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TECHNICAL NOTE

Multiple Coaxial Catheter System for Reliable Access in Interventional Stroke Therapy

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Abstract In some patients with acute cerebral vessel occlusion, navigating mechanical thrombectomy systems is difficult due to tortuous anatomy of the aortic arch, carotid arteries, or vertebral arteries. Our purpose was to describe a multiple coaxial catheter system used for mechanical revascularization that helps navigation and manipulations in tortuous vessels. A triple or quadruple coaxial catheter system was built in 28 consecutive cases presenting with acute ischemic stroke. All cases were treated by mechanical thrombectomy with the Penumbra System. In cases of unsuccessful thrombo-aspiration, additional thrombolysis or angioplasty with stent placement was used for improving recanalization. The catheter system consisted of an outermost 8-Fr and an intermediate 6-Fr guiding catheter, containing the inner Penumbra reperfusion catheters. The largest, 4.1-Fr, reperfusion catheter was navigated over a Prowler Select Plus microcatheter. The catheter system provided access to reach the cerebral lesions and provided stability for the mechanically demanding manipulations of thromboaspiration and stent navigation in all cases. Apart from their mechanical role, the specific parts of the system could also provide access to different types of interventions, like carotid stenting through the 8-Fr guiding catheter and intracranial stenting and thrombolysis through the Prowler Select Plus microcatheter. In this series, there were no complications related to the catheter system. In conclusion, building up a triple or quadruple coaxial system proved to be safe and efficient in our experience for the mechanical thrombectomy treatment of acute ischemic stroke.

Keywords Ischemic stroke · Thrombectomy · Coaxial catheter system · Thromboaspiration · Intracranial stent

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Introduction

Recently, a number of mechanical approaches have shown promise for restoring blood flow in an acutely occluded cerebral artery. However, tortuous anatomy of the aorta and other extracranial vessels may create problems during acute interventions for revascularization, sometimes making it very difficult or even impossible to deploy endovascular devices to the intracranial vessels. Thus, under these conditions, these systems may require proximal catheter support for successful interventions. The Penumbra System (PS; Penumbra Inc., Alameda, CA, USA) is a new mechanical thrombectomy device, specifically designed to remove the thrombus in acute ischemic stroke secondary to large vessel thromboembolism. The purpose of this study is to evaluate whether a special multiple coaxial catheter system, when used in combination with the PS, may improve its navigation and revascularization effectiveness.

Methods and Results

Technique

Twenty-eight consecutive patients with a mean age of 66 years who presented with acute ischemic stroke were treated with the PS as first-choice interventional therapy at our stroke center. In 24 cases, the occlusions were located in the anterior circulation, and the rest (four cases) were in the vertebrobasilar arteries. The endovascular intervention was performed with the use of at least a triple coaxial catheter system. Mechanical thrombectomy procedures were performed with the PS and thrombolysis was effected by intra-arterial administration of r-tPA. Thromboembolic lesions not responding to these interventions were treated with the Enterprise self-expanding stent (Codman & Shurtleff, Inc., Raynham, MA, USA). Intracranial occlusive atherosclerotic lesions were treated with the Wingspan self-expanding stent (Boston Scientific, Natick, MA, USA). In cases where cervical occlusive atherosclerotic lesions were causing intracranial perfusion deficit, the Wallstent system (Boston Scientific) was used for vessel reconstruction.

Standard Technique

Under general anesthesia, a standard unilateral 8-Fr transfemoral approach was used. Periprocedural heparinization for systemic anticoagulation was accomplished with a bolus dose of 2000 IU followed by boluses of 1000 IU every 60 min thereafter. Flush solution of the catheter system was not heparinized and the anticoagulation status of the patients was not monitored during the intervention.

Catheter System and Revascularization Technique

All catheters used were connected to continuous high-pressure saline flush lines. As a first step, a double coaxial system was assembled by an outermost 80-cm-long, 8-Fr Vista Brite Tip catheter (VBT; Cordis Corp., USA) and an inner, 100-cm-long, 5-Fr diagnostic catheter of simple or complex tip shape, depending on the vascular anatomy. The system was then introduced over a 0.035- or 0.038-in. Radiofocus guidewire (Terumo Europe, Cedex, France) in the arterial tree. The intermediate catheter was advanced so there was a 5- to 10-cm distance between the tips of the two catheters. The inner catheter was then advanced by conventional technique over the wire in the target vessel, followed from time to time by the advancement of the VBT, always maintaining a certain distance between the catheter tips. As soon as the inner catheter had reached the desired position, together with the guidewire, they were able to provide enough support to allow for advancement of the outer catheter. The VBT catheter was adjusted to reach the middistal portion of the common carotid or the proximal portion of the subclavian artery. The diagnostic catheter was then removed and replaced in the majority of the cases with a 6-Fr, regular, 90-cm-long guiding catheter to reach the target vessel, i.e., cervical internal carotid or vertebral artery. In a small number of cases, 100-cm-long guiding catheters were used when the natural height of the patients or the proximal tortuosity of the aorta required a more stable position in the target vessel. The 2-Fr size difference between the two guiding catheters was required to allow for continuous saline flushing.

After positioning of the inner guiding catheter, the PS was introduced coaxially. In cases of distal vessel lesions, such as thromboembolic occlusions of the M2–M3 segments of the middle cerebral artery or the P2 segment of the posterior cerebral artery, intermediate- and smaller-sized (0.032- and 0.028-in.) reperfusion catheters were used for the revascularization procedure. In such cases the reperfusion catheter was navigated to the lesion site over a regular, 0.014-in. microwire.

In more proximal, major vessel occlusions (carotid T, M1 segment, vertebral and basilar arteries, P1 segments), the 0.041-in. reperfusion catheter was used for thromboaspiration. Although this catheter is highly flexible, navigation over a regular microwire to the intracranial vasculature may be problematic, given its relatively large inner and outer diameter. To overcome this issue, another double coaxial system was assembled and used inside the already-placed guiding catheters (a quadruple system). This inner system consisted of an outer 0.041-in. sized reperfusion catheter and an innermost, microwire-guided Prowler Select Plus microcatheter (PSP; Codman & Shurtleff, Inc., Raynham, MA, USA). The 0.041-in. reperfusion catheter was navigated over the PSP microcatheter, so that the tip reached the proximal end of the clot (Fig. 1). The inner PSP microcatheter with guidewire was then removed. In both systems, a continuous aspiration-debulking process was performed as previously described [1]. If, after six to eight passages of aspiration through the occluded area, revascularization was not achieved or was considered insufficient, the separator was removed and the PSP microcatheter reintroduced over the wire. Local rt-PA was then injected in a fractionated manner.

Angioplasty with Stenting in Cervical and Intracranial Lesions

Adjunctive stent treatment in this patient series was considered and carried out under two conditions. First, in complete or subtotal occlusion of the cervical origin of the internal carotid artery, carotid angioplasty and stenting was performed at this level. In this setting, the 8-Fr VBT

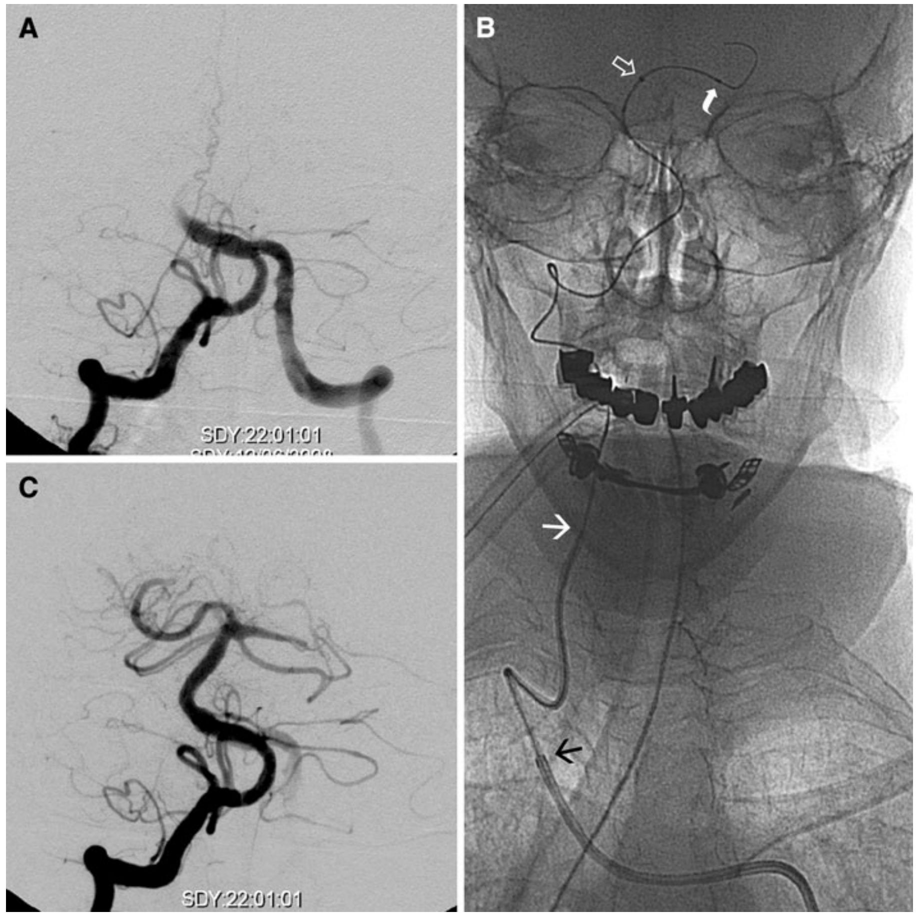

Fig. 1 Acute thromboembolic occlusion of the basilar artery in an 83-year-old woman (**A**). To overcome the significant proximal and distal vascular tortuosity, a quadruple coaxial catheter system was built. The outermost 8-Fr VBT catheter is positioned in the proximal right subclavian artery (*black arrow*); the 6-Fr Envoy catheter, in the proximal V2 segment of the right vertebral artery (white arrow); the 4.1-Fr Penumbra reperfusion catheter, in the distal basilar trunk (*empty arrow*); and the 2.3-Fr Prowler Select Plus microcatheter, containing a 0.014-in. microwire, reaching the P1–P2 segment of the left posterior cerebral artery (*curved arrow*) (**B**). Postrevascularization angiogram showing complete reopening of the basilar artery and its main branches; however, both distal posterior cerebral arteries remained occluded (**C**)

catheter was used for stent delivery under filter protection. After access to the intracranial circulation was re-established by the angioplasty procedure, the 6-Fr guiding catheter was advanced to extend beyond the stent.

Second, intracranial stenting was performed in persistent intracranial thromboembolic occlusions or concomitant occlusive atherosclerotic stenosis. For the first case scenario the same PSP microcatheter was used and provided access for deployment of a self-expanding Enterprise stent. This stent has a closed-cell design with flared ends; both aspects were considered an advantage when it came to trapping a clot along the vessel wall. Given its maximal available length of 37 mm, this device is long enough to cover extensive lesions without the need for multiple stent deployment. In cases of atherosclerotic stenosis or occlusion, the Wingspan stent was used for angioplasty and deobstruction.

Differentiation of atherosclerotic lesions from thromboembolic ones was mainly subjective and based on the following: (1) calcification seen on the preoperative CT scan at the occlusion site was considered as the basis for an atherosclerotic lesion, (2) occlusions at bifurcations (internal carotid artery, medial carotid artery, or basilar artery bifurcations) were taken as thromboembolic lesions, and (3) all lesions were first accessed with the reperfusion catheters. When the reperfusion catheter was not able to be advanced through the occlusion site due to mechanical blockage, an atherosclerotic lesion was again suspected. In cases of stent use, additional thromboembolic protection medication was used by IV tirofiban infusion (Aggrastat). The sizes of the specific catheters are listed in Table 1.

In our cases, this technique provided a 100% lesion site access rate in a relatively elderly population, where 50% of patients were older than 70 years.

Discussion

Vascular tortuosity is a major cause of difficulty or failure in treating intracranial lesions [2, 3]. Acute ischemic stroke patients are usually from the older population and often present with risk factors such as atherosclerosis and vessel tortuosity that may render access to the target lesion difficult. In the MERCI and MultiMerci trials, 4 of 151 patients (2.6%) and 5 of 171 patients (2.9%), respectively, had an unsuccessful treatment attempt due to vessel tortuosity or due to the fact that the clot could not be reached by the microcatheter [4, 5]. In the Penumbra trial, 3

Table 1 Catheters used for coaxial systems

Catheter type	Outer diameter (prox./dist.)	Inner diameter	Usable length (cm)
Vista Brite Tip	8 Fr (0.104 in., 2.6 mm)	0.088 in. (2.2 mm)	80
Intermediate guiding catheter, Envoy	6 Fr (0.079 in., 2 mm)	0.070 in. (1.8 mm)	90 or 100
Penumbra reperfusion catheters			
0.041 in.	4.1 Fr (0.054 in., 1.37 mm)	0.041 in. (1.04 mm)	137
0.032 in.	4.1 Fr (0.054 in., 1.37 mm)/3.4 Fr (0.045 in., 1.14 mm)	0.032 in. (0.81 mm)	150
0.026 in.	3.9 Fr (0.051 in., 1.3 mm)/2.8 Fr (0.037 in., 0.94 mm)	0.026 in. (0.66 mm)	150
Prowler Select Plus	2.8 Fr (0.037 in., 0.94 mm)/2.3 Fr (0.03 in., 0.76 mm)	0.021 in. (0.53 mm)	155

patients of 23 (13%) had to be abandoned because of accessing difficulties [1]. Our experience has shown that for intracranial thromboembolic vessel occlusions, a multiple coaxial system was useful for providing stable support for acute revascularization by the PS.

On the other hand, once the lesions are reached with a catheter system that is not stable enough, the system may not support further mechanically demanding manipulations (like stent advancement) and may become unstable during the intervention. The instability and continuous movement of the coaxial system during the procedure may cause mechanical irritation of the catheterized vessel wall (i.e., internal carotid or vertebral artery), leading to vasospasm or even intimal dissection. Lack of proximal support may cause buckling of guiding catheters back in the common carotid artery, subclavian arteries, or aortic arch, resulting in sudden unexpected movements at the intracranial level, also being a possible cause of complications.

In our practice, the triple or quadruple coaxial system provided adequate proximal mechanical support from the groin to the level of the common carotid or subclavian arteries. In this system an 8-Fr Vista Brite Tip (VBT; Cordis Corp.), 80-cm-long catheter was used as the outermost catheter. This catheter has a consistent large lumen, and is kink resitant. The outermost VBT catheter assured a straighter access path to the precerebral vessels for the 6-Fr guiding catheter. The mechanical strain of the 6-Fr guiding catheter was thus reduced, resulting in a more stable position at the level of the internal carotid and vertebral arteries. On the other hand, this double system was also stiff enough to prevent retrograde bucklings in the aorta or aortic arch.

Besides the mechanical advantages, the unique parts of the coaxial system could also provide several other options. When needed, the 8-Fr VBT catheter was useful to provide an easy access for cervical carotid artery angioplasty and stent placement. After angioplasty had been done, there was no need for catheter change and the same route was used to provide access to the 6-Fr guiding catheter. The inner 6-Fr guiding catheter, besides providing a stable support for the revascularization catheters, also provided access for intracranial angioplasty with the Wingspan stent. The PSP microcatheter, which was mostly used for advancement of the 0.041-in. revascularization catheter, was also used for local thrombolysis and, when none of these manipulations were effective, stent-assisted revascularization with the Enterprise stent.

There may be several concerns with regard to using a multiple coaxial system. Building it up is more time-consuming than using only a double setting, and handling it, in terms of both catheterization and having several saline flush lines on the table, may be more demanding from the technical point of view. However, in our experience the time needed to prepare such systems is easily regained during the procedure because of the efficiency in accessing the target lesions and providing stable support. The other concern may be related to the size of the outer diameter of the external catheter and the risk of vessel wall injury during catheterization. The system has a de-escalating outer diameter and mechanical stiffness profile that are designed to be atraumatic for the vasculature. The advancement of the VBT catheter over an inner 5- or 6-Fr catheter and a guidewire proved to be safe in our experience. We think that in tortuous anatomy, such a stable system carries less risks of vessel wall injury and better prevents the inadvertent bucklings and movements of the intracranial devices, compared to double coaxial systems.

Other Possible Clinical Applications

The multiple coaxial system may be used in almost all neuroendovascular procedures, for example, aneurysm treatment with or without balloon or stent assistance. For interventions demanding a smaller-sized system such as aneurysm treatment of the vertebrobasilar circulation, a step down in size can be used, with an outer 7-Fr VBT and an intermediate 5-Fr catheter.

Conclusions

Building up a triple or quadruple coaxial system proved to be safe and efficient in our experience for mechanical thrombectomy treatment of acute ischemic stroke. The system has major advantages in cases with tortuous anatomy and severe generalized atherosclerosis, where access and system stability are of crucial importance. Besides their mechanical role, the different parts of the system may play different roles,and provide the possibility to perform different types of interventions in the same setting. We believe that the multiple coaxial system may improve the success rate and provides more safety in neuroendovascular procedures, without increasing the risk of injuries during catheterization.

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