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Diagnostic and therapeutic aspects of neuroradiology in acute ischemic stroke affecting the anterior circulation

Thesis

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PUBLICATIONS

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I. **Nagy C** , Bajzik G , Skobrák A , Csorba E , Lajtai A , Balogh G , Nagy F , Vajda Z . Gyermekkori sporadikus hemiplegiás migrén arteria cerebri media hipoperfúzióval [Childhood sporadic type of hemiplegic migraine with arteria cerebri media hypoperfusion]. *Ideggyogy Sz*. (2017) 30;70(9-10): 343-348. – case report; **IF: 0,252**

II. **Nagy C**, Héger J, Balogh G, Gubucz I, Nardai S, Lenzsér G, Bajzik G, Fehér M, Moizs M, Repa I, Nagy F, Vajda Z. Endovascular Recanalization of Tandem Internal Carotid Occlusions Using the Balloon-assisted Tracking Technique. *Clin Neuroradiol*. (2021) doi: 10.1007/s00062-021-01078-2. – original publication; **IF: 3,649**

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VI. Kalmár JP, Tárkányi G, Karádi NZ, Bosnyák E, **Nagy BC**, Csécsei P, Lenzsér G, Büki A, Janszky J, Szapáry L. A mechanikus thrombectomiát megelőző intravénás thrombolysis szerepe az akut agyi nagyérelzáródások kezelésében [The role of intravenous thrombolysis before mechanical thrombectomy in the treatment of large vessel occlusion strokes]. Ideggyogy Sz. 2022 Jan 30;75(1-02):23-29. Hungarian. doi: 10.18071/isz.75.0023. PMID: 35112518. **IF: 0,427**

INTRODUCTION

Acute ischemic stroke (AIS) is a cerebrovascular accident resulting from insufficient focal cerebral blood flow. The blockage diminishes essential oxygen and glucose perfusion to the brain, leading to damage or death of brain cells. If circulation isn't restored in time, brain damage can be unavoidable. The importance of this disease is that it causes major social and economic burdens to society because it can be a significant cause of morbidity with long lasting disability and mortality. Globally, stroke is the second leading cause of death and is a leading cause of serious long-term disability. Rapid recanalization of arterial occlusion and restoration of blood flow can prevent disability and save lives. Anterior circulation ischemic strokes are the most common of all ischemic strokes and account for approximately 70% of ischemic stroke cases. The main cause of this disease is the obstruction of one of the large arteries of the anterior circulation or the small perforator arteries. Causes of arterial occlusion involving the major cerebral arteries mainly are emboli arising from atherosclerotic arterial stenosis at the bifurcation of the common carotid or the origin of the internal carotid artery, from cardiac sources and from atheroma in the aortic arch. Symptoms and severity depend on the level and length of occlusion. Occlusion of the internal carotid artery can be silent when collaterals open up if the occlusion occurs steadily over a period of time. In other cases, tandem occlusion of the internal carotid artery can develop which is characterized by proximal occlusion of ICA, either due to acute thrombosis of an unstable atherosclerotic plaque or dissection, resulting in the embolic blockage of the ICA terminus and/or the main trunk (M1 segment) of the middle cerebral artery. The condition is responsible for up to 20% of acute ischemic stroke cases, responds poorly to intravenous thrombolysis and is associated with poor prognosis without timely and successful recanalization. Rapid neurovascular imaging is critical in identifying eligible patients for endovascular therapy. Recent innovations in neuroimaging have allowed for better assessment of risks/benefits of endovascular therapy and appropriate triage of patients. Primary and most cost-effective tool used in case of suspected acute stroke is non-contrast computed tomography. More advanced non-invasive imaging techniques are computed tomography angiography (CTA) either expanded with perfusion study (CTP) or magnetic resonance (MR) imaging with different sequences including angiography (MRA). Computed tomography is a tool that can be used to differentiate between ischemic and hemorrhagic stroke and can show the exact location of the blood clot in a timely manner with a low cost. Findings on the CTA have triage consequences and preventive implications for the stroke patient. Diagnosing supra-aortic large vessel stenosis

or occlusion referable to the neurological symptoms is essential for acute stroke patients to warrant the adequate treatment option. Specialized computed tomography especially perfusion studies and magnetic resonance imaging (MRI or MR) are helpful for expanding the time window or aid further therapeutic guidance. Computed tomography perfusion (CTP) allows us to acquire real-time physiology parameters from the brain parenchyma. Recently randomized controlled trials (RCT) verified that patients who had acute ischemic stroke with anterior-circulation large vessel occlusion have a benefit from endovascular treatment when intraarterial treatment is carried out within 6 hours after stroke onset, but later two clinical trials have demonstrated evidence that a subgroup of patients can benefit from reperfusion therapy after 16 or even 24 hours from stroke onset. For the recanalization of large vessel occlusion in acute ischemic stroke besides intravenous thrombolytic therapy is endovascular mechanical clot removal. The main goal in acute ischemic stroke is the rapid and technically straightforward recanalization as soon as possible and during mechanical thrombectomy the embolus is physically removed from the artery avoiding further damage within the penumbra. The number of stroke patients eligible for thrombectomy is increasing as the growing evidence and expanding guidelines permit more patients to be treated effectively without harm. Even 20% of acute ischemic strokes are caused by tandem occlusion of intracranial anterior large vessel and concomitant extracranial internal carotid artery. Although the literature on the endovascular treatment of TO in AIS is rapidly expanding, data on the safe and efficient maneuvers for the recanalization of the occluded ICA plaque is still sparse.

When diagnosing stroke patients stroke mimics can be a significant percentage of acute stroke hospital admissions, but in these cases a non-vascular condition causes neurological deficit alike in acute stroke patients. Despite state-of-the-art imaging modalities available in daily routine excluding conditions which only imitate stroke still takes time. But treating stroke patients time is the most important circumstance that we must consider, so to be aware and understand these conditions is mandatory to those diagnosing and treating stroke patients.

Supra-aortic stenting has been shown to increase the therapeutic value of balloon angioplasty for the treatment of these arterial lesions in preventing acute ischemic stroke. The main drawback of stent placement is the mandatory initiation of dual antiplatelet therapy besides the occurrence of in-stent restenosis (ISR). The occurrence of in-stent restenosis can be as high as 10,6% in the extracranial internal carotid artery, 31% in the intracranial arteries and 15.9% in the orifice of the vertebral arteries. Conventional DSA is the current criterion standard follow up

examination, but a non-invasive alternative method for assessment of the stented supra-aortic vessels would be highly desired.

Aims

Part 1 We introduced a novel method the balloon-assisted tracking technique (BAT) in the treatment of tandem large vessel occlusive lesions in acute ischemic stroke cases causing neurological symptoms, which account for up to 20% of acute ischemic stroke patient and associated with poor prognosis if complete recanalization is not achieved. Our aim was to describe the technique in detail and demonstrate our experience using the BAT technique in the endovascular recanalization of tandem occlusive lesions showing its applicability, feasibility, safety and efficacy, because endovascular recanalization might be challenging due to difficulties in the safe passage of the occluded plaque at the origin of the internal carotid artery (ICA).

Part 2 Besides this technical presentation through a case report one of our aims is to show how challenging can be to assess patients with stroke mimics especially with hemiplegic migraine starting in childhood.

Part 3 Nevertheless in a retrospective study we aimed to determine whether the 64-slice dual energy CT angiography after intravenous contrast medium administration is suitable for the evaluation of luminal patency and in-stent restenosis after supra-aortic percutan transluminal angioplasty and stenting involving intracranial and extracranial atherosclerotic lesions.

Methods

Tandem occlusion (TO) of the internal carotid artery is characterized by proximal occlusion of ICA, either due to acute thrombosis of an unstable atherosclerotic plaque or dissection, resulting in the embolic blockage of the ICA terminus (ICA-T) and/or the main trunk (M1 segment) of the middle cerebral artery. The condition is responsible for up to 20% of acute ischemic stroke cases. Despite the high incidence and large clinical impact, the initial large, randomized trials showing the efficiency of endovascular treatment (EVT) of large vessel occlusion in acute ischemic stroke either did not report key technical and clinical results from this subgroup or entirely excluded these patients from the analysis. Although the literature on the endovascular treatment of TO in AIS is rapidly expanding, data on the safe and efficient maneuvers for the recanalization of the occluded ICA plaque are still sparse. The balloon-assisted tracking technique, where a partially deflated balloon is exposed out of the catheter tip to facilitate

its passage through stenosed or spastic arterial segments was introduced by interventional cardiologists, and recent case studies proposed the applicability of the technique in the field of neurointerventions as well. We illustrate the technical aspects of our method in detail which was carried out on more than 100 patients and has been a well-established method to treat tandem occlusions at our Institute. In our study we also report our detailed experience with the BAT technique in the endovascular recanalization of 107 AIS patients with tandem occlusion. After accessing a femoral artery an 8 F introducer sheath was inserted and an 8F guiding catheter was advanced into the common carotid artery (CCA) on the affected side. The recanalization of the occluded ICA was performed through the guide-catheter using a slightly shaped hydrophilic 0.014" micro guidewire supported by a low profile 4 mm PTCA balloon catheter. The wire was carefully advanced through the occluded plaque with special attention to keep the wire in a true intraluminal position by navigating it through the tiny stump of the ICA identified on initial angiographic series. This was followed by angioplasty of the plaque using the undersized, 4 mm balloon catheter, following intravenous administration of atropine if necessary. The balloon was partially deflated thereafter and the guide catheter was advanced to partially cover it, with the half-deflated balloon protruding out from the catheter tip, forming a streamlined outline of the balloon-catheter tip complex, so that the rim of the catheter tip cannot get in contact with the irregular plaque surface, then the guide catheter was gently advanced with the half-inflated balloon acting as a „stylet" through the ruptured plaque and occluded cervical segment of ICA to prevent the razor effect of the rim of the guide catheter. The balloon was then slowly deflated and removed together with the microguidewire. The 8F guiding catheter was detached from the hemostatic valve and carefully moved and torqued forth and back under gentle manual aspiration using a 50 ml perfusor syringe, removing thereby the thrombotic material in the cervical ICA segment. Extra care was taken during this step to prevent the vessel wall to be sucked in by the tip of the catheter to prevent dissection. The hemostatic valve was then reattached and stent-retriever or direct aspiration thrombectomy of the carotid-T or MCA was performed in the usual technique. During distal thrombectomy the guide catheter was kept in the newly opened proximal ICA causing flow arrest and acting as dilator. A schematic drawing of the BAT maneuver is shown in Figure 1. We evaluated 107 AIS patients with tandem occlusion lesions. The data was retrospectively collected and analyzed. It was driven to detect the safety and efficacy of the method we used to treat this subgroup of stroke patients. Recorded baseline data included age, sex, history of hypertension, atrial fibrillation, diabetes and dyslipidemia. Admission clinical parameters such as CT ASPECTS score, NIHSS score, ictus to needle time, occlusion site, use of recombinant tissue plasminogen activator (rtPA) was also retrieved. The CT imaging data was

reviewed by the radiologist on call and the interventionalist performing the treatment in all cases and ASPECTS values were determined by consensus. Continuous variables were reported as median with range and categorical variables as number and percentage. Categorical variables were compared using the χ^2-test or Fisher's exact test for small cell values, p values less than 0,05 were interpreted as statistically significant. Analyses were performed using SPSS, Version 26.0 (IBM, Armonk, NY, USA).

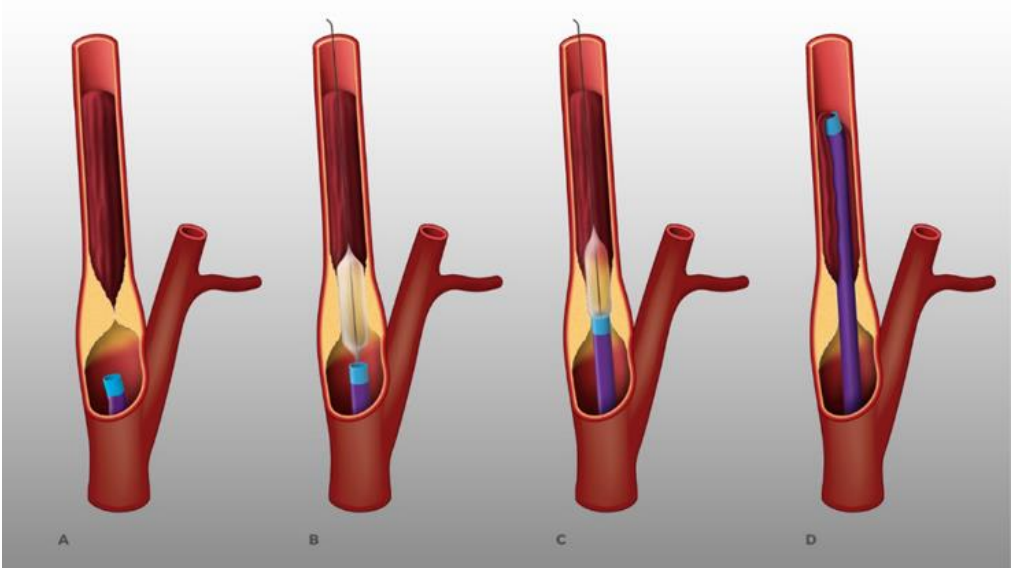


Figure 1. Schematic drawing illustrating key steps of the application of the balloon-assisted tracking technique in the recanalization of an occlusive plaque at the origin of the ICA. (A) A guide catheter is positioned in front of the ICA stump. (B) A 0.014" micro-guidewire is carefully passed through the ICA stump and angioplasty is performed with an undersized, low-profile balloon. (C) The guide catheter is then tracked by the partially deflated balloon over the plaque into the occluded lumen of the ICA. The protruding balloon acts as a stylet preventing contact between the irregular plaque surface and the catheter rim. (D) Finally, the balloon and microwire are removed and the thrombus is extracted by aspiration.

In the case report the diagnostic difficulties were shown and demonstrated stroke mimics which have to be taken into account when treating these patients. In our case a 13-year-old girl without any comorbidities was admitted to the emergency department due to left temporal headache associated with vomiting, speech disorder and confusion. After admission, neurological symptoms progressed further, sensorimotor aphasia, disorientation, and somnolence developed. 5-6 hours after her admission, her level of consciousness varied from somnolence to sopor. Routine laboratory and microscopic examination of the cerebrospinal fluid was carried out as well as electrophoresis (ELFO) of the cerebrospinal fluid (CF). Initial head CT followed by head MRI with time-of-flight (TOF) MRA was performed.

In the other study we evaluated 54 consecutive patients with 72 supra-aortic stents (47 cervical carotid, one brachiocephalic trunk, 5 subclavian, 11 ostial vertebral and 8 intracranial). Recorded baseline data included sex, history of hypertension, diabetes, dyslipidemia and the treated vessel. We compared the diagnostic accuracy of a 64-slice dual energy CT angiography with other modalities and whether it is suitable for the evaluation of luminal patency and in-stent restenosis after supra-aortic percutan transluminal angioplasty and stenting involving intracranial and extracranial atherosclerotic lesions.

Results

Between June 2013 and December 2020, 592 patients with acute ischemic stroke were treated by endovascular recanalization at our Institution (Neurovascular and Interventional Unit, Somogy County Moritz Kaposi Teaching Hospital) in Kaposvár. Tandem occlusion of the ICA and MCA was the primary pathomechanism in 113 (19%) cases. Of these patients 6 (5%) were excluded from the analysis because of having proximal ICA dissection as pathomechanism. The remaining 107 (77, 72% male, median age 66 years, range 45–87 years) cases with atherosclerotic origin were included in the study. The median (IQR, range) for ASPECTS and NIHSS on admission were 8 (2, 3-10) and 14 (6, 3-22), respectively. Successful recanalization of the cervical ICA could be achieved in 100 (93%) cases. Details of the unsuccessful 7 (7%) cases were: in two patients (2%) the occluded ICA plaque could not be passed even after multiple attempts; in one patient (1%) the mid segment of the cervical ICA and in one patient (1%) the terminal segment of the ICA was perforated with guidewire and active extravasation could not be sealed with a balloon, so the ICA had to be reoccluded with coils; in three cases (3%) the microguidewire penetrated into the subintimal space during the ICA recanalization attempt and no reentry could

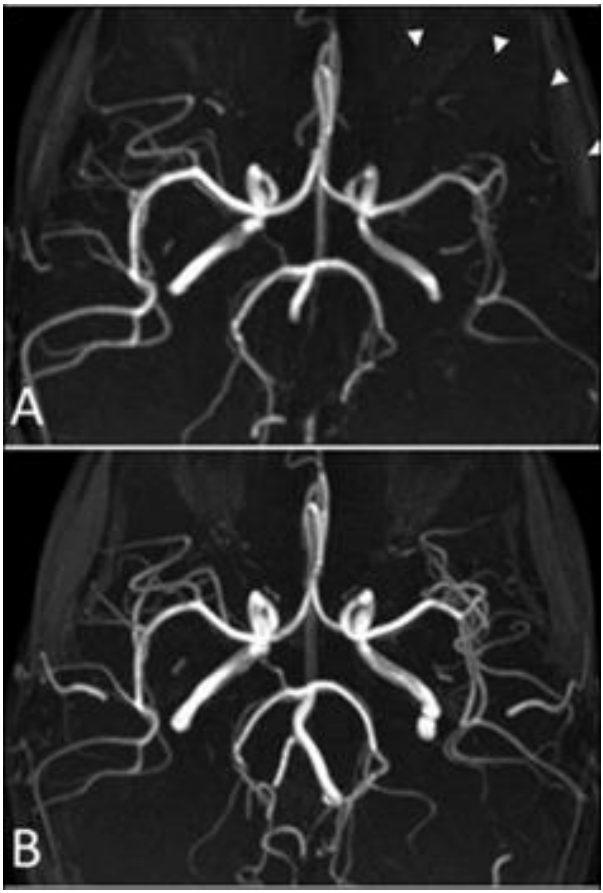
be achieved at any level even after multiple attempts. Successful intracranial recanalization, defined asTICI2b-3 was achieved in 88 (82%) patients, thereof TICI2b in 50 (46.7%) and TICI3 in 38 (35.5%) cases. Attempts of intracranial revascularization following the successful recanalization of the cervical ICA failed in 12 (11%) patients, resulting in TICI0 in 1 (1%) and TICI2a in 11 (10%) cases. Intraprocedural stent implantation in the proximal ICA followed by balloon angioplasty was performed in 40 (37%) patients due to high-grade (>70%) residual stenotic lesion resistant to angioplasty, flow limiting dissection and/or visible floating thrombus on the recanalized ICA plaque. Delayed occlusion of the stent implanted in the acute setting occluded in 1 (2%) of the case, and the single ICA stent reocclusion case was asymptomatic. Out of the 42 (70%) patients with regular US follow-up of the recanalized ICA, 6 (10%) reoccluded without any newly developed neurological deficit and 21 (35%) received delayed stent placement due to asymptomatic, but progressive high-grade restenosis (>70%) in a second session, giving a combined rate of reocclusion and revascularization of 45% (27/60). Intraprocedural complications occurred in 9 (8%) patients: subarachnoid hemorrhage Fisher grade 1 in 7 (6%) cases, intracranial vessel perforation resulting in Fisher grade 4 subarachnoid hemorrhage in 1 (1%) case and termination of the procedure due to extracranial vessel perforation in 1 (1%) case. None of the complications were related to the BAT technique. A non-significant trend could be observed towards developing an ICH following emergent stent implantation (p= 0,407, OR= 3,15, 95% CI= 0,35–27,94). Good functional outcome (mRS 0–2) at 3 months was observed in 54 (50%) patients, 27 (25%) patients were still severely disabled (mRS 3-5) at 3 months and 26 (24%) patients died (mRS 6) before the follow up at 3 months. Successful intracranial recanalization was significantly associated with good clinical outcome (mRS 0–2): 59% (52/88) in the TICI2b-3 group versus 11% (2/19) in the TICI0-2a group, (p< 0.001, OR= 12,28, 95% CI= 2.67-56.45). Emergent stenting versus angioplasty did not significantly influence the rate of favorable clinical results, although there was a trend towards good clinical outcome in stented group (mRS 0-2 in the emergent stenting group: 58%, 23/40; mRS 0-2 in angioplasty group 52%, 31/60; p=0,261, OR= 1,57, 95% CI= 0,71–3,46). Mortality was not affected by emergent stenting (p=0.737, OR= 1.17,95% CI= 0.46–2.95). A summary of demographic, baseline medical, neurological, imaging, procedural and follow-up data are given in Table 1.

Number of patients (n)	107
Baseline characteristics	
Age (years) (median, range)	66 (45-87)
Gender - Male (n, %)	77 (72%)
Left-hemispheral stroke (n, %)	62 (58%)
Arterial hypertension (n, %)	79 (74%)
Atrial fibrillation (n, %)	5 (5%)
Diabetes mellitus n (%)	31 (29%)
Dyslipidemia/Obesity n (%)	7 (7%)
NIHSS baseline (median, IQR, range)	14, 6 (3-22)
IVT n (%)	47 (44%)
ASPECTS baseline (median, IQR, range)	8, 2 (3-10)
Occlusion site	
CCA-ICA-MCA n (%)	2 (2%)
ICA-MCA n (%)	104 (97%)
ICA-ACA n (%)	1 (1%)
Time intervals, procedural data	
Onset to groin [min] (median, range)	346 (158-1405)
Groin to ICA passage [min] (median, range)	16 (5-108)
Groin to complete revascularization [min] (median, range)	51 (10-178)
Unsuccessful reperfusion (TICI 0-2a) n (%)	12 (11%)
TICI 0 flow n (%)	1 (1%)
TICI 1 flow n (%)	0
TICI 2a flow n (%)	11 (10%)
Successful reperfusion ICA/intracranial (TICI 2b-3) n (%)	100 (93%) / 88 (82%)
TICI 2B flow n (%)	50 (46.7%)
TICI 3 flow n (%)	38 (35.5%)
Intraprocedural ICA stent implantation n (%)	40 (37%)
Intraprocedural complications n (%)	9 (8%)
Postprocedural adverse events n (%)	6 (5%)
Clinical outcome	
mRS <=2 after 90 days n (%)	54 (50%)
Mortality after 90 days n (%)	26 (24%)
Delayed proximal ICA revascularization with stent implantation n (%)	21 (31%)
Delayed reocclusion / stent thrombosis n (%)	6 (10%) / 1(2%)

Table 1. Summary of demographic, baseline medical, neurological, imaging, procedural and follow-up data.

In our case report the routine laboratory and microscopic examination of the cerebrospinal fluid, head computed tomography (CT) and head magnetic resonance imaging (MRI) of the brain parenchyma did not show any abnormalities. Time-of-flight (TOF) magnetic resonance angiography (MRA) showed diminished flow signal in the end branches of the left middle cerebral artery (MCA). Normal protein pattern was found with electrophoresis (ELFO) of the cerebrospinal fluid. No activity suggestive of epileptic dysfunction was observed with electroencephalogram (EEG). On the other hand, 5-hydroxyindoleacetic acid (5-HIAA) measurement was performed from the cerebrospinal fluid during the attack and it showed a level which was 10 times above the normal value. Nevertheless, in our publication, the early diagnosis of HM was not based on the elevated level of 5-HIAA but on the clinical status. The 5-HIAA measurement was performed because we had no knowledge of any previous similar attacks at the time of sampling, and we were looking for additional markers due to the differential diagnostic difficulties. It is hypothesized that one of the triggers of the attack may be serotonin release,

resulting in a consequent reduction in intracranial flow. This is followed by reflex compensation, which causes an increase in flow. In our case, the MRI was performed at an early stage, while the symptoms were still present. This may explain the hypoperfusion seen within the MCA territory shown on Figure 2. As the cerebral hypoperfusion did not decrease below a critical limit for ischemic parenchymal damage (12–20 ml/100 g brain tissue/min), therefore neither the acute, nor



the check-up MRI performed days later showed any structural lesion in the parenchyma.

Figure 2. (A) Maximal intensity projection (MIP) reconstruction images of TOF MRA sequences prepared during the attack, spasm of the left ICA and main branches of the MCA is seen with diminished flow signal in the end branches of the left MCA (arrow heads), suggesting severe hypoperfusion. (B) Check-up TOF MRA prepared four days later showing normal lumen and good flow in all visible arteries.

In the CT angiography study 54 consecutive patients with 72 stents were evaluated. 21 (29%) stents were suspected restenotic. In 11 instances, these patients with suspected restenosis underwent catheter based digital subtraction angiography. 5 patients had significant restenosis, 6 did not. In another group of patients twenty conventional digital subtraction angiographies were performed after the CT angiography. The sensitivity of CT angiography was 67% and the specificity was 91%. The negative predictive value was much stronger than the positive predictive value (95%, 50% respectively). Thirty-four patients underwent extracranial carotid artery stenting in our study group. In this group results obtained from CT angiography were compared with duplex ultrasonography which has gained wide acceptance to estimate restenosis rate. More than 70% of these cases with suspected restenosis found on ultrasonography was confirmed with CT angiography and in only four cases additional invasive procedures had to be done to confirm the diagnosis. Color Doppler ultrasound (CDUS) had a sensitivity of 92% and a specificity of 62% in our cohort, and this method also has a strong negative predictive value.

Discussion

Although there is a rapid expansion in the literature on the treatment of tandem occlusions in acute ischemic stroke recently, key aspects including distal-to-proximal versus proximal-to-distal recanalization approach, placement versus non-placement of a stent in the acute setting, perioperative and postoperative antithrombotic medication and the role of embolic protection devices are still debated. The pathophysiology of the disease is a combination of several distinct vascular and hemostatic pathologies: atherothrombosis, artery-to-artery thromboembolism and less frequently dissection. The key steps of the recanalization are the safe passage of the ICA plaque with the microwire avoiding perforation and dissection, and the access of the cervical ICA segment with a large lumen catheter for aspiration and further intracranial recanalization. In our opinion, emergent implantation of a stent in the ICA origin to facilitate access to the cervical and intracranial segments before removing the bulk of the thrombotic material from the cervical ICA might be counterproductive and in cases of heavily calcified plaques and/or extensive supra-aortic elongation, the struts of a partially wall-adapted stent can indeed hamper the access to the ICA and can result in serious difficulties at the withdrawal of a stent-retriever during the intracranial recanalization. There is no consensus in the literature regarding the extracranial versus intracranial first approach. In the present work, the BAT

technique allowed the exquisite use of the extracranial first approach in all the cases, with a median total procedural time of 51 min combined with a good clinical outcome rate of 50%. In the present series, the large lumen guiding catheter could safely be inserted into the occluded cervical ICA segment over the thrombosed plaque using the BAT technique in all cases, without the need for a stent implantation. The primary angioplasty of the ICA plaque is done with a 4 mm balloon, which is only slightly larger than the catheter, resulting in recoiling of the plaque and the proximal ICA around the perimeter of the catheter, providing flow arrest and thereby an inherent proximal protection against embolization during intracranial thrombectomy/aspiration, eliminating the need of an embolic protection device. Using the BAT technique, tiny emboli in new territories were detected only in 2 patients, both of them recovering to mRS 0–1 at the 3 months clinical follow-up. There were no procedural complications attributable to the BAT technique in the present series. Potential disadvantages of the BAT technique should however be noted. In cases of plaque dissection, unnoticed by the operator prior to the angioplasty, the inflation of the balloon can lead to progression of the intimal tear, rendering further recanalization attempts impossible and extreme cases can result in vessel perforation and serious extravasation. In our experience, a steep learning curve can be achieved with the technique, bypassing the abovementioned potential disadvantages. This single center retrospective analysis has some limitations. The observational and nonrandomized design is subject to methodologic and selection biases inherent in this form of study. The imaging findings were not confirmed using a core lab. There may be bias due to patients lost to follow-up and missing data in the retrospective dataset.

Differential diagnosis of stroke and migraine with aura of hemiplegic migraine (HM), especially in cases of first attack in childhood is very challenging. To the best of our knowledge, the presented case is the first case of HM in Hungary in which the spasm of the branches of the large arteries supplying the cerebral area responsible for the symptoms was confirmed by imaging during an attack. The presented case confirms the role of acute MRI in the differential diagnosis of acute diseases with severe neurological symptoms in childhood and may help us understand the pathomechanism of HM as well.

The accurate assessment of supra-aortic stenosis and restenosis is crucial for planning of stenting or reinterventions. 64-multi-slice dual energy CT angiography is a valuable imaging modality for the follow-up of patients after supra-aortic stenting including intracranial interventions even though it has its limitations. It has a high negative predictive value, but in ambiguous cases and suspected restenosis further, even invasive follow up should be carried out. With a properly performed CT angiography and adequate post processing high quality images can be obtained noninvasively to facilitate patient comfort and satisfaction.

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