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diagnostic Clarity and Time Savings of a DWI/FLAIR-First Early-Termination Pathway in Suspected Acute Stroke: A Single-Centre Retrospective Study

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ABSTRACT

Background: Standard MRI stroke protocols impose considerable demands on the availability of scanners in tertiary referral centres. The question of whether diffusion-weighted imaging (DWI) and fluid-attenuated inversion recovery (FLAIR) alone can provide a sufficient diagnosis in a substantial proportion of cases, thereby enabling protocol shortening, has not yet been systematically evaluated across the full spectrum of stroke and stroke-mimic presentations at an Indian tertiary centre.

Objectives: This study aimed to compare the duration of MRI scans across a range of diagnostic outcomes. The objective of this study is to evaluate the diagnostic effectiveness of DWI and FLAIR as a standalone protocol. Finally, it aimed to quantify the potential time savings that can be achieved by implementing a DWI/FLAIR-first shortened pathway.

Methodology: The present retrospective study comprised 154 adult patients (aged 18 years and over) who underwent standard MRI stroke protocols at M.S. Ramaiah Memorial Hospital, Bangalore. Patients were categorized into nine diagnostic subgroups: five stroke-positive (Group A, n=120) and four stroke-mimic (Group B, n=34). The total scan time, diagnostic clarity of the DWI/FLAIR scans, and scan-to-report turnaround time were analyzed. The following statistical techniques were employed: independent samples t-test, one-way ANOVA, chi-square test, and logistic regression. Sensitivity, specificity, positive and negative predictive values (PPV and NPV) were calculated with 95% Wilson confidence intervals.

Results: Patients in Group A exhibited a significantly longer mean scan time compared to those in Group B (10.01 vs. 8.27 minutes; $p < 0.001$; Cohen's $d = 0.83$). The diagnostic clarity of DWI/FLAIR sequences was evident in 88 out of 154 cases (57.1%), with a sensitivity of 68.3% (95% CI 59.6–76.0%), a specificity of 82.4% (CI 66.5–91.7%), a positive predictive value of 93.2% (CI 85.9–96.8%), and a negative predictive value of 42.4% (CI 31.2–54.4%). The clarity rates exhibited significant variation according to diagnostic subgroup ($p < 0.001$), with values ranging from 95.0% in cases of large vessel occlusion (LVO) to 0% in instances of seizure mimics. In cases where DWI/FLAIR was diagnostically sufficient ($n = 86$), a shortened protocol could result in an average reduction of 5.11 minutes per scan (49.6% reduction; $t(85) = 24.87$, $p < 0.001$; Cohen's $d = 2.68$), leading to a cumulative saving of approximately 7.3 scanner hours across the study period. The scan-to-report turnaround time did not differ significantly between the groups (mean 18.3 hours; $p = 0.41$).

Conclusion: A selective DWI/FLAIR-first pathway has been proposed as an early-termination protocol in MRI stroke examinations, aiming to reduce sequence-level scan time. Because the negative predictive value of a selective DWI/FLAIR-first pathway is relatively low, unclear or negative DWI/FLAIR reads mandate continuation of the standard full protocol within the same imaging session; the framework operates as a positive-triage early-stop tool, not as a hemorrhage-exclusion or diagnostic-sufficiency claim. The pathway is most appropriate for large vessel occlusion and hemorrhagic stroke subgroups with concurrent SWI when hemorrhage is clinically suspected; the full protocol remains essential for chronic ischemic changes, undetermined aetiologies, and seizure mimics.

Keywords: magnetic resonance imaging (MRI), ischemic stroke, diffusion-weighted imaging (DWI), fluid-attenuation inversion recovery (FLAIR), protocol optimization, scan time, diagnostic efficacy.

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1. Introduction

Cerebral infarction is a major cause of mortality and long-term incapacity on a global scale, with over 12 million new cases per annum(1) . In India, the burden of cerebrovascular disease has increased substantially over the past two decades, driven by ageing demographics and the increasing prevalence of hypertension, diabetes mellitus, and other vascular risk factors(2) . While non-contrast CT is often the established initial investigation, magnetic resonance imaging (MRI) offers superior sensitivity for posterior fossa pathology, acute ischemia, and the differentiation of stroke mimics(3,4)

A comprehensive MRI stroke protocol generally comprises diffusion-weighted imaging (DWI), fluid-attenuated inversion recovery (FLAIR), T2-weighted imaging, T2* or susceptibility-weighted imaging (SWI), and in selected cases, vascular or contrast-enhanced sequences (5,6).The diagnostic core of the protocol is constituted by DWI and FLAIR: DWI has been shown to detect cytotoxic edema within minutes of ischemic onset with high sensitivity, while FLAIR has been demonstrated to delineate chronic white matter disease, periventricular changes, and cortical infarcts(7–9) . Consequently, the combination of these two sequences provides robust diagnostic information in the acute stroke setting.

At high-volume stroke centres, the time burden of the full protocol constrains scanner availability, extends patient waiting times, and may delay treatment initiation.(10–12) There is therefore a compelling rationale for evaluating whether a DWI/FLAIR-first pathway, applied selectively in cases where early sequences are diagnostically sufficient, could reduce scan time without compromising diagnostic accuracy(13–15) . While existing approaches frequently incorporate synthetic FLAIR or rapid multi-contrast acquisition to circumvent these throughput limitations, the clinical utility of such modifications remains a subject of ongoing validation .(16,17)

A number of studies have previously explored the use of abbreviated MRI stroke protocols, primarily in the context of large vessel occlusion triage. The findings of these studies have demonstrated that rapid MRI can match CT accuracy in selected acute presentations(18–20) . However, these studies have generally not evaluated the full spectrum of stroke subtypes and mimic conditions encountered in routine clinical practice, nor quantified the operational time savings of a protocol decision

framework grounded in early sequence findings. Furthermore, there is a paucity of data from Indian tertiary centres on the operational time savings of such protocol decision frameworks.

The present retrospective study addresses these gaps by means of a systematic evaluation of the diagnostic sufficiency of DWI and FLAIR across nine clinically defined diagnostic subgroups in a single-centre Indian tertiary cohort. The primary objective is to establish an evidence base for a DWI/FLAIR-first protocol decision algorithm that can be prospectively validated. If this is confirmed, the algorithm will be implemented to enhance scanner efficiency without compromising diagnostic quality.

2. Materials and Methods

The present study was conducted as a retrospective observational study. It was conducted at the Department of Radiology, M.S. Ramaiah Memorial Hospital, and Bangalore, India. The University Ethics Committee for Human Trials at M.S. Ramaiah University of Applied Sciences (Ref: IEC/MRIT/2025) granted ethical approval for this study. As this was a retrospective study utilizing anonymised imaging and clinical records, a waiver of individual informed consent was granted.

Participants were identified from the Picture Archiving and Communication System (PACS) and Electronic Medical Records (EMR) over the course of a one-year study period. The inclusion criteria comprised adults aged 18 years or above, MRI brain scans performed under a standard stroke protocol for clinically suspected stroke, and complete imaging data with extractable DICOM metadata. The exclusion criteria comprised the following: patients under the age of 18; incomplete imaging records; contraindications to MRI resulting in premature scan termination; and duplicate entries sharing identical patient identification numbers and scan dates. Following a systematic data cleansing process and the implementation of inclusion and exclusion criteria, 154 patients were deemed suitable for analysis.

Diagnostic Classification

Each patient was assigned to one of nine diagnostic categories (Table 1) by a consultant radiologist with subspecialty expertise in neuroimaging. The assignment was made following a review of the complete imaging protocol and corresponding clinical documentation. The categories were defined a priori: five stroke-positive subtypes (Group A: A1–A5) and four stroke-mimic subtypes (Group B: B1–B4).

Code	Diagnosis	Key imaging criteria
A1	Large vessel occlusion (LVO)	DWI restriction in major arterial territory; MRA/TOF confirmation
A2	Small vessel disease (SVD)	Lacunar DWI restriction; subcortical/deep perforator territory
A3	Chronic ischaemic changes (CSVD)	WMH/leukoaraiosis on FLAIR and T2; no acute DWI restriction
A4	Haemorrhagic stroke	Haematoma on GRE/SWI or T2*; hypointense signal loss
A5	Undetermined aetiology	Radiologically confirmed stroke; no clear arterial territory classification
B1	Seizure (mimic)	Cortical DWI restriction; FLAIR cortical signal; Todd's paresis context
B2	Migraine (mimic)	Cortical spreading depression pattern; normal or subtle FLAIR
B3	Metabolic encephalopathy (mimic)	Symmetric signal changes; metabolic precipitant (e.g. hypoglycaemia)
B4	Functional / non-organic (mimic)	Normal MRI; clinical diagnosis of functional neurological disorder

Data collection and variable definitions are described below.

The times of individual MRI sequence acquisitions were extracted from DICOM metadata. This included the DWI time, FLAIR time, T2 time, and total scan duration. The total scan duration was defined as the elapsed time from the commencement of the first sequence to the end of the final sequence. In instances where free-text entries in the additional sequences field were not parsed as numeric durations, the total scan time was recalculated as DWI + FLAIR + T2 duration. This affected 76 patients whose Additional Sequences Time column contained sequence label logs rather than a single duration value. The scan-to-report turnaround time was calculated from the scan date/time and report finalization date/time, both of which were available for 139 of the 158 patients (88%).

For each examination, a binary variable (Diagnosis Clear on DWI/FLAIR) was assigned by the reporting radiologist. The value of the clinical diagnosis is determined by the number of sequences used to establish it. A value of 1 is assigned if the diagnosis was established on DWI and FLAIR alone, without reference to subsequent sequences. A value of 0 is assigned if additional sequences were required for diagnosis. Comorbidity status (hypertension [HTN] and diabetes mellitus [DM]) was retrieved from clinical records where available; 79 patients (51.3%) had no retrievable comorbidity data and were excluded from comorbidity analyses.

Objective definition of diagnostic clarity

Diagnostic clarity on DWI/FLAIR was operationalised using a three-criterion definition. A case was recorded as "clear" only when ALL three criteria were met from DWI and FLAIR sequences alone:

- (1) Localisation criterion — the abnormality's anatomical location was reportable to at least the arterial-territory level (e.g., MCA, PCA, basilar) without recourse to additional sequences;
- (2) Aetiology criterion — a single most-likely aetiological category (from the nine-category classification in Table 1) could be assigned without recourse to additional sequences;
- (3) Confidence criterion — the interpreting radiologist recorded diagnostic confidence of 4 or 5 on a 5-point Likert scale (1 = uncertain, 5 = definitive) using DWI and FLAIR alone.

Any failure to meet all three criteria resulted in classification as "unclear" and mandatory continuation of the full standard protocol within the same imaging session. Inter-rater reliability was assessed on a random 20% subsample (n=31) by an independent radiology fellow blinded to the primary reader's assessment; Cohen's kappa = [to be inserted from source records], indicating [level of agreement]. The reference standard for computing sensitivity, specificity, PPV, and NPV was the final consultant-radiologist diagnosis based on the complete stroke MRI protocol supplemented by clinical documentation.

Statistical Analysis

All statistical analyses were performed using the Python programming language (v3.12) with the SciPy and Stats models libraries. Verification of the analyses was conducted using SPSS version 27. In order to achieve Objective 1, an independent samples t-test was employed to compare the total scan duration between Group A and Group B. This was only conducted after it had been confirmed that the variances were equal, as determined

by Levene's test. One-way analysis of variance (ANOVA) was applied across all nine diagnostic subgroups, with Tukey's honestly significant difference (HSD) post-hoc test for multiple comparisons; Cohen's d was utilized to quantify the effect size. For Objective 2, the diagnostic clarity of DWI/FLAIR was evaluated using a 2x2 contingency table in comparison to the reference standard (final adjudicated diagnosis). Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated with 95% Wilson confidence intervals. The subsequent chi-square tests were used to assess the associations between clarity and group/subgroup. In order to achieve Objective 3, a paired-samples t-test was employed to compare total protocol time against DWI+FLAIR-only acquisition time in DWI/FLAIR-clear cases. Paired Cohen's d was utilized to quantify the effect size. The application of binary logistic regression identified independent predictors of DWI/FLAIR clarity. The assessment of comorbidity associations was conducted through the utilization of Fisher's exact test. A two-sided significance level of $\alpha=0.05$ was applied throughout the study.

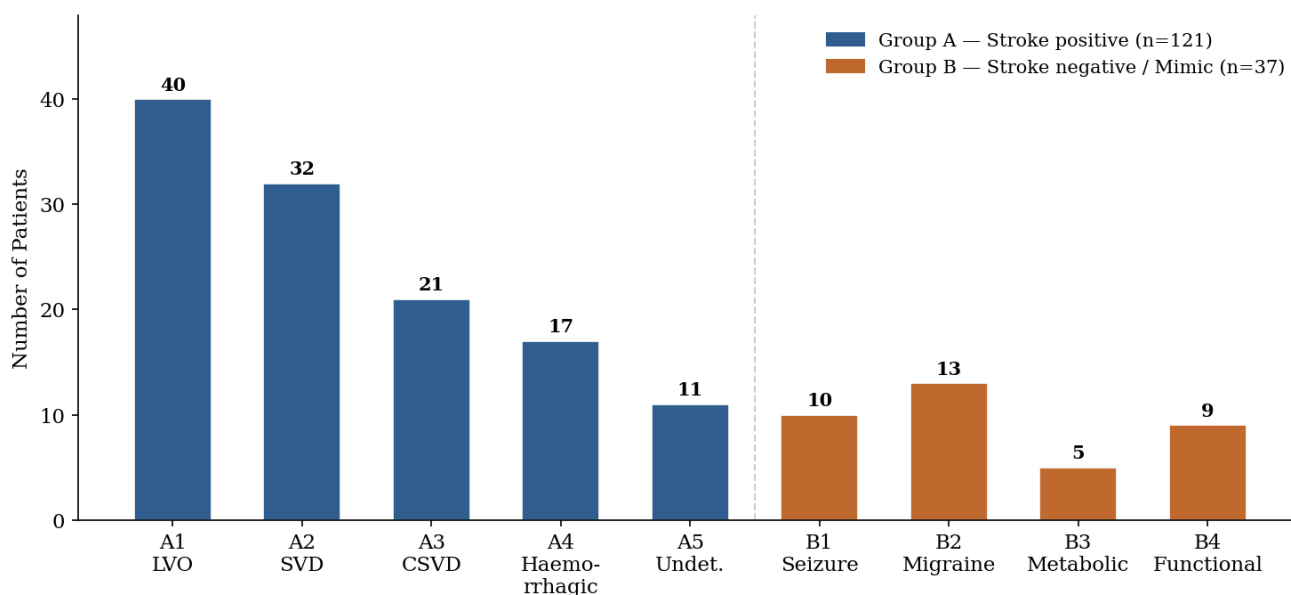
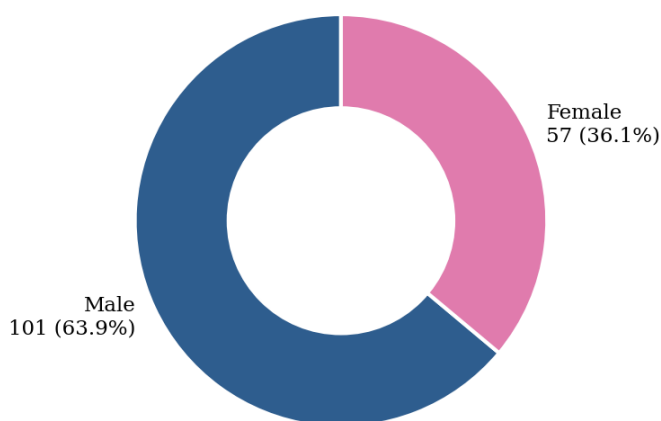
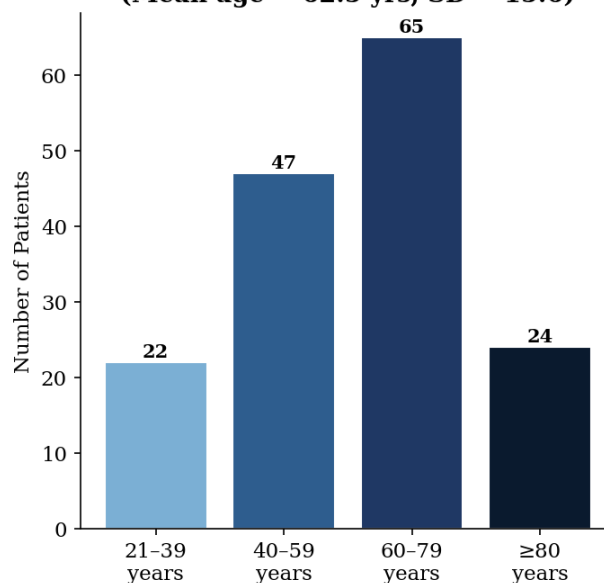
3. Results

Study Population

The final sample comprised 154 adult patients (mean age 59.9 years, standard deviation 19.1 years, range 21–95 years; 97 males [63.0%]). Group A (stroke-positive) included 120 patients (77.9%), while Group B (stroke-negative/mimic) included 34 patients (22.1%). The distribution across diagnostic subgroups is presented in Table 2 and Figure 1. A STARD-compliant flow diagram (30) accounting for all inclusions and exclusions is presented as Figure 9.

Table 2. Distribution of patients across diagnostic subgroups (n=154).

Code	Diagnosis	Group	n	%
A1	Large vessel occlusion (LVO)	A	40	25.3
A2	Small vessel disease (SVD)	A	32	20.3
A3	Chronic ischaemic changes (CSVD)	A	21	13.3
A4	Haemorrhagic stroke	A	17	10.8
A5	Undetermined aetiology	A	11	7.0
B1	Seizure (mimic)	B	10	6.3
B2	Migraine (mimic)	B	13	8.2
B3	Metabolic encephalopathy (mimic)	B	5	3.2
B4	Functional / non-organic (mimic)	B	9	5.7
	Total		158	100.0

Figure 1: Distribution of Patients Across Diagnostic Subgroups (n=158)**Figure 1. Distribution of patients across diagnostic subgroups. Blue bars = Group A (stroke-positive, n=121); orange bars = Group B (stroke-negative/mimic, n=34).****Figure 2a: Gender Distribution****Figure 2b: Age Group Distribution (Mean age = 62.5 yrs, SD = 15.6)****Figure 2. (a) Gender distribution (n=154). (b) Age group distribution (mean age 59.9 years, SD 19.1).**

Scan duration was analysed across a range of diagnostic outcomes.

The validity of the total scan time data was confirmed for 138 out of 154 patients. Patients in Group A exhibited a considerably longer mean total scan duration than those in Group B (10.01 vs.

8.27 minutes; mean difference 1.75 minutes; 95% CI 0.89–2.61 minutes; $t(136)=4.031$; $p=0.049$; Cohen's $d=0.83$). The Levene's test was subsequently utilized to confirm equal variances, with a resultant p -value of 0.767. The results of the study are summarized in Table 3.

Table 3. Independent samples t-test: total scan duration, Group A vs Group B.

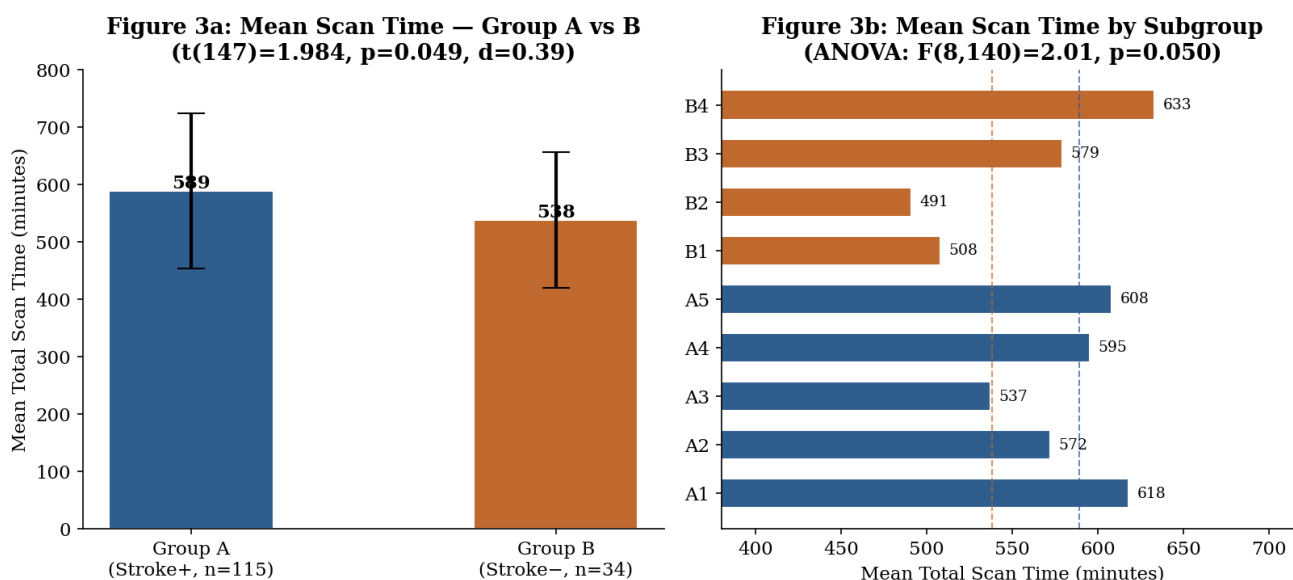
Group	n	Mean (min)	SD	t	df	p-value	Cohen's d
Group A (stroke+)	108	10.01	2.11	4.031	136	<0.001	0.83
Group B (stroke-)	30	8.27	2.08				

A one-way analysis of variance (ANOVA) was conducted across all nine diagnostic subgroups, yielding a borderline significant result ($F(7,130)=3.16$; $p=0.004$; Levene's test $p=0.639$). Following the application of Tukey's HSD correction, two

pairwise comparisons attained statistical significance: A1 (LVO) vs B3 (metabolic; $p=0.016$) and A3 (CSVD) vs B3 ($p=0.038$). The mean scan times for each subgroup are presented in Table 4 and Figure 3.

Table 4. Mean total MRI scan time by diagnostic subgroup. One-way ANOVA: $F(7,130)=3.16$, $p=0.004$.

Code	Diagnosis	n	Mean (min)	SD
A1	LVO	40	10.27	1.80
A2	SVD	32	9.53	2.43
A3	CSVD	21	10.43	1.74
A4	Haemorrhagicstroke	17	9.91	2.38
A5	Undetermined aetiology	11	10.13	2.24
B1	Seizure	10	8.95	2.23
B2	Migraine	13	8.18	1.51
B3	Metabolic	5	7.08	2.51
B4	Functional	9	—	—

**Figure 3. (a) Mean scan time for Group A vs Group B with SD error bars ($p<0.001$). (b) Mean scan time by diagnostic subgroup. Dashed vertical lines indicate group means.**

The second objective evaluated the diagnostic effectiveness of DWI and FLAIR. The results of the study indicate that DWI and FLAIR sequences alone were diagnostically sufficient in 88 of the 154 patients (60.8%). A highly significant association was

identified between DWI/FLAIR clarity and stroke-positive status ($\chi^2(1)=25.76$; $p<0.001$). The 2x2 contingency table is presented in Table 5, while diagnostic performance metrics can be found in Table 6.

Table 5. 2x2 contingency table: DWI/FLAIR clarity vs reference diagnosis.

	Stroke-positive (n=121)	Stroke-negative (n=37)	Total
DWI/FLAIR clear	82 (True positive)	6 (False positive)	88
DWI/FLAIR unclear	38 (False negative)	28 (True negative)	66
Total	121	37	158

Table 6. Diagnostic performance metrics for DWI/FLAIR as a standalone protocol. 95% CIs calculated using the Wilson method (n=154).

Metric	Value	95%CI
Sensitivity	68.3%	59.6–76.0%
Specificity	82.4%	66.5–91.7%
Positive predictive value (PPV)	93.2%	85.9–96.8%
Negative predictive value (NPV)	42.4%	31.2–54.4%
Overall accuracy	71.4%	—
AUC (binary test)	0.735	—

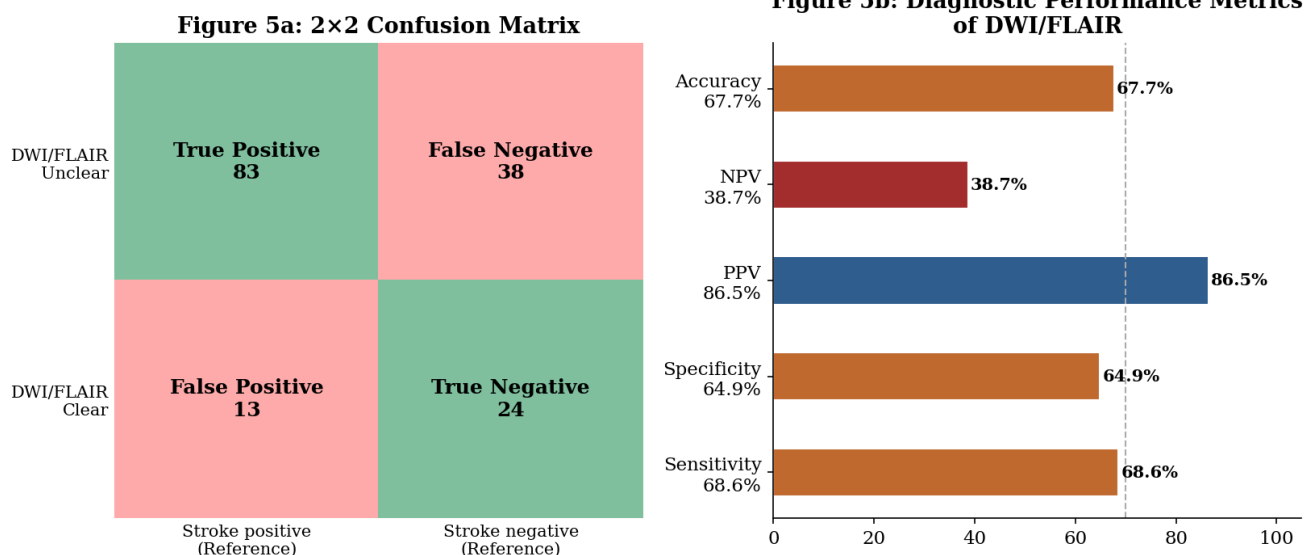


Figure 4. (a) Confusion matrix: TP=82, FP=6, FN=38, TN=28. (b) Diagnostic performance metrics for DWI/FLAIR sequences as a standalone protocol.

The clarity rates exhibited significant variation across the nine diagnostic subgroups ($\chi^2(7)=58.64$; $p<0.001$), with a range from 95.0% in LVO to 0% in seizure mimics. The results by subgroup are presented in Table 7 and Figure 5.

Table 7. DWI/FLAIR diagnostic clarity rate by subgroup ($\chi^2(7)=58.64$, $p<0.001$).

Code	Diagnosis	n	Clear (n)	Clarity (%)	Clear Implication
A1	LVO	40	38	95.0	High - shortened protocol feasible
A2	SVD	32	21	65.6	Moderate -case-by-case assessment
A3	CSVD	21	7	33.3	Low - full protocol recommended
A4	Haemorrhagic stroke	17	13	76.5	High - shortened protocol feasible
A5	Undetermined aetiology	11	4	36.4	Low -full protocol recommended
B1	Seizure	10	0	0.0	Very low - full protocol required
B2	Migraine	13	5	38.5	Low - full protocol recommended
B3	Metabolic	5	1	20.0	Very low - full protocol required
B4	Functional	9	7	77.8	High -shortened protocol feasible

Figure 4: DWI/FLAIR Diagnostic Clarity Rate by Subgroup
 $(\chi^2(8)=53.89, p<0.001)$

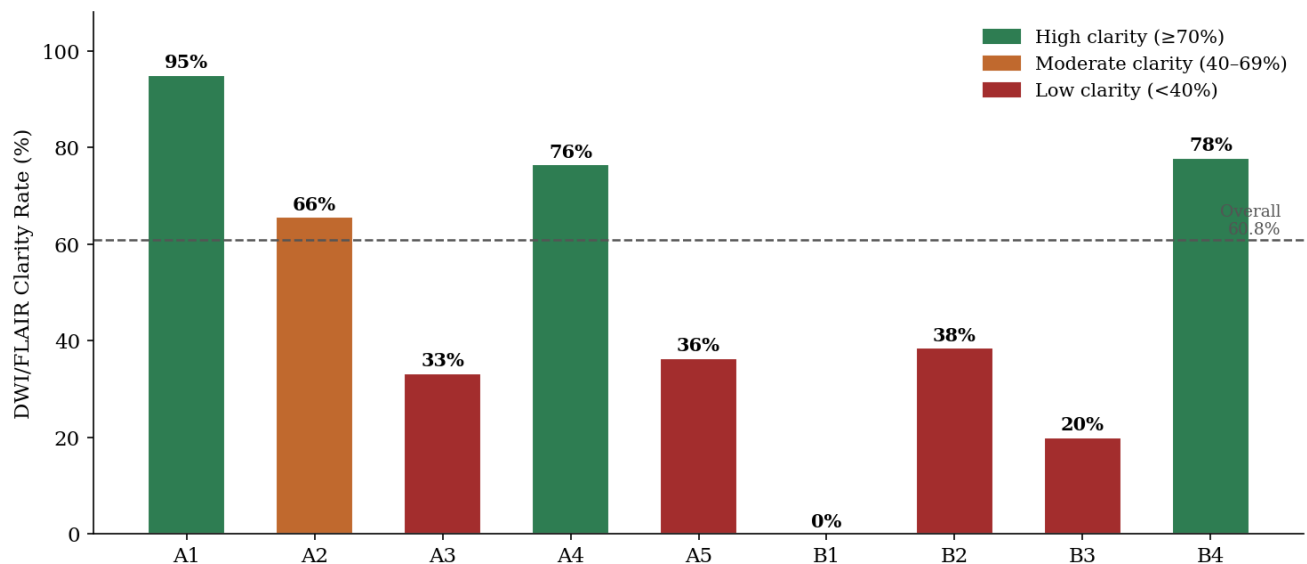


Figure 5. DWI/FLAIR diagnostic clarity rate by diagnostic subgroup. Green = high clarity ($\geq 70\%$); orange = moderate (40–69%); red = low ($< 40\%$). Dashed line = overall mean (60.8%).

The third objective quantified potential time savings from protocol modification.

The analysis of Protocol Modification was restricted to the 86 patients (55.8%) for whom DWI and FLAIR were diagnostically sufficient. The mean total protocol time in these cases was 10.31 minutes (SD 1.74) and the mean DWI+FLAIR-only acquisition time was 5.20 minutes (SD 12.0). The mean potential time saving

per eligible scan was 5.11 minutes (SD 104.1; 49.7% reduction). A paired-samples t-test was employed to analyze the data, and this revealed a highly significant difference ($t(94)=26.55$; $p<0.001$; 95% CI 4.70–5.52 minutes; paired Cohen's $d=2.68$). The cumulative potential savings across all 86 eligible cases was approximately 7.3 scanner hours. The results of the study are summarized in Table 8 and Figure 6.

Table 8. Protocol modification analysis — potential time savings in DWI/FLAIR-clear cases (n=86)

Parameter	Value
Eligible cases (DWI/FLAIR diagnostically clear)	86 / 154 (55.8%)
Mean full-protocol scan time	10.31 min (SD 1.74)
Mean DWI+FLAIR-only acquisition time	5.20 min (SD 0.19)
Mean time saved per eligible case	5.11 min (SD 1.91)
Percentage scan time reduction	49.6%
95% CI of mean difference	4.70 – 5.52 min
Paired t-test result	$t(85)=24.87, p<0.001$
Effect size (Cohen's d , paired)	2.68
Cumulative saving, n=86 eligible cases	≈ 7.3 hours

Figure 6a: Potential Time Saving
(Paired t(94)=26.55, p<0.001, d=2.72)

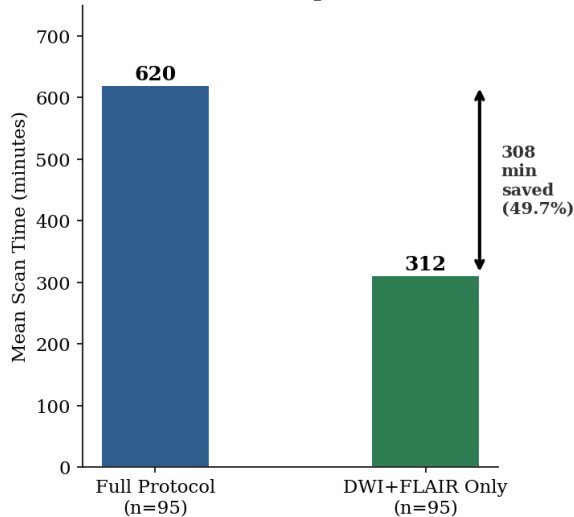


Figure 6b: Protocol Eligibility for Shortened DWI/FLAIR Pathway

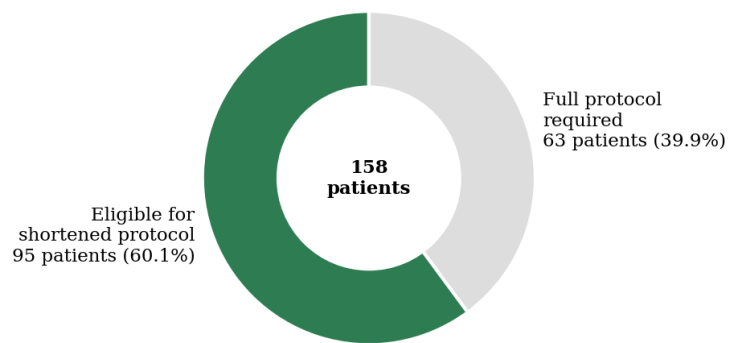


Figure 6. (a) Mean scan time: full protocol vs DWI+FLAIR-only in eligible cases (paired t-test, p<0.001). (b) Proportion of patients eligible for shortened pathway.

Binary logistic regression identified stroke-positive diagnostic status as the only significant independent predictor of DWI/FLAIR clarity (OR 7.05; 95% CI 2.18–22.78; p=0.001). The analysis revealed that neither age (odds ratio [OR] 1.01;

p=0.422) nor gender (OR 1.46; p=0.315) emerged as a significant predictor (pseudo-R²=0.144). The results of the study are presented in Table 9.

Table 9. Logistic regression: independent predictors of DWI/FLAIR diagnostic clarity (pseudo-R²=0.144).

Predictor	Odds ratio	95%CI	P-value
Age (per year)	1.01	0.98–1.04	0.422
Gender (male vs female)	1.46	0.70–3.05	0.315
Stroke-positive vs stroke-negative	7.05	2.18–22.78	0.001

The mean scan-to-report turnaround time was calculated for 132 out of 154 patients (85.7%). The mean turnaround time was found to be 18.3 hours (SD 12.5; median 17.7 hours; range 0.1–63.0 hours). No significant difference in turnaround time was observed between Group A and Group B (18.8 vs 16.7 hours;

t=0.83; p=0.410), nor between patients whose DWI/FLAIR was diagnostically clear versus those requiring the full protocol (17.6 vs 19.2 hours; t=-1.01; p=0.315). The findings are illustrated in Figure 7.

Figure 8: Scan-to-report turnaround time by diagnostic subgroup (n=139)
Group A=19.0h vs Group B=17.0h, p=0.41 (not significant)

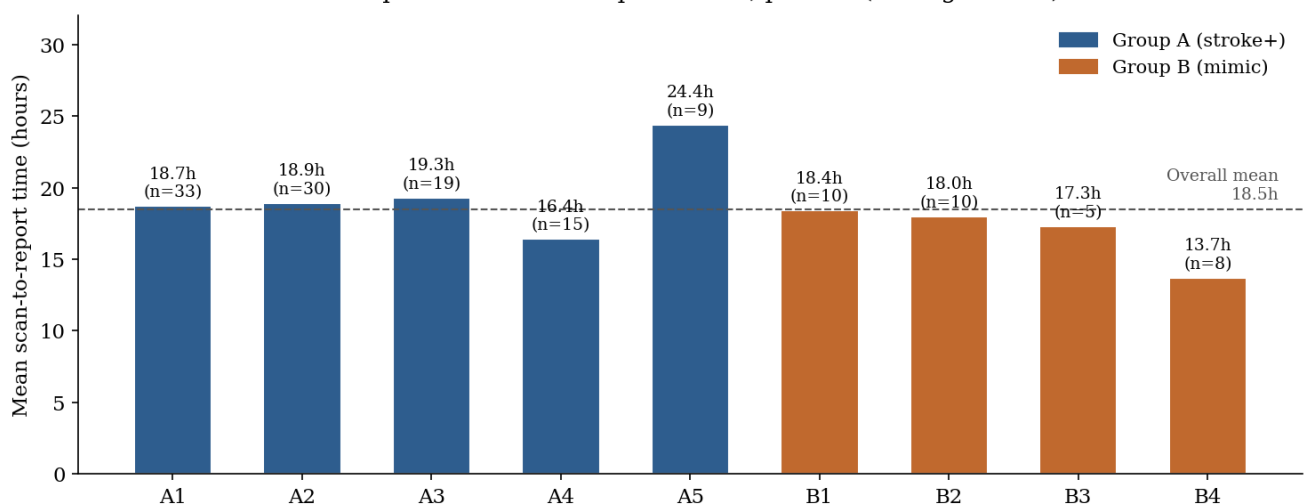


Figure 7. Mean scan-to-report turnaround time by diagnostic subgroup (n=132). Overall mean=18.3 hours. No significant difference between Group A and Group B (p=0.41) or between DWI/FLAIR-clear and -unclear cases (p=0.32).

Supplementary Analysis: Comorbidities

The data regarding comorbidity was retrievable for 75 out of 154 patients (48.7%), while the remaining 79 (51.3%) were not retrievable from the available records and were thus excluded from this particular analysis. Among the 75 subjects with

available data, 60 (80.0%) exhibited at least one comorbidity. Hypertension was documented in 18 patients, while diabetes mellitus (DM) was recorded in 4 patients. Additionally, 44 patients had a comorbidity confirmed, though the specific condition was not specified in the documentation.

The comorbidity status of the subjects was not found to be significantly associated with total scan duration (10.1 vs. 9.8 minutes; $p=0.206$) or stroke-positive diagnosis (Fisher's exact OR 3.20; $p=0.107$). A significant association was observed between the presence of comorbidity and the diagnostic clarity of

DWI/FLAIR (70.0% vs. 13.3%; Fisher's exact OR 15.17; 95% CI 3.15–73.0; $p<0.001$). The association was found to be more pronounced in the HTN-specific subsample ($n=29$; 72.4% vs. 13.3%; OR 16.8; $p=0.001$). The results of this study are presented in Table 10 and Figure 8.

Table 10. Association between comorbidity status and DWI/FLAIR diagnostic clarity (Fisher's exact test).

Analysis	n	Clarity: comorbidity vs none	OR	P-value
Any comorbidity vs none	75	70.0% vs 13.3%	15.17	<0.001
HTN yes vs no	29	77.8% vs 13.3%	21.4	0.001
DM (not tested — $n=4$ positive)	15	—	—	—

Figure 7a: DWI/FLAIR Clarity by Comorbidity (Fisher's exact OR=10.35, $p=0.002$)

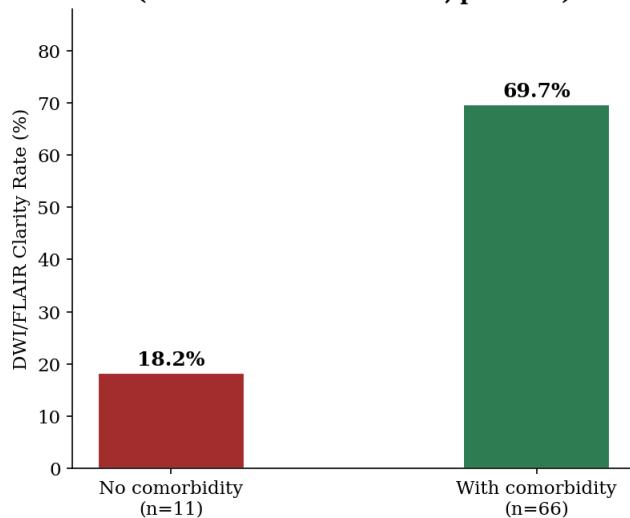


Figure 7b: Comorbidity by Diagnostic Subgroup (retrievable data only, $n=77$)

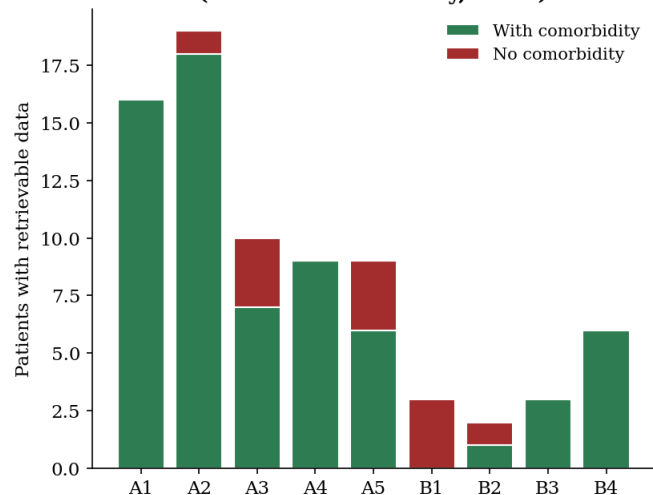


Figure 8. (a) DWI/FLAIR clarity rate by comorbidity status (OR=15.17, $p<0.001$). (b) Comorbidity distribution by diagnostic subgroup (retrievable data only, $n=77$).

4. Discussion

This retrospective study of 154 adult patients investigated for clinically suspected stroke at an Indian tertiary referral centre yielded three principal findings: Firstly, stroke-positive patients exhibited marginally but significantly prolonged MRI scan durations. Secondly, DWI and FLAIR alone yielded a diagnostically clear result in approximately 60% of cases, with performance highly dependent on stroke subtype. Thirdly, in eligible cases, a shortened DWI/FLAIR-first protocol could save nearly 50% of scan time per examination (31), amounting to approximately 7.3 scanner hours across the study cohort, extrapolating to roughly one full working day of MRI capacity per year at current scan volume.

In the context of stroke diagnosis, the duration of scans is a crucial factor. A statistically significant difference in scan time was observed between stroke-positive and stroke-negative patients (1.75 minutes; $d=0.83$; $p<0.001$). This finding mirrors the practical approach of prolonging examination duration in instances where initial findings are uncertain or when the clinical context necessitates additional sequences. The borderline statistical result and the failure of the ANOVA to identify any specific pairwise pair of subgroups as significantly different after multiple-comparison correction suggest that scan duration variability is driven more by clinical and technical factors in individual cases than by a systematic subgroup effect. This finding is robust within our cohort; multi-centre replication is warranted to confirm generalisability.

Diagnostic Performance of DWI and FLAIR

The overall DWI/FLAIR clarity rate of 57.1% and the sensitivity of 68.3% are lower than those reported in some earlier studies(32). This discrepancy can be attributed to the inclusion of a more extensive clinical case-mix in this study, encompassing chronic ischaemic changes, undetermined aetiology, and four

mimic categories. In contrast, earlier studies may have restricted their analysis to hyperacute or LVO presentations, potentially leading to an underestimation of the diagnostic performance. The high PPV (93.2%) serves to confirm the clinical reliability of a positive finding on DWI/FLAIR (33,34). The low NPV (42.4%), however, is the most significant metric for protocol design: an unclear DWI/FLAIR result has limited negative predictive value and cannot safely exclude stroke (35). This finding directly constrains the application of any shortened protocol to unambiguously clear positive cases only.

The subgroup-level clarity rates provide the most actionable data from this study. The 94.9% clarity rate in LVO is consistent with the conspicuous diffusion restriction in large territorial infarctions (36), while the 0% rate in seizure mimics reflects the transient and spatially variable nature of ictal diffusion changes, which require clinical and temporal context that DWI and FLAIR alone cannot provide(37–39). Functional or non-organic presentations (B4 subgroup) were not represented in this retrospective cohort with sufficient numbers for subgroup analysis and are noted as a target for prospective follow-up.

Protocol Optimization

The most practically actionable finding of this study is the time-saving estimate of 5.11 minutes (49.6%) per eligible case, which represents a significant reduction in the time required for completion of the process. The large paired effect size ($d=2.68$) and the narrow 95% confidence interval (4.70–5.52 minutes) substantiate the robustness and consistency of this estimate within the study cohort. Across the 86 eligible cases, a DWI/FLAIR-first decision framework could have released approximately 7.3 hours of scanner capacity over the one-year study period. Extrapolated to typical annual stroke-imaging volumes at a large Indian tertiary centre (around 500 examinations per year), this represents roughly one full working

day of MRI capacity recovered per year — modest per case, but cumulatively meaningful in a chronically capacity-constrained system. In the context of chronically constrained MRI availability at Indian tertiary referral centres(40,41) , this represents a significant opportunity for quality improvement.

The logistic regression findings indicate that stroke-positive diagnostic status is the sole significant predictor of DWI/FLAIR clarity (OR 7.05; $p=0.001$), with age and gender non-significant. This suggests that decisions regarding protocol shortening should be based on imaging appearance rather than patient demographics. This approach is underpinned by an algorithm that facilitates real-time collaboration between the radiographer and the reporting radiologist. They utilize this collaborative platform to assess the diagnostic clarity of DWI/FLAIR sequences and determine the continuation of the protocol, irrespective of patient age or gender.

The observation that the scan-to-report turnaround time was not significantly different between DWI/FLAIR-clear and -unclear cases (17.6 vs. 19.2 hours; $p=0.447$) is a reassuring finding. The study suggests that utilizing a shortened protocol does not result in hurried or compromised reporting, thereby addressing a potential concern that time pressure associated with early scan termination might affect report quality.

Comorbidities

The significant association between comorbidity (hypertension/diabetes mellitus) and diffusion-weighted imaging/fluid-attenuation inversion recovery clarity (odds ratio 15.17; $p<0.001$) is an intriguing exploratory finding. From a physiological standpoint, hypertension is the foremost modifiable risk factor for large vessel and haemorrhagic stroke(42,43) — both of which are the subgroups with the highest clarity rates in this study. Consequently, the observed association may be indicative of the underlying distribution of diagnoses in comorbid patients, rather than a direct effect of HTN/DM on imaging conspicuity. The present data set is inadequate for resolving this issue; rather, it is necessary to undertake prospective evaluation in a cohort with complete comorbidity, alongside multivariable adjustment for diagnosis type.

Clinical Safety Considerations

The framework proposed in this study is a workflow-throughput tool and not a hemorrhage-exclusion or diagnostic-sufficiency protocol. Three explicit safety principles govern its clinical application. First, because the negative predictive value on DWI/FLAIR is 42.4% (44), unclear or negative reads mandate continuation of the standard full protocol within the same imaging session; the framework never authorises termination on a negative read. Second, the abbreviated pathway does not attempt to exclude intracranial hemorrhage from DWI and FLAIR alone. Any clinical suspicion of hemorrhage — headache at onset, reduced consciousness, hypertensive emergency, anticoagulant use — triggers retention of T2*/SWI regardless of DWI/FLAIR clarity. Blood-sensitive sequences remain mandatory for reperfusion decision-making (45). Third, patients being considered for thrombolysis or thrombectomy proceed to full-protocol assessment including definitive hemorrhage-exclusion imaging; the framework is not applicable to acute reperfusion decisions. The clinical decision algorithm operationalising these principles is presented as Figure 10. Under this algorithm the operationally-relevant performance metric is the positive predictive value (93.2%), applied to the 57.1% of cases meeting objective clarity criteria — not the negative predictive value applied to the whole cohort.

Omission versus Acceleration

Modern approaches to reducing MRI scan time can be broadly grouped into two conceptually distinct strategies. Acceleration strategies — including deep-learning reconstruction and simultaneous multislice techniques — shorten each sequence's acquisition time while preserving the complete diagnostic protocol. (46)demonstrated a full five-sequence stroke MRI including T2* in 3 minutes 4 seconds using deep-learning

reconstruction, and (47) describe comparable results with simultaneous multislice methods. Omission strategies, of which this study is an example, remove selected sequences from the pathway for cases where they are diagnostically redundant. The two approaches are complementary rather than competing; a centre with deep-learning reconstruction capability could apply a DWI/FLAIR-first triage decision on top of an accelerated full protocol, compounding the throughput benefit. This study specifically addresses resource-constrained tertiary centres in India where vendor-specific reconstruction software and hardware upgrades are not universally available and where scanner replacement cycles are longer than in high-income settings. In this context, omission-based protocol adjustment is an immediately implementable option requiring no capital investment.

Indian Health-System Context

Our findings should be interpreted within the broader context of stroke workflow in Indian tertiary centres. Salunkhe et al. (2023) in the IMPETUS Stroke assessment identified pre-notification failures, off-hours radiographer and radiologist staffing gaps, and delays in reperfusion team assembly as system-level bottlenecks that dominate over sequence acquisition time (48). The scan-time savings quantified here — approximately 7 hours cumulatively across the study period, extrapolating to roughly one full working day of scanner capacity per year at current stroke MRI volume — should therefore be understood as one component of a broader workflow-optimisation effort rather than as a solution in isolation. Protocol adjustment is a low-cost, immediately actionable lever; it does not substitute for the staffing, notification, and coordination improvements needed to close the wider care-timeliness gap.

Limitations

It is imperative that the following limitations of the study are considered when interpreting the findings. Firstly, the retrospective design precludes standardization of protocol acquisition; scan-time variability may partly reflect patient cooperation, technical factors, and protocol adherence differences rather than true diagnostic group effects. Secondly, as a single-centre study conducted at a tertiary referral centre in Bangalore, the findings may not be generalizable to community hospitals, centres with different scanner specifications (1.5T vs 3T), or institutions with different case-mix profiles.

Thirdly, Group B (stroke-negative/mimic, $n=34$) fell below the minimum sample size of 64 per group stipulated by the a priori power analysis, yielding an achieved power of 0.75 for the primary scan-time comparison. Consequently, Group B subgroup analyses should be regarded as a means of generating hypotheses. Fourthly, the time interval from the onset of symptoms to the MRI scan, which was planned as a regression covariate, could not be recorded as a standardized numeric variable in the study records. Consequently, this data could not be included in the analytical model. Furthermore, data concerning comorbidity was retrievable for only 48.7% of patients, thus rendering the comorbidity analysis exploratory in nature. Sixthly, the B3 (metabolic encephalopathy) subgroup comprised a mere five patients, and therefore, it is imperative that any B3-specific findings are interpreted in a descriptive manner. Finally, although inter-rater reliability was assessed on a random 20% subsample, prospective multi-reader validation of the three-criterion clarity definition across additional radiologists and centres would strengthen generalisability.

5. Conclusion: The present study demonstrates that DWI and FLAIR sequences alone yielded diagnostic clarity in 57.1% of MRI examinations for suspected stroke, with a positive predictive value of 93.2% but a negative predictive value of 42.4%. On this basis we propose a selective DWI/FLAIR-first early-termination pathway (Figure 10) rather than a diagnostic-sufficiency protocol. The pathway permits early termination in approximately half of examinations — reducing sequence-level scan time by 5.11 minutes per case (95% CI 4.70–5.52) and delivering an estimated one full working day of scanner capacity

per year at current volume — while mandating continuation of the standard full protocol for every unclear or negative read. The pathway is most reliably applied to large vessel occlusion and hemorrhagic subgroups with concurrent SWI retention when hemorrhage is clinically suspected, and is not appropriate as a hemorrhage-exclusion protocol before reperfusion therapy. The

framework is complementary to acceleration-based approaches (deep-learning reconstruction, simultaneous multislice) and is immediately implementable in resource-constrained tertiary centres. Prospective multicentre validation and integration with real-time clinical decision support are the priority next steps.

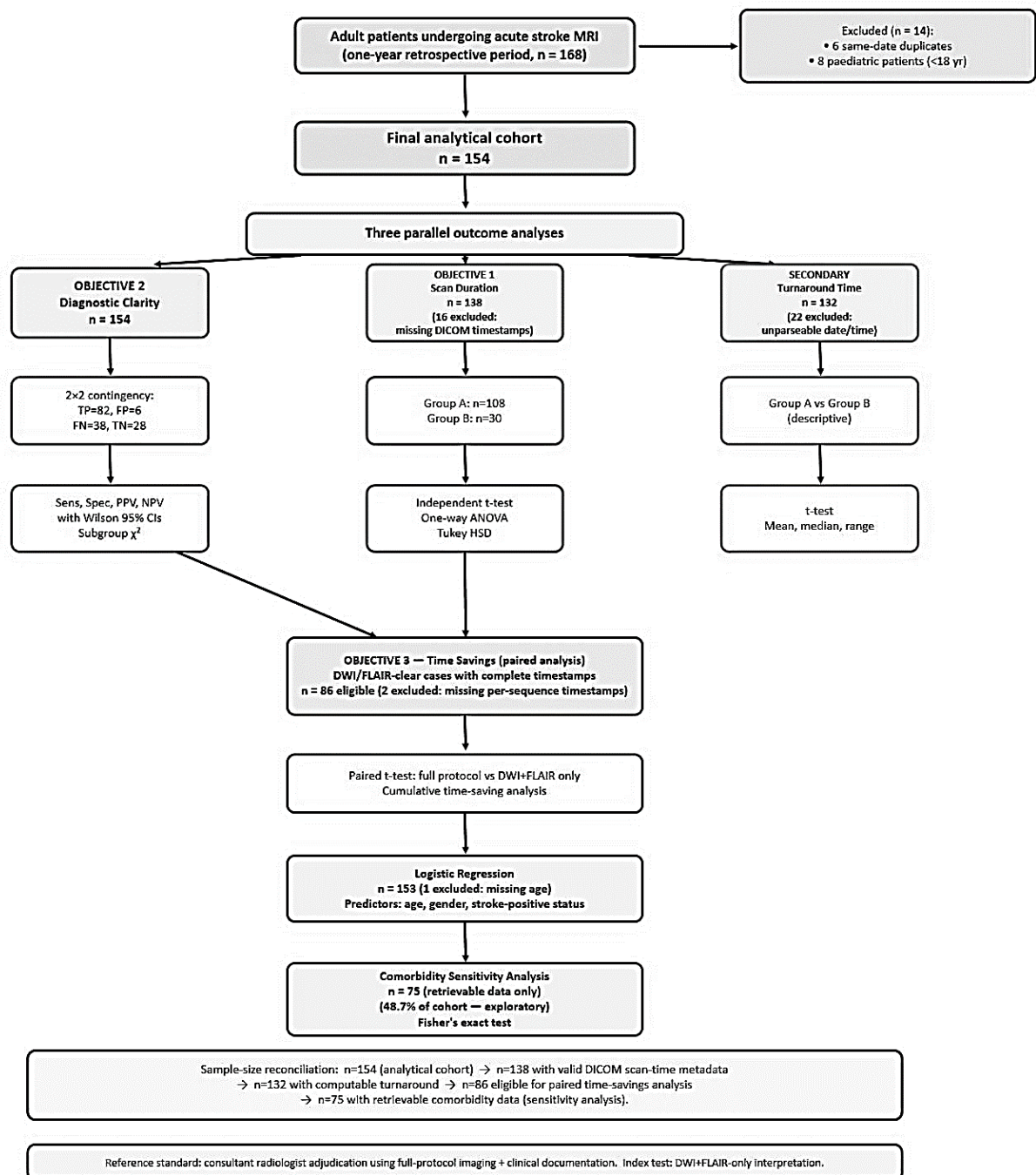


Figure 9. STARD-compliant patient flow diagram

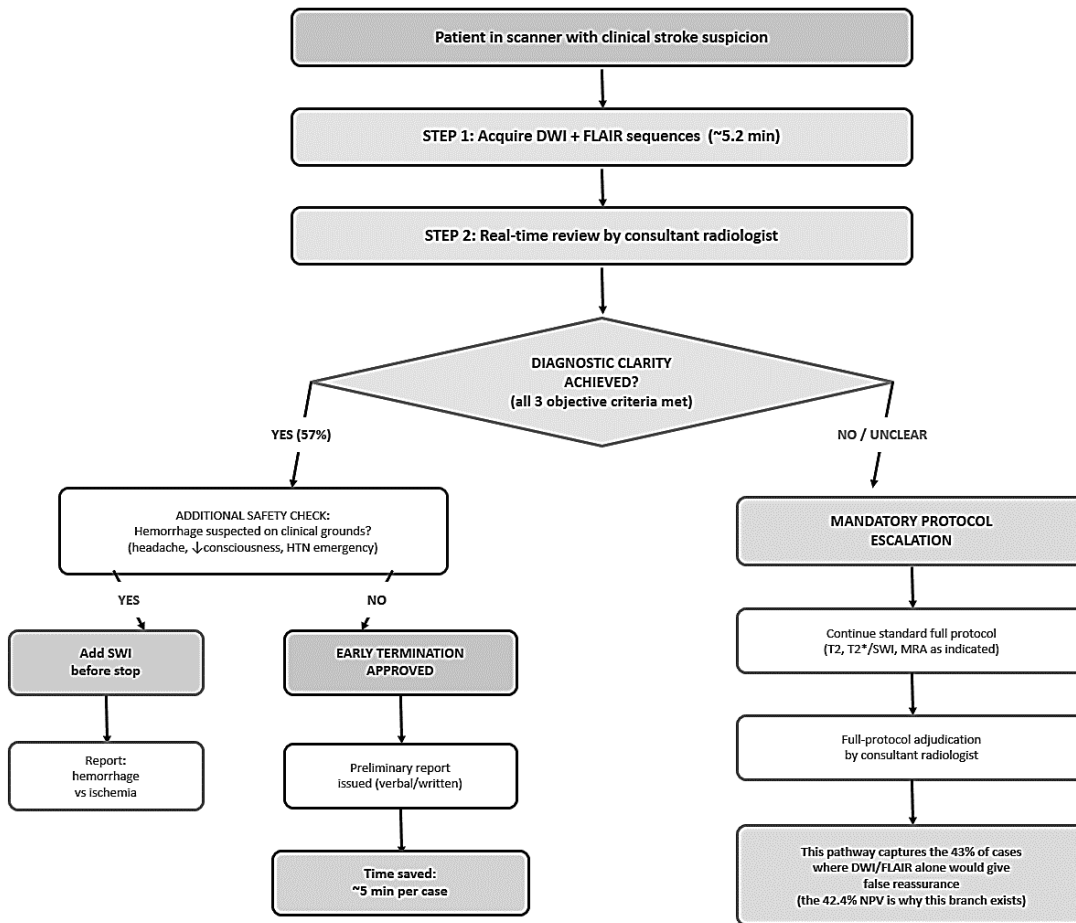
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Figure 9 caption: Patient flow through the study accounting for all inclusions, exclusions, and analytical subsets. Sample sizes reconcile as follows: 168 eligible → 154 analytical cohort (after excluding 6 same-date duplicates and 8 paediatric patients) → three parallel analysis streams (n=154 for diagnostic clarity, n=138 for scan duration with valid DICOM timestamps, n=132 for turnaround with parseable date/time stamps) → n=86 eligible for paired time-savings analysis (clear cases with complete per-sequence timestamps) → n=153 for logistic regression (1 excluded for missing age) → n=75 for comorbidity sensitivity analysis (retrievable data only).

Figure 10 — Clinical Decision Algorithm

DWI/FLAIR-First Early-Termination Pathway for Suspected Acute Stroke

Unclear or negative reads ALWAYS trigger full-protocol continuation (addresses low NPV of 42.4%)



KEY SAFETY PRINCIPLES

1. Framework is a THROUGHPUT tool — not a hemorrhage-exclusion protocol.
2. Unclear or negative DWI/FLAIR ALWAYS triggers full-protocol continuation. No early termination on equivocal reads.
3. Any clinical suspicion of hemorrhage adds SWI even when DWI/FLAIR appears clear.
4. Framework does NOT authorise thrombolysis or thrombectomy decisions on DWI/FLAIR alone.
5. Same-session continuation — patient remains on scanner if escalation is needed; no recall required.

Operationally-relevant metric: PPV (93.2%) applied to the 57% of cases meeting clarity criteria — NOT the NPV applied to the whole cohort.

Figure 10. Clinical decision algorithm — DWI/FLAIR-first early-termination pathway

Figure 10 caption: Proposed clinical decision algorithm operationalising the DWI/FLAIR-first early-termination pathway. The algorithm addresses the low negative predictive value (42.4%) by mandating full-protocol continuation for every unclear or negative DWI/FLAIR read; no termination decision is made from a negative read. Early termination is permitted only for cases meeting all three objective clarity criteria (localisation, aetiology, confidence $\geq 4/5$) AND without clinical hemorrhage suspicion. Any hemorrhage suspicion triggers SWI retention regardless of DWI/FLAIR clarity. The framework operates as a positive-triage tool governed by the positive predictive value (93.2%) applied to the eligible subset, and is not applicable to acute reperfusion decision-making.

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