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Effect of Perfusion CT on Time Required to Evaluate Indications for Thrombectomy for Acute Cerebral Infarction

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Background: Rapid treatment of patients with emergency large vessel occlusion (ELVO) improves outcomes. With Vitrea software, the cerebral infarct size and penumbra can be quantified, and 4D images can be constructed quickly. We investigated the performance of Vitrea in ELVO patients.

Methods: To evaluate indications for mechanical thrombectomy, we performed plain brain CT, then MRI (group 1, n=30). In May 2022 we acquired perfusion CT scans with Vitrea after plain CT on the same equipment (group 2, n=27) and then compared time from onset to the end of mechanical thrombectomy. At 1 month post-treatment we recorded the neurological outcome by using the modified Rankin scale (mRS). We also compared the infarction areas identified with Vitrea and MRI the day after treatment using DWI-ASPECTS in 25 of 27 patients in group 2. We excluded 2 patients with basilar artery occlusion because this type of occlusion is not included in DWI-ASPECTS.

Results: There were no significant intergroup differences in patient characteristics, time from admission or puncture to re-canalization, and outcome 1 month after treatment. Vitrea overestimated the infarct area in 1 of 25 patients (4.0%). Times from admission to transit for examination, to the examination end, and time from admission to puncture, were significantly shorter in group 2.

Conclusions: In ascertaining indications for thrombectomy in patients with acute cerebral stroke, perfusion CT with Vitrea shortened time to treatment. However, further investigation is needed to confirm the accuracy of Vitrea in determining the infarct area. (J Nippon Med Sch 2025; 92: 97–103)

Key words: perfusion CT, mechanical thrombectomy, emergency large vessel occlusion, embolization, ischemic stroke

Introduction

Emergency large vessel occlusion (ELVO) involving the internal carotid artery (ICA) or the middle cerebral artery (MCA) results in severe neurological symptoms and poor functional outcomes[1–4]. Functional prognosis can be improved by early recanalization via endovascular treatment[5,6]. Because delayed treatment risks bleeding complications and reperfusion injury, the time from vessel occlusion to reperfusion must be short[5,7]. Vitrea software uses the results of intracranial contrast-enhanced CT to analyze cerebral blood flow and volume to quantify the infarct area and intact areas vulnerable to infarction[8].

Vitrea also enables construction of 4D images of intracranial blood vessels, thereby facilitating identification of occluded vessels. The process of analyzing and constructing the penumbra and area of cerebral infarcts plus the acquisition of 4D-CT angiographs takes 2 minutes. According to Jenson et al.[9], Vitrea software shortens the time to treatment, although identified cerebral infarcts may include areas not yet infarcted. Consequently, patients likely to benefit from treatment may be classified as treatment-ineligible by Vitrea, and overestimation of the ischemic core remains a challenge[10].

We investigated the diagnostic accuracy of Vitrea in

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https://doi.org/10.1272/jnms.JNMS.2025_92-115
Journal Website (https://www.nms.ac.jp/sh/jnms/)

patients with cerebral infarcts and examined its effect on reducing time to treatment and predicting the functional outcomes of patients who underwent mechanical thrombectomy for cerebral artery occlusion.

Patients and Methods

Our study was approved by the ethics committee of Chiba Hokusoh Hospital, Nippon Medical School (No. H-2023-052). Because patients could opt out on our hospitals' homepages, written informed consent for inclusion in our study was waived.

Between January 2021 and October 2023, 68 patients with acute major trunk cerebral artery occlusion underwent mechanical thrombectomy. We excluded 11 patients: 6 patients with in-hospital stroke onset, 2 who had undergone both perfusion CT and MRI, 1 with vertebral artery occlusion, 1 with posterior cerebral artery occlusion, and 1 with data from plain CT images only.

Indication for Mechanical Thrombectomy

Patients 18 years or older who presented with main artery occlusion of the anterior circulation (ICA or MCA M 1 segment) underwent mechanical thrombectomy. On the basis of earlier reports[11–17] the indications for such treatment were:

(1) A score of at least 6 on the Alberta stroke program early CT score (ASPECTS) on head CT or MRI diffusion weighted images (DWI), a pre-stroke modified Rankin Scale (mRS) score of 0 or 1, and a National Institutes of Health Stroke Scale (NIHSS) score of 6 or higher within 6 hours from stroke onset;

(2) An ASPECTS of 7 or higher on MRI DWI scans or a mismatch between the ischemic core volume on perfusion images and neurological symptoms or a perfusion delay on such images, a pre-stroke mRS score of 0 or 1, and a NIHSS score of 10 or higher within 24 hours before the stroke;

(3) Evidence of widespread ischemia with an ASPECTS score less than 6, a NIHSS score less than 6 or cerebral infarction with a pre-onset mRS score of 2 or higher.

Patients with these indications recorded within 6 hours from stroke onset were considered eligible for treatment. On the basis of symptoms and imaging findings obtained within 6 hours from stroke onset, patients with occlusion of the M2 portion of the MCA underwent mechanical thrombectomy. Patients with basilar artery occlusion and a pre-stroke mRS score of 0 or 1, an NIHSS score of 10 or higher, and a posterior circulation-ASPECTS of 6 or higher also underwent the procedure within 24 hours of stroke onset.

When perfusion CT confirmed impairment of the eloquent area (motor or language area) by the infarct that resulted in aphasia or paresis, we considered the patient ineligible for mechanical thrombectomy even within 24 hours of symptom onset. Patients with vertebral artery and posterior cerebral artery occlusion were excluded.

To confirm that mechanical thrombectomy was indicated, we first acquired a plain brain CT scan in 30 group 1 patients and then performed MRI (DWI + FLAIR + MRA; total imaging time, 6.5 minutes).

After its introduction in May 2022, perfusion CT scans using Vitrea software were acquired (group 2, n =27). Using the same equipment as in group 1, we first performed plain CT and then perfusion CT with Vitrea. The latter procedure required for image acquisition and analysis totaled 2 minutes (1 minute each) and was the first-choice diagnostic method for patients with suspected ELVO. In patients for whom perfusion CT was impossible because of contrast allergy or renal dysfunction, we used the diagnostic protocol employed in group 1. At our hospital the imaging suites and emergency outpatient area are located close to each other.

For fluoroscopy-guided mechanical thrombectomy we inserted a sheath from the femoral or brachial artery, using a guiding catheter with a stent retriever and/or suction catheter[18]. Combined techniques are our first choice. Immediately after treatment, a brain CT scan was acquired to confirm intracranial hemorrhage, and an MRI scan was performed on the next day to assess the infarction area, the presence of a hemorrhagic component, and the patency of the main arteries. Determination of stroke type relied on these findings, and antithrombotic therapy was started.

We compared time from symptom onset to recanalization and from puncture to recanalization in the 2 groups. When time of onset was unclear we recorded the point just before stroke manifestation as the time of onset. Neurological symptoms were compared on the pre- and post-treatment NIHSS, and treatment outcome was obtained by referring to the pre-treatment mRS and the mRS recorded 1 month after mechanical thrombectomy.

To examine whether Vitrea software overestimated the size of the ischemic core, we used DWI-ASPECTS to determine whether infarcts identified by Vitrea at the time of admission were also identified by MRI (DWI, FLAIR, T2*, T2, MRA, ASL) on the first post-treatment day. Two patients with basilar artery occlusion were excluded because this type of occlusion is not included in DWI-ASPECTS.

Table 1 Patient characteristics

	Group 1	Group 2	p value
Number of patients	30	27	
Males	20 (67%)	14 (52%)	ns
Females	10 (33%)	13 (48%)	ns
Age (mean)	74	77	ns
NIHSS (mean)	17	18	ns
Occlusion site		ns	
ICA+M1/BA/M2	26/3/1	25/2/0	ns
Cause of infarction			
Cardiogenic	60%	63%	ns
Atherosclerosis	27%	26%	ns
ESUS	7%	0	ns
Trousseau syndrome	3%	4%	ns
Dissection	3%	7%	ns
Stroke onset to admission (minutes)	200	233	ns

ICA, internal cerebral artery; BA, basilar artery; NIHSS, National Institutes of Health Stroke Scale; ESUS, embolic stroke of undetermined source; ns, not significant

Table 2 Intervals (in minutes) from admission to examination: time from admission to the emergency department to arrival in the examination room

	Group 1	Group 2	p value
Number of patients	30	27	
Stroke onset to puncture	232	287	ns
Admission to examination	27	10	<0.001
Admission to end of examination	44	22	<0.001
Admission to puncture	81	54	<0.001
Admission to re-canalization	129	113	ns
Puncture to re-canalization	48	61	ns

ns, not significant

Statistical analysis was performed with IBM SPSS for Windows ver. 25.0 (IBM Corp., Armonk, NY, USA). Pre- and post-treatment scores were evaluated with the Wilcoxon signed-rank test, and the Mann-Whitney *U*-test was used for intergroup comparisons. A p value of <0.05 was considered statistically significant. All values were expressed as mean ± standard deviation.

Results

In this study 30 patients were in group 1 and 27 in group 2. There were no patients who, after the introduction of Vitrea, could not undergo perfusion CT because of contrast allergy or renal dysfunction.

There was no significant intergroup difference in any patient background characteristic (**Table 1**). The intervals from admission to puncture and admission to examination (i.e., time from admission to the emergency department to transit to the examination room) were significantly shorter in group 2. However, the intervals from admission to recanalization and from puncture to recanalization were not significantly different, and the intervals from stroke onset to admission and from onset to puncture did not significantly differ (**Table 2**). There was no significant intergroup difference in patient outcome at 1 month post-treatment (**Table 3**). As shown in **Figure 1**, Vitrea overestimated infarct size in 1 of the 25 patients in group 2 (4.0%).

Discussion

MRI scans can be affected by metals in or on the body[19], as the heat they generate increases opacity[19–21]. To avoid this, we carefully evaluate each patient for such issues before the procedure. Because accurate information cannot be obtained from patients with impaired conscious-

Table 3 Post-treatment outcomes

	Group 1	Group 2	p value
Number of patients	30	27	
Successful recanalization TICI grade 2B + 3	28 (93%)	20 (74%)	ns
mRS after 1 month (mean)	2.9	3.3	ns
0 - 3	14 (47%)	13 (48%)	ns
4 - 5	16 (53%)	14 (52%)	

ns, not significant; mRS, modified Rankin Scale; TICI, thrombolysis in cerebral infarct

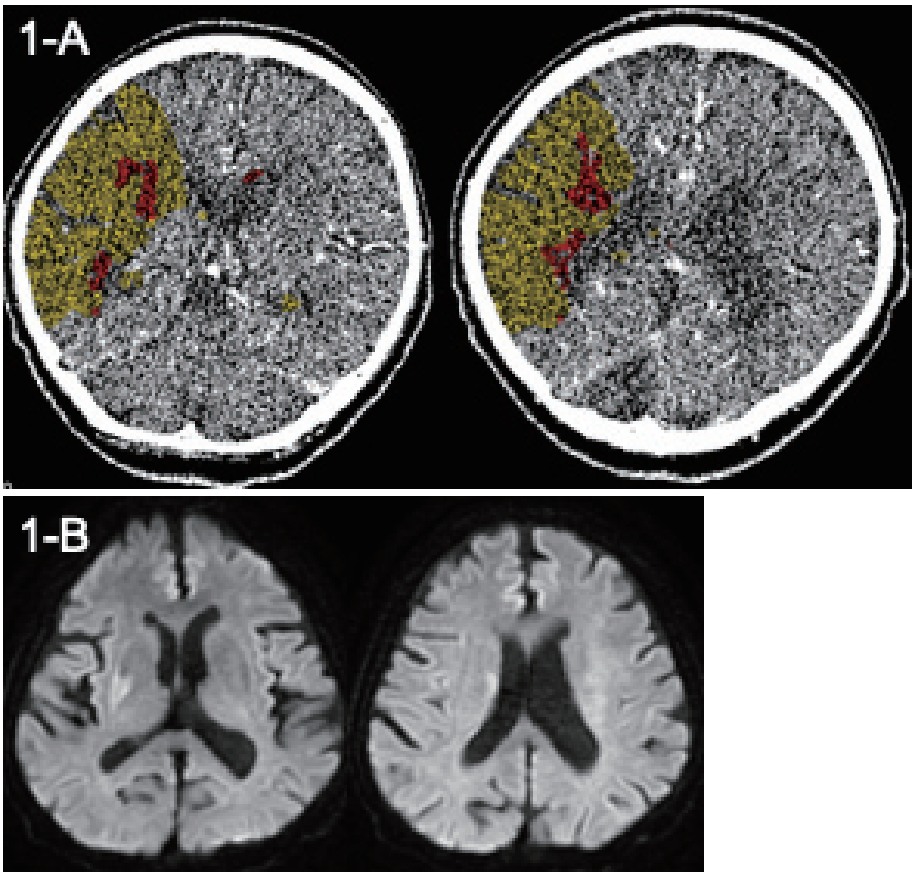

Fig. 1 Overestimation of the infarct area by Vitrea software
A: On a CT perfusion scan, there is an increase of 8 points (lens nucleus, insula, and corona radiata).
B: On an MRI scan obtained the next day, there is an increase of 9 points (lens nucleus and corona radiata).

ness[9], we obtain chest and abdominal X-rays to determine whether metals are present, despite the time required. This significantly increased time from admission to examination in group 1. To evaluate renal function before contrast perfusion CT, we perform blood-gas tests. To avoid hypersensitivity reactions, we use non-ionic contrast media, which reportedly elicited mild immediate reactions in 0.7-3.1%, severe immediate reactions in 0.02-0.04%[22–25], and delayed allergies in 0.42-14.3% of individuals[26]. Patients with asthma or other suspected risk factors for contrast allergy are premedicated with antihistamines and steroids before contrast examinations. During this study no patient had a severe drug allergy. Prior informed consent for the use of contrast media was provided by the patients or their legal representatives.

The radiation exposure from our head perfusion CT scans was approximately 3.3 mSv, i.e., less than the exposure from 2 regular plain head CT scans. Acquisition of

brain MRI scans (DWI, FLAIR, MRA) in our stroke patients took 6.5 minutes; perfusion CT imaging required about 1 minute and image analysis required 1 minute.

As in other studies[9], the time from stroke onset to mechanical thrombectomy was significantly shorter in patients who underwent perfusion CT using Vitrea software (group 2).

In the CLEAR study[27], 15 centers in 5 countries (1,530 patients with acute cerebral infarction) participated in evaluating indications for mechanical thrombectomy by using plain CT, perfusion CT, and MRI. Others[28,29] reported that among patients with different backgrounds, perfusion CT was diagnostically superior to MRI. The characteristics of our 2 patient groups were not significantly different, which might explain why the time reduction yielded by Vitrea had no effect on their post-stroke outcomes. Brain T2* MRI helps to identify thrombotic properties and occlusion sites[30], which can help in selecting thrombectomy techniques[31]; perfusion CT alone does not provide sufficient information. We use a combined technique in which both an aspiration catheter and stent retriever are placed for mechanical thrombectomy. We suspect that information obtained from T2* MRI scans would not have changed patient outcomes.

Vitrea defines the area where Tmax is at least 2.2 seconds longer than on the contralateral side and where cerebral blood volume, i.e., the amount of blood (in milliliters) in 100 g of brain tissue, is decreased by 40% or more in the cerebral infarction area. Areas without such findings are considered the non-infarcted salvageable penumbra. Rava et al.[10] compared 81 patients with cerebral infarcts and a pre-thrombectomy diagnosis that involved Vitrea with 110 patients who were treated conservatively. They compared predicted cerebral infarction volume on preoperative perfusion CT with the actual cerebral infarction volume observed on the day after surgery on high-signal DWI MRI scans and found that Vitrea slightly overestimated the infarct area. Although the mean difference in infarct size was 5.8 ± 5.9 mL, the range was −46.9 mL to +58.5 mL, and Vitrea findings included both overestimates and underestimates. While overestimation avoids excluding patients for whom thrombectomy might be indicated, the procedure could increase the risk of cerebral hemorrhage[32]. Rava et al.[8] suggested that underestimation of the infarct area is preferable to overestimation.

Among our 58 patients, none developed neurological sequelae or symptomatic intracerebral hemorrhage associated with the procedure, and we believe that the effect of underestimation was small. Overestimation of the ischemic core might be affected by the interval from symptom onset to the timing of imaging studies and by poor collateral flow.

Factors such as hypoperfusion severity and duration and cellular resistance to ischemia are involved in brain cell infarction[33,34]. Perfusion images determine the ischemic core by analyzing hypoperfusion severity; they do not consider the duration of hypoperfusion. Consequently, the size of the ischemic core may be overestimated when hypoperfusion duration is short[33].

A study that compared the infarct volume identified on perfusion CT scans at the time of admission and MRI scans acquired the next day showed that the infarct volume was significantly overestimated in patients who underwent perfusion CT within 185 minutes of symptom onset[34]. We identified infarct overestimation in a patient who underwent imaging studies within 82 minutes of symptom onset. The overestimation pertained to the basal ganglia, where collateral flow is low[35,36]. In this patient, overestimation of the infarct area changed the DWI-ASPECTS by only 1 point and did not alter the indication for treatment. Because treatment-eligible patients might not undergo thrombectomy because of overestimation by Vitrea, we acquire pre-procedural MRI scans to ensure that thrombectomy is appropriate.

Our study has some limitations. The study sample was small. As we did not include patients with Vitrea findings that contraindicated thrombectomy, we need to compare the characteristics and outcomes of these patients with those of patients who underwent mechanical thrombectomy. In addition, surgeons who operated in the pre-Vitrea era (January 2021 through May 2022; group 1) regularly acquired MRI scans when acute major artery occlusion was suspected. Only surgeons who treated patients thereafter recorded Vitrea findings. Times from admission to puncture and to recanalization were shorter in group 2, but the interval between puncture and recanalization was longer. Recanalization was also less successful in group 2, although the intergroup difference was not significant. After April 2022, only 1 endovascular specialist was available in our department; therefore, the procedures tended to be performed by non-specialists. This may explain the lower rate of successful recanalization in group 2.

Conclusions

In patients with acute cerebral stroke, Vitrea software shortened the interval from stoke onset to mechanical

thrombectomy. Future studies should investigate the accuracy of the infarct area identified by the Vitrea software.

Conflict of Interest: The authors declare no conflicts of interest and no commercial relationships and received no support from pharmaceutical or other companies.

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(Received, August 27, 2024)
(Accepted, October 30, 2024)