI can detect relatively small cortical lesions and deep or sub cortical lesions including those in the brain stem or cerebellum areas which are often poorly visualized with standard MRI sequences and CT scan [5].

MR angiography (MRA) is a vascular imaging technique which provides an essential piece of information in the initial assessment of acute stroke patients and in the evaluation of the outcome of reperfusion therapies. In fact, location and extension of the vascular occlusion provides valuable information in predicting response to intravenous thrombolysis and, therefore, for selecting appropriate candidates for intra-arterial thrombectomy [6]. MRA is commonly performed in combination with brain MRI in the setting of acute stroke to guide therapeutic decision making [3, 7]. In nutshell CT-based protocols are easily available, time efficient, relatively free of motion artifacts and patient cooperation but MRI offers better infarct assessment, saving contrast use, radiation safety, better detection of posterior fossa infarct and micro bleeds. Additional Perfusion studies in CT-based protocol may address extent of infarct and oligemia much better though has inherent complexities in routine performance and interpretation.

The objective of this study is comparison of functional outcome in CT-based versus MRI-based evaluation of functional outcome in acute ischemic stroke.

Methods

This study is a prospective gathered in house registry (PMU/085/09/2018-09/2020) consisting of all patients with acute ischemic stroke at our Comprehensive stroke center. Participants were 152 patients admitted from September 2, 2018 to September 2, 2020 with acute ischemic stroke who underwent mechanical thrombectomy treatment. Patients with a clinical diagnosis of acute stroke were evaluated using National Institutes of Health Stroke Scale (NIHSS), modified Rankin scale (mRS) and were randomized into MRI brain-based protocol or CT-based protocol consecutively.

The regional review board has approved the use of human subjects for this study. All participants had given written informed consent. This Study did not require further approval as it used existing standard imaging, such as CT scan and MRI. There was no new drug or invasive procedure used in this study outside the standard existing recommendation.

Patient inclusion and exclusion criteria

Patients aged 18–80 years with acute ischemic stroke and symptomatic anterior proximal large vessel occlusion on CTA/MRA/DSA with NIHSS of at least 2 points within 6 h of stroke onset with informed consent was included in the study. A specific exclusion criterion for intended mechanical thrombectomy is concurrent myocardial infarction or severe infection (endocarditis or sepsis), uncontrollable hypertension defined as systolic blood pressure > 185 mmHg or diastolic pressure > 110 mmHg, Life expectancy of less than 90 days before stroke onset, pregnant or lactating women, known severe allergy to radiographic contrast medium and improvement of NIHSS score > 4 in less than 1 h. CT or MRI evidence of significant mass effect with midline shift, CT or MRI showing more than 1/3 of MCA territory infarct, CT or MRI evidence of intracranial hemorrhage (ICH), Subarachnoid Hemorrhage (SAH), Aneurysm or Cerebral arteriovenous malformations (CAVMs).

Fast imaging techniques such as echo-planar imaging (EPI), Propeller (GE)/ BLADE (Siemens) and turbo spin echo has significantly reduced the timing of MRI scan without compromising the image quality. The purpose of this study was to establish the feasibility of a fast MR protocol that can be obtained in ≈13 min.

In MRI on a 1.5 T (Siemens Essenza) MR system, we followed a protocol of MRI consuming less time taken with imaging protocol including diffusion-weighted imaging (DWI), EPI fluid attenuation inversion recovery imaging (FLAIR), EPI-gradient recalled echo (GRE), MRA brain & neck (TOF). We removed the sagittal T2, coronal FLAIR and axial T1 and axial T2 sequences from the fast MR protocol for acute stroke to reduce

timing as the above mentioned sequences does not affect the diagnosis of the stroke. If there is stroke mimic-like condition than we add these sequences for further additional information.

In addition to the new sequences which consume lesser amount of time, we have changed the certain parameters of the sequences. We have reduced the phase resolution from 80 to 70 in axial FLAIR and SWI sequences avoiding the 500 B value images and only acquired the 0 and 1000 B value images in DWI this further reduced the timings of the MRI scan. We have also changed the slice thickness of TOF angiography neck and brain from 0.6 to 0.8 and reduced phase FOV from 100 to 80–85 (vary according the patient) and also reduced the base resolution of angiography from 320 to 256 and phase resolution to 70 to 63 reduce the scan time dramatically and when this MR scan compared with the MR scan obtained by the sequences with normal parameters (provided by factory settings of the machine), No significant difference in the image quality was shown.

Detailed parameters of sequence timings are shifting and preparation time-2 min, localizer-20 s, DWI Axial 1 min 10 s, SWI Axial 1 min 27 s, FLAIR Axial 2 min 5 s, TOF MRA Brain 2 min 50 s, Localizer Neck 15 s and TOF MRA Neck 2 min 50 s. The time taken for the post processing of TOF angiography is negligible as after acquiring the TOF raw data we can obtain 3D image reconstruction in just 10 s each for brain and neck angiography. Total duration of the scan time is 12 min and 57 s.

The 13-min time is an estimate calculated based on all steps required to complete the image acquisition. It should be noted that acquisition time may vary on a case by case basis depending on factors, such as patient cooperation and technical difficulties.

All the CT scan head and CT angiography were performed on the 128 slice dual source CT scanner of Somatom definition by Siemens.

When, we see the only scan timing, which is less than a minute, but few additional time consuming process which are also necessary for scan. The total, calculated time of CT scanning with reconstruction is approximately 10 min which is less than the time taken for MR stroke protocol. It does not include the timing of contrast filling in the injector as it is already prepared before patient shift.

The Various details of the timing for CT scan are shifting and positioning 2 min, Topogram and planning 20 s, CT head scan time 18 s, Reconstruction time 2 min 30 s, Plain Angio scan 6 s, Contrast Bolus tracking 40 s, Angio run contrast 20 s, Angio reconstruction 3 Min, total time is 9 min 23 s (Fig. 1).

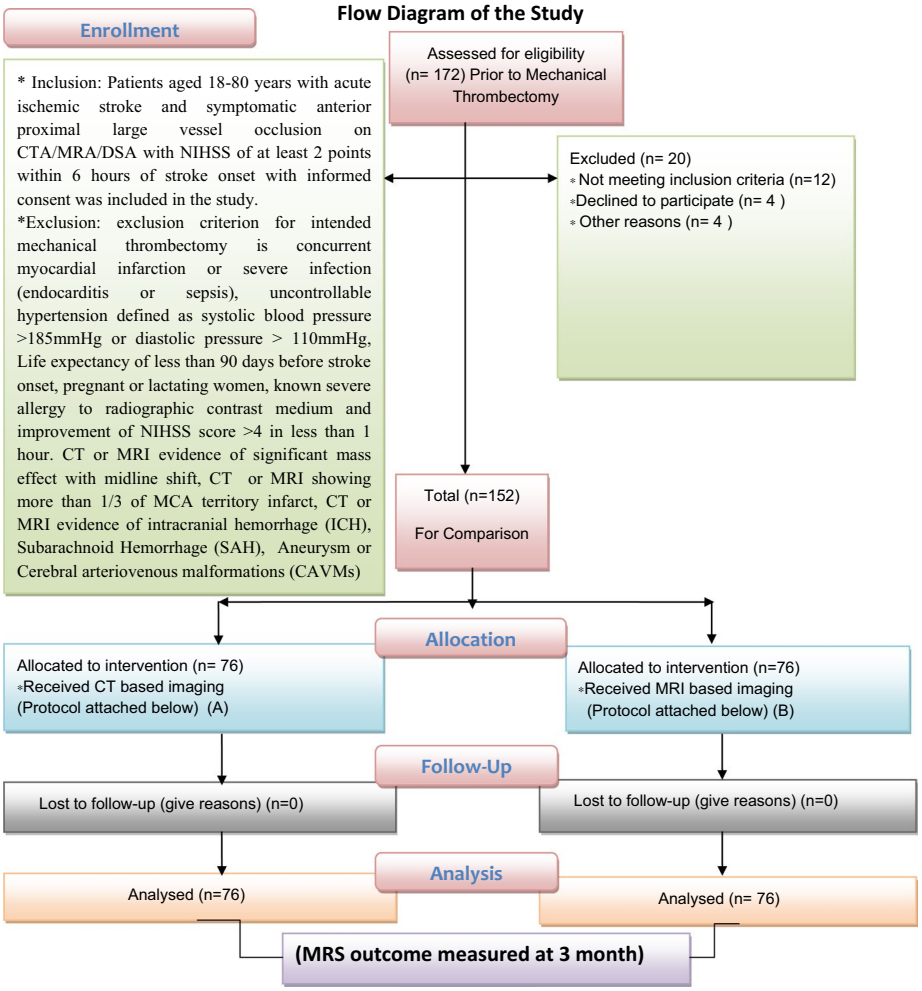
We performed Modified Rankin Scale (MRS) at admission, and at 3 months. Patients who refused to sign the informed consent, non cooperative or non fit for MRI or CT scan for the study, were excluded before randomization. To achieve the objective the hypothesis is framed which is further tested (Table 2). There is no significant difference on outcome based on CT and MRI scan after 3 months.

Statistical analysis

The CT and MRI groups were compared using the Mann–Whitney *U* test for quantitative variables and the χ^2 test for qualitative variables. Factors with a significant ($P < 0.10$) association with favorable outcome in analysis—that is, age, hypertension, hyperlipidemia ischemic heart disease, National Institutes of Health Stroke Scale score, diabetes mellitus, history of previous stroke. For two groups CT-based versus MRI-based outcome prior to mechanical thrombectomy, and imaging modality (MRI versus CT)—were candidates for the model. Reported *P* values were two-sided, with values < 0.05 indicative of a significant difference. All tests were two-sided. The statistical analysis was performed using SPSS (Version 25.0; IBM,)

Results

Total 152 patients were included in the study with mean age of 54.6 (range 22–80) years with male and female being 102 and 50, respectively. Both groups CT protocol performed and MRI protocol performed had 76 patients each. Mean NIHSS on admission was 17 (4–30) and 16(4–30) and at discharge was 7 (2–23) and 6 (2–22) in CT-based and MRI-based groups, respectively. Results showed that 44.07% and 43.42% of the patients had hypertension, smoker 30.26% and 34.21%, diabetes mellitus 27.63% and 38.15% hyperlipidemia 55.26% and 50%, ischemic heart disease 15.78% and 13.15%, tobacco chewing 60.52% and 57.89%, alcohol 28.94% and 23.68%, history of previous stroke 19.73% and 18.42%, as a risk factor of stroke in CT and MRI group, respectively. There was no statistical significant difference in as tandem lesion is 6.57% and 7.89% in CT and MRI group, respectively, ICAD is 18.42% and 19.73% in CT and MRI group, respectively, T occlusion is 26.3% and 30.26% in CT and MRI group, respectively, and IV rt-PA is 28.95% and 27.63% in CT and MRI group, respectively, before enrollment in the study (Table 1). Both groups were age, sex matched and risk factors were not statistically different. Average stroke onset to door time was 227 min (range 45–360) and 229(47–360), door to needle time was 110 (range 54–300) and 125 (range 60–310) and stroke to groin puncture time was 342 min (range 120–600) and 350 min (range 126–610) in CT and MRI group,



CT Timing Protocol Used (A)

S.No.	Process/Planning	Timing
1.	Shifting & positioning	2 min
2.	Topogram and planning	20 sec
3.	CT head scan time	18 sec
4.	Reconstruction time	2 min 30 sec
5.	Plain Angio scan	6 sec
6.	Contrast Bolus tracking	40 sec
7.	Angio run contrast	20 sec
8	Angio reconstruction	3 Min
9.	**Total**	**9 min 23 sec**

MRI Timing Protocol Used (B)

S.No.	Sequence/Planning	Timing
1.	Shifting & Preparation Time	2 min
2.	Localizer	20 sec
3.	DWI Axial	1 min10 sec
4.	SWI Axial	1 min 27 sec
5.	FLAIR Axial	2 min 5 sec
6.	TOF MRA Brain	2min 50 sec
7.	Localizer Neck	15 sec
8.	TOF MRA Neck	2 min 50 sec
	TOTAL	**12 min 57 sec**

Fig. 1 Flow diagram of the study. CT and MRI timing protocols used in the study. The CT and MRI groups were compared using the Mann–Whitney *U* test for quantitative variables and the χ^2 test for qualitative variables

Table 1 Baseline characteristics and outcome parameters according to the proposed criteria of the CT and MRI

(*n* = 152)	CT	MRI	*p* values
Characteristics	*N* = 76 *n* (%)	*N* = 76 *n* (%)	0.34
Age mean (range) (years)	51.4 (22–76)	57.8 (23–80)	0.23
Sex (male) %	50 (65.78%)	52 (68.42%)	0.31
Smoker	23 (30.26%)	26 (34.21%)	0.42
Diabetes mellitus	21 (27.63%)	29 (38.15%)	0.54
Hypertension	34 (44.07%)	33 (43.42%)	0.64
hyperlipidemia	42 (55.26%)	38 (50%)	0.65
Ischemic heart disease	12 (15.78%)	10 (13.15%)	0.66
Tobacco chewing	46 (60.52%)	44 (57.89%)	0.67
Alcohol	22 (28.94%)	18 (23.68%)	0.73
History of previous stroke	15 (19.73%)	14 (18.42%)	0.76
IV rtPA	26 (28.95%)	23 (27.63%)	0.56
Tandem lesions	5 (6.57%)	6 (7.89%)	0.48
ICAD	14 (18.42%)	15 (19.73%)	0.62
T-occlusion	20 (26.31%)	23 (30.26%)	0.54
Baseline NIHSS—median (IQR)	17 (4–30)	16 (4–30)	0.86
mRS at 90 days—median (IQR)	5 (3–6) (*n* = 76)	1(0–2) (*n* = 76)	0.006*

Data are presented as *n*/*N* (%) or median (interquartile range). *CT* computed tomography, *MRI* magnetic resonance imaging, *NIHSS* National Institutes of Health Stroke Scale, *ICAD* Intracranial atherosclerotic disease

* Significant

respectively (Table 2). In the MRI group 65.5% patients had good outcome (MRS between 0 and 2) at 3-month follow-up in comparison to 35.51% in CT group. In this study recanalization rate were comparable in both CT and MRI group.TICI 2b-3 in 92% in MRI group and 90% in CT group. There is statistically significant difference in hemorrhagic transformation after the procedure in CT (27.63%) and MRI (2.63%) group, respectively. Hypothesis testing result suggest that MRI protocol group had better modified Rankin scale-based outcome compared to CT scan protocol group. Imaging modality was not significantly associated with functional outcome in the multivariable analysis. (Tables 3, 4, Figs. 2, 3.)

Discussion

We compared our study's CT and MRI evaluation protocol groups and also compared with big trials using CT-based protocols, such as MR CLEAN, ESCAPE, EXTEND IA, SWIFT PRIME, and REVASCAT. We can see that the stroke onset to door time in our institution is longer, with a difference 23 min with CT group and 25 min with MRI group compared to MR CLEAN, 58 min with CT group and 60 min with MRI group compared to ESCAPE, 37 min with CT group and 39 min with MRI group compared to SWIFT PRIME, and 4 min with CT group and 6 min with MRI group compared to REVASCAT. This means that we need improvement in several points such as educating people in our city for stroke awareness and also improve the quality service of the picking up patients using ambulance [8]

This means that despite the use of MRI Brain as protocol of neuroimaging in acute stroke ischemic patients, our door to groin puncture time is not significantly different from CT-based studies [8].

The result of follow-up of our study reveals good outcome (MRS 0–2),in 65.5% of MRI group patients compared to 35.51% in CT group patients, while in other CT-based studies, good outcome was present in 33% in MR CLEAN [9], 51% in ESCAPE [10], 75% in EXTEND IA [11], 59% in SWIFT PRIME, and 44% in REVASCAT [12]. In follow-up outcome (MRS at 3 months), our studies is only inferior to EXTEND IA studies. This means that in reality our treatment is slightly delayed due to MRI examination. We had better or non inferior patients outcome compared to our own and other major studies published (MR CLEAN, ESCAPE, EXTEND IA, SWIFT PRIME, and REVASCAT) [8].

Probably MRI brain offers better selection for mechanical thrombectomy due to better assessment of extent of infarct, thereby increasing safer outcome of patients.

Table 2 Comparison data between our study and five major mechanical thrombectomy trials

	PMCH Total *N* = 152		MR CLEAN *N* = 233	ESCAPE *N* = 165	EXTEND IA *N* = 35	SWIFT PRIME *N* = 98	REVASCAT *N* = 103
	CT *N* = 76	MRI *N* = 76					
Imaging modalities	CT, CTA	MRI, MRA	CT, CTA, MRA perfusion	CT,CTA	CT, CTA, CT Perfusion	CT, CTA, CT Perfusion	CT, CTA, MRI
Stroke onset to Door time	227	229	204	169	–	190	223
Door to Groin Puncture time	110	125	–	90	113	95	109
Stroke onset to groin puncture time	342	350	260	–	210	224	269

PMCH Pacific Medical College and Hospital

Table 3 Comparison of MRS (%) scores at 3 months between our study and other clinical trials

MRS	MRI	MR CLEAN	ESCAPE	EXTENDIA	SWIFT PRIME	REVASCT
0	18.42	3	14	25	17	7
1	27.63	9	20	25	25	18
2	19.73	21	17	20	17	19
3	11.84	19	16	17	12	18
4	7.89	22	13	3	15	8
5	10.52	6	6	0	3	12
6	3.94	21	10	9	9	18
Good (MRS 0–2)	65.78	33	51	70	59	44
Bad (MRS 3–6)	34.19	68	45	29	39	56

Table 4 Patients MRS Score after 3 months, evaluated through CT and MRI

MRS	PMCH	
	CT %	MRI%
0	7.89	18.42
1	11.84	27.63
2	15.78	19.73
3	14.47	11.84
4	25	7.89
5	15.78	10.52
6	9.21	3.94
Good (MRS 0–2)	35.51	65.78
Bad (MRS 3–6)	64.46	34.19

PCMH Pacific Medical College and Hospital

Similar results were shown in patients undergoing IVT in extended window period patients in MRI-based protocols [13]. Few previous studies compared CT and MRI-based protocol in acute ischemic stroke prior to endovascular therapy with no overall increase in better outcome with MRI though reduced risk of symptomatic intra cerebral hemorrhage was reported [14, 15].

Conclusion

The current standard neuroimaging in acute ischemic stroke patients is CT and CTA brain. Using MRI over CT scan for acute ischemic stroke may improve clinical outcomes for the subgroup of patients who have an unclear prognosis, diagnosis and who have higher risk with mechanical thrombectomy. It appears that clearer and

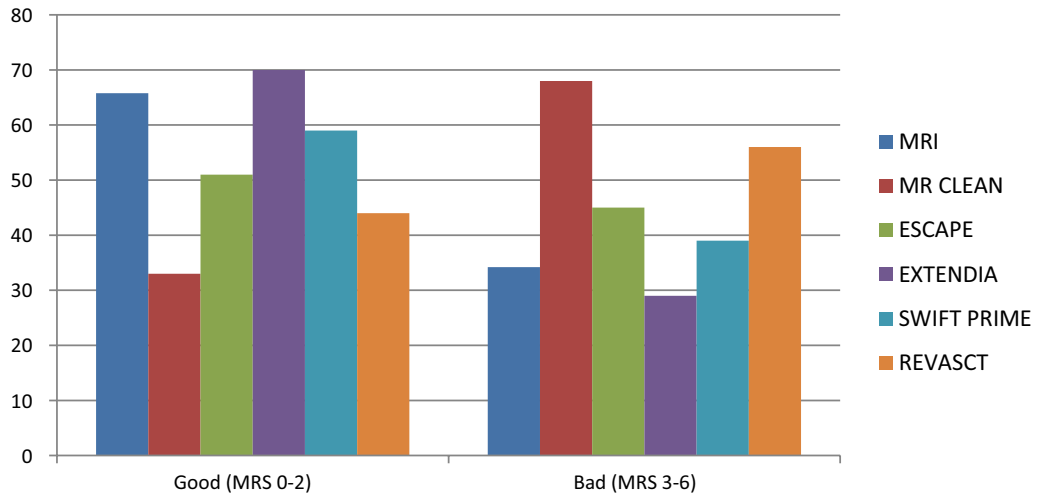


Fig. 2 Comparison of outcomes with PMCH MRI trial and other five clinical trials. *PCMH* Pacific Medical College and Hospital

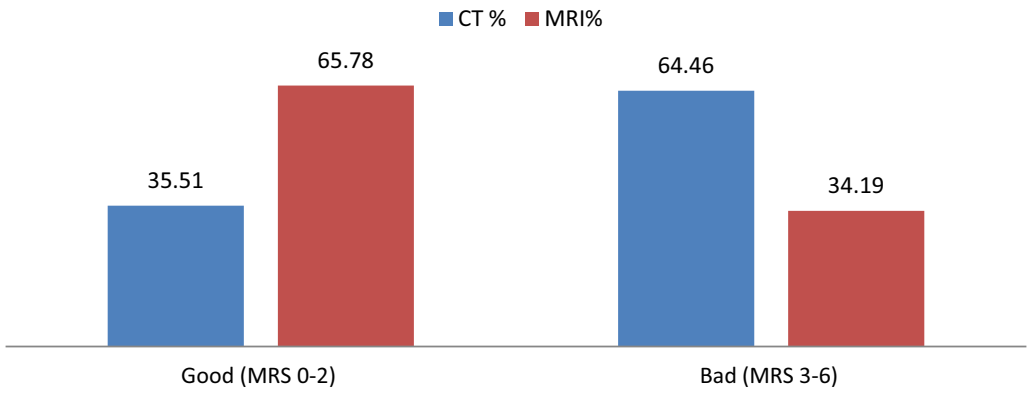


Fig. 3 Percentage of patients MRS scores after 3 months, evaluated through CT and MRI

earlier visualization of bigger infarct on MRI and MRA compared to CT and CTA might save patient from futile recanalization, hemorrhagic transformation, poor outcome and extra cost despite slightly longer MRI acquision time especially in the absence of perfusion imaging.

Abbreviations

CT: Computed tomography; CTA: Computed tomography angiography; MRA: Magnetic resonance angiography; MRI: Magnetic resonance imaging; DWI: Diffusion-weighted imaging; mRS: Modified rankin; GCS: Glasgow Coma Scale; NIHSS: National Institutes of Health stroke scale; MT: Mechanical thrombectomy; DSA: Digital subtraction angiography; ICH: Intracranial hemorrhage; SAH: Subarachnoid hemorrhage; CAVMs: Aneurysm or cerebral arteriovenous malformations; FLAIR: EPI fluid attenuation inversion recovery imaging; GRE: EPI-gradient recalled echo; PMCH: Pacific Medical College and Hospital.

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Authors' contributions

AV, MV, ST, LBY, NM, and KV implemented the study. KV performed Imaging modalities and protocol. ST and LBY, KV, DJ, SD, data collection. AV and ST, LBY performed data analyses and data interpretation. AV, ST, LBY, and MV drafted the initial manuscript. AV, NM, DJ, SD, KV, ST, LBY, and MV critically reviewed the manuscript and provided inputs. AV, ST, and LBY contributed equally. All authors read and approved the manuscript.

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Availability of data and materials

All authors confirm the availability of data and materials.

Declarations

Ethics approval and consent to participate

The Institutional ethics committee Pacific Medical University has approved the use of human subjects for this study. With approval Dated 6th of September 2018 with the reference number (PMU/085/09/2018-09/2020) consisting of all patients with acute ischemic stroke at our Comprehensive stroke center. All participants had given written, informed consent.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests**.**

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