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Analysis of the baseline multiphase computed tomographic angiography findings to predict clinical outcomes in patients with middle cerebral artery M1 occlusion treated with mechanical thrombectomy

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PURPOSE

We aimed to evaluate the predictive ability of baseline multiphase computed tomographic angiography (mCTA) findings and the time from symptom onset to imaging in predicting functional outcomes in patients with middle cerebral artery (MCA) M1 occlusion treated with mechanical thrombectomy (MT).

METHODS

A total of 70 patients were evaluated retrospectively. The time between the onset of symptoms and imaging, thrombus density, estimated thrombus length, the Alberta Stroke Program Early CT Score (ASPECTS) on non-contrast CT, collateral circulation (CC), actual thrombus length, and clot burden score were assessed on mCTA images. Patients with a 90-day modified Rankin scale score of 0–2 were categorized as having good outcomes, whereas the others were categorized as having poor outcomes. The mCTA findings of patients with good and poor outcomes were compared, and binary logistic regression analysis was performed to identify independent predictors that could affect clinical outcomes.

RESULTS

The estimated thrombus length, the ASPECTS, thrombus density, clot burden score, and CC grade were not significantly different between patients with good and poor outcomes. The actual thrombus length was shorter in patients with good outcomes than in those with poor outcomes (15.9 mm versus 21.5 mm, $P = 0.001$). Binary logistic regression analysis revealed that actual thrombus length [$P = 0.005$, odds ratio (OR): 0.754, 95% confidence interval (CI): 0.61–0.92] and thrombus density ($P = 0.022$, OR: 1.167, 95% CI: 1.02–1.33) were independent variables for a good outcome. The optimal cut-off value for actual thrombus length was 18.7 mm (area under the curve, 0.74; 95% CI: 0.62–0.86; $P = 0.001$) to predict good outcomes.

CONCLUSION

Higher thrombus density and actual thrombus length shorter than 18.7 mm were associated with good clinical outcomes. However, no significant correlation was found between clinical outcomes and the ASPECTS, CC degree, or clot burden scores.

CLINICAL SIGNIFICANCE

Thrombus length and density are associated with the clinical outcome of patients with MCA M1 occlusion treated with MT who have distal collateral filling sufficient to depict thrombus margins in mCTA.

KEYWORDS

CT angiography, ischemic stroke, mechanical thrombectomy, prognosis, thrombosis

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Stroke is the second leading cause of death, according to 2022 World Health Organization data.[1] The global prevalence of stroke was 93.8 million in 2021, and 69.9 million of those cases were ischemic.[2,3] Strokes secondary to large-vessel occlusions constitute approximately one-third of all acute ischemic stroke cases; however, they have a larger infarct size than those caused by non-large-vessel occlusions.[4,5] Furthermore, large-vessel occlusions cause 60% of dependency and more than 90% of mortality in all cases.[6]

Neuroimaging is fundamental in acute stroke management, as it demonstrates stroke type (hemorrhagic or ischemic), identifies vessel occlusion, and assesses the affected and salvageable brain areas.[7] The American Heart Association/American Stroke Association 2019 update to the 2018 Guidelines for the Early Management of Acute Ischemic Stroke recommends that all patients with suspected acute stroke undergo non-contrast computed tomography (NCCT) or diffusion-weighted imaging for initial evaluation as quickly as possible. The guidelines also recommend non-invasive vascular imaging with computed tomographic angiography (CTA) or magnetic resonance angiography for patients who meet the criteria for mechanical thrombectomy (MT).[8] The ultimate goal of neuroimaging in patients with acute ischemic stroke is to identify those who may safely and effectively benefit from appropriate treatment options, such as intravenous thrombolytic therapy and/or MT.[7-9]

Many studies have been conducted on the utility of neuroimaging findings and scores to predict outcomes in patients with acute stroke.[10-18] These studies use one or more imaging modalities, such as magnetic resonance imaging (MRI), NCCT, single-phase CTA (sCTA), multiphase CTA (mCTA), CT perfusion, or digital subtraction angiography. Different studies have analyzed the possible effect of individual or combined imaging findings and thrombus characteristics on prognosis.[10-18] In some studies, the patient population was heterogeneous in terms of management (intravenous thrombolytics and/or MT or none).[17,18]

The Alberta Stroke Program Early CT Score (ASPECTS) is a 10-point topographic CT scan score developed to predict clinical outcomes in patients with middle cerebral artery (MCA) stroke. It is calculated by subtracting 1 point from the total of 10 points for each region (cortical M1–6 and insula, subcortical lentiform nucleus, internal capsule, and caudate) where early ischemic changes (intraparenchymal hypoattenuation and focal swelling) are detected.[19]

We aim to evaluate the ability of mCTA findings, including the ASPECTS, estimated and actual thrombus length, thrombus density, clot burden score, collateral circulation (CC) status at first admission to the emergency department, and time from symptom onset to imaging, to predict functional outcomes in a selected group of patients who underwent MT for MCA M1 occlusion.

Main points

- Multi-phase computed tomographic angiography is an increasingly important imaging modality in the initial evaluation and management of patients with acute ischemic stroke.
- Thrombus density reflects its structure; erythrocyte-rich thrombus shows higher Hounsfield units than platelet-rich thrombus.
- Thrombus characteristics influence the clinical outcome in patients with acute ischemic stroke.
- The higher thrombus density and shorter thrombus length than 18.7 mm were associated with good clinical outcomes of patients.

Methods

Study design and patient inclusion and exclusion criteria

This study was conducted in accordance with the tenets of the Declaration of Helsinki. This retrospective study was approved by the Ethics Committee of the Ankara Bilkent City Hospital, (approval number: E1-23-4231, date: 1.11.2023). Written informed consent could not be obtained due to the retrospective nature of the study. The medical records of patients who underwent MT between March 2022 and November 2023 were evaluated. Patients with MCA M1 segment occlusion, symptom onset of less than 6 hours, and a standard local mCTA protocol adjusted according to the method described by Menon et al.[20] were included in the study. The mCTA protocol developed by Menon et al.[20] was applied to patients over 18 years of age who presented to the emergency department with stroke-related symptoms within 12 hours of symptom onset. Patients diagnosed at another health center and referred to our hospital for the interventional procedure; those with missing or noisy CT images; undetected actual thrombus length (due to curved vessels and/or poor CC status); occlusion or considerable stenosis of the contralateral MCA; thrombosis of the internal carotid artery (ICA); pre-stroke modified Rankin scale (mRS) score greater than 2; and/or patients younger than 18 years were excluded from the study.

A total of 127 patients who underwent MT between March 2022 and October 2023 were evaluated, and 70 patients who met the inclusion criteria were included in the study (Figure 1).

Imaging procedures

CT scans were obtained using two devices with 128-detector and 64-detector systems (GE Revolution EVO 128 and 64 Slice CT Scanner, GE Medical Systems, Milwaukee, WI, USA). The standard acute stroke CTA protocol, identical for both 128- and 64-detector devices at our institution, included NCCT with 2.5 mm section thickness acquired using the following parameters: 120 kV, 350 mA, 20 mm collimation, 0.6 s/rotation, and pitch 0.531. The mCTA included three phases, each 8 seconds apart. Using the bolus-tracking technique, CTA was acquired by injection of 40–45 mL of contrast material (350 mg/mL iodine), followed by a 20 mL saline chaser via an 18–20 G cannula in the upper limb at a flow rate of 4 mL/s. The arterial phase was obtained from the aortic arch to the vertex using the following parameters: 100 kV, 300 mA, 0.6 s/rotation, 0.984 mm/rotation table speed, and 1.25 mm section thickness. Early and late venous phases were obtained sequentially from the skull base to the vertex, 8 seconds apart from the previous phase, using the same parameters. Scans were reformatted to a 0.6 mm thickness and 10 mm maximum intensity projection (MIP) images. Further image processing and analysis were performed at a remote workstation.

Image analysis

An emergency radiologist with more than 10 years of experience, blinded to clinical findings, analyzed the images on a remote workstation. The density of the thrombus was measured on NCCT images. In 54 of the 70 patients, the thrombus could be differentiated on NCCT, and the estimated thrombus length was measured. In 16 patients, the estimated thrombus length could not be measured because the thrombus was not depicted in the MCA on NCCT images. Patients' ASPECTS were evaluated on narrow window (window width: 40, window level: 30) NCCT images. The mCTA

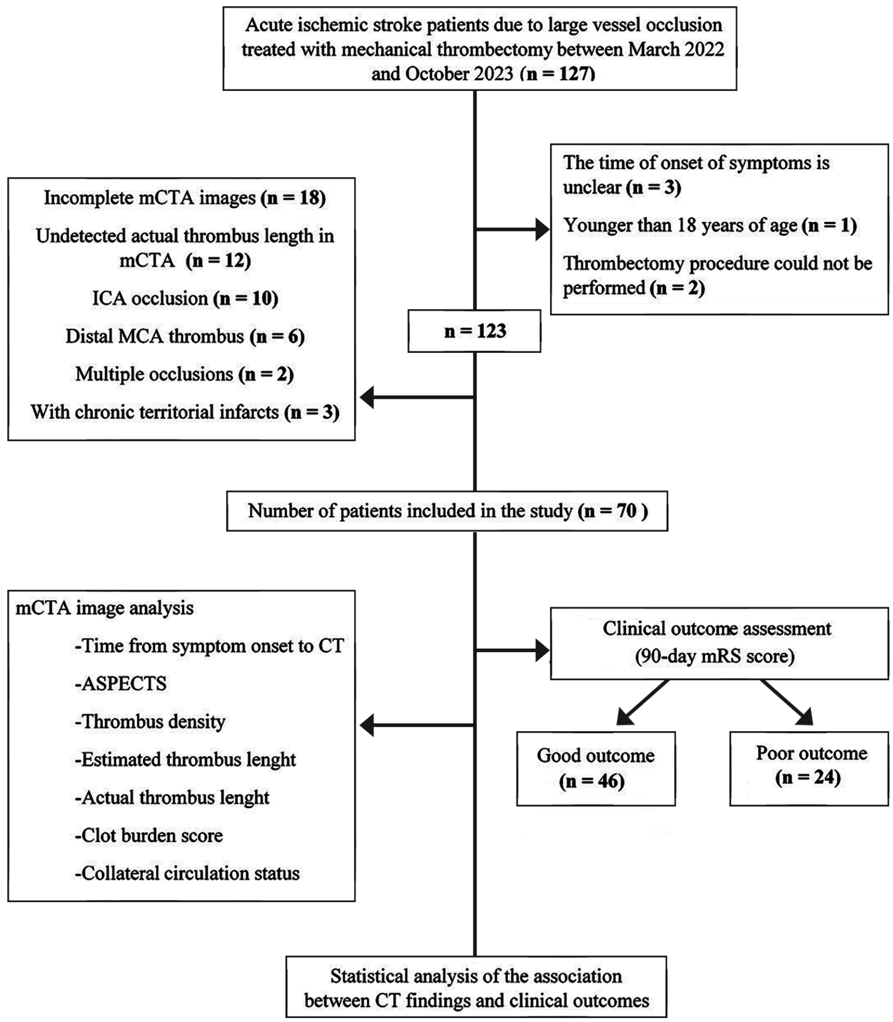

Figure 1. Flowchart of the study. mCTA, multiphase computed tomography angiography; ICA, internal carotid artery; MCA, middle cerebral artery; mRS, modified Rankin scale; ASPECTS, the Alberta Stroke Program Early CT Score.

images were used to measure the actual thrombus length (Figure 2c). Occlusions in curved vessels were calculated on multiplanar reformation images, and when the thrombus extended into branches of the MCA, the longest thrombus length was measured. Based on the pial arterial filling score within the symptomatic ischemic zone, CC status was evaluated on MIP images.[20] Patients were classified as having poor (grade 0–3) or good (grade 4–5) CC. The clot burden score was calculated, and a score of ≤5 was classified as a high thrombus burden.[10]

Assessment of clinical data: patient outcomes

A single neurologist documented patients' demographic data and 90-day mRS scores using electronic medical records. A good clinical outcome was defined as a 90-day mRS score of 0–2, and a poor clinical outcome as an mRS score of 3–6.

Statistical analysis

The demographic, clinical, and radiological characteristics of the patients included in the study were summarized using descriptive statistics. For continuous variables, mean ± standard deviation or median (minimum–maximum) values were used, whereas for categorical variables, frequencies (percentages) were reported.

For intergroup comparisons, the Mann–Whitney U test was applied to continuous variables that did not follow a normal distribution, the chi-square test was used for categorical variables, and for cross-tables with expected value issues, the Fisher exact test was applied for 2 × 2 tables, whereas the Fisher–Freeman–Halton test was used for k × k tables. The threshold for statistical significance was set at $P < 0.05$.

Binary logistic regression analysis was performed to identify independent predictors that could influence clinical outcomes. The dependent variable was defined as an mRS score of 0–2 at 90 days (indicating a good clinical outcome). Independent variables included the time from symptom onset to CTA, the ASPECTS, estimated and actual thrombus length, thrombus density, clot burden score, and patterns of CC. The logistic regression analysis results were reported as β ± standard error, odds ratio (OR), and 95% confidence interval (CI). Model fit was assessed using Cox and Snell R^2 and Nagelkerke R^2 coefficients.

The cut-off value was obtained by applying receiver operating characteristic analysis for the effective numerical independent variables according to the model results. The statistical significance level for regression analysis was set at $\alpha = 0.05$. All statistical analyses were conducted using the Statistical Package for the Social Sciences (IBM SPSS Statistics for Windows, Version 30.0, IBM Corp., Armonk, NY, USA).

Result

Patient characteristics

The mean age of the patients was 68.56 ± 13.99 years, and the number of female (n = 35) and male (n = 35) patients was similar. Successful thrombectomy (thrombolysis in cerebral infarction 2b–3) was achieved in 66 (94.2%) patients. Of the 70 patients, 46 (65.7%) had a good clinical outcome and 24 (34.2%) had a poor clinical outcome. The 90-day mortality rate was 21.4% (n = 15). The mean age of patients was slightly, but not significantly, lower in those with good clinical outcomes than in those with poor clinical outcomes (63.04 ± 13.81 years versus 69.54 ± 14.57 years, $P = 0.590$). There was no significant difference in gender distribution between the two outcome groups [good clinical outcome: women (n = 24), men (n = 22); poor clinical outcome: women (n = 11), men (n = 13); $P = 0.615$]. The comparison of imaging findings between patients with good and poor clinical outcomes is shown in Table 1. The estimated thrombus length was slightly, but not significantly, shorter in patients with good clinical outcomes than in those with poor outcomes (12.8 mm vs. 15.0 mm; $P = 0.359$). Although a poor CC pattern was observed more frequently in patients with poor clinical outcomes than in those with good outcomes, this difference was not statistically significant ($P = 0.232$). A similar pattern was observed in CC subgroups evaluated using the Fisher–Freeman–Halton test ($P = 0.091$). The ASPECTS, thrombus density, and clot burden score were not significantly different between patients with good and poor clinical outcomes. Figures 2 and 3 show the imaging findings of two different patients with good and poor clinical outcomes, respectively. The mean actual thrombus length of the study population was 17.2 (5–36) mm. The actual thrombus length was shorter in patients with good clinical outcomes than in those with poor outcomes (15.9 mm vs. 21.5 mm; $P = 0.001$) (Figure 4).

The binary logistic regression analysis of the prediction of good clinical outcome by time from onset of symptoms to imaging and baseline mCTA findings in patients with MCA M1 occlusion treated with MT is shown in Table 2. With this model, 37.6% of the variation in the dependent variable was explained according to the Cox and Snell calculation, and 51.8% according to the Nagelkerke calculation. The actual thrombus length [$P = 0.005$; OR: 0.754 (95% CI: 0.61–0.92)] and thrombus density [$P = 0.022$; OR: 1.167 (95% CI: 1.02–1.33)] were predictors of good clinical outcomes in patients with MCA M1 occlusion treated with MT. The optimal cut-off value for actual thrombus length was 18.7 mm, with a sensitivity of 72.5% and specificity of 61.8% [area under the curve: 0.74 ± 0.06 (95% CI: 0.62–0.86); $P = 0.001$] (Figure 5).

Discussion

In this study, we found that actual thrombus length and density measured on mCTA images were useful in predicting clinical outcomes in patients with MCA M1 occlusion treated with MT.

The NCCT is used to assess the presence of intracranial hemorrhage, well-established hypodense ischemia (ASPECTS), and hyperdense vessel signs in patients with suspected acute ischemic stroke, and it also allows measurement of thrombus density, which reflects thrombus composition. Borst et al.[11] evaluated the value of thrombus CT characteristics, including thrombus density, in 199 patients with acute ischemic stroke and found that relative thrombus density on CTA was an independent predictor of functional outcome in multivariable analysis [adjusted common OR of 1.21 per 10% (95% CI: 1.02–

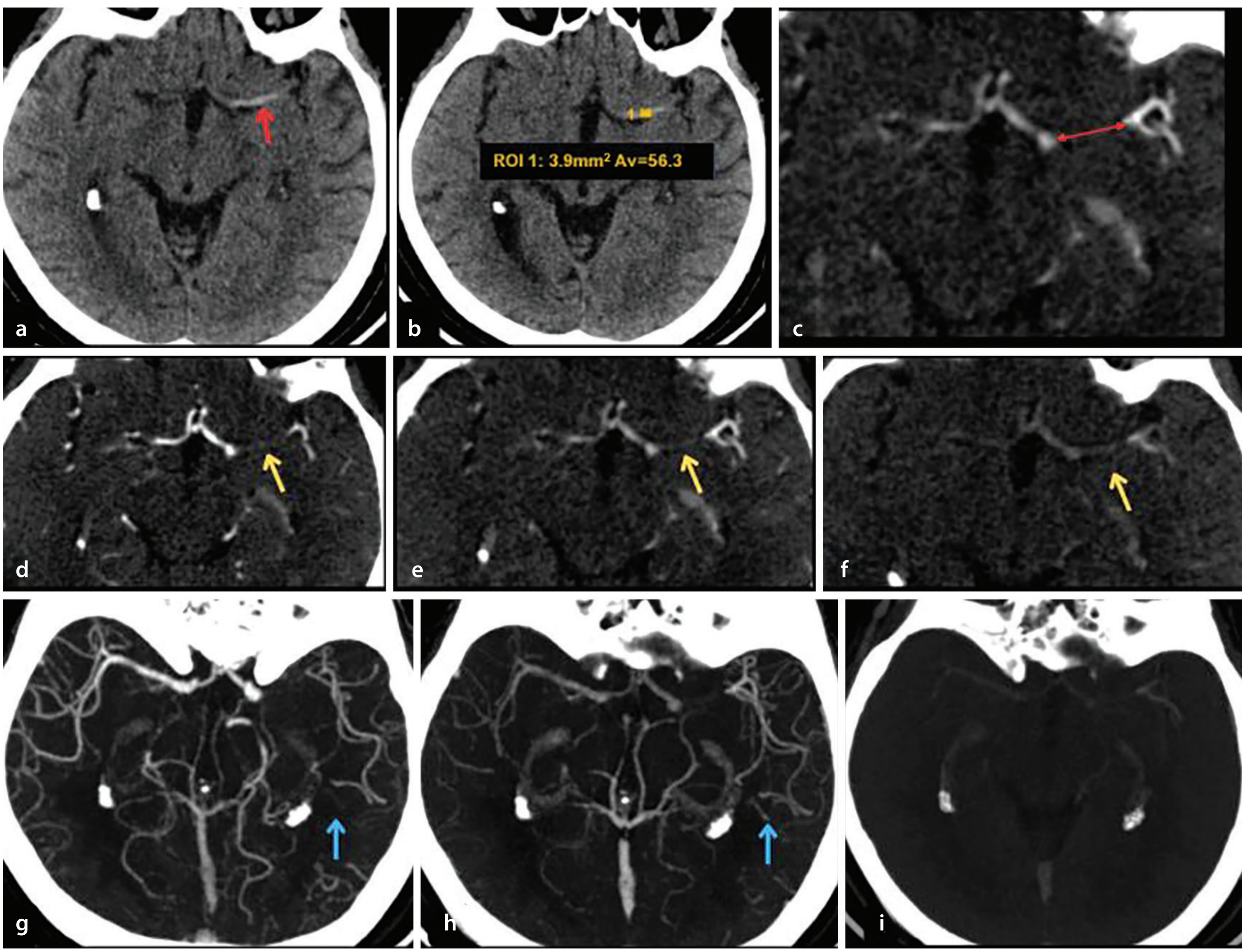

Figure 2. Non-contrast CT **(a, b)** and mCTA images **(c-i)** of a 68-year-old woman with acute ischemic stroke. The time from symptom onset to mCTA was 170 minutes. **(a)** NCCT shows a hyperdense MCA sign (*red arrow*); **(b)** thrombus density was calculated as 56 Hounsfield units (*yellow point*); **(c)** thrombus margins (*red arrow*) were best seen on the early venous phase image, and the actual thrombus length measured 15 mm (*not shown*). **(d)** Arterial phase, **(e)** early venous phase, and **(f)** late venous phase axial mCTA images show the thrombus (*yellow arrows*) in the MCA M1 segment. The thrombus was located in the proximal and distal parts of the MCA M1 segment, and the clot burden score was calculated as 10 – 2 – 2 = 6 points. MIP images of **(g)** arterial, **(h)** early venous, and **(i)** late venous phase mCTA images show grade 5 collateral circulation filling (*blue arrows*) in the peripheral vessels distal to the thrombus. Successful recanalization was achieved with mechanical thrombectomy, and the patient had a good outcome (90-day modified Rankin scale score = 1). NCCT, non-contrast computed tomography; mCTA, multiphase computed tomographic angiography; MIP, maximum intensity projection; CT, computed tomography; MCA, middle cerebral artery.

1.43); *P* = 0.029]. In a study of 141 patients with acute ischemia undergoing intra-arterial therapy, thrombus density was measured on 4.8 mm thick NCCT images, and no significant correlation was found between thrombus density and functional outcome.[12] In the present study, a significant positive correlation [*P* = 0.022; OR = 1.16 (95% CI: 1.02–1.33)] was found between thrombus density and good clinical outcomes, but there was no statistically significant difference in thrombus density between patients with good and poor outcomes. Thrombus density reflects its structure: erythrocyte-rich thrombi show higher Hounsfield units than platelet-rich thrombi and appear as a hyperdense MCA sign on NCCT.[21] Thrombus composition affects successful recanalization in thrombolytic therapy and thrombectomy,[22] and thus the prognosis of patients.

In previous studies of acute ischemic stroke, patients with a time from symptom onset to recanalization of >300 minutes had better clinical outcomes when the ASPECTS on baseline CT was >7 compared with those with an ASPECTS of ≤7, and MT showed no beneficial impact on the clinical outcomes of patients with a score of ≤4, regardless of time to recanalization.[13,14] Patients with a baseline ASPECTS of ≤7 have a higher probability of good outcomes when reperfusion is achieved within <300 minutes of symptom onset.[13] The current study included patients with a symptom onset of <300 minutes, and the ASPECTS was precisely calculated in narrow window settings (window width: 40, window level: 30) on 2.5 mm thick NCCT images; no statistically significant difference was found between the ASPECTS values of patients with good and poor clinical outcomes. This may have been due to the point reduction in the ASPECTS, regardless of the proportion of each anatomical region affected by ischemia, as all ASPECTS regions may have different predictive abilities for patients' functional outcomes.[23] Though not the subject of this study, parenchymal volumes and localizations affected by ischemia could vary greatly among patients with the same ASPECTS, leading to different prognoses. Broocks et al.[24] reported a retrospective analysis of 100 patients with large vessel occlusion treated with endovascular therapy, showing that even patients with an ASPECTS of ≤5 could have better functional outcomes if they were younger than 73 years and had good collateral status. In our study, patients with poor outcomes were older than those with good outcomes (63.04 ± 13.81 years versus 69.54 ± 14.57 years, *P* = 0.590), and the rate of poor collaterals was higher in the poor outcome group, though not statistically significant (good outcome poor collaterals: 23.9% vs. poor outcome poor collaterals: 37.5%, *P* = 0.232).

mCTA is an increasingly important imaging modality in the initial evaluation of patients with acute ischemic stroke.[25,26] It is useful for detecting large vessel occlusions and showing distal arterial occlusion (delayed vessel sign),[27] and it allows the assessment of CC and the measurement of thrombus length.[9,20,28] In patients with poor CC, arterial phase CTA images may overestimate the actual thrombus length. Delayed phase contrast-enhanced CT images are useful for accurately measuring thrombus length.[28] To overcome this limitation, we excluded patients in whom the actual thrombus length could not be measured because of poor CC. Therefore, we had no patients with grade 0 collateral, and the number of patients with poor CC (20 out of 70) was lower than those with good CC (50 out of 70) in the study group.

The probability of recanalization with intravenous thrombolysis is almost impossible when the thrombus length exceeds 8

Table 1. Comparison of imaging findings between patients with good outcomes and poor outcomes

Imaging findings		All median (min–max) or n (%)	Good clinical outcome median (min–max) or n (%)	Poor clinical outcome median (min–max) n (%)	*P*
Time from symptom onset to CT		111 (26–350)	120 (26–258)	108 (35–350)	0.924$^{\beta}$
Non-contrast computed tomography					
ASPECTS		9 (4–10)	9 (5–10)	8.5 (4–10)	0.454$^{\beta}$
>7		47 (67.1%)	32 (69.6%)	15 (62.5%)	0.598$^{\alpha}$
≤7		23 (32.9%)	14 (30.4)	9 (37.5%)	
Thrombus density (HU)		55.0 (37–66)	57.0 (37–66)	53.0 (40–65)	0.053$^{\beta}$
Estimated thrombus length (mm)		13.0 (5–29)	12.85 (5–29)	15.0 (8–25)	0.359$^{\beta}$
Multiphase computed tomography angiography					
Actual thrombus length (mm)		17.25 (5–36)	15.9 (5–26)	21.5 (11–36)	0.001$^{\beta}$ *
Clot burden score		6.0 (4–9)	6.0 (4–9)	6.0 (4–9)	0.325$^{\beta}$
>5		58 (82.9%)	40 (87.0%)	18 (75.0%)	0.316$^{\alpha}$
≤5		12 (17.1%)	6 (13.0%)	6 (25.0)	
Collateral circulation	1	2 (2.9%)	0 (0%)	2 (8.3%)	0.091$^{\theta}$
	2	11 (15.7%)	5 (10.9%)	6 (25.0%)	
	3	7 (10%)	6 (13%)	1 (4.2%)	
	4	39 (55.7%)	26 (56.5%)	13 (54.2%)	
	5	11 (15.7%)	9 (19.6%)	2 (18.3%)	
Collateral circulation	Poor collateral	20 (28.6%)	11 (23.9%)	9 (37.5%)	0.232$^{\alpha}$
	Good collateral	50 (71.4%)	35 (76.1%)	15 (62.5%)	

*$P < 0.05$; $^{\alpha}$, Fisher's exact test *P* value; β, Mann–Whitney U test *P* value; $^{\theta}$, Fisher–Freeman–Halton test *P* value. HU, Hounsfield unit; mm, Millimeter; CT, computed tomography; min-max, minimum-maximum; ASPECTS, Alberta Stroke Program Early CT Score

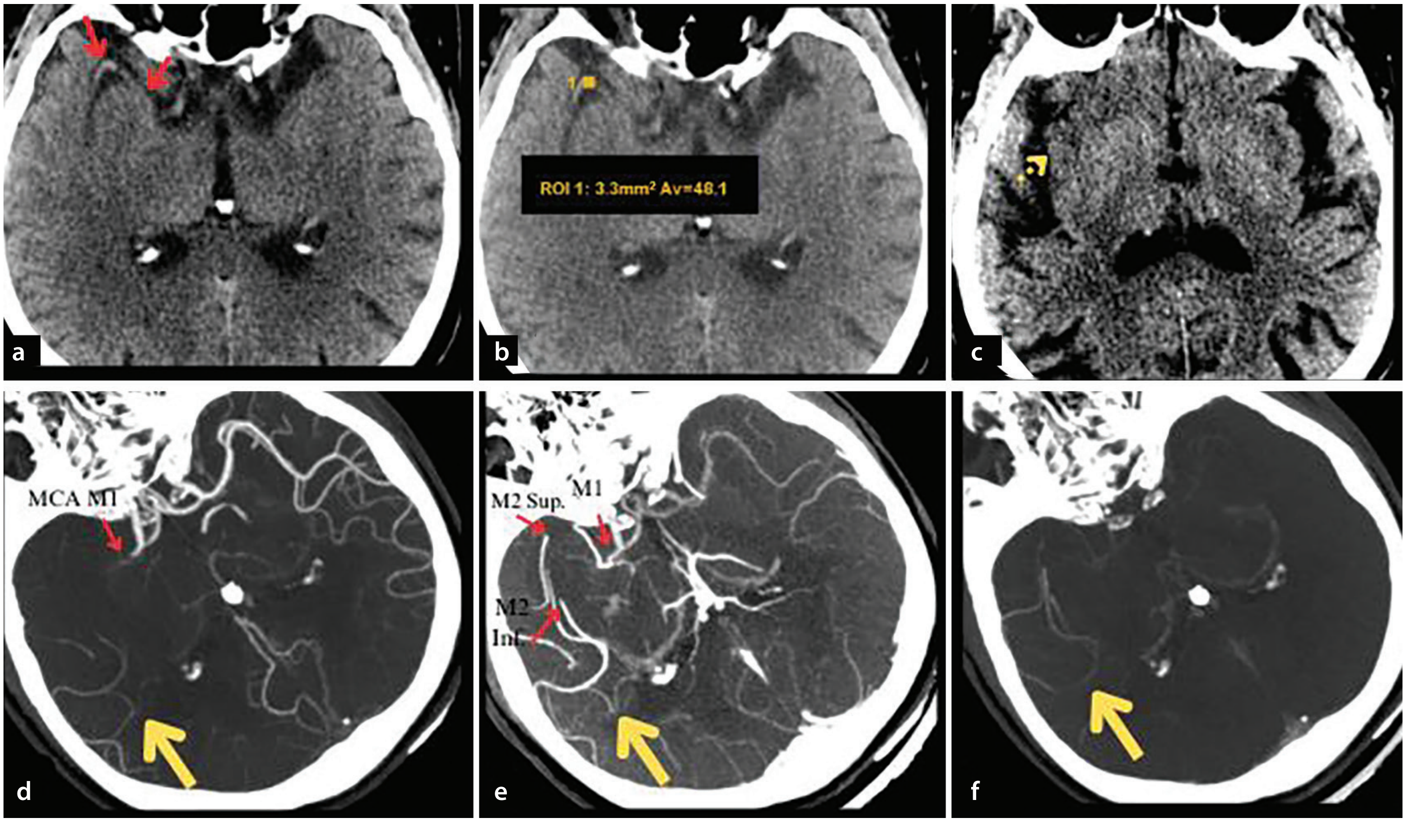

Figure 3. Non-contrast CT and mCTA images **(a-f)** of a 70-year-old man with acute ischemic stroke. The time from symptom onset to mCTA was 47 minutes. **(a)** The proximal M2 segment of the MCA was slightly hyperdense, but the M1 segment was isodense on NCCT (*red arrows*). **(b)** Thrombus density was calculated as 48 Hounsfield units (*yellow square*). **(c)** Axial NCCT image (width: 40; level: 30) at the level of the basal ganglia shows mild hypodensity (*dotted yellow arrow*) consistent with early ischemic changes in the right insula (ASPECTS: 9). **(d)** Arterial and **(e)** early venous phase MIP mCTA images show the thrombus extending from the proximal M1 segment to the superior (M2 sup) and inferior (M2 inf) divisions of the M2 segment in the MCA. The actual thrombus length, best delineated on early venous phase mCTA images (*red arrows*), measured 31 mm from the M1 segment to the M2 inferior division (*not shown*). The clot burden score was calculated as 10 – 2 – 2 – 1 – 1 = 4 points. **(d)** Arterial, **(e)** early venous, and **(f)** late venous phase MIP mCTA images show a one-phase delay in collateral filling (*yellow arrows*) in the peripheral vessels (grade 4 collateral circulation). Although successful recanalization was achieved with mechanical thrombectomy, the patient passed away after hospital discharge (90-day modified Rankin scale score = 6). NCCT, non-contrast computed tomography; mCTA, multiphase computed tomographic angiography; ASPECTS, Alberta Stroke Program Early CT Score; MIP, maximum intensity projection; mCTA, multiphase computed tomographic angiography; CT, computed tomography.

Table 2. Binary logistic regression analysis of the prediction of good clinical outcomes based on baseline multiphasic CTA findings and time from symptom onset to CTA

Independent variables	B ± SE	OR (95% CI)	*P*
Time from symptom onset to CTA	0.001 ± 0.006	1.001 (0.990–1.013)	0.847
Non-contrast computed tomography			
ASPECTS	0.340 ± 0.336	1.404 (0.727–2.713)	0.315
Estimated thrombus length	0.047 ± 0.080	1.048 (0.897–1.225)	0.575
Thrombus density	0.154 ± 0.067	1.167* (1.023–1.331)	0.022*
Multiphase computed tomography angiography			
Actual thrombus length	−0.282 ± 0.104	0.754** (0.615–.925)	0.005*
Clot burden score	−0.398 ± 0.457	0.671 (0.274–1.643)	0.398
Collateral circulation	−0.025 ± 0.442	0.975 (0.410–2.320)	0.207
Poor collateral (1)	0.340 ± 0.915	1.404 (0.234–8.432)	0.124
Poor to good (2)	−2.13 ± 41.690	0.118 (0.004–3.247)	0.306

$P < 0.05$; dependent variable, 90-day mRS (0–2); R^2, Cox and Snell: 0.376; Nagelkerke: 0.518; Hosmer–Lemeshow goodness-of-fit test, χ^2: 4.720; *$P > 0.05$. CTA, computed tomography angiography; ASPECTS, Alberta Stroke Program Early Computed Tomography Score; CI, confidence interval; OR, odds ratio

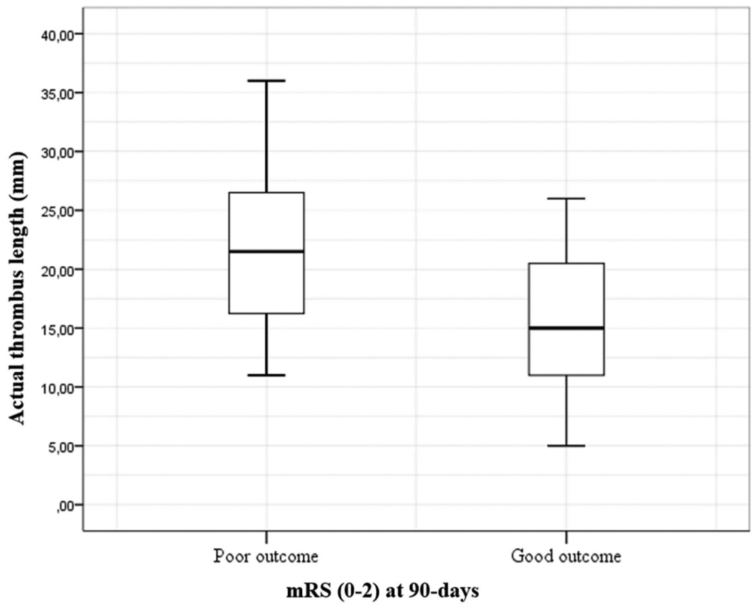

Figure 4. Comparison of the actual thrombus length between patients with poor and good clinical outcomes is shown using box plots. mRS, modified Rankin scale.

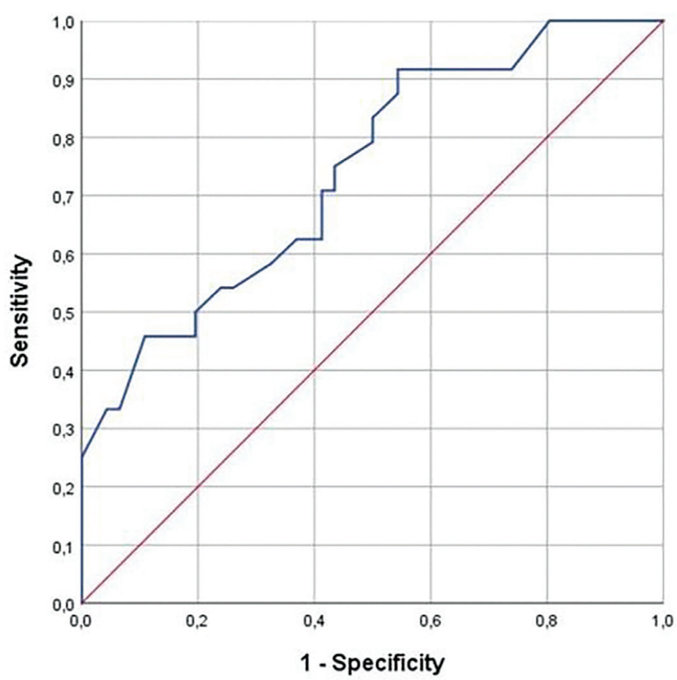

Figure 5. Receiver operating characteristic curve analysis of the actual thrombus length for predicting good clinical outcomes in patients with MCA occlusion treated with mechanical thrombectomy. The optimal cut-off value of thrombus length was 18.7 mm, with a sensitivity of 72.5% and specificity of 61.8% (area under the curve: 0.74 ± 0.06; 95% confidence interval: 0.62–0.86; $P = 0.001$). MCA, middle cerebral artery.

mm,[29] and it remains controversial whether a longer thrombus affects recanalization in thrombectomy and procedural or post-procedural complications.[15,30] Borst et al.[11] measured thrombus length on NCCT images coregistered with CTA using software that calculated thrombus length marked on images and reported that a median thrombus length greater than 8 mm was associated with functional outcomes in patients with acute ischemic stroke ($P < 0.05$). Seker et al.[15] analyzed the impact of thrombus length on neurological outcomes in 72 patients with M1 occlusion treated with MT. They used at least two perpendicular planes to measure thrombus length in multiplanar reformatted MR angiography or CTA images, and when they were uncertain about the distal extension of the thrombus, they used susceptibility-weighted MR sequences or NCCT scans to estimate thrombus length. They found no association between thrombus length and the probability of a good clinical outcome (OR: 0.95; 95% CI: 0.84–1.03; $P = 0.176$).[15] Seker et al.[15] used MRI, CTA, and NCCT images to depict thrombus length, whereas in our study, we used mCTA images, which may be more accurate than sCTA and NCCT in depicting thrombus length. Spiotta et al.[12] calculated the estimated thrombus length on sCTA MIP images of 141 patients undergoing intra-arterial therapy for acute ischemia. By measuring the filling defect in the affected vessel, they found no significant associations between either thrombus length or functional outcome at 90 days.[12] The current study showed a significant negative correlation between actual thrombus length and good clinical outcome ($P = 0.005$; OR: 0.754; 95% CI: 0.61–0.92) and found that an actual thrombus length of 18.7 mm was the cut-off value for estimating good clinical outcome, with a sensitivity of 72.5% and a specificity of 61.8% [$P = 0.001$ (95% CI: 0.62–0.86)]. These discrepancies between studies may be because each researcher used a different method or modality to measure the estimated thrombus length.

Lee and Bang[16] reviewed recent reports and summarized the relationship between CC status and clinical outcomes in patients with acute ischemic stroke treated with thrombectomy. There are two studies in the literature estimating prognosis using the pial arterial filling score in mCTA, but unlike our study, the treatment methods in these studies were heterogeneous and did not include only patients treated with MT.[17,18] Drozdov et al.[17] found that the area under the curve of CC status (pial arterial filling score >3 vs. ≤3) in predicting a good outcome was 0.66 [OR: 4.11 (1.35–12.54); $P = 0.013$]. In the present study, no correlation was found between CC grade and clinical outcomes; this may be due to the smaller number of patients with poor collaterals in the study group for the reasons mentioned above. Larger series studies on mCTA collateral scoring in patient groups treated with the same method may clarify this issue.

Regarding the impact of the clot burden score on clinical outcomes, it is known that patients are considerably more likely to have good clinical outcomes and less likely to die as the clot burden score increases. Puetz et al.[10] demonstrated that high thrombus burden (clot burden score ≤5) was a predictor of mortality and functional outcome in patients with acute ischemic stroke. The present study found no association between clot burden score and clinical outcomes. This discrepancy might be due to the exclusion of patients with terminal ICA and/or anterior cerebral artery occlusion.

Our study has several limitations. It is a single-center retrospective study. To maintain homogeneity of the study group, we included only patients with MCA M1 occlusion who had sufficient CC to allow clear delineation of the thrombus edges, which resulted in a relatively small sample size. The small sample size may limit the reliability and generalizability of the results. The evaluation of CT images and measurements was performed by a single observer. We could not assess the effect of perfusion parameters on clinical outcomes, as perfusion CT is not routinely used in the management of patients with suspected acute stroke at our institution. Another limitation was the lack of venous flow evaluation.

In conclusion, higher thrombus density and thrombus lengths shorter than 18.7 mm were associated with good clinical outcomes in patients with MCA M1 occlusion treated with MT. However, no considerable correlation was found between clinical outcomes and the ASPECTS, CC degree, or clot burden score. Further multicenter studies with larger patient groups are needed to confirm these findings and to clarify the role of thrombus characteristics and other imaging features that may influence patient outcomes.

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Footnotes

Conflict of Interest

The authors declared no conflicts of interest.

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