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Perfusion CT in acute stroke: prediction of vessel recanalization and clinical outcome in intravenous thrombolytic therapy

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Abstract This study evaluated perfusion computed tomography (PCT) for the prediction of vessel recanalization and clinical outcome in patients undergoing intravenous thrombolysis. Thirty-nine patients with acute ischemic stroke of the middle cerebral artery territory underwent intravenous thrombolysis within 3 h of symptom onset. They all had non-enhanced CT (NECT), PCT, and CT angiography (CTA) before treatment. The Alberta Stroke Program Early Computed Tomography (ASPECT) score was applied to NECT and PCT maps to assess the extent of ischemia. CTA was assessed for the site of vessel occlusion. The National Institute of

Health Stroke Scale (NIHSS) score was used for initial clinical assessment. Three-month clinical outcome was assessed using the modified Rankin scale. Vessel recanalization was determined by follow-up ultrasound. Of the PCT maps, a cerebral blood volume (CBV) ASPECT score of >6 versus ≤6 was the best predictor for clinical outcome (odds ratio, 31.43; 95% confidence interval, 3.41–289.58; $P < 0.002$), and was superior to NIHSS, NECT and CTA. No significant differences in ASPECT scores were found for the prediction of vessel recanalization. ASPECT score applied to PCT maps in acute stroke patients predicts the clinical outcome of intravenous thrombolysis and is superior to both early NECT and clinical parameters.

Keywords Stroke · Computed tomography · Perfusion · Thrombolysis · Outcome

Introduction

Intravenous thrombolysis for treatment of patients with ischemic stroke was the first ever evidence-based therapy for acute stroke and has been widely adopted [1, 2]. Thrombolysis offers substantial benefits to patients with acute brain ischemia with respect to clinical outcome [3, 4]. This treatment may have severe side effects, however; in particular, secondary cerebral hemorrhage. Currently, strong efforts are made to better identify patients that will

benefit from this type of aggressive treatment, and a more refined diagnostic imaging is demanded [5, 6].

Although magnetic resonance imaging (MRI) is more sensitive for the early detection of small cerebral infarction [6, 7], computed tomography (CT) of the brain is still the primary imaging modality used in acute stroke patients, mainly for the exclusion of intracranial hemorrhage and the revelation of early signs of brain infarction [8, 9]. In the very early stage of brain infarction, however, signs of brain swelling and oedema can be depicted only in a minority of

patients on non-enhanced CT (NECT), and the use of NECT alone comprises uncertainty of assessment [10]. To achieve much better information about the location and size of brain ischemia, perfusion computed tomography (PCT) was established by the late 1990s as a new imaging modality to be used in patients with acute stroke [11, 12]. Since then, PCT has proven to increase the sensitivity and inter-rater reliability for early detection of ischemic brain infarct [13].

The Alberta Stroke Program Early CT (ASPECT) score was presented originally to improve the reliability of detection of subtle early ischemic changes in the middle cerebral artery (MCA) territory on NECT [14]. However, application of the ASPECT score approach to NECT in order to identify candidates for systemic thrombolysis did not reveal reliable results [15]. By contrast, applying the ASPECT score applied to perfusion-weighted CT and PCT images turned out to be much more promising and was even able to predict the clinical outcome in recent studies [16, 17].

Bringing together the recent advances of PCT stroke imaging and the easy application of the ASPECT score, the aims of this study were (1) to compare ASPECT score during initial NECT and PCT maps with the 3-month clinical outcome of stroke patients receiving standard intravenous thrombolysis; (2) to compare ASPECT score during initial NECT and PCT maps with the presence or absence of vessel recanalization of stroke patients receiving standard intravenous thrombolysis; (3) to identify predictors for clinical outcome and vessel recanalization on initial multimodal CT imaging of stroke patients receiving standard intravenous thrombolysis.

Materials and methods

Overview

We retrospectively reviewed the clinical and imaging findings of 56 consecutive patients who presented within 3 h of symptoms onset for acute stroke. Only patients who fulfilled the criteria of (1) infarction of the MCA territory, (2) complete multimodal CT imaging and (3) exclusive intravenous thrombolysis within the first 3 h according to standard protocol were included. Seventeen patients were excluded due to incomplete imaging caused by patient motion ($n=2$), a diagnosis other than infarction of the MCA territory ($n=10$), and exclusive or additional intra-arterial thrombolysis ($n=5$). Of the remaining 39 patients (16 women, 23 men; age 69.6 ± 11.2 years) imaging was performed within 112 ± 32 min after onset of symptoms. Imaging and treatment was performed according to the hospital guidelines for suspected acute stroke. Informed consent was obtained by the patients or their next of kin according to legal requirements. The study was approved by the local ethics commission.

Initial clinical assessment

The neurological impairment on admission was assessed with the National Institutes of Health Stroke Scale (NIHSS) score [18] with a mean of 14.5 ± 5.5 for the 39 individuals included. In general, a NIHSS score of less than 15 reflects a mild to moderate stroke, whereas a score of more than 15 reflects a severe stroke.

Initial CT imaging

The initial multimodal CT imaging included NECT, PCT, and CT angiography (CTA) on a multidetector-row CT scanner (Somatom Sensation 16; Siemens Medical Solutions, Forchheim, Germany). All contrast injections were performed through an 18-gauge canula (Insyte-W; BD Biosciences, Madrid, Spain) placed in an antecubital vein with a double-piston power injector (Injektron CT 2; Medtron, Saarbruecken, Germany) using iopromide with 370 mg iodine per ml (Ultravist 370; Bayer Schering Pharma, Berlin, Germany).

First, a NECT (detector collimation, 16×0.75 mm; tube voltage, 120 kVp; tube current, 400 mAs; reconstructed slice thickness, 5 mm) of the brain was performed. The sections of the following PCT (detector collimation, 16×1.5 mm; tube voltage, 80 kVp; tube current, 180 mAs; contrast agent, 30 ml; saline flush, 30 ml; flow rate, 6 ml/s; scan delay, 4 s) covered the level of the basal ganglia and the adjacent periventricular region. Four adjacent 6-mm thick sections were reconstructed. Colour-coded maps of the cerebral blood flow (CBF), the cerebral blood volume (CBV), and the time to peak (TTP) were calculated using commercial software relying on the maximum slope model (NeuroPCT; Siemens Medical Solutions, Forchheim, Germany). The underlying algorithm has been described elsewhere [19].

CTA (detector collimation, 16×0.75 mm; tube voltage, 120 kVp; tube current, 130 mAs; reconstructed slice thickness, 1 mm; contrast agent, 100 ml; saline flush, 50 ml; flow rate, 4 ml/s; test bolus-triggered delay) covered a scanning range extending from the level of the sixth cervical vertebra to the vertex and 1-mm thick maximum intensity projections in transverse view were reconstructed.

Follow-up imaging

The extent of infarction was assessed by follow-up imaging of the brain with CT or MRI performed 2 days after admission. Exceptions were made in case of unproved infarction at initial imaging or clinical deterioration with an earlier follow-up performed on day 1 or 2. Delayed follow-up on day 4 or later was accepted if permanent monitor status of the patient on the stroke unit was necessary. For follow-up CT, the scanning protocol was the same as that

used for initial NECT. NECT was considered sufficient for follow-up if (1) ischemia was clearly visualized at the initial examination, (2) the critical situation of the patient did not allow MRI, or (3) the patient had contraindications for MRI. For all other patients, MRI was performed with a 1.5-Tesla magnetic resonance system (Intera Gyroscan; Philips, Best, The Netherlands) and consisted of a transverse fluid-attenuated inversion-recovery sequence (TR 8,000 ms, TE 120 ms, slice thickness of 6.0 mm) and a transverse diffusion-weighted sequence (TR 4,079 ms, TE 95 ms, slice thickness of 6.0 mm).

Image analysis

The physicians who performed the image analysis were blinded to detailed clinical information (i.e. side of hemiplegia), but were aware of the diagnosis of suspected acute stroke. The initial NECT as well as the CT or MRI follow-up examinations were reviewed separately in arbitrary order by two radiologists (S.P.K., T.F.) in consensus for signs of infarction [20] on the CT workstation (Leonardo; Siemens Medical Solutions, Forchheim, Germany) and the MRI workstation (Easy Vision; Philips, Best, The Netherlands). The different colour-coded perfusion maps of the initial PCT were visually evaluated in consensus by two radiologists (S.P.K., T.F.) for areas of perfusion abnormalities [21, 22]. The extent of ischemia and infarction was measured according to the ASPECT score for all modalities. The ASPECT score is a weighted

volumetric scale used to score the degree of ischemic change present on acute stroke patient's CT scan [14]. The score applies to the MCA territory only and ranges from 0 to 10, with 10 implying no evidence of ischemic change and 0 implying a complete MCA territory infarct (Fig. 1).

The CTA data were reviewed on the CT workstation (Leonardo; Siemens Medical Solutions, Forchheim, Germany) for intracranial artery occlusion by two radiologists (S.P.K., T.F.) in consensus. The findings were assessed in four grades for (1) occlusion of the internal carotid "T", (2) occlusion of the M1 segment of the MCA, (3) occlusion of a M2 segment of the MCA, and (4) no occlusion.

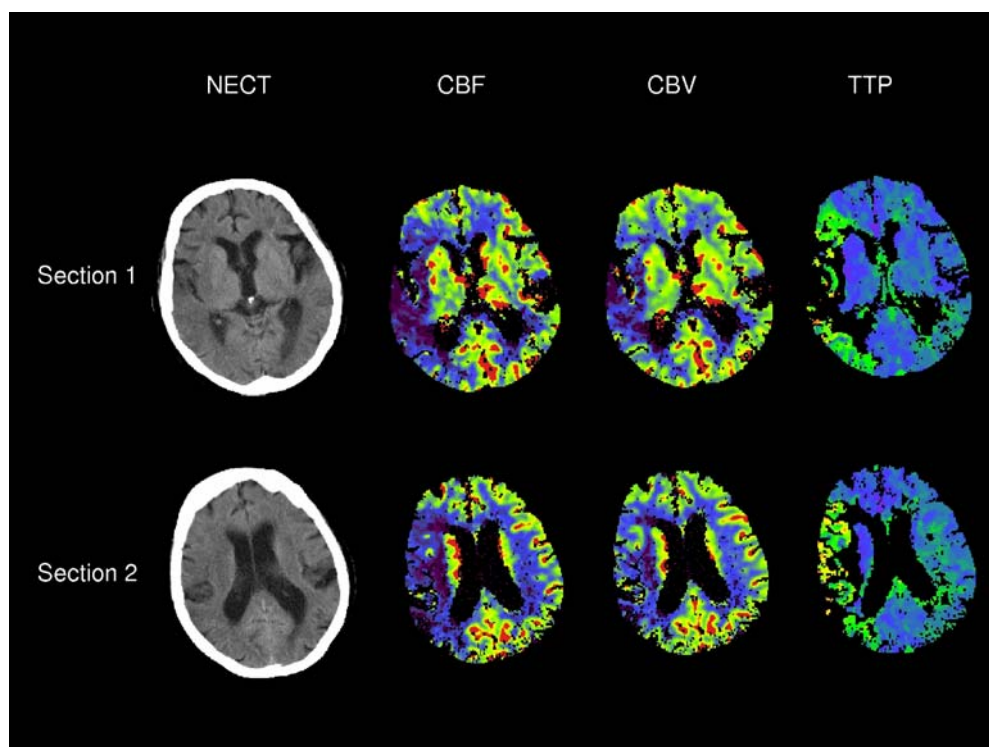
Intravenous thrombolysis

Inclusion to treatment was based on clinical examination and NECT findings. All patients underwent intravenous thrombolysis with recombinant tissue-type plasminogen activator (Actilyse, Boehringer-Ingelheim, Ingelheim, Germany) at a dosage of 0.9mg per kg bodyweight according to standard guidelines [1, 2].

Follow-up ultrasound

In all patients, follow-up intracranial vessel status 24h after admission was obtained by a specially trained neurologist (R.D., D.G.N.) with transcranial ultrasound [23–25]. The

Fig. 1 Application of ASPECT score to multimodal CT The initial multimodal CT of a 71-year-old female patient was performed 1.5 h after symptom onset with left-sided hemiparesis (NIHSS score of 14). The non-enhanced CT (NECT) revealed subtle hypodensity of insular ribbon and crowding of the sulci of the temporal and parietal lobe resulting in a NECT ASPECT score of 6. More obvious perfusion abnormalities were found in the perfusion CT. The ASPECT criteria applied on the color-coded maps of cerebral blood flow (CBF), cerebral blood volume (CBV), and time to peak (TTP) revealed a CBF ASPECT score of 3, a CBV ASPECT score of 4, and a TTP ASPECT score of 3



examination of the intracranial arteries by transcranial Doppler (2 MHz probe, Multidop X/Multidop P, DWL) and transcranial colour-coded sonography (2-2.5 MHz, Hewlett Packard/HDI 5000, ATL) included the documentation of the flow velocities and other flow properties of the cerebral arteries and the collateral flow pathways, if present.

Recanalization of formerly occluded vessels was judged in comparison to the initial CTA findings and trichotomized into (1) none, (2) partial and (3) complete recanalization.

Follow-up clinical assessment

Recovery was assessed by using the modified Rankin Scale (mRS) [26] with an average of 3.23 ± 1.98 for the included 39 individuals. Six patients died (mRS=6) due to stroke or stroke-related complications. The mRS is a global assessment of patient function. It is based on the patient's ability to perform activities of daily living, and the score ranges from 0, which indicates no symptoms at all, to 6, which indicates death. Scores of 0, 1, and 2 indicate independency from external help and were defined as "favourable" outcome.

Statistics

First, the mean baseline ASPECT score on initial CT modalities was compared with each other using paired *t*-test.

Second, mean ASPECT score comparison between subgroups with and without vessel recanalization (defined as either partial or complete vessel reopening from initial CTA to follow-up transcranial ultrasound) was performed for each initial CT modality using one-way ANOVA analysis.

Third, mean ASPECT score comparison between subgroups with and without a favourable clinical outcome (defined as mRS ≤ 2) was performed for each initial CT modality using one-way ANOVA analysis.

Fourth, single factor logistic regression analysis was used to compare the odds ratio (OR) and 95% confidence interval (95%CI) of favourable patient outcome and vessel recanalization when the ASPECT score of the initial CT modalities were dichotomized. Besides the traditional cut-off point of >7 versus ≤ 7 , the cut-off points >6 versus ≤ 6 , >5 versus ≤ 5 , >4 versus ≤ 4 , >3 versus ≤ 3 , and >2 versus ≤ 2 were assessed for NECT and the PCT maps. Other independent variables used in the logistic regression analysis were: (1) NIHSS score of ≤ 15 versus >15 ; (2) age with an arbitrary cut-off point of ≤ 70 years versus >70 years; (3) the side of affected hemisphere; and (4) the absence versus presence of vessel occlusion on initial CTA.

SPSS 11.0 (SPSS, Chicago, Ill.) was used for all calculations. All results are expressed as the mean \pm standard deviation unless indicated otherwise. Percentage is expressed for the number of finally included individuals

unless indicated otherwise. Appropriately corrected *P* values <0.05 were considered to indicate a statistically significant difference.

Results

The cerebral infarction was located in the right and left hemisphere in 22 and 17 patients, respectively. The application of the ASPECT score criteria to the initial multimodal CT imaging revealed average ASPECT score for NECT of 8.28 ± 2.03 , for CBF of 4.69 ± 2.98 , for CBV of 5.85 ± 2.63 , and for TTP of 3.46 ± 3.12 . The comparison by the paired *t*-test showed significant differences of means between NECT and all PCT maps with $P < 0.001$, indicating a much larger extent of MCA ischemia visible by PCT versus NECT.

Occlusion of the terminal carotid artery and the proximal M1 segment of the MCA ("carotid T") on initial CTA was visualized in four patients (10.3%), M1 occlusion in 17 patients (43.6%), and M2 occlusion in six patients (15.4%). No occlusion was found in 12 patients (30.6%). The follow-up TCD on day 1 of the 27 patients with initial pathological findings on CTA revealed persistent occlusion of the vessel in six patients (22.2%), partial recanalization in 20 patients (74.1%) and complete recanalization in one patient (3.7%). The one-way ANOVA analysis between the subgroup of vessel recanalization versus no vessel recanalization showed no significant differences of mean for the ASPECT score of NECT and the PCT maps (Fig. 2).

The clinical assessment on admission revealed a neurological impairment with a NIHSS score ≤ 15 in 22

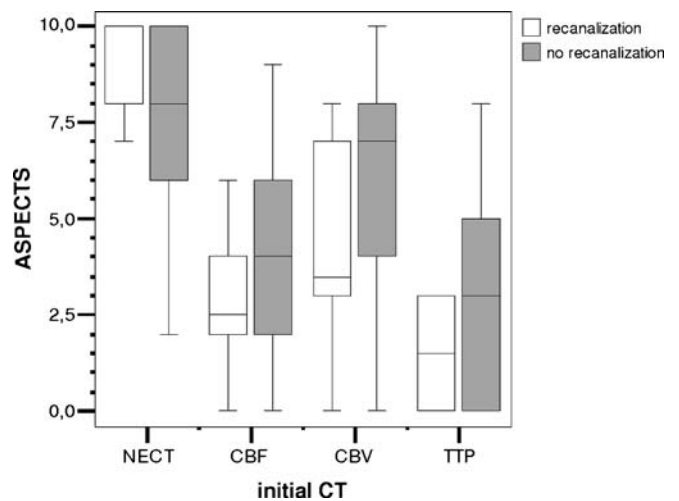


Fig. 2 Box-whiskers plot: ASPECT score of the initial multimodal CT for vessel recanalization versus no vessel recanalization. Median ASPECT score, 25% and 75% quartile, and 95% CIs shown for initial multimodal CT imaging. No significant differences of mean between subgroups for ANOVA analysis ($P < 0.05$) (NECT non-enhanced CT; CBF cerebral blood flow; CBV cerebral blood volume; TTP time to peak)

patients (56.4%) and a NIHSS score >15 in 17 patients (43.6%). The 3-month clinical outcome was judged favourable with a mRS ≤2 in 12 patients (30.8%) and unfavourable with a mRS >2 in 27 patients (69.2%). The one-way ANOVA analysis between the subgroups with favourable versus unfavourable outcome showed significant differences of mean for the ASPECT score of CBF, CBV, and TTP ($P<0.05$), but not for the ASPECT score of NECT (Fig. 3).

On single factor logistic regression analysis, the dichotomized NIHSS score, ASPECT score of CBF, CBV, and TTP were significant predictors of the clinical outcome. A CBV ASPECT score of ≤6 (OR, 31.43; 95%CI, 3.41–289.58; $P<0.002$) was the most significant single predictor for unfavourable clinical outcome with a rate of 95.2%. TTP ASPECT score of >7 (OR, 13.00; 95%CI, 1.26–133.63; $P<0.031$) was the best discriminator for favourable clinical outcome with a rate of 80.0%. Moreover, TTP ASPECT score ≤3 (OR, 11.87; 95%CI, 2.11–66.87; $P<0.005$) could correctly predict poor outcome in 90.5% of the patients. For CBF ASPECT score a dichotomization of >4 versus ≤4 was the best discriminator for clinical outcome (OR, 7.27; 95%CI, 1.33–39.86; $P<0.022$) but was inferior compared with CBV and TTP ASPECT score. The dichotomous NIHSS score with a cut-off point of <15 versus ≥15 was statistically significant (OR, 6.25; 95%CI, 1.14–34.12; $P<0.034$). However, it had a lower OR for predicting clinical outcome compared with CBF, CBV and TTP ASPECT score. The dichotomized variables for age (≤70 versus >70), side of affected hemisphere (right versus left), vessel occlusion on initial CTA (presence versus absence) and several NECT ASPECT score cut-off

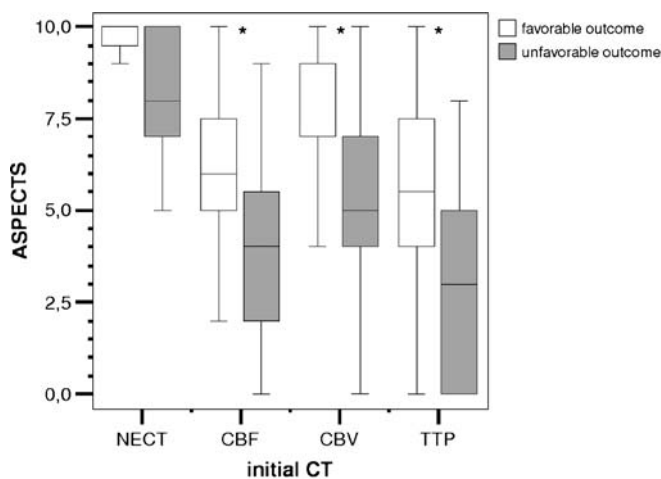


Fig. 3 Box-whiskers plot: ASPECT score of the initial multimodal CT for favourable (mRS >2) versus unfavourable (mRS >2) outcome. Median ASPECT score, 25% and 75% quartile, and 95% CIs shown for initial multimodal CT imaging; * indicates significant differences of mean between subgroups for ANOVA analysis ($P<0.05$) (mRS modified Rankin Scale; NECT non-enhanced CT; CBF cerebral blood flow; CBV cerebral blood volume; TTP time to peak)

points did not reach statistical significance for the prediction of the clinical outcome. The detailed results are shown in Table 1.

Among all dichotomized variables, no significant predictor of vessel recanalization was found in single factor logistic regression analysis.

Discussion

Our data show a relatively high rate of patients with unfavourable outcome and stroke related death. However, it has to be taken into consideration that the population examined consisted of patients with clinical signs of severe stroke on average. It is known from rt-PA trials [3, 27] that patients with high initial NIHSS score are more likely to have poor outcome in thrombolysis [28, 29]. Moreover, MRI studies demonstrated that large infarctions are more likely to result in permanent disability irrespective of treatment [30, 31].

Some recent publications showed that MRI with diffusion and perfusion imaging can predict clinical outcome in acute stroke patients receiving intravenous thrombolysis [29, 32]. The clinical assessment by the NIHSS score, however, remained the most powerful single prognostic factor in these studies. For CT imaging, the application of the ASPECT score to both, NECT and PCT, has proven to facilitate a reliable estimation of the size of MCA ischemia and lead to a high inter-rater reliability [14, 16, 17]. Our results demonstrate that ASPECT score applied to PCT maps is a more accurate predictor of clinical outcome than NECT. In agreement with the findings of Demchuk et al. [15], NECT was not predictive of clinical outcome in our study. In agreement with the results of Parsons et al. [17], our study showed that a CBV ASPECT score of >6 versus ≤6 is the most significant predictor for clinical outcome. Interestingly, the cut-off point of >6 versus ≤6 revealed a higher odds ratio compared with the traditional cut-off point of >7 versus ≤7 if chosen from acute NECT. In our opinion, this finding reflects the better prediction of irreversibly damaged tissue by CBV ASPECT score compared with NECT, particularly in the early stage of ischemia. Similar findings have also been reported in earlier studies [33, 34]. We demonstrated that a CBV ASPECT score of ≤6 is highly predictive for an unfavourable outcome, whereas a CBV ASPECT score of >6 is only a fair predictor of favourable clinical outcome. Irrespective of the kind of treatment, large infarctions on initial brain imaging have a higher likelihood to result in unfavourable outcome [29, 31]. Moreover, large infarctions on initial CT imaging are more likely to develop haemorrhage on thrombolysis and can therefore increase the rate of poor clinical outcome [35]. We found that the TTP ASPECT score is predictive of clinical outcome in both directions. For a TTP ASPECT score of >7 it is likely to result in favourable outcome, whereas a TTP ASPECT score of ≤3 is

Table 1 Logistic regression analysis using dichotomous ASPECT score cut-off points for favourable outcome (mRS ≤ 2)

ASPECT score cut-off points	Favourable outcome (%)	Odds ratio (95% CI)	<i>P</i>
NIHSS ≤ 15 vs $>15^a$	45.5 vs 11.8	6.25 (1.14–34.12)	0.034
Age ≤ 70 vs $>70^b$	15.4 vs 15.4	1.08 (0.28–4.20)	0.915
Affected hemisphere (right vs left)	27.3 vs 35.3	0.69 (0.18–2.70)	0.591
Absence vs presence of vessel occlusion ^b	33.3 vs 29.6	1.19 (0.28–5.10)	0.817
NECT >7 vs $\leq 7^b$	38.5 vs 15.4	3.44 (0.63–18.83)	0.155
NECT >6 vs $\leq 6^b$	32.3 vs 25.0	1.43 (0.24–8.38)	0.693
NECT >5 vs $\leq 5^b$	31.4 vs 25.0	1.37 (0.13–14.75)	0.793
CBF >7 vs $\leq 7^b$	50.0 vs 25.8	2.87 (0.58–14.28)	0.196
CBF >6 vs $\leq 6^a$	53.8 vs 19.2	4.90 (1.13–21.16)	0.033
CBF >5 vs $\leq 5^a$	50.0 vs 14.3	5.60 (1.30–27.75)	0.022
CBF >4 vs $\leq 4^a$	47.6 vs 11.1	7.27 (1.33–39.86)	0.022
CBF >3 vs $\leq 3^b$	43.5 vs 12.5	5.39 (0.99–29.34)	0.052
CBF >2 vs $\leq 2^b$	35.7 vs 18.2	2.50 (0.45–13.91)	0.295
CBV >7 vs $\leq 7^b$	54.5 vs 21.4	4.40 (0.99–19.54)	0.051
CBV >6 vs $\leq 6^a$	61.1 vs 4.8	31.43 (3.41–289.58)	0.002
CBV >5 vs $\leq 5^a$	50.0 vs 5.9	15.99 (1.80–142.28)	0.013
CBV >4 vs $\leq 4^b$	39.3 vs 9.1	6.47 (0.72–57.88)	0.095
TTP >7 vs $\leq 7^a$	80.0 vs 23.5	13.00 (1.26–133.63)	0.031
TTP >6 vs $\leq 6^a$	71.4 vs 21.9	8.93 (1.42–56.31)	0.020
TTP >5 vs $\leq 5^a$	53.8 vs 19.2	4.90 (1.13–21.16)	0.033
TTP >4 vs $\leq 4^a$	52.9 vs 13.6	7.12 (1.52–33.43)	0.013
TTP >3 vs $\leq 3^a$	55.6 vs 9.5	11.87 (2.11–66.87)	0.005
TTP >2 vs $\leq 2^b$	43.5 vs 12.5	5.38 (0.99–29.34)	0.052

^aSignificant, with $P < 0.05$

^bNot significant

NECT cut-off point of >4 vs ≤ 4 , >3 vs ≤ 3 , and >2 vs ≤ 2 not valid because there were too few patients with initial ASPECT score ≤ 4 , ≤ 3 , and ≤ 2 , respectively. Similarly, CBV cut-off points of >3 vs ≤ 3 and >2 vs ≤ 2 not valid because there were too few patients with initial ASPECT score ≤ 3 and ≤ 2 , respectively

highly associated with unfavourable outcome. This reflects again that TTP is a reliable indicator of the total size of critical ischemia [36], including the portion of still vital tissue potentially salvageable by thrombolysis.

The relationship between baseline CT angiography findings and clinical outcome is rated inconsistently [37, 38] in the literature. In contrast to the reported impact of initial CT and MRI angiography findings for clinical outcome in acute stroke patients receiving thrombolysis [29, 39], our results did not show a relationship. However, clinical outcome following intravenous thrombolysis does not only depend on the site of vessel occlusion or its recanalization, but also on the presence and capacity of collateral pathways, particularly the circle of Willis and the leptomeningeal network [40]. Hence, a more or less effective compensation of blood flow within the available time period will be able to restore the blood flow via pre-existing collaterals. Moreover, the time to recanalize could not be assessed more precisely since permanent monitoring is

laborious and time-consuming in intravenous thrombolysis [28, 41].

Finally, neither clinical variables nor components of the multimodal CT imaging were predictors for vessel recanalization in intravenous thrombolysis in our study. This observation might be related to the limited number of patients in our study and their clinical characteristics. Thus, this finding comprises some uncertainty. On the other hand, the type of thrombus might also determine the success of intravenous thrombolysis but cannot, however, be assessed by CTA.

Several limitations of our study have to be mentioned. First, the number of patients is limited in our study and the data were assessed retrospectively. Second, our PCT software used in this study cannot calculate mean transit time (MTT) maps. Therefore, MTT maps could not be evaluated although this parameter might be of relevance for mismatch imaging [42]. Third, the method for imaging of the cerebral vasculature differs between initial and follow-up examination and obviates the direct comparison.

In conclusion, NECT still remains an important component of acute stroke CT imaging, in particular for the exclusion of acute cerebral hemorrhage. But the predictive value of NECT for clinical outcome in intravenous thrombolysis is limited. In contrast, PCT can visualise different parameters of cerebral perfusion. Our results show that ASPECT score applied to PCT maps predict well clinical outcome in intravenous thrombolysis and is superior to NECT and the initial clinical assessment by the NIHSS score. This might be of particular interest for patient stratification beyond 3 h of symptom onset, where

the benefit/risk ratio of intravenous thrombolysis is lower [4]. A TTPASPECT score of >7 would be associated with a high likelihood of favourable clinical outcome, whereas a CBVASPECT score of ≤ 6 and a TTPASPECT score of ≤ 3 would frequently result in unfavourable clinical outcome. However, such a suggested treatment algorithm—similar to the prognostic MOSAIC score based on multimodal CT [43]—has to be prospectively validated in a large study.

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