Clinical Features And Neuroimaging Findings In Acute Cerebral Infarction Patients Using RAPID Artificial Intelligent (RAPID AI) Software Analysis – A Series Of 54 Cases

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Abstract

Background: Stroke is the second leading cause of death and the leading cause of permanent disability globally. Vietnam is a developing country with a high prevalence of stroke but is under-resourced in terms of specialist staff able to interpret complex brain imaging.

Methods: A case series of 54 stroke patients admitted between October 2019 and October 2020 where thrombectomy was being considered and where 'Rapid' Artificial Intelligence (AI) was used to analyze images of stroke.

Results: The mean age of patients was 73.39 ± 12.46 years with 57% male. The most common risk factors were (76%), atrial fibrillation (24%), diabetes (20%), alcohol (15%), and smoking (9%). The most common clinical signs were hemiparesis in 76% of the patients, followed by dysphasia in 50% and memory loss in 28% of the sample. 7% presented with dizziness and 7% with headache. 6% were unconscious on admission. ASPECTS evaluation showed that 24 (44%) patients had good ASPECTS scores of 8-10, 17 (32%) patients had ASPECTS scores of 5-7, and 13 (24%) patients had ASPECTS scores of 0-4. The number of patients with an infarct core volume <70 mL was 50 (93%), while a mismatch volume of >15 mL was observed in 31 (55%) patients and 22 (41%) patients had a mismatch ratio >1.8 . The assessment of CT imaging of thrombi showed 51 cases of anterior cerebral circulation, including 13 (24%) cases diagnosed as ICA, 30 (76%) cases diagnosed as MCA, and 8 (15%) cases diagnosed as SA. There were 10 cases of MCA-M1 (19%), 7 cases of MCA-M2 and MCA-M4 (13%) cases and 6 cases of MCA-M3 (11%), respectively. There were three cases of posterior cerebral circulation, comprising Posterior Cerebral artery (PCA) infarction and two cases of Basilar Artery (BA) territory infarction.

Conclusions: RAPID Artificial Intelligent (RAPID AI) Software Analysis combined with clinical assessment can be used in identify the size and site of cerebral infarction and diffusion perfusion mismatch in routine clinical practice in Vietnam.

Background

Stroke is the second leading cause of death and the leading cause of disability globally [1]. In recent years, the burden of stroke associated with mortality, morbidity, and disability has been increasing across the world [2, 3]. Risk factors associated with stroke can be divided into groups of modifiable and nonmodifiable features. The group of modifiable risk factors includes hypertension, smoking, diet, and physical inactivity, while the group of nonmodifiable risk factors comprises age, sex, family history, and race/ethnicity [4].

Vietnam is a developing country with nearly 100,000 million people, and strokes and stroke treatment are a major health burden in Vietnam [2, 5, 6]. About 200,000 people have a stroke each year with a 50% mortality rate, and with only 10% of patients returning to a normal life after stroke [6]. The facilities for the diagnosis and treatment of stroke are limited. The diagnosis of stroke is currently based on clinical

findings combined with computer tomography imaging (CT) or magnetic resonance (MRI), however CT imaging or MRI facilities are not readily available and affordable in all hospitals and access to neuroradiology expertise is very limited.

Phu Tho Provincial General Hospital (GHP) is the leading provincial public hospital and the largest hospital in the northwest of Vietnam. The hospital has 1500 beds and well-equipped facilities for image diagnosis with both modern CT and MRI machines. The stroke center of GHP was established in 2018, containing 150 beds for inpatient treatment of people who suffered acute stroke and who require rehabilitation after stroke. In June 2019, the hospital began to use RAPID artificial intelligent (RAPID AI) software (iSchemaView, USA), for the imaging analysis of stroke characteristics based on an artificial intelligence technique.

This study presents the diagnostic and treatment features of stroke patients based on RAPID AI software assessment in Phu Tho Provincial General Hospital in Vietnam in 2019–2020.

Methods

Study Design

This study was a case series based on the data from electronic medical records of stroke patients admitted to Phu Tho Provincial General Hospital between October 2019 and October 2020, for whom Rapid AI was used to analyze images of stroke. The study was testing the practicability and value of using the technology in routine practice in Vietnam.

Patients

The stroke patients studied in this study had Rapid AI used for the diagnosis and analysis of cerebral images. All patients had CT or MRI scans performed within 24–48 h after the onset of stroke and were being considered for late thrombectomy. Information on the patients was collected using electronic medical records (Fig. 1). All patients gave written informed consent for participation in the study.

Demographic Characteristics

Demographic data collected included age, sex, work status, living area, time onset of stroke, reasons for admission, hospitalization status, treatment duration, and discharge status.

Risk Factors for Stroke and Clinical Presentation

Information concerning risk factors for stroke, including age, sex, hypertension, diabetes, atrial fibrillation, smoking, and alcohol habits, was extracted from the electronic medical record profiles. The smoking habits, alcohol consumption, and onset time were determined in the present study by a neurologist questioning patients and/or relatives who had observed the onset and who were aware of the patient's recent health and clinical characteristics on admission were recorded

Laboratory Investigations

Diabetes was defined as a fasting blood glucose of greater than 7mmol/l or use of hypoglycemic medications, and hyperlipidemia as serum levels of total cholesterol of greater than 5.2 mmol/dl.

Sociodemographic characteristics

Table 1. Sociodemographic characteristics of the studied patients.

Sociodemographic Characteristics		Studied Patients	
		Frequency	Percent
Age	<40	1	1.9
	40–49	1	1.9
	50–59	6	11.1
	60–69	10	18.5
	70–79	21	38.9
	>80	15	27.8
	Mean $\pm$ SD	73.39 $\pm$ 12.46	
Gender	Male	31	57.4
	Female	23	42.6
Work status	Farmers	14	25.9
	Employees	10	18.5
	Retired	23	42.6
	Business work/free work	7	13.0
Living area	Rural	35	64.8
	Town/city	19	35.2
Time from onset to hospital arrival	0–6 h	28	51.9
	6–24 h	24	44.4
	>24 h	2	3.7
Hospital admission status	Consciousness/awareness	23	42.6
	Unconsciousness/unawareness	27	50.0
	Coma	4	7.4
Hospital-discharged status	Better	40	74.0
	Worse	7	13.0
	Died/worst	7	13.0

CT Imaging and Perfusion Imaging Analyzed Based using RAPID AI

On admission, ischemic stroke was diagnosed using clinical findings and brain imaging. The CT perfusion image characteristics were characterized in terms of ASPECTS, infarct core volume, and

mismatch volume. Stroke patients were divided into four categories as follows: total anterior circulation infarcts, partial anterior circulation infarcts, posterior circulation infarcts, and lacunar infarcts. The imaging data of all patients were analyzed independently by two experienced neurologists. Lesions were divided into the following four categories: infarction of the anterior cerebral artery territory, middle cerebral artery territory, posterior cerebral artery territory, and vertebrobasilar artery territory. Cerebral imaging parameters were used to determine the locations of the lesions and then to identify infarctions in either a single vascular territory or multi-vascular territories (vascular territories ≥ 2).

Statistical Analysis

SPSS (version 22.0; IBM Corp., Armonk, NY, USA) was used for data analysis. Descriptive statistics were used to summarize sociodemographic and clinical information as well as subclinical data. Categorical variables were expressed as frequencies and percentages.

Ethics Approval

The study was approved by the Ethics Committee of Phu Tho Provincial General Hospital. The confidentiality of the information regarding patients was ensured in such a way that the data could only be used for the study purpose. The information obtained from the patients' electronic medical records is also presented only in a collective manner.

Results

Patient Characteristics

In total, 54 electronic medical records of patients diagnosed with ischemic stroke were identified. The age range of the 54 ischemic stroke patients was from 18 to 95 years of age. The mean age of the patients was 73.39 ± 12.46 years old, and the majority of patients (85.2%) were in the age group of > 60 years old. Male patients comprised 31 (57.4%) of the total patients. The majority of the patients were retired (42.6%) and living in rural areas (64.8%). The time from onset to hospital arrival ranged from 0–6 h for 28 patients (51.9%), from 6 to 24 h for 24 patients (44.4%), and beyond 24 h for 2 patients (3.7%). Patients admitted to hospital were mostly in states of unconsciousness (50.0%) and coma (7.4%), while 42.6% of patients were conscious. The number of patients discharged from the hospital who had made some recovery was 40 (74.0%), while 7 (13%) patients became worse or died (Table 2).

Risk Factors and Clinical Presentations of the Studied Patients

The most commonly identified risk factor was hypertension (75.9%) followed by atrial fibrillation (24.1%), diabetes (20.4%), alcohol (14.8%), and smoking (9.3%). 76% of patients had hemiparesis 50% dysphasia 28%. memory loss, 7% dizziness, and 7% headache. 5.6% of stroke patients had a poor prognosis with unconscious and near-death presentations (Table 3).

Table 3. Risk factors and clinical characteristics of the studied patients.

Risk Factors and Clinical Characteristics		Studied Patients (N=54)	
		Frequency	Percentage
Hypertension	Yes	41	75.9
	No	13	24.1
Diabetes	Yes	11	20.4
	No	43	79.6
Atrial fibrillation	Yes	13	24.1
	No	41	75.9
Smoking habits	Yes	5	9.3
	No	49	90.7
Alcohol habits	Yes	8	14.8
	No	46	85.2
Clinical presentations	Hemiparesis	41	75.9
	Memory loss	15	27.8
	Dysarthria	27	50.0
	Dizziness	4	7.4
	Headache	4	7.4
	Unconsciousness	3	5.6
	Nearly died	3	5.6

High blood pressure was seen in 48 (88.9%) of the 54 recorded stroke patients, the median systolic blood pressure was 151.22 ± 22.9 mmHg. The red blood cells of male and female patients mostly showed normal concentrations at 77.4% and 82.6%, respectively. Similarly, 45 (83.3%) patients were normal in terms of their triglyceride level and 9 (16.7%) patients were high in triglyceride. A prevalence of elevated blood glucose was observed in 40.7% patients, while the prevalence of high cholesterol was 33.3%. 3 (5.6%) patients had a low platelet count. Only two (3.7%) patients were high in INR, while most of the studied patients (96.3%) had a normal INR (Table 4).

Table 4. Distribution of patients' laboratory results.

Characteristics		Studied Patients			
		Low	Normal	High	Mean $\pm$ SD
Blood pressure		1 (1.9%)	5 (9.3%)	48 (88.9)	151 $\pm$ 23 mmHg
Red blood cells (Tera/L)	Male	6 (19.4%)	24 (77.42%)	1 (3.23%)	4.94 $\pm$ 0.68
	Female	2 (8.7%)	19 (82.6%)	2 (8.7%)	4.3 $\pm$ 0.46
Blood glucose (mg/dL)		2 (3.7%)	30 (55.6%)	22 (40.7%)	2.37 $\pm$ 0.56
Cholesterol (mg/dL)		10 (18.5%)	26 (48.1%)	18 (33.3%)	2.14 $\pm$ 0.71
Platelet count		3 (5.6%)	51 (94.4%)	0	1.94 $\pm$ 0.23
INR		0	52 (96.3%)	2 (3.7%)	1.04 $\pm$ 0.19
Triglyceride		0	45 (83.3%)	9 (16.7%)	1.58 $\pm$ 0.85

3.3. CT Perfusion Images Based on RAPID AI Analysis

The distribution of the ASPECTS score is given in Table 5. Only 4 (7.4%) patients had an infarct core volume greater than 70 mL compared to 50 (92.6%) patients with an infarct core volume smaller than 70 mL. The mismatch volume was greater than 15 mL in 31 (54.7%) patients, while 23 (45.3%) patients had a mismatch smaller than 15 mL. In total, 32 (59.3%) patients had a mismatch ratio under 1.8, but 22 (40.7%) patients had a mismatch ratio over 1.8 (Table 5).

Table 5. Distribution of studied patients based on the RAPID AI perfusion analysis.

Radiological measures		Time from Onset to Hospital			Frequency
		0–6 h	6–24 h	>24 h	
ASPECTS	8–10 (good)	14 (50%)	10 (41.7%)	0	24 (44.4%)
	5–7 (bad)	8 (28.6%)	9 (37.5%)	0	17 (31.5%)
	0–4 (worst)	6 (21.4%)	5 (20.8%)	2 (100%)	13 (24.1%)
	Total	28 (100%)	24 (100%)	2 (100%)	54 (100%)
Infarct core volume	<70 mL	26 (92.9%)	23 (95.8%)	1 (50%)	50 (92.6%)
	≥0 mL	2 (7.1%)	1 (4.2%)	1 (50%)	4 (7.4%)
	Total	28 (100%)	24 (100%)	2 (100%)	54 (100%)
Mismatch volume	<15 mL	14 (50%)	7 (29.2%)	2 (100%)	23 (45.3%)
	≥15 mL	14 (50%)	17 (70.8%)	0	31 (54.7%)
	Total	28 (100%)	24 (100%)	2 (100%)	54 (100%)
Mismatch ratio	<1.8	19 (67.9%)	12 (50%)	1 (50%)	32 (59.3%)
	≥1.8	9 (31.1%)	12 (50%)	1 (50%)	22 (40.7%)
	Total	28 (100%)	24 (100%)	2 (100%)	54 (100%)

In our study, we observed 51 cases of anterior cerebral circulation including 13 (24.07%) cases that were due to ICA occlusion, 30 (75.93%) cases diagnosed as MCA occlusion, and 8 (14.81%) cases diagnosed as Small Artery occlusion (SA). Of these, the number of cases of MCA-M1 was 10 (18.5%), the number of cases of each MCA-M2 and MCA-M4 was 7 (13%), and the number of cases of MCA-M3 was 6 (11%), respectively. There were only three cases of posterior cerebral circulation, including one (1.9%) case of PCA and two (3.7%) cases of BA. In total, 28 stroke patients were admitted to the hospital within the first 6 h after onset, and 24 patients were admitted within 6 to 24 h. Only two patients were admitted beyond 24 h (Table 6).

Table 6. Cerebral occlusive position based on the RAPID AI analysis ($n = 54$).

Occlusal Position		Time from Onset to Hospital Admission			Frequency
		0–6 h	6–24	>24 h	
Anterior cerebral circulation (<i>n</i> = 51)	MCA-M1	6 (21.4%)	4 (16.7%)	0	10 (18.5%)
	MCA-M2	3 (10.7%)	3 (12.5%)	1 (50.0%)	7 (13%)
	MCA-M3	3 (10.7%)	2 (8.3%)	1 (50.0%)	6 (11%)
	MCA-M4	3 (10.7%)	4 (16.7%)	0	7 (13%)
	ICA	7 (25.0%)	6 (25.0%)	0	13 (24%)
	SA	5 (17.9%)	3 (12.5%)	0	8 (14.8%)
Posterior cerebral circulation (<i>n</i> = 3)	PCA	1 (3.6%)	0	0	1 (1.9%)
	BA	0	2 (8.3%)	0	2 (3.7%)
Total		28 (100%)	24 (100%)	2 (100%)	54 (100%)

The cerebral occlusive position M1: spheroidal or horizontal segment; M2: insular segment; M3: opercular segment; M4: cortical segment; PCA: posterior cerebral artery; ICA: internal carotid artery; SA: small artery; BA: basal artery.

Discussion

Phu Tho Provincial General Hospital was the first hospital in to Vietnam introduce RAPID AI technology for the diagnosis and treatment of stroke patients. This study presents the results of the diagnosis and treatment of stroke patients for whom RAPID AI combined with neuroimaging was used for the detection, characterization, and prognostication of acute strokes. AI technology is a rapidly developing field and represents a promising avenue for fast and efficient imaging analysis [7]. RAPID AI has been approved and certified by the FDA for perfusion imaging and is currently used in 50 countries. RAPID AI software can be used for perfusion imaging in stroke. The RAPID AI software was validated in the DEFUSE 2 study in 2012 and received FDA approval in 2013 [8]. RAPID software analyzes CT and MRI perfusion within 3 minutes and generates colorimetric perfusion maps of stroke penumbra as well as the core mismatch volume and mismatch ratio [9]. The penumbra mismatch sensitivity is 100% and specificity is 91% [10–13]. RAPID AI technology was used in the recent large LVO ET trials EXTEND IA, SWIFT PRIME, CRISP, DEFUSE 2 and 3, and DAWN [8, 10, 14–16].

Stroke incidence increases with age and is more common in males [17]. The analysis of this cohort of 54 patients' electronic medical records were the first to be assessed using AI in Phu Tho Provincial General Hospital, Vietnam from October 2019 to June 2020. The results of our study agree with those of previous

studies in terms of demographic characteristics conducted by Albers et al. in Gondar University Hospital [18], Tirschwell et al. in Danang Hospital [19], and Yue in China [20] 21].

The time from symptom onset to hospital arrival (time to hospital) is a key factor for delivering effective treatment and improved outcomes of stroke patients, especially for patients with ischemic stroke. Our results for time to hospital showed that about half of patients arrive after six hours and are therefore less likely to be eligible for reperfusion treatment. If outcomes are to improve in Vietnam the systems for prehospital care in terms of patient and population awareness of the symptoms of stroke and emergency medical services need to improve. The patients who do present are predominantly very severe stroke with over half having reduced levels of consciousness. These results were similar to those of a study in Hong Kong [22] and Shanghai [23], which showed that 56.3% and 51.9% of patients arrived at a hospital within 6 h after the first symptom of stroke. Previous studies have presented a median arrival time that varied from 2.51 to 15 h [24]. However, studies on the time to hospital of patients in European countries reported that the majority of patients arrived within 3 h of onset, earlier than in Asian countries, which is due to the higher rate of ambulance transport of stroke patients and better stroke awareness knowledge in these countries [25].

In our study, we found that the most common risk factor was hypertension, identified in 75.9% of patients, followed by atrial fibrillation in 24.1% of patients, and diabetes in 20.4% of patients. These results align with previous studies indicating that uncontrolled hypertension is the most important risk factor for stroke in developing and developed countries [26]. This may reflect the fact that hypertension has been identified as the most prevalent modifiable risk factor and is a powerful modifiable risk factor. On the other hand, the numbers of stroke patients with smoking and alcohol habits in this study were lower (< 15%) than in other studies, [27].

Hemiparesis and dysarthria were two of the most common clinical presentations of stroke in our study, at 75.9% and 50% of the total, respectively. This is similar to cohorts reported from Egypt [28] and India [29], which showed that 76.1% of patients had hemiparesis and 60% of patients had dysarthria. Memory loss commonly occurs as a result of stroke and was observed in 27.8% of patients in our study. Other investigators have reported a dementia incidence of approximately 25% at 3 months after ischemic stroke. In the current study, a small number of patients suffered from dizziness and headache (7.4%), and unconsciousness and near death (5.6%). These results also agree with the results of El Tallawy [28].

There was a variety in the laboratory tests requested as this depends on the stroke clinicians rather than a formal protocol. In our study, the laboratory tests included BP, RBC, BG, cholesterol, PC, INR, and triglyceride. These tests were examined to evaluate patients before the administration of tPA. Some of the tests are necessary to determine suitability for intravenous thrombolysis but some are often unnecessary and just delay commencement of acute treatments. [32].

The application of RAPID AI to read CT perfusion images was first applied in Phu Tho Provincial General Hospital, Vietnam, in June 2019. RAPID AI technology processing takes within 3 minutes to send the results of ASPECTS, infarct core volume, mismatch volume, and mismatch ratio to PACS and RAPID

mobile apps. This application was developed by an experienced neurologist, Greg Alber [33]. The ASPECTS is a 10-point quantitative topographic CT scan score used for patients with middle cerebral artery (MCA) stroke [34]. Our study showed the ASPECTS score was good in 44.4% of patients, compared with 31.5% showing a bad score and 24.1% showing the worst possible score. The assessment of the ASPECTS score has been used to direct therapies. Those with a low ASPECTS score, suggesting a large MCA infarction, can be excluded from futile intra-arterial treatments, which are unlikely to result in patients gaining functional independence and increase the risk of hemorrhage [34]. The infarct core volume shows the part of the AIS which was already infarcted or was irrevocably destined to infarct regardless of reperfusion [35]. The inclusion criteria used to select patients eligible for interventional thrombectomy in the case of patients admitted to hospital within or beyond 6 h onset include an initial infarct volume of < 70 mL, a ratio of ischemic penumbra to infarct core of ≥ 1.8 , and an absolute mismatch of ≥ 15 mL [36, 37]. Our results showed that the majority of patients had an infarct core volume of < 70 mL, at 50 (92.6%) patients; a mismatch volume of > 15 mL was observed in 31 (54.7%) patients, and 22 (40.7%) patients had a mismatch ratio of > 1.8 . Previous studies have indicated that the automated RAPID AI system is sufficiently accurate and fast to be used for routine care as well as in clinical trials [11, 38]. The evidence of using RAPID showed the diffusion–perfusion mismatch identified by RAPID was in agreement with the observation of a human reader in 60 cases (95.2%) and in disagreement in 3 cases (4.8%, 3 false positives) [11]. RAPID was able to identify mismatches with 100% sensitivity and 91% specificity (false positive rate = 9.1%, false negative rate = 0%) in analyses with the observations of the human reader as a ground truth [11].

The RAPID software enabled information about the location, size, and whether there was any potentially salvageable brain enabling the physicians to make decisions on the suitable treatment, whether thrombolysis or thrombectomy [39]. The diagnostic evaluation of occlusive thrombi on noninvasive studies now constitutes an integral component of acute stroke management [39]. In a hospital with limited access to neuroradiology 24 hours a day, seven days a week, such a facility is of critical importance and has huge potential to improve the quality of clinical care in hospitals and countries with limited resources. Clearly, this needs to be combined with improving public awareness that stroke is a treatable condition if they get to hospital quickly after the onset of symptoms, and an improved emergency medical service. The current poor outcomes with a 50% mortality and only 10% making a full recovery are unacceptable. Using modern technology such as RAPID or similar artificial intelligence systems will be important to improve outcomes.

Conclusions

The majority of studied patients in this study had severe stroke and presented late. While work is needed to improve prehospital care the value of artificial intelligence software to identify which patients might still benefit from reperfusion will be important, particularly in resource poor settings to improve the quality of care and outcomes. This is the first study to present results on the diagnostic and treatment features of stroke patients in Vietnam for whom RAPID AI was used for their screening and management.

Declarations

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Author Contributions: N.N.H. and H.M.V. designed the study, analyzed the data, and wrote, edited, and reviewed the manuscript. N.A.Q., N.T.V, and T.L.Q. performed the experiments, acquired and analyzed the data. A.R and T.N.M.N wrote, edited, and reviewed the manuscript. All authors have read and agreed to the published version of the manuscript.

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Ethics declarations

Ethics approval and consent to participate

The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of Phu Tho General Hospital (Decision of 1533/QĐ-BV on October 05, 2018)

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Data Availability Statement: All relevant data are available in the article and/or supplemental file. Due to privacy and other restrictions, the primary data cannot be made openly available. Details about requesting access to the data are available from the corresponding author.

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Table 2

Table 2 is not available with this version

Figures

Figure 1

Flow diagram of the study and selected eligible patients based on RAPID