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Predictors for basal ganglia viability after mechanical thrombectomy in proximal middle cerebral artery occlusion

Marius Georg Kaschner[a,*], Raul Lande[a], Christian Rubbert[a], Julian Caspers[a,b], John-Ih Lee[c], Michael Gliem[c], Sebastian Jander[c], Bernd Turowski[a]

[a] Department of Diagnostic and Interventional Radiology, Heinrich Heine University Duesseldorf, Medical Faculty, Germany
[b] Institute of Neuroscience and Medicine (INM-1), Research Centre Jülich, Germany
[c] Department of Neurology, Heinrich Heine University Duesseldorf, Medical Faculty, Germany

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ABSTRACT

Background/purpose: In acute proximal middle cerebral artery (MCA) occlusion covering the lenticulostriate arteries (LSA), ischemic tolerance of basal ganglia is limited due to supposed lack of collateral supply. However, in several patients, basal ganglia (BG) infarction was absent after successful mechanical thrombectomy (MTE). Purpose of our study was to evaluate predictors for BG viability in stroke patients despite prolonged MCA mainstem occlusion.

Material/methods: We retrospectively reviewed all stroke patients from our local registry with MCA mainstem occlusion after mechanical thrombectomy between November 2009 and October 2016. All patients underwent non-enhanced post-interventional cranial CT imaging (NCCT) and were classified according to 6 patterns of BG viability: complete: putamen (P) and globus pallidus (GP); partial: P or GP, and combination of complete or partial BG and/or adjacent white matter/cortical (WMC) viability. We compared viability patterns with respect to pre-interventional stroke imaging including NCCT, CT-angiography (CTA), CT perfusion (CTP); demographics, pre- and intra-procedural data and occurrence of post-procedural intracerebral hematoma (ICH). CTP imaging of the affected and contralateral BG-territories were obtained separately and CTA-collateral score (CS) was assessed.

Results: A significant correlation between higher collateral score and viability of GP (OR = 1.949; p = .011), P (OR = 2.039, p = .011), and the combination of GP, P and WMC (OR = 2.767, p = .007) was revealed. Higher relative CBV ratio (rCBVR) was significantly associated with viability of the pattern GP + WMC (univariate: OR = 3.160, p = .014; multivariate: OR = 6.058; p = .021).

Conclusion: CTA collateral score and rCBVR were predictive for BG viability in stroke patients after successful MTE in prolonged complete MCA-mainstem and LSA occlusion.

1. Introduction

Prolonged occlusion of the pre-bifurcation M1 segment of the middle cerebral artery (MCA) and lenticulostriate artery (LSA) ostia commonly results in basal ganglia (BG) infarction. Occasionally sparing of adjacent deep white matter can be observed in MCA infarction with occlusion of the MCA mainstem, because collaterals may sustain tissue in the peripheral MCA territory. Since BG are supposed not to possess a significant collateral blood supply, ischemic tolerance should be lower than that of the hemispheric cortex and the white matter. In contrast, we found in preliminary observations absent BG infarction after successful mechanical thrombectomy (MTE) in many patients with M1 segment occlusion, that covered the anatomic region of LSA ostia.

Infarction of basal nuclei is associated with higher rates of hemorrhagic transformation, worse dysfunction and disability at discharge, and longer hospitalization [1].

Therefore risk assessment of intracerebral hemorrhage (ICH) due to BG infarction is necessary for neurointerventionalists to adapt endovascular procedures, in order to retain clinical effectiveness in relation to the risk of significant intracerebral hemorrhage (ICH). We investigated imaging parameters, in particular computed tomography angiography (CTA) collateralization, CT perfusion (CTP), procedural,

* Corresponding author at: Department of Diagnostic and Interventional Radiology, Heinrich Heine University Duesseldorf, Medical Faculty, Moorenstr.5, 40225 Duesseldorf, Germany.
E-mail address: marius.kaschner@med.uni-duesseldorf.de (M.G. Kaschner).

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and clinical and demographic data to indicate predictors for survival of BG in acute stroke patients with M1 segment and LSA occlusion.

2. Material and methods

We retrospectively reviewed all patients undergoing MTE treated in our hospital between November 2009 and October 2016 according to protocol approved by our local Ethics Committee. The acute stroke imaging protocol at our institution includes non-enhanced cranial CT (NCCT) and segmental brain CTP followed by craniocervical CTA for all patients with suspected acute ischemic stroke clinically evaluated by a neurologist. Only patients with proximal MCA M1 segment occlusion or tandem ICA and M1 segment obturation, that covered the LSA ostia documented on CTA were included, to ensure that no blood supply to the LSA existed and if integrity of the BG in NCCT and CTP before MTE was preserved. Subsequent digital subtraction angiography (DSA) in patients treated with MTE confirmed proximal M1 occlusion prior to MTE and reperfusion of LSA immediately after recanalization. Furthermore, DSA allowed detecting anatomical variants of BG collateralization retrospectively. BG viability was evaluated at routinely post-interventional follow-up NCCT after 24 h.

For all included patients, the following data were collected (Table 1): demographics (gender, age, cerebrovascular risk factors), admission NIHSS (National Institutes of Health Stroke Scale Score), time from symptom onset to stroke imaging, treatment details (use of intravenous recombinant tissue plasminogen activator (rt-PA) in the emergency room, time from stroke imaging to opened stent retriever and to recanalization, intraarterial local rt-PA, antiaggregation in permanent stent implantation). We recorded the final revascularization result of the primary arterial occlusive lesion from the angiogram by TICI score (Thrombolysis in cerebral infarction). Clinical outcome data included discharge NIHSS, discharge modified Rankin Scale (mRS), duration of hospitalization. ICH was defined as hemorrhagic infarction (HI) or parenchymal hematoma (PH) according to the European Cooperative Acute Stroke Study classification (ECASS) and was assessed by post-interventional NCCT after 6–24 h [2].

Table 1
Baseline characteristic and treatment outcome.

Subject sample n = 92	
Socialdemographic characteristics	
Age (years), mean ± SD	72 ± 13.4
Female	n = 53 (57.6%)
Pre-existing conditions:	
Coronary artery disease	n = 26 (29.5%)
Myocardial infarction	n = 7 (7.6%)
Atrial fibrillation	n = 45 (51.1%)
Arterial hypertension	n = 69 (78.4%)
Peripheral arterial occlusive disease (PAOD)	n = 7 (8%)
Diabetes mellitus	n = 22 (23.9%)
Dyslipidaemia	n = 37 (42%)
COPD	n = 15 (17%)
Glucose level (mmol/L) (mean ± SD)	123.5 ± 31.5
Coumarin treatment	n = 10 (11.5%)
Previous stroke	n = 0 (0%)
Treatment details	
Admission NIHSS median (mean ± SD)	14 (13.4 ± 5.5)
Collateral status (0–3) median	2
IV rtPA	n = 69 (77.5%)
IA rtPA	n = 47 (52.2%)
Mean time (min) (mean ± SD)	
- From symptom onset to imaging	99.9 ± 78.7
- First flow M1	220.8 ± 91.5
- To final recanalization M1	232.6 ± 101.4
Treatment and clinical outcome	
TICI 2b-3	n = 80 (86.9%)
TICI 2a	n = 12 (13.0%)
TICI 2b	n = 37 (40.2%)
TICI 3	n = 43 (46.7%)
Discharge NIHSS median (mean ± SD)	7 (7.9 ± 6.1)
Symptomatic intracranial hemorrhage (ECASS:PH2)	n = 11 (11.9%)

2.1. Imaging protocol

2.1.1. CT stroke protocol

The CT stroke protocol, performed on different multisection scanners (Somatom Definition Flash, 128 detector rows; Somatom Definition AS, 64 detector rows; both Siemens Erlangen, Germany). Standard CT protocol included pre- and post-contrast CT head scans with the following parameters:

2.1.2. Non-contrast CT (NCCT)

120 kV (peak) (kVp), 250 mAs, 0.6 mm collimation, 1 s/rotation, and table speed of 1 mm/rotation.

2.1.3. CT-perfusion (CTP)

Sectional CTP was acquired at level of the cella media, angled parallel to the orbitomeatal plane CTP scan parameters were 80 kVp, 180 mAs (Somatom-FLASH) or 80 kVp, 120 mAs (Somatom Definition AS), 1 second rotation and iodinated contrast medium infusion of 30 ml iomeprol 400 mg J/ml (Imeron®, Bracco, Milan, Italy) at Somatom-FLASH, and 40 ml iohexol 300 mg J/ml (Accupaque GE Healthcare Buchler GmbH &Co, Munich, Germany) at Somatom Definition AS, via automated antecubital injection at 5 ml/s with a 3 second delay, followed by 30 ml saline solution, collimation of 1 × 10 mm (Definition FLASH) or 64 × 0.6 mm (Definition AS). Reconstructions covered 2 × 1 cm representative slices of the MCA territory.

Calculation of perfusion maps including time to maximum (Tmax), mean transit time (MTT), relative cerebral blood volume (rCBV), and relative cerebral blood flow (rCBF) were performed with manufactured in-house software (STROKETOOL-CT) (Version 2.0, H.-J. Wittsack, http://www.digitalimagesolutions.de).

Quantitative analysis of DICOM-data from parameter images (MTT, Tmax, rCBF, rCBV) was performed semiautomatically using the imaging processing software Angiotux CT 2D (ECCET 2006/Beck A., Aurich V.)

2.1.4. CT-angiography (CTA)

CTA covered the aortic arch to the vertex with continuous axial sections parallel to the orbitomeatal line; with collimation 128 × 0.6 mm, 120 kVp, 100 mAs, 1 s/rotation, and table feed of 1 mm/rotation (Somatom Definiton FLASH) or with collimation 64 × 0.6 mm, 120 kVp, 175 mAs, 1 s/rotation, and table feed of 1 mm/rotation (Somatom Definition AS).

After a single bolus of intravenous contrast injection (70–80 ml iomeprol 400 mg J/ml) at 4 ml/s flow rate, acquisitions were started auto-triggered by appearance of contrast in a region of interest manually placed in the ascending aorta.

CTA data were processed to reconstruct 2D-multiplanar 9-mm maximum intensity projections (MIP) in axial, coronal and sagittal plane, 1-mm coronal and sagittal multiplanar reconstructions (MPR) and 0.75- and 4-mm axial CTA source images.

2.1.5. Endovascular treatment

MTE of the anterior circulation was performed under local anesthesia of the groin, intra-venous application of 5000 IU heparin (after intraarterial 8F, 80 cm sheath placement) and 1 g metamizol. The occluded vessel was probed by a microcatheter through a 5F or 6F intermediate catheter (e.g., Navien, Medtronic, Irvine, California, USA; Neurobridge, Acandis, Pforzheim, Germany; SOFIA®, MicroVention, Düsseldorf, Germany) and in elongated vessel anatomy an additional 8F guiding-catheter was used. MTE was subsequently performed after passage of the clot using a stent-retriever system (e.g., Aperio®, Acandis, Pforzheim, Germany). In cases of incomplete recanalization after MTE additional procedures, such as intra-arterial thrombolysis,

angioplasty or wire fragmentation of the clot were used. Internal carotid stenting (Carotid WALLSTENT™, Boston Scientific, Marlborough, MA, USA) of high-grade stenosis was performed to establish access to intracranial vessel occlusions if required.

2.2. Imaging analysis

2.2.1. CTP

Relative CBV (rCBV), relative CBF (rCBF), Tmax and MTT values of BG were recorded using region of interest (ROIs) in anatomic structures that are exclusively supplied from M1-perforators (globus pallidus and putamen). Relative CBV ratio (rCBVR) and relative CBF ratio (rCBFR) were defined as quotient of ipsi- and contralateral rCBV, and rCBF, respectively [3].

2.2.2. Angiography

Post-treatment recanalization was graded according to the Thrombolysis in Cerebral Infarction (TICI) classification on final DSA images subsequent to recanalization [4]. TICI grade 0 and 1 were considered non-recanalized, grade 2a with incomplete distal branch filling of < 50% of the expected territory as inadequate reperfusion. TICI grade 2b (incomplete distal branch filling > 50%) to 3 (complete distal branch filling) were defined as successful recanalization of the occluded MCA territory.

2.2.3. CTA collateral score

Collateral supply of the occluded MCA territory from pre- interventional CTA scans was scored on the basis of the CTA collateral grading system by Tan et al. on a scale of 0–3 [5]. A score of 0 corresponds to absent collateral supply, a score of 1 to collateral supply filling < 50% but > 0%, and a score of 2 corresponds to collateral supply filling > 50% but < 100% of the occluded MCA territory. One hundred percent collateral supply of the occluded MCA territory was scored as 3.

2.2.4. Basal ganglion infarction and hemorrhagic transformation (HT)

BG regions, that were exclusively supplied by the M1-perforators (globus pallidus and putamen = nucleus lentiformis) were selected for assessment on NCCT.

Six patterns of non-infarcted (viable) basal ganglia were identified on NCCT:

- putamen (P),
- globus pallidus (GP),
- both, globus pallidus and putamen (GP + P),
- putamen and adjacent white matter/cortical region (P + WMC) of the middle cerebral artery (MCA) territory,
- globus pallidus and adjacent white matter/cortical region (GP + WMC) of the MCA territory,
- both, globus pallidus and putamen and adjacent white matter/cortical region (GP + P + WMC) of the MCA territory.

Any hemorrhagic transformation (HT), including hemorrhagic infarction (HI) and HT with parenchymal hematoma (PH) was evaluated according to ECASS classification.

Representative cases of basal ganglia infarction patterns are given in Figs. 1–3.

2.2.5. Imaging reading

Imaging reading was performed by three readers (R.L., M.G.K., and B.T.). R.L. is a final-year medical student extensively instructed and trained in the evaluation of CTP images, of the Tan CTA collateral score, in TICI scoring on cerebral angiograms, and in the evaluation of infarct patterns on NCCT. M.G.K. and B.T. are senior interventional neuroradiologists with 10 and 20 years' experience in (neuro-) radiology, respectively.

Retrospective assessment of CTP values, assessment of collateralization (Tan score), revascularization success (TICI) and infarct pattern (NCCT) were performed by R.L., M.G.K. and B.T. by consensus reading. To avoid recall bias, CTP images, CTA collateral scores, angiograms and post-interventional NCCT images were evaluated independently of each other and personal patient data were anonymized, so that readers were blinded to the results of the other image modalities of the respective case.

2.3. Statistical analysis

Statistical analysis was conducted in SPSS version 21.0.0 (IBM, Armonk, New York). Odds ratios (OR) were calculated by binary univariate logistic regression analysis to quantify association between BG/WMC region viability with respect to the above mentioned viability patterns and the following baseline characteristics and treatment outcome data, summarized in Table 1: socialdemographic characteristics, pre-existing conditions including cardiovascular risk factors; treatment details, and treatment- and clinical outcome. OR to determine correlation between BG/WMC viability and pre-interventional perfusion parameters (CBV, Tmax, CBF, MTT) was calculated by binary uni- and multivariate logistic regression analysis. To determine correlation between prementioned factors and percental viability of WMC region a linear logistic regression analysis was performed. For BG/WMC viability Fisher's exact ratio test was used as significance test for the OR. Results were considered significant at a level of $p < .05$.

3. Results

3.1. Baseline characteristics

A total of 92 patients meeting the inclusion criteria were enrolled.

Demographic data, pre-existing cardio-vascular diseases and risk factors of included patients are shown in Table 1. There was no significant correlation between demographic parameters and basal ganglia viability.

A significantly negative correlation was observed between elevated blood glucose level and basal ganglia viability in all basal ganglia and white matter patterns summarized in Table 2 (OR = 0.938–0.975; p = .012–0.043). The remaining pre-existing cardio-vascular diseases and risk factors had no influence on viability of BG/WMC region.

3.1.1. CTA collateral score

Univariate regression analysis revealed a significant correlation between higher CTA collateral score (CS) and integrity of BG for all predefined parts of BG and white matter/cortical region patterns of the middle cerebral artery (MCA) territory (Table 3). The strongest positive correlation between BG viability and high CS values was observed for the unit of globus pallidus and white matter/cortical-MCA region (GP + WMC) (OR 3.006, p = .003) and for the unit of P + WMC or GP + Putamen + WMC (GP + P + WMC, OR: 2.767; p = .007). Linear logistic regression analysis revealed a highly significant influence of CS on percental viability of the WMC region (regression coefficient: 0.247, R^2: 0.385, p = .000).

3.1.2. Procedural data

TICI 2b and 3 recanalization was achieved in 86.9%. Mean time from symptom onset to initial CT perfusion imaging was 99.9 min (SD ± 78.7) and to first flow in the M1 segment 220.8 min (SD ± 91.5). In 3 cases a Penumbra system was used for recanalization of the M1 segment (1 case in 2009, 2 cases in 2012). In all three patients TICI 2b final recanalization grade was achieved. Stent retriever thrombectomy was performed with a Solitaire stent retriever (Medtronic) in 6 cases and in one case with a TREVO stent retriever system (Stryker). The other cases in that stent retriever thrombectomy was performed the Aperio system was used. There was no significant

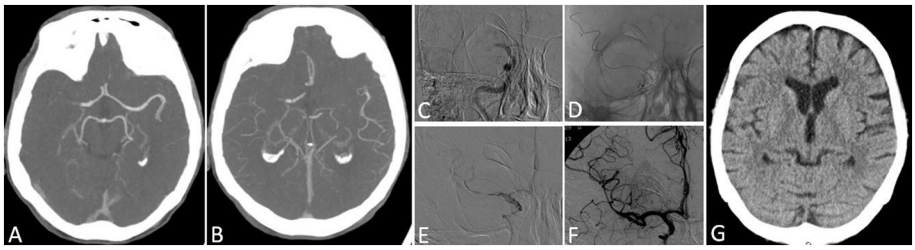

Fig. 1. Exemplary axial CTA maximum intensity projection (MIP) demonstrate proximal occlusion of the right-sided M1 segment (A) with good collaterals. Tan Score was 2 (> 50% of affected MCA territory opacified in comparison to non-affected MCA territory) (B). The combination of both angiographic images via guiding-catheter proximal the occlusion site (C) and via microcatheter after thrombus passage (D) demonstrates thrombus extension. Angiographic control run with opened stent retriever (Aperio) covering the thrombus (E). TICI 3 final recanalization was achieved (F). Basal ganglia without signs of infarction on postinterventional control NCCT (G).

correlation between BG viability and pre-treatment factors (admission NIHSS, i.v. rt-PA), procedural factors (i.a. rt-PA, duration from onset to recanalization), and recanalization rate (TICI) (Table 1). Hemorrhagic transformation (PH1, PH2) of white matter and cortical region of the MCA territory correlated significantly with decreased BG viability (Table 4). We identified no anatomical variants of BG collateralization in any patient in final DSA scan after successful MTE.

3.1.3. Perfusion analysis

There is a significant correlation between rCBV ratio (rCBVR) values and integrity of globus pallidus (GP) in conjunction with white matter/cortical (WMC) region of the MCA territory (OR = 3.160; p = .014). There was a positive correlation between viability of GP and WMC and higher rCBVR values but without significance for the remaining BG/WMC patterns. The multivariate analysis including rCBVR, rCBFR, Tmax and MTT revealed an increased OR 6.058 for rCBVR as a predictor for GP + WMC viability (p = .021, Table 5). rCBF, Tmax and MTT were not significantly correlated with BG/WMC viability.

4. Discussion

BG infarction is associated with an increased risk of parenchymal hematoma (PH) and hemorrhagic infarction (HI). In most cases MCA occlusion with complete LSA blockade results in broad BG infarction in the dependent LSA territories, even after rapid and technically successful recanalization [6]. However, in our own study population there were several cases with predominantly none infarcted BG after successful recanalization, where no anatomical vascular variants explain these findings. Hence, the intention was to identify predictors for BG viability in MCA-mainstem occlusion covering LSA.

In the present study high rCBVR values significantly correlated with viability of the BG in combination with white matter and cortical region of the MCA territory. Mokin et al. separately analyzed BG and cortical CTP abnormalities to predict hemorrhagic transformation and clinical outcomes in patients with MCA occlusion undergoing endovascular therapy. Decreased rCBV correlated significantly with parenchymal hematoma and hemorrhagic infarction [7]. Loh et al. classified terminal ICA and M1 occlusions according to diffusion MRI patterns ranging from complete BG infarct to relative sparing of the BG in patients with terminal ICA and M1 occlusion before MTE. Patients with completed BG infarction had a higher rate of parenchymal hemorrhagic transformation than the other groups (OR 6.7, 95% CI 1.02 to 183.3). PH was associated with higher rates of death and dependency at discharge. Patients with complete BG infarction had also worse pre- and post-thrombectomy NIHSS, longer hospital length of stay, and higher rates of discharge mRS [1].

As a further predictor for BG integrity in the current study the CTA based collateralization score correlated significantly with all pre-defined BG and WMC viability patterns of the MCA-territory. Patients with a good collateralization of the MCA territory showed a significant higher rate of BG integrity. Patients with high collateral score values might not only have a better leptomeningeal collateral blood supply, but also increased blood flow in general, including the recurrent artery of Heubner, the anterior choroidal artery and perforators arising from the P1segment and the posterior communicating artery. Accordingly, viability of globus pallidus could be explained in this way.

Interestingly also putamen, seems to profit from high collateral scores, although no collaterals of the putamen, with the exception of its anterior part, could be detected in angiographic examinations [8]. Infarcted and viable lateral BG showed no significantly different rCBVR values. This discrepancy might be caused by low sensitivity of rCBVR to detect perfusion differences between intact and infarcted lateral BG. A sufficient collateral circulation protects the brain against ischemic injury and can potentially mitigate the effect of an occluded artery, thereby the time window for clinical effective mechanical recanalization can be extended based on additional information on collateral flow und local perfusion. Several studies showed an excellent correlation between collateralization, infarct volume and clinical outcome [5,9–13]. Although in CT based collateral score systems the ASPECT- and regional leptomeningeal collateral score offer scoring of regional collateralization separately for BG [10,11] to our knowledge there are no studies available that evaluated the impact of CT based collateral scores as a predictor for BG infarction in particular. Kim et al. tested a modified regional angiographic collateral score, in that collateral flow was recorded for 15 anatomic areas based on vascular territories. Angiographic collateral score correlated with infarct volume on follow-up CTs and follow-up NIHSS. A high accuracy was obtained for the MCA territory (AUC: 0.76–0.92) and the lowest accuracy was observed for the BG (AUC: 0.87). The authors assumed that BG are supplied by end arteries and are least affected by collaterals. Angiographic

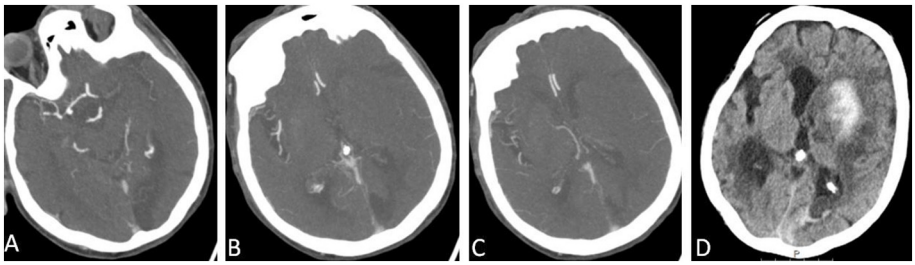

Fig. 2. Exemplary representative axial CTA maximum MIPs demonstrate proximal occlusion of the left-sided M1 segment (A) with poor collaterals. Tan Score was 1 (< 50% of affected MCA territory opacified in comparison to non-affected MCA territory) (B + C). Infarction pattern with lesions of the entire basal ganglia, white matter, and associated cortex. Hyperattenuation due to parenchymal hematoma and contrast media extravasation within the infarct is shown (D).

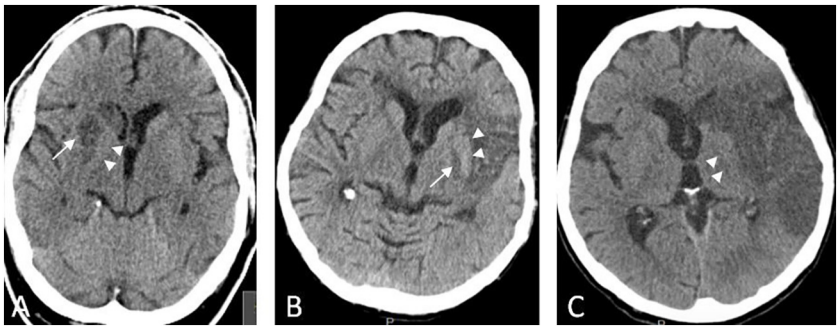

Fig. 3. Representative examples for incomplete basal ganglia infarction on control NCCT after MTE: Hypoattenuation of the putamen (arrow) and caudate nucleus as sign of infarction, while the pallidum is not affected (arrowheads) (A). Hypoattenuation of the pallidum (arrow) and supraganglionic MCA territory indicates infarction, while the putamen (arrowheads) has a normal appearance on post-interventional NCCT (B). Caudate nucleus, putamen and broad areas of the MCA territory are infarcted. Medial part of the BG representing the pallidum (arrowheads) shows no signs of infarction (C).

Table 2
Negative correlation between elevated glucose level, and viability of basal ganglia and WMC region.

Cerebral region	Glucose (mg/dl)	
	OR (95% CI), intact BG	p
GP	0.971 (0.949–0.994)	.015
P	0.975 (0.952–0.998)	.037
GP + P	0.958 (0.926–0.990)	.012
GP + WMC	0.968 (0.938–0.999)	.043
P + WMC	0.938 (0.888–0.991)	.022
GP + P + WMC	0.971 (0.949–0.994)	.015

GP, globus pallidus; P, putamen; WMC, white matter/cortical region.

Table 3
Correlation between CTA collateral score and basal ganglia and WMC region viability.

Cerebral region	CTA collateral score (0–3)	
	OR (95% CI), intact BG	p
GP	1.949 (1.169–3.252)	.011
P	2.039 (1.179–3.526)	.011
GP + P	2.260 (1.276–4.003)	.005
GP + WMC	3.006 (1.457–6.205)	.003
P + WMC	2.767 (1.314–5.828)	.007
GP + P + WMC	2.767 (1.314–5.828)	.007

GP, globus pallidus; P, putamen; WMC, white matter/cortical region.

Table 4
Correlation between hemorrhagic transformation of the WMC region of the MCA territory and basal ganglia viability.

Cerebral region	Hemorrhagic transformation (PH1-PH2) of WMC region	
	OR (95% CI), intact BG	p
GP	0.198 (0.053–0.731)	.015
P	0.265 (0.074–0.944)	.040
GP + P	0.275 (0.078–0.975)	.046
GP or P	0.190 (0.051–0.708)	.013

Table 5
Correlation between rCBVratio (rCBVR) and viability of Globus pallidus + WMC unit; uni- and multivariate regression analysis.

Parameter	OR (95% CI), viability of globus pallidus + WMC unit			
	Univariate	p	Multivariate	p
rCBVR BG	3.160 (1.260–7.923)	0.014	6.058 (1.317–27.869)	.021
rCBFR BG	1.058 (0.886–1.264)	0.532	1.041 (0.853–1.272)	.691
MTT BG	1.018 (0.969–1.070)	0.475	0.952 (0.879–1.031)	.223
Tmax BG	0.944 (0.828–1.076)	0.390	1.052 (0.902–1.226)	.521

BG, basal ganglia; WMC, white matter/cortical region.

hypervascularization of BG, indicating “luxury perfusion” was only an imprecise predictor for infarction [12]. Although the CTA score assesses collateralization in general and does not allow a separate assessment of BG collateralization, our study shows that collateral status is a strong and independent predictor of BG viability. Based on these results, we hypothesize, contrarily to the prementioned studies, that variable unspecific deep parenchymal collaterals of the striatum might exist, so that a sufficient collateralization in general also supplies the BG that way [14]. A further indication of deep parenchymal collateralization of BG might be our observation of significant negative correlation between hematoma of white matter and cortical regions and increased rate of basal ganglia infarction. Regional scores take in consideration that neurological outcome depends on lesion localization. Previous studies confirm that the volume of abnormality on CTA source images at baseline is a very close accordance to the volume of final infarct on follow-up scanning in case of contemporary recanalization. Future studies have to approve if CTA score parameters are predictive for irreversible extensive BG infarction to estimate risk of symptomatic BG reperfusion hematoma. In our own study CTA collateral score was more predictive for BG infarction than CTP but the impact of these findings are limited by the retrospective nature of this study.

Kleine et al. evaluated in an angiographic study the effect of MTE to prevent striatal infarction in patients with acute isolated M1 occlusion. In seven of the 22 patients, that did not develop the expected infarction pattern there were no variants of vascular supply detectable as explanation for the false positive results [6]. These findings support our own observations, that in exceptional cases BG might have an increased ischemic tolerance. Further trials have to focus on these special cases to evaluate determinants that allow to identify salvageable tissue and to predict infarct expansion of BG. Preexisting hyperglycemia worsens the clinical outcome of acute stroke [15]. However, elevated blood glucose had only a minor influence to BG viability in this study. A major limitation of this study is the use of a consensus reading design that might include restrictions like absent of recorded variability in the readers' interpretations and bias due to possible influence of junior readers from senior readers. One limitation might be evaluation of BG infarction on NCCT instead of MRI that is more sensitive for early signs of infarction. However, reliability of NCCT in the determination of early phase basal ganglia infarction has been demonstrated as a sensitive imaging modality, too. Hypoattenuation specifically in the basal ganglia as an early ischemic stroke sign can be observed within 6 h after onset [16]. Decreased attenuation of the lentiform nucleus (obscuration of the lentiform nucleus), leading to a less clear delineation between white and grey matter, indicates cytotoxic edema and can be observed within 2 h after stroke onset on NCCT already [17]. To reduce bias by different imaging modalities, we included only patients with NCCT follow-up into this study. At last, future prospective studies involving a large number of patients will be needed to get more detailed information about blood supply of the BG in the setting of ischemic stroke due to MCA mainstem occlusion.

5. Conclusion

Extended MCA mainstem occlusion generally causes broad BG infarction. Yet, BG integrity after technically effective MTE in complete MCA occlusion was observed in several patients. CT collateralization score and rCBV ratio values were predictive for postinterventional BG condition, and may help guiding endovascular treatment decisions.

The authors declare that they have no conflict of interest.

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