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Perfusion patterns as a tool for emergency stroke diagnosis: differentiating proximal and distal MCA occlusions

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ABSTRACT

Background To evaluate the effectiveness of a novel Perfusion Pattern (PP) scale in differentiating between proximal and distal middle cerebral artery (MCA) occlusions in patients with acute ischaemic stroke.

Methods This retrospective study included 201 patients with acute ischaemic stroke, categorised into two groups: those with M1 segment occlusions (n=114) and those with distal medium vessel occlusions (n=87). We analysed multimodal stroke CT imaging and clinical data, focusing on the occlusion site, hypoperfusion extent and basal ganglia involvement. Patients with tandem stenosis or multiple acute occlusions were excluded. Perfusion patterns were categorised into three types (PP-1, PP-2 and PP-3) based on the extent of hypoperfusion. Statistical analysis explored associations between the occlusion site, perfusion pattern and collateral status.

Results Among the 201 patients (mean age 75±14 years, 86 men), PP-1 was observed in 36.8% of patients (74/201), PP-2 in 27.4% (55/201) and PP-3 in 35.8% (72/201). The distribution of PP varied significantly by occlusion site (p<0.0001). Distal medium vessel occlusions were associated with PP-1 in 78.4% of cases (58/74), while PP-3 was most prevalent in M1 occlusions (90.3%, 65/72). The contingency coefficient revealed that occlusion location had a stronger association with the perfusion pattern (c=0.556) than collateral type (c=0.245). However, 21.6% of M1 occlusions (16/74) showed a PP-1 pattern and 9.7% of distal medium vessel occlusions (7/72) exhibited PP-3. Basal ganglia infarction presence was a reliable indicator of M1 occlusion with a 94% likelihood.

Conclusions Perfusion patterns can effectively differentiate between proximal and distal medium vessel MCA occlusions, aiding targeted assessment of CT angiography.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Acute ischaemic stroke diagnosis and treatment often rely on CT angiography (CTA) to detect large vessel occlusions, but CTA can miss up to 35%–45% of medium vessel occlusions. Supplementary techniques like CT perfusion could improve the detection of occlusion sites. While it has been assumed that the extent of cerebral hypoperfusion correlates with the arterial occlusion site, this relationship has not been systematically evaluated.

WHAT THIS STUDY ADDS

⇒ This study introduces a visual scale, the Perfusion Pattern (PP) scale, which categorises the extent of cerebral hypoperfusion into three distinct patterns (PP-1, PP-2 and PP-3). The scale reliably distinguishes between proximal (M1) and distal (M2/M3) middle cerebral artery (MCA) occlusions, with PP-3 strongly associated with M1 occlusions and PP-1 with distal occlusions. Notably, exceptions were observed: 21.6% of M1 occlusions displayed a PP-1 pattern, and 9.7% of M2/M3 occlusions produced a PP-3 pattern.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study highlights the potential of the PP scale as a practical tool for differentiating proximal (M1) from distal (M2/M3) MCA occlusions in acute ischaemic stroke. By integrating the PP scale into clinical workflows, radiologists can prioritise areas for evaluation on CTA, reducing the risk of missed occlusions and enhancing diagnostic accuracy.

INTRODUCTION

Non-contrast CT (NCCT) and CT angiography (CTA) are currently considered adequate for selecting treatment for patients with acute ischaemic stroke within the early time window.[1 2] However, many tertiary hospitals also include CT brain perfusion in their imaging protocol to gather more information.[3] Haemodynamic maps generated by CT perfusion allow easy identification of brain tissue that can be saved and determine the extent of the ischaemic core.[4] Expert observers have reported that using CT perfusion in addition to NCCT can affect treatment

decisions[5–7] and lead to changes in decisions about intravenous thrombolysis in up to 35% of cases.[8]

CTA is a reliable imaging technique for diagnosing proximal brain artery occlusion.[9–11] However, diagnosing acute occlusions by CTA alone can be challenging due to such image quality issues as motion artefacts, low levels of contrast of arteries and other factors.[10] False negatives in CTA can result in missed opportunities for endovascular mechanical thrombectomy. This is particularly true for occluded arteries located distal to the M1 segment of the middle cerebral artery (MCA), with up to 35%–45% of the M2 segment occlusions being missed at initial CTA evaluation.[10 12] Olive-Gadea *et al*[13] retrospectively observed that approximately 30% of their mechanical thrombectomies would be deemed 'negative' on CTA when evaluated independently from the CT perfusion scan, emphasising the value of the complementary information provided by CT perfusion studies. We further believe that CT perfusion may also aid in detecting multiple concurrent acute intracranial occlusions, present in approximately 20% of acute ischaemic strokes.[14 15]

CTA evaluation should focus first on the side and arteries most likely to cause the patient's symptoms. However, clinical information alone can be unreliable as various arteries can cause similar neurological deficits,[16] and a detailed neurological assessment before imaging may not always be feasible. Additionally, acute neurological symptoms may not be related to large vessel occlusion in 67% of patients.[17] Some studies have suggested that including CT brain perfusion in stroke imaging protocols confers an additional advantage for guiding a more targeted evaluation of the CTA results.[10 18]

To correlate CT perfusion with CTA features in acute ischaemic stroke, we developed the three-thirds Perfusion Pattern (PP) scale. This scale categorises the perfusion pattern into three levels (PP-1, PP-2 and PP-3) based on the extent of hypoperfusion.

This study aims to determine whether the three-thirds PP scale can predict the location of the MCA occlusions and thus serve as a valuable tool in guiding CTA evaluation. By focusing on arterial segments most likely to be affected based on the PP scale or confirming uncertain findings from the CTA, the application of a straightforward, validated perfusion classification system becomes a highly practical approach for enhancing diagnostic precision.

METHODS

Study design and patient enrolment

We conducted a single-centre retrospective analysis of patients with M2 segment or distal MCA occlusion (n=87), comparing their perfusion patterns and clinical data with other patients that had angiographically verified M1 segment occlusions (n=114). The M1 occlusion group was retrieved from the mechanical thrombectomies performed during 2017 and 2018. Patients with distal medium vessel MCA occlusions were identified through a comprehensive search of radiological reports. Only cases in which M2 or M3 occlusion was reported (figure 1) were included. Patients were included if diagnosed with acute ischaemic stroke within 8 hours of symptom onset. Cases with multiple intracranial occlusions or tandem extracranial stenosis were excluded. Instances where clots extended from the M1 to M2 segment were considered M1 occlusions.

Medical histories and vascular risk factors were retrieved from medical records (refer to online supplemental

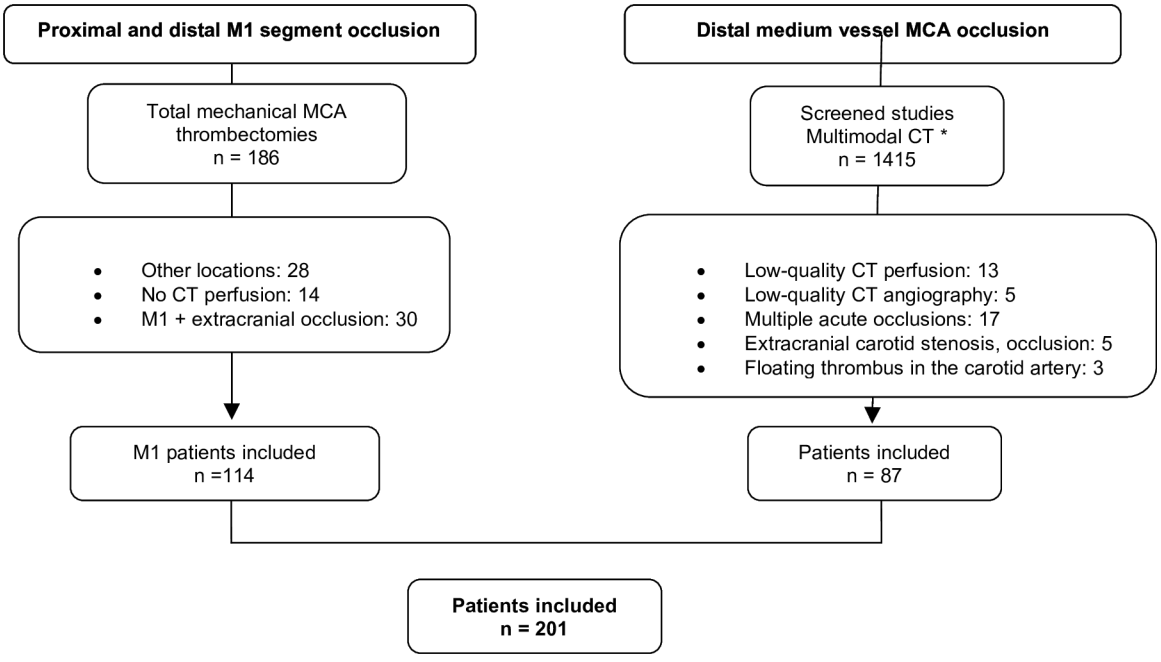

Figure 1 Flow chart. *The majority of the CT studies were negative for the target diagnosis but were included in the list of 1415 due to the presence of 'distal vessel occlusion' in the radiological report. MCA, middle cerebral artery.

materials and methods). The National Institutes of Health Stroke Scale (NIHSS) score at presentation and on day 3 or 4 and treatment type (intravenous thrombolysis, conservative therapy) were also on record.

CT acquisition

All patients underwent multimodal CT, including NCCT, CT perfusion and CTA. Scans were performed using a SOMATOM Definition Flash scanner (Siemens Healthineers). As per protocol, CT perfusion was performed after single-shot CTA. An intravenous bolus of 80 mL of iodinated contrast had been administered before CTA. However, with advancements in technology, boluses can now be reduced. Further details are presented in online supplemental materials and methods. CTA started at the aortic arch moving caudocranially, with the following parameters: pitch 0.55, 100 kVp, 300 mA, rotation time 0.5 s and CTDIvol 30 mGy. Image reconstruction was 1 mm slice thickness. Following a 3 min pause, a CT perfusion scan was performed in the craniocaudal direction using the following parameters: 4D range 100 mm with 1.5 s cycle time, 1.5 s scan time, 0.28 s rotation time, 25 scans, total examination time 38 s and CTDIvol 118 mGy. Images were reconstructed from 1.5 mm slices using the H20f kernel and 1 mm increments. All source images from the CTA, 1.5 mm axial, sagittal and coronal plane CT angiography reconstructions, and CT perfusion were analysed using Siemens software (Syngo.via), and the results were transferred to the Picture Archiving and Communication System (PACS). Re-evaluation for this retrospective study was based on stored PACS data.

Radiological assessment

A single reader (AVG) evaluated the NCCT scans for signs of acute ischaemia in the basal ganglia, including the internal capsule, globus pallidus, putamen and head of the caudate nucleus. Criteria for positivity included partial or total ipsilateral hypodensities.

CBF maps were examined and categorised using a three-pattern scale (figure 2). PP-1 indicated reduced blood flow in one-third or less of the MCA territory; PP-2 indicated reduced flow from more than one-third to two-thirds of the MCA territory; and PP-3 indicated reduced flow from two-thirds to throughout the MCA territory. Deep basal ganglia involvement was separately assessed. Where clarification between acute and chronic changes was required, NCCT was used to screen for old infarcts and enhance clarity in the CT perfusion evaluation.

CTA was used to identify the occlusion location and verify the thrombus using multiplanar reconstructions and maximum intensity projection reconstructions. The leptomeningeal collateral circulation was assessed as symmetric or asymmetric based on single-phase CTA. In cases of uncertainty, raw data from brain perfusion was used for clarification.

The M1 segment was defined as the first section of the MCA up to the major bifurcation.[15] In the coronal plane, the M2 segment was defined as starting from the main bifurcation of the MCA and was divided into proximal horizontal and distal vertical segments. The M3 segment of the MCA was the horizontal continuation of the distal M2 segment with a lateral course in the coronal plane.

Statistical methods

Analyses were performed using SPSS, V.29.0. Continuous variables were reported as medians with the IQR, and categorical variables were presented as absolute and relative frequencies. Comparisons between groups were performed using the Mann-Whitney U test or Kruskal-Wallis test for continuous variables because of the non-normal distribution of the data. For categorical variables, differences between groups were assessed using a χ^2 test or, where necessary, Fisher's exact test instead. The contingency coefficient (c) was calculated to evaluate the strength of association between categorical variables. All p values reported are two-sided.

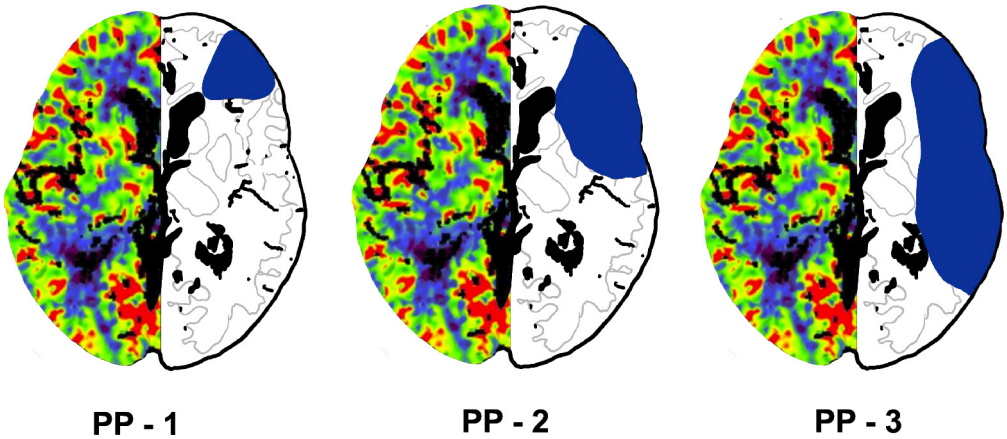

Figure 2 Perfusion Patterns (PP). PP-1: perfusion deficit of less than or equal to one-third of the MCA territory; PP-2: perfusion deficit up to two-thirds of the MCA territory; PP-3: perfusion deficit up to three-thirds of the MCA territory. *Potential concomitant basal ganglia involvement was evaluated separately. MCA, middle cerebral artery; PP, Perfusion Pattern.

Table 1 Baseline characteristics

Parameter	Total n=201	Occluded segment		P value
		M1 n=114	M2 or M3 n=87	
Age				0.922
Median	78	78	78	
IQR	70–84	70–84	69–85	
Mean, SD	75±14	75±14	74±15	
No. of women	115 (57.2%)	64 (56.1%)	51 (58.6%)	0.725
Hypertension	133 (66.2%)	70 (61.4%)	63 (72.4%)	0.102
Dyslipidaemia	79 (39.3%)	24 (21.1%)	55 (63.2%)	<0.0001
Atrial fibrillation (AF)	104 (51.7%)	54 (26.9%)	50 (24.9%)	0.887
Newly diagnosed AF	52 (25.9%)	29 (25.4%)	23 (26.4%)	
Previously diagnosed AF	52 (25.9%)	31 (27.2%)	21 (24.1%)	
Diabetes	43 (21.4%)	25 (21.9%)	18 (20.7%)	0.832
Smoker	27 (13.4%)	12 (10.5%)	15 (17.2%)	0.167
Anticoagulation/antiplatelet	93 (46.3%)	51 (44.7%)	42 (48.3%)	0.618
Left-side stroke	103 (51.2%)	45 (39.5%)	58 (66.7%)	0.0001
Basal ganglia infarct	66 (32.8%)	62 (54.4%)	4 (4.6%)	<0.0001
Symmetrical collaterals	98 (48.7%)	48 (42.1%)	50 (57.5%)	0.0308
Intravenous lysis	102 (50.7%)	61 (53.5%)	41 (47.1%)	0.3680
Final NIHSS				0.007
Median	4	4	6	
IQR	2–9	2–7	2–14	
Not available	54	21	33	
Haemorrhagic complications (%)				0.256
With mass effect	7 (3.5%)	5 (4.4%)	2 (2.3%)	
Without mass effect*	33 (16.4%)	21 (18.4%)	12 (13.8%)	

P values: Mann-Whitney U test for continuous variables and χ^2 test for categorical variables except for haemorrhagic complications, which were analysed using Fisher's exact test.
*Including patients with subarachnoid haemorrhage.
†All patients with proximal occlusions underwent mechanical thrombectomy, as this group of patients had been specifically selected from the hospital system based on that variable.
NIHSS, National Institutes of Health Stroke Scale.

RESULTS

We analysed 201 patients (mean age 75 years, 57.2% women), including 114 with M1 occlusions and 87 with M2 or distal occlusions. Table 1 presents the baseline characteristics. The M2 and distal occlusion group (n=87) comprised 53 proximal M2, 17 distal M2 and 13 M3 segment occlusions. Additionally, this group included four cases of minimal hypoperfusion assumed to be caused by distal vessel occlusion. The proximal occlusion group comprised 114 cases of M1 segment occlusion (59 proximal and 55 distal).

Overall, perfusion pattern frequencies were: PP-1, 36.8% (74/201); PP-2, 27.4% (55/201); and PP-3, 35.8% (72/201). These patterns varied significantly by occlusion location, aiding in distinguishing between proximal (M1 segment occlusions) and distal medium vessel occlusions (M2 and M3 segment occlusions) (p<0.0001). A simplified visual abstract of the results of our study is available in online supplemental figure 1.

PP-1, that is, perfusion deficits in up to one-third of the MCA territory, was observed in 78.4% of cases with medium and distal occlusions (58/74), while proximal occlusions caused PP-1 in 21.6% of those cases (16/74). Conversely, PP-3, that is, hypoperfusion in more than two-thirds of the MCA territory, was observed in 90.3% of cases with M1 occlusions (65/72). In the remaining 9.7% (7/72), distal medium vessel occlusion of the MCA gave rise to a PP-3 pattern. Table 2 gives further details.

A perfusion deficit from between one and two-thirds of the MCA territory (PP-2), intermediate between PP-1 and PP-3, was observed for all occlusion sites. It was more prevalent for proximal occlusions (60%, 33/55) than for distal medium vessel occlusions (40%, 22/55).

Table 2 Frequencies of anatomical occlusions by perfusion pattern

Parameter	Total n=201	PP-1 n=74	PP-2 n=55	PP-3 n=72	P value
Occlusion location					<0.0001
Proximal occlusions	**114 (56.7%)**	**16 (21.6%)**	**33 (60%)**	**65 (90.3%)**	
Proximal M1	59 (29.4%)	3 (4.1%)	14 (25.5%)	42 (58.3%)	
Distal M1	55 (27.4%)	13 (17.6%)	19 (34.5%)	23 (31.9%)	
Distal occlusions	**87 (43.3%)**	**58 (78.4%)**	**22 (40%)**	**7 (9.7%)**	
Proximal M2	53 (26.4%)	30 (40.5%)	18 (32.7%)	5 (6.9%)	
Distal M2	17 (8.5%)	13 (17.6%)	3 (5.5%)	1 (1.4%)	
M3 segment	13 (6.5%)	11 (14.9%)	1 (1.8%)	1 (1.4%)	
Not visible on CTA	4 (2%)	4 (5.4%)	–	–	
Collaterals					0.0016
Symmetrical	98 (48.7%)	48 (64.8%)	24 (43.6%)	26 (36.1%)	
Asymmetrical	103 (51.2%)	26 (35.1%)	31 (56.4%)	46 (63.9%)	
Neurological symptoms					
Initial NIHSS					0.00396
Median	14	12	14	15	
IQR	9–17	(6–16)	(9–17)	(12–18)	
Not available	*34*	*17*	*15*	*2*	
Final NIHSS					0.7864
Median	4	4	2	4	
IQR	2–9	(2–12)	(2–8)	(2–7)	
Not available	*54*	*19*	*19*	*16*	

P values: The χ^2 test was used except for the NIHSS scores, for which the Kruskal-Wallis test was used.
CTA, CT angiography; NIHSS, National Institutes of Health Stroke Scale; PP, Perfusion Pattern.

Interestingly, the distribution of collaterals varied among the three perfusion patterns, and more specifically, asymmetrical collaterals were more common in PP-3 (63.9%, 46/72), while symmetrical collaterals were more prevalent in PP-1 (64.8%, 48/74). We used the contingency coefficient to evaluate the impact of collateral type on the appearance of a specific PP and compare it to the effect of the anatomical location of the occlusion. The contingency coefficient revealed that occlusion location had a stronger association with the perfusion pattern (c=0.556) than collateral type (c=0.245).

Acute ipsilateral deep basal ganglia involvement was observed in 32.8% of cases (66/201). Nearly half of the cases with M1 occlusion showed concomitant acute basal ganglia infarct (54.4%, 62/114), accounting for 95% of these infarcts. Only four cases were associated with a distal medium vessel occlusion (6.1%, 4/66). Table 3 presents the incidence of deep basal ganglia infarction for each perfusion pattern. An infarct in the basal ganglia was associated with a slightly higher NIHSS score at presentation.

The median initial NIHSS score was 15 (IQR 13–18) compared with 13 (IQR 8–16) when there was no affectation of the basal ganglia (p<0.0001). Although there was no significant difference in NIHSS score between the two groups at day 4 (median 4 IQR 3–10) versus 4 (IQR 2–8) (p=0.121), the data in online supplemental table S1 suggests that basal ganglia infarction may have worse clinical outcomes when associated with distal arterial occlusions than with proximal occlusions.

Table 3 Distribution of basal ganglia infarction by perfusion pattern

	Basal ganglia involvement		
	Yes n=66	No n=135	P value
Perfusion Pattern			<0.0001
PP-1	9 (13.6%)	65 (48.1%)	
PP-2	17 (25.8%)	38 (28.1%)	
PP-3	40 (60.6%)	32 (23.7%)	

PP-1: minor perfusion deficits that affect an area less than or equal to one-third of the middle cerebral artery (MCA) territory; PP-2: perfusion deficits that affect an area of more than one-third to two-thirds of the MCA territory. PP-3: perfusion deficits extending beyond two-thirds of the MCA territory. Basal ganglia involvement was evaluated separately. This classification scheme did not take the extent of basal ganglia hypoperfusion into account. P value: χ^2 test.
PP, Perfusion Pattern.

Table 4 NIHSS scores by perfusion pattern

Occlusion location	Perfusion pattern PP-1 n=74	PP-2 n=55	PP-3 n=65	P value
Pre-NIHSS score				0.0039
Median	12	14	15	
IQR	(6–16)	(9–17)	(12–18)	
Post-NIHSS score				0.7864
Median	4	2	4	
IQR	(2–12)	(2–8)	(2–7)	

P value: Kruskal-Wallis test.
NIHSS, National Institutes of Health Stroke Scale; PP, Perfusion Pattern.

Table 4 sets out the association between perfusion pattern and NIHSS score. The final clinical neurological symptoms observed in the PP-1 patients (median final NIHSS score 4 (IQR 2–12)) were not statistically significant (p=0.7864) when compared with the other groups with larger initial perfusion deficits. However, the PP-1 patients had a consistently lower NIHSS score at presentation (median 12 points, IQR 6–16) than the PP-3 patients (median 15 points, IQR 12–18) (p<0.002).

In this study, all patients with M1 occlusions underwent mechanical thrombectomy compared with 47.1% of patients (41/87) with distal occlusions who underwent mechanical thrombectomy. Additionally, in the latter group, 41 patients (47.1%) received intravenous lysis, and 21 patients (24.1%) received both treatments. Subarachnoid haemorrhage (SAH) occurred after mechanical thrombectomy in 4.4% of cases (14/201), with a higher incidence in patients with distal medium vessel occlusions (64.3%, 9/14) than with M1 occlusions (35.7%, 5/14) (p=0.160). Bleeding complications, including SAH, were observed in 19.9% of cases (40/201), and 7 cases (3.5%) developed intracranial haemorrhage with mass effect. Total mortality during hospitalisation was 19.9% (20/201), in three cases due to haemorrhagic complications with mass effect.

DISCUSSION

The three-thirds PP is a novel visual scale capable of distinguishing between proximal (M1) and distal medium vessel (M2 and M3) intracranial occlusions. PP-3 indicates a slowdown of perfusion from more than two-thirds to three-thirds of the MCA territory and was produced by M1 segment occlusions in 90% of cases. Conversely, PP-1 exhibits small wedge-shaped perfusion deficits affecting up to one-third of the MCA territory and was produced by occlusions of the M2 and M3 segments in 78.4% of cases. Notably, PP-1 was also observed in 20% of M1 segment occlusions, while nearly 10% of distal medium vessel occlusions could also manifest as PP-3.

Previous research indicated that M2 occlusions result in a smaller perfusion lesion volume (median 47 mL (IQR 27–82) than M1 occlusions (median 98 mL, IQR 59–139).[19] Our study confirms the association of PP-3 with M1 occlusions (90% of cases) yet also highlights exceptions. Specifically, 8% of all distal, medium vessel occlusions (7/87) exhibited a PP-3 pattern, that is, 9.5% of all PP-3 cases (7/72). Although the underlying mechanism remains unclear, these findings suggest that acute haemodynamic changes may extend beyond the territorial boundaries of the occluded artery. Various factors, such as the absence of good leptomeningeal collaterals,[20 21] intracerebral steal phenomenon from neighbouring vascular territories,[22] post-ictal perfusion abnormalities concurrent with acute stroke,[23 24] reversible vasoconstriction syndrome[22 25] and delayed restoration of microvascular perfusion despite reopening of larger blood vessels[26] could contribute to discrepancies in perfusion changes relative to the occlusion site.

The PP-3 pattern was typically associated with proximal occlusion; however, M1 occlusions also accounted for 60% of PP-2 cases and 20% of PP-1 cases. Regardless of the specific pattern, analysis of the NCCT scan can provide valuable insights for determining the arterial culprit. Deep brain regions such as the basal ganglia have limited collateralisation, resulting in hypoperfusion even with robust leptomeningeal collateral circulation.[27] In our study, an acute infarct in the deep basal ganglia on NCCT was strongly associated with a 94% likelihood of a concomitant M1 segment occlusion. Given the anatomical exit zone of the lenticulostriate arteries along the M1 segment, this association was not unexpected.[28] Furthermore, we observed no significant impairment in early NIHSS outcomes in this patient group. Similarly, other studies have also reported no differences in 90-day functional outcomes in patients with basal ganglia infarction.[29] However, cognitive impairments, such as memory and attention deficits, have been noted.[30]

It is important to emphasise the strategic value of identifying an infarct in the basal ganglia as a radiological marker for M1 occlusion, detectable through the readily available NCCT technique.[28] This marker can improve the accuracy of thrombectomy transfers,[17] especially in the absence of the hyperdense media sign.[31] The overall incidence of basal ganglia infarctions is high in clinical practice. While the striatum is known to be highly susceptible to ischaemia,[32] our present findings align with experimental results suggesting a potentially higher incidence of M1 embolisms than previously thought.[33] Although the vast majority of these emboli are likely to undergo physiological clearance,[34] this raises the question of whether acute basal ganglia infarction observed on NCCT should prompt comprehensive intracerebral vascular imaging, given the strong association with M1 occlusions observed in our study.

Finally, our study revealed that both occlusion location and the presence of symmetric or asymmetric collaterals influence perfusion patterns, with the occlusion site

emerging as the primary determinant. Enhanced blood flow through the superficial small pial cerebral arteries has been linked to more favourable clinical outcomes.[35] Consistent with earlier research, our results showed that good collaterals are more frequently observed in the distal medium vessel occlusions than in proximal vessel occlusions.[36 37] However, our understanding of how collateral flow affects the size of perfusion deficits in cerebral blood flow maps remains limited. While in some cases strong collaterals provide sufficient blood supply to completely occluded territories without discernible changes on CT perfusion imaging,[38] effective collaterals generally mitigate the size of the infarct core by delaying the onset of irreversible damage without altering the overall extent of the perfusion deficit.[20]

Limitations

This study has several limitations. We did not analyse the correlation between visually assigned perfusion patterns and quantitative or volumetric hypoperfusion measurements. While we excluded other arterial diseases, such as tandem stenosis, that can potentially affect baseline cerebral perfusion, we did not evaluate other possible confounding factors, such as the time elapsed between symptom onset and imaging. However, all patients presented within a time window of fewer than 8 hours from symptom onset.

Categorisation of the collateral circulation into dichotomous groups (good vs bad collaterals) limited the depth of the analysis. Using more descriptive classifications or alternative imaging methods, such as dynamic CTA or multiphase CTA, might have yielded different results. Additionally, this study did not assess vascular variants. Given the angiographic verification of the M1 occlusion group, the likelihood of misallocation of thrombi due to M1 variants, that is, short M1 segments, was minimal. Moreover, there was no assessment of hyperdense MCA or Alberta Stroke Programme Early CT Score. Although this does not alter the value of our results, it warrants further investigation. Comparing 87 M2 and M3 segment occlusions with 114 M1 occlusions provides valuable insights; however, the sample size may limit other meaningful conclusions. Further analysis may be required to gain a better understanding of our results, that is, regarding any potential 'discrepancies' between the arterial occlusion site and the extent of the perfusion changes.

CONCLUSIONS

Identifying the occluded arterial segment in acute ischaemic stroke is critical to making the right treatment decisions. While CTA is a reliable imaging technique for diagnosing proximal brain artery occlusions, it can be challenging for medium and distal occlusions, often leading to false negatives. The PP scale effectively differentiates between proximal and distal medium vessel intracranial occlusions. This can help confirm uncertain findings on CTA or assist radiologists in prioritising areas on the CTA scan for evaluation.

Patients with PP-1 consistently showed lower NIHSS scores than those with PP-3, although no major differences in NIHSS scores on day 4 were recorded. While PP-3 typically indicated an M1 occlusion, PP-1 cases were caused by a distal medium vessel occlusion in almost 80% of cases. However, exceptions were noted, with 21.6% of M1 segment occlusions also displaying the PP-1 pattern and 9.7% (7/72) of (single) M2 and M3 occlusions producing a PP-3 pattern. These findings suggest that haemodynamic changes in acute stroke may extend beyond potential anatomical variations and territorial boundaries of the occluded artery, warranting further research into the underlying mechanisms, beyond just the pial collaterals. Furthermore, the presence of basal ganglia infarction on NCCT was found to be a reliable marker of M1 occlusion, with a 94% likelihood. This 'early' marker may help to avoid misinterpretation in cases of intermediate (PP-2) perfusion or smaller PP-1 deficits, thereby facilitating the identification of probable thrombectomy candidates.

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Patient consent for publication Not applicable.

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Data availability statement Data are available upon reasonable request. Supporting data for this study are available upon reasonable request from the corresponding author.

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