Chapter 3

Distal Access Catheter Techniques for Large Vessel Occlusion Stroke Thrombectomy

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Abstract

Endovascular mechanical thrombectomy (MT) is effective for acute ischemic strokes caused by large vessel occlusion (LVO). The repertoire of MT techniques employed in the treatment of hyperacute strokes continues to evolve, driven by deployment of new devices and improvisation of existing technology, to overcome specific case challenges faced by interventional neuroradiologists. In this review, we describe our initial experience with the Arc™ Intracranial Support Catheter, deployed with and without the Solitaire™ stent retriever device, for MT in 48 patients with LVO, with data from three University hospitals performed between June 2016 and May 2018. We outline a number of endovascular techniques utilizing the ARC™ catheter, the circumstances where they are applicable, and the outcomes achieved.

1. Introduction

Stroke continues to be a major cause of mortality and morbidity; it is the second commonest cause of death globally [1], and the third commonest cause of death in the UK [2]. Rapid, safe, and effective arterial recanalization, to restore blood flow and improve functional outcome, remains the primary goal of hyperacute ischaemic stroke management [3]. Until relatively recently, intravenous thrombolysis with recombinant tissue-type plasminogen activator (r-tPA) was the only licensed treatment for acute ischaemic stroke. However, a growing body of evidence from published randomized controlled trials (RCTs) confirms the superiority of MT for the treatment of acute LVO stroke [4]. So far, since November 2014, nine RCTs of MT have published positive outcomes in patients with acute LVO. [5-13] these studies show that the number needed to treat (NNT) for improved functional outcome following successful MT can be less than 3 (2.6 in HERMES meta-analysis). Accordingly, MT is becoming the standard of care for the treatment of acute ischaemic stroke.

Early recanalization is imperative: it is associated with a 5-fold increase in the proportion of patients alive and independent at 3-month follow-up [14].

The mantra is: "Time is brain", and thus key concerns with the MT procedure now revolve around the ability to navigate to and access the site of the occlusion easily and rapidly; reducing the time to taken to remove the clot, achieve recanalization, and restore blood flow in the affected vessel. In addition, the provision of distal protection to avoid dislodging further emboli into unaffected territory during MT is vitally important. The Medtronic ARC™ Intracranial Support Catheter and ARC™ Mini Intracranial Support Catheter are indicated for the introduction of interventional devices into the peripheral and neurovasculature. The ARC™ Intracranial Support Catheter, with infinity zone shaft design, potentially offers faster and superior navigation with low track force; additionally, it has a high degree of kink resistance and lumen patency for improved M1 middle cerebral artery access. [17] The ARC™ Intracranial Support Catheter, with continuous inner liner and a large effective flow lumen, has been designed to provide the greatest aspiration support during thrombus retrieval with the Solitaire™ stent retriever device [17].

2. Initial Experience in Intracranial Thrombectomy

We have evaluated the ARC™ Intracranial Support Catheter, with and without the Solitaire 2™ revascularization device, for MT in an initial case series of 48 patients with acute stroke in the anterior and posterior circulation during the period, June 2016 to May 2018. Summary details of these interventions are presented in **Table 1**.

Table 1: Initial experience with ARC™ (June 2016 to May 2018)

Total cases	**n = 48**
Anterior Circulation	42
Posterior Circulation	6
Aspiration only with ARC™	30
ARC™ + Solitaire™	12

Recanalization	**n = 48**
TICI 2b or 3	44 (91%)

Outcomes so far	**n = 48**
Median NIHSS	18
Median NIHSS at Discharge	6
mRS ≤ 2 at 3 months	23 (48%)
Mortality	7(15%)
Complications (Type 2 parenchymal haematoma)	3 (6%)

Abbreviations: TICI: Thrombolysis in Cerebral Infarction Scale; NIHSS: National Institutes of Health Stroke Scale; mRS: modified Rankin Scale.

2.1. Appropriate Mechanical thrombectomy techniques with ARC™

Our initial experience with the 132cm 6F ARC™ Intracranial Support Catheter supports the feasibility of its use in the following MT techniques.

3. Tri-axial System: ARC™ for Distal Access/Support in Conjunction with Solitaire™

Three technique variations using the ARC™ Intracranial Support Catheter in conjunction with the Solitaire™ stent retriever device, within a tri-axial system, have been used successfully and are summarised below. In all the described techniques the ARC™ Intracranial Support Catheter was deployed in combination with a 160 cm Marksman™ microcatheter as it is compatible with the longer length of ARC™ catheter.

3.1. Distal access support technique to maximise suction force

Scenario: This is the standard procedure of choice for a thrombus in the proximal MCA in patients with associated cervical Internal carotid artery (ICA) vessel tortuosity which necessitates the use of a distal access catheter (ARC™) for providing distal vascular support and to maximize the suction force during a stent-retriever thrombectomy.

3.1.1. Technique

This technique uses a tri-axial system utilising an 8F guide catheter (Neuron™ MAX). This guide catheter requires a femoral approach, and is navigated to the arch of aorta under fluoroscopic guidance, and then placed into the target vessel ICA. The ARC™ Intracranial Support Catheter is navigated to the level of the middle cerebral artery (MCA) clot and positioned just proximal to the clot. A microcatheter (Marksman™) is then negotiated across the thrombus by tracking over a guidewire. The stent-retriever device (Solitaire™) is then passed through the microcatheter so that it is positioned across the thrombus. Next, the device is unsheathed and concurrently deployed by withdrawal of the microcatheter, straddling the thrombus. After 3-5 minutes the solitaire device is retrieved in its expanded state, containing the thrombus into the ARC™ catheter, with continuous suction applied through the ARC™ catheter with a 50 mL syringe. A key advantage of this technique is that it usually results in an improved suction force due to close proximity of the suction catheter (ARC™) with the clot. **Figure 1**, below, illustrates our application of the distal access support technique in a 68-year old male patient where access to a right MCA thrombus was challenged by significant vessel tortuosity.

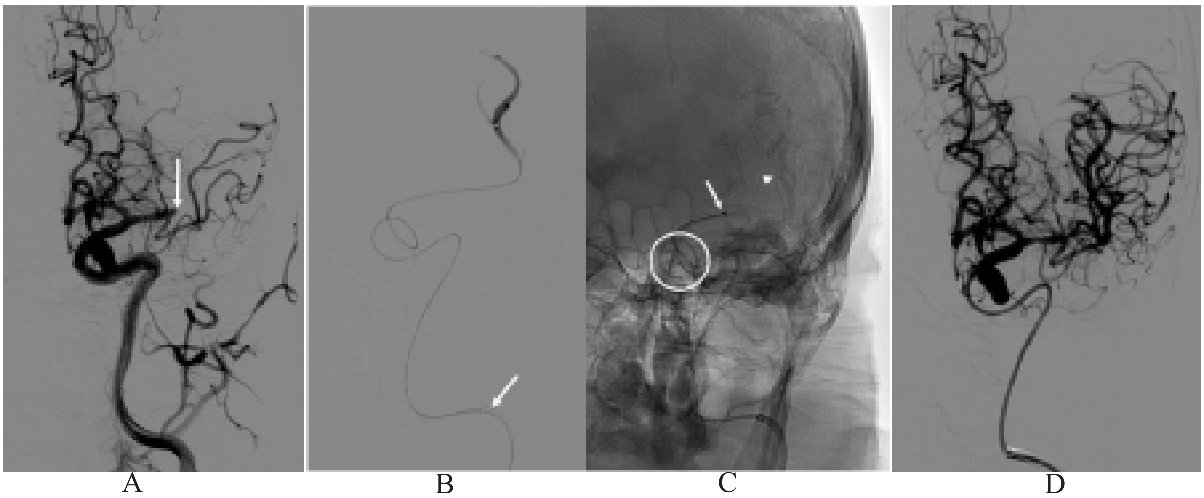

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Figure 1: Distal access support technique to maximise suction force.

Figure 1: Technique 1.1 in a 68-year old male with dense right sided weakness and aphasia (NIHSS 18)

A. Pre-procedure DSA shows a left MCA occlusion (arrow)

B. DSA image after navigating the left ICA reveals a tortuous ICA vessel, where an Arc support catheter would be beneficial. The arrow shows the 8Fr guide catheter positioned within the proximal ICA as described in the technique.

C. The Arc™ intracranial support catheter is passed beyond the very tortuous part of the ICA (circle). The Arc tip is positioned just proximal to the clot in the MCA (arrow). The Marksman microcatheter has been withdrawn with the deployed Solitaire stent-retriever at the arrowhead.

D. Post-procedure DSA shows good angiographic outcome (TICI 3) and the patient recovered clinically with NIHSS score 0 at 48 hours.

3.2. Distal access support technique to maximise retrieval force

Scenario: Same as scenario 1.1 with the aim to maximise the retrieval force rather than the suction force during a stent-retriever thrombectomy. For optimal clot extraction, the retrieval force relies on the vector of the traction gradient which should be optimally aligned parallel to the thrombus for achieving successful recanalization.

Technique: This technique uses a tri-axial system and the ARC™ Intracranial Support Catheter is navigated to a position within the distal part of the ICA, preferably the cavernous ICA segment. The middle cerebral artery (MCA) clot, and the Solitaire™ device is positioned and deployed as described in 1.1 above. After 3-5 minutes, suction is applied continuously through the ARC™ catheter, and the solitaire device is retrieved in its expanded state containing the thrombus. A key advantage of this technique is that it usually results in an improved traction force (retrieval force). **Figure 2**, presented below, illustrates our application of the distal access support technique to maximise retrieval force in an 85-year old female with a right MCA occlusion, where access to a right MCA thrombus was challenged by significant vessel tortuosity.

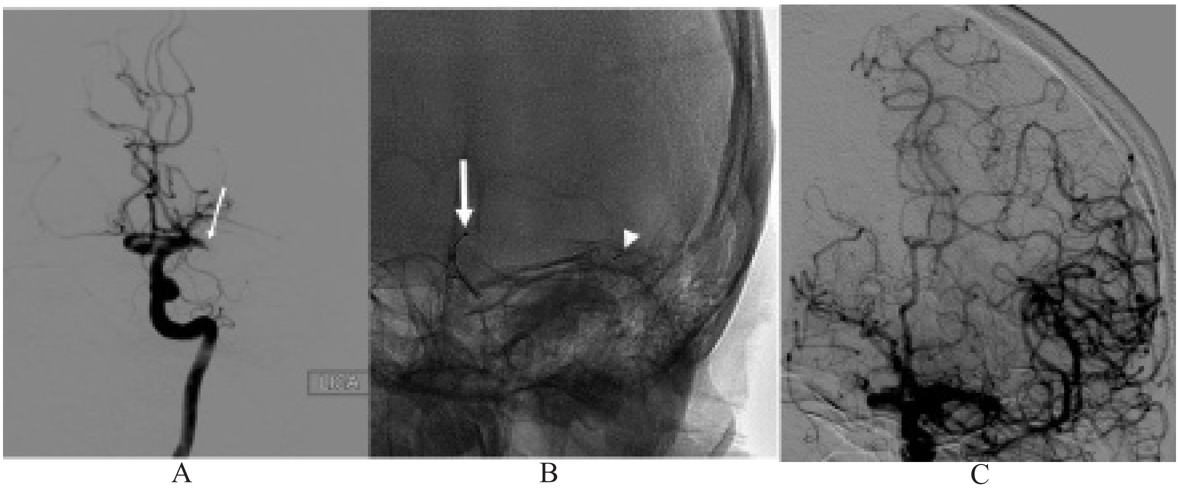

Figure 2: Technique 1.2 in an 82-year old male with right sided weakness (NIHSS 18)

A. Pre-procedure DSA shows a left MCA occlusion.

B. The Arc™ catheter is positioned in the distal ICA (arrow) to improve the traction gradient. The Solitaire device is deployed across the thrombus with its tip marked at the arrowhead. Note that the MCA is angulated inferiorly from its origin making the mechanical retrieval force suboptimal.

C. Post-procedure DSA shows good angiographic outcome (TICI 2b) and the patient improved clinically with an NIHSS score of 2 at 24 hours.

3.3. Combined distal access support and retrieval technique

Scenario: A tortuous ICA and MCA is characterized by a marked difference in direction between the internal carotid artery and the middle cerebral artery . In this situation, the mechanical pulling force from the guide catheter is in the suboptimal direction to dislodge the thrombus. The mechanical stent-retriever vector force is applied inferiorly in anatomical terms, whereas, the MCA tortuosity means that the thrombus must move superiorly to be dislodged.

Technique: This technique uses a tri-axial system and the ARC™ Intracranial Support Catheter is navigated to the level of the MCA clot, and the Solitaire™ device is positioned and deployed as described in 1.1 above. Continuous suction via a 50mls syringe is applied through the 8F guide catheter (Neuron™ MAX), and then both the ARC™ catheter and the Solitaire™ device are retrieved as a complete assembly through the 8F guide catheter. A key advantage of this technique is that it results in both improved distal support and retrieval force to optimise clot retrieval in select cases. **Figure 3**, presented below, illustrates our application of the combined distal access support and retrieval technique in an 82-year old male patient with right MCA occlusion.

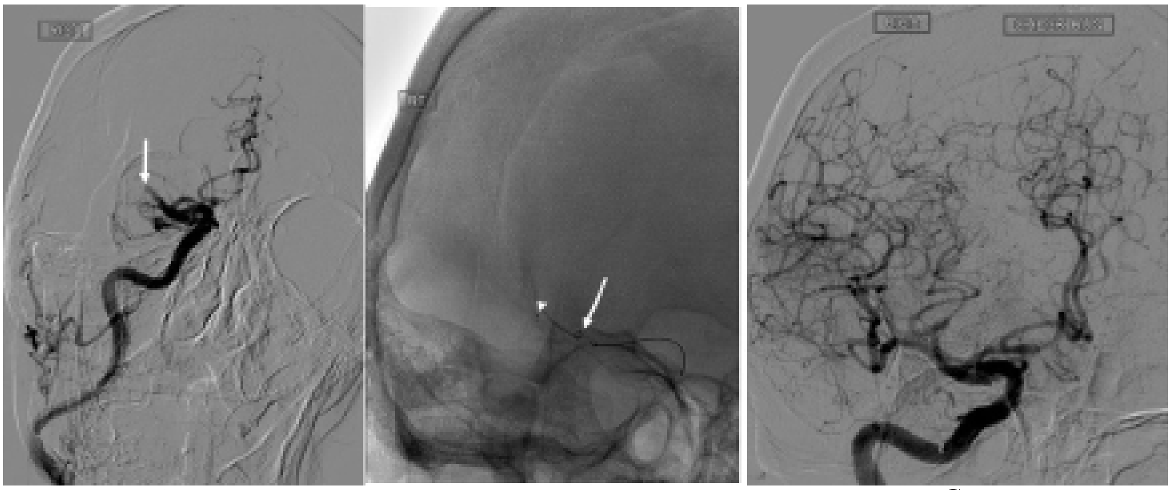

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Figure 3: Technique 1.3 in an 85-year old female with dense left sided weakness (NIHSS 16)

A. Pre-procedure DSA shows a right MCA occlusion (arrow).

B. The Solitaire™ device has been deployed across the thrombus with its tip shown by the arrowhead. The Arc™ intracranial support catheter (arrow) is positioned parallel to the clot to maximise retrieval force.

C. Post-procedure DSA shows good angiographic outcome (TICI 3) and the patient improved clinically with an NIHSS score of 4 at 48 hours.

4. Direct Suction Thrombectomy

Scenario: ICA , MCA, VA (Vertebral artery) or BA (Basilar artery) thrombus.

Technique: This technique utilises an 8F guide catheter (Neuron™ MAX) which is navigated to the arch of aorta under fluoroscopic guidance and then placed into the target vessel ICA via a femoral approach. ARC™ Intracranial Support Catheter is then navigated via the 8F guide catheter directly to the thrombus within the MCA or ICA and suction is performed through the ARC™ catheter which is engaged with the thrombus and suction is applied directly with a 20mls syringe. Direct suction is applied while moving the ARC™ catheter backwards and forwards into/and at the level of the thrombus, in a continuous fashion, to engage and retrieve the thrombus. Direct suction thrombectomy with the ARC™ catheter has the advantage of a rapid total procedure time. In one of our patients, a 61-year old male with a right MCA occlusion and an admission NIHSS score of 22, the total procedure was conducted in seven minutes. This patient's NIHSS score at 48 hours post-procedure had improved to 12, and on repatriation was nine. We have also successfully intervened in a 75-year old female with complete basilar occlusion.

Figure 4, presented below, illustrates our application of the direct suction thrombectomy technique in a 61-year old male with right MCA occlusion, and **Figure 5** illustrates direct suction thrombectomy in a 75-year old female with complete basilar occlusion.

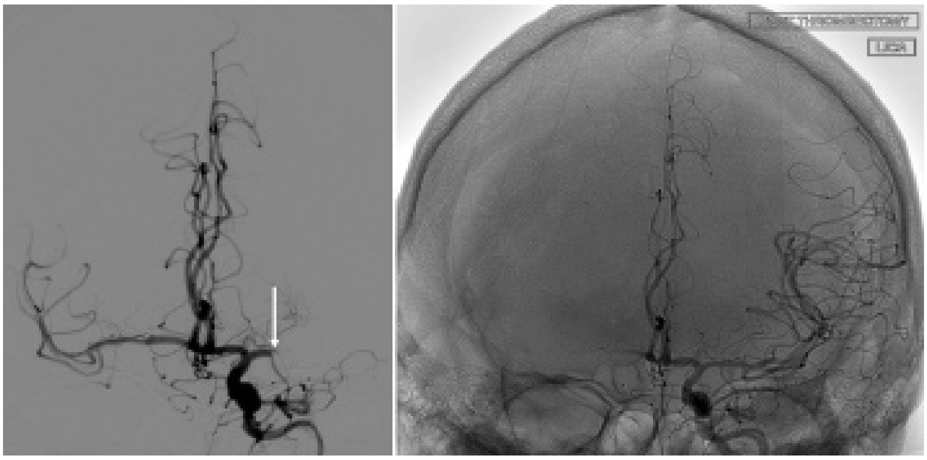

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Figure 4: Technique 2 in a 61-year old male with right sided weakness and aphasia (NIHSS 22). The patient was transferred from another hospital and a rapid procedure was favoured.

A. Pre-procedure DSA shows a left MCA occlusion.

B. Post-procedure DSA shows good angiographic outcome (TICI 3) and the patient improved clinically with an NIHSS score of 12 at 48 hours and NIHSS score of 9 at repatriation.

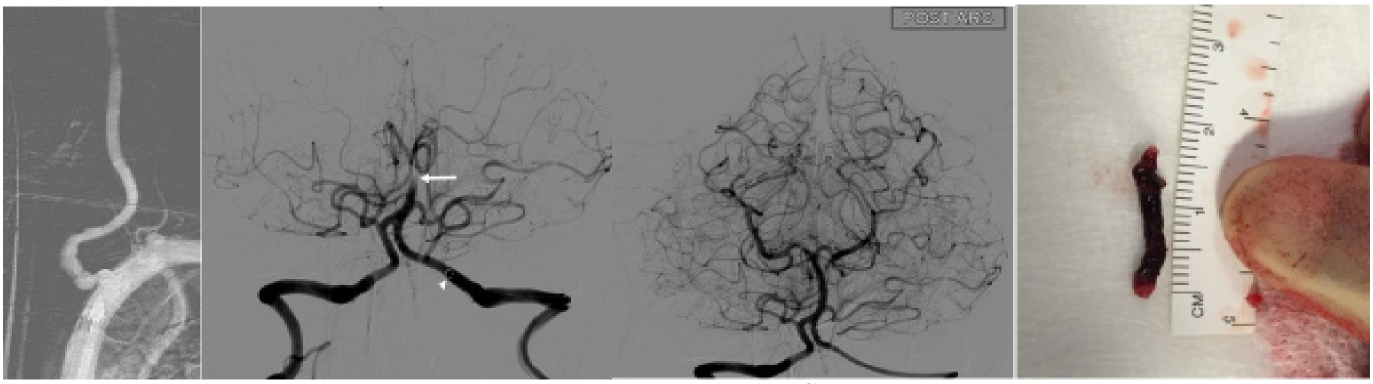

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Figure 5: Technique 2 in a 75-year old female with a GCS score of 4 from basilar occlusion.

A. DSA shows a tortuous proximal left vertebral artery.

B. DSA shows the arc catheter navigated into the distal left vertebral artery (arrowhead) and a mid-basilar occlusion (arrow).

C. Following direction suction thrombectomy with Arc™, DSA shows good angiographic outcome (TICI 3).

D. Thrombus yielded from suction thrombectomy was approximately 2cm long.

5. Combined Initial Suction Thrombectomy Followed By Stent-Retriever Thrombectomy in Large Volume Clots

Scenario: Large volume and long length clots within the ICA and MCA where the clot lenght is usually greater than 10 mm.

Technique: This 2-step technique is suitable for large volume clots; it involves initial partial suction as described in technique 2 provided by the ARC™ catheter to remove most of the thrombus within the ICA, followed by ARC™ Catheter and Solitaire™ deployment to remove any remaining thrombus in the middle cerebral artery M1 or M2 segments as described in techniques 1.1 to 1.3. Figure illustrates our application of this technique in a 79-year old male with a left paraclinoid ICA occlusion.

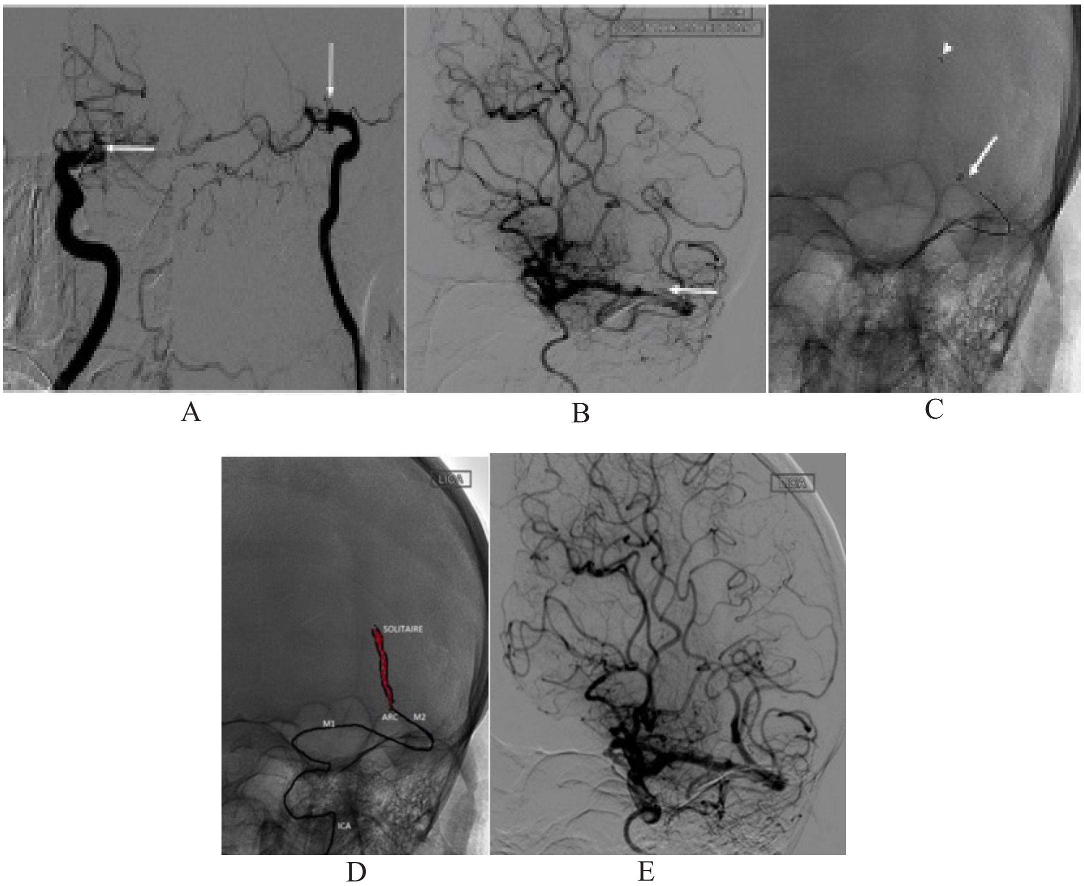

Figure 6: Technique 3 in a 79-year old male with right sided weakness (NIHSS score 21).

A. Frontal and lateral DSA shows left paraclinoid ICA occlusion.

B. DSA following suction thrombectomy of left ICA and proximal MCA with the Arc catheter shows clearance of the proximal MCA (arrowheads) but occlusion more distal M2 segment (arrow).

C. The Arc catheter is now positioned in M2 (arrow) with the Solitaire™ stent-retriever positioned across the thrombus (arrowhead).

D. A representative sketch diagram of C.

E. Post-procedure DSA shows good angiographic outcome (TICI 2b) with improvement of NIHSS score to 8 at 24 hours.

6. Unusual Scenarios

We have found the ARC™ Intracranial Support Catheter useful in an unusual case where a 68-year old male presented with complete basilar occlusion and a Glasgow Coma

Scale (GCS) score of three. The dominant left vertebral artery was dissected making access for thrombectomy extremely difficult. In this case, the ARC™ catheter was navigated through the dissected artery to engage with the thrombus and apply direct suction. Successful removal of the thrombus and subsequent recanalization improved the GCS score, increasing it to 12. The patient, although aphasic, was capable of moving all four limbs, and his overall post-thrombectomy outcome was assessed on the Thrombolysis in Cerebral Infarction (TICI) score as 2b, and at three months' follow-up, his clinical outcome mRS score was three. Our direct suction technique to remove the thrombus through the dissected vertebral artery is illustrated in **Figure 7**.

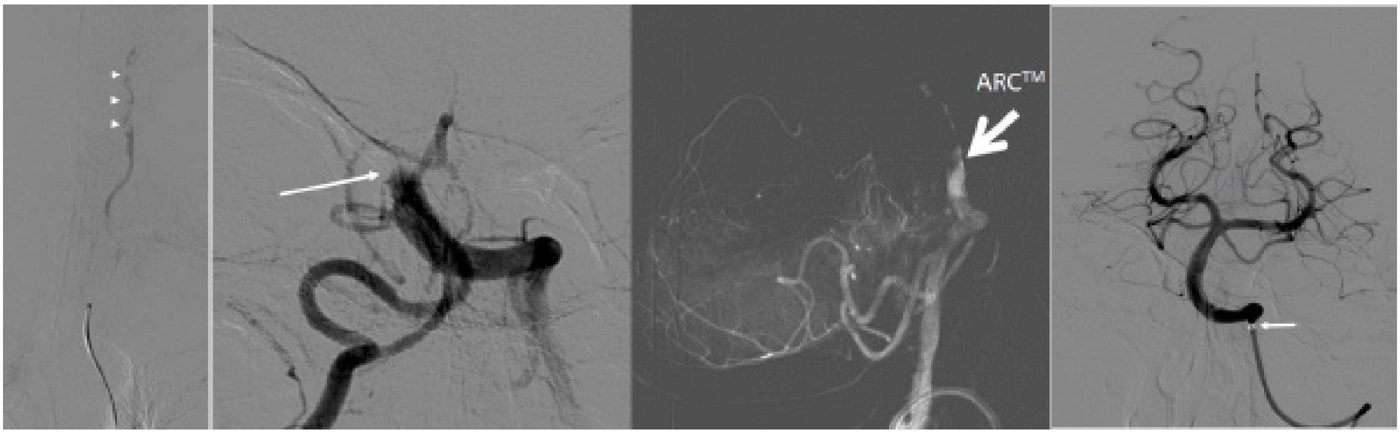

Figure 7: Technique 4 in 68-year old male with GCS 3 from basilar occlusion.

A. Pre-procedure DSA shows dissection of the dominant left vertebral artery (arrowheads)

B. DSA also shows basilar occlusion (arrow) with a hypoplastic left vertebral artery.

C. The Arc catheter has navigated the dissected left vertebral artery and has its tip in the basilar artery engaged with the thrombus (arrow).

D. The DSA performed through Arc (arrow)post-suction thrombectomy of the basilar thrombus with good angiographic outcome. (TICI 2b). GCS recovered to 12 immediately post-procedure.

7. Discussion

MT using modern devices has proved to be efficacious in re-establishing intracranial circulation and reduced procedural times [18]. We have described our initial experience with the newest generation of intracranial support catheters, the Arc™ Support Catheter, used for intracranial thrombectomy, and also as a support catheter to improve the retrieval force in stent-retriever thrombectomy with the Solitaire™ device. Aspiration devices achieve consistently high recanalization rates (68–100%), but clinical outcomes with aspiration are variable with studies showing very poor recovery rates [19]. ASTER trial showed no difference and no inferiority was shown in COMPASS trial [23, 24]. Aspiration is also associated with higher rates of distal embolization [19]. Consequently, it is important that correct low risk aspiration techniques are employed during thrombectomy procedures, as described in this review. It is vital to engage the suction catheter directly with the thrombus, moving the catheter forwards and backwards into the thrombus, in a continuous fashion, while performing suction thrombectomy. In this way, any associated gap between the thrombus and the suction catheter can be avoided. After occlusion of a large artery, the ensuing drop in perfusion pressure, distally, generates a pressure gradient between neighbouring arterial fields, resulting in changes in flow direction and rate. Collateral flow changes occur almost immediately, within 1–4 seconds [19].

If suction is applied with a gap between the suction catheter and the thrombus, this leads to flow reversal in the proximal/ collateral vessels, leading to a decrease in the perfusion pressure within the ischemic brain penumbra. This, in turn, would produce a vicious cycle of further reduction of blood flow in other collateral vessels, thereby incorporating a significant proportion of the salvageable penumbra into the ischemic core [19]. The amount of blood aspirated could also be limited by manual suction with a 20-50 mL syringe rather than a pump where larger volumes of blood can be removed. These concerns [19] are illustrated in **Figure 8**.

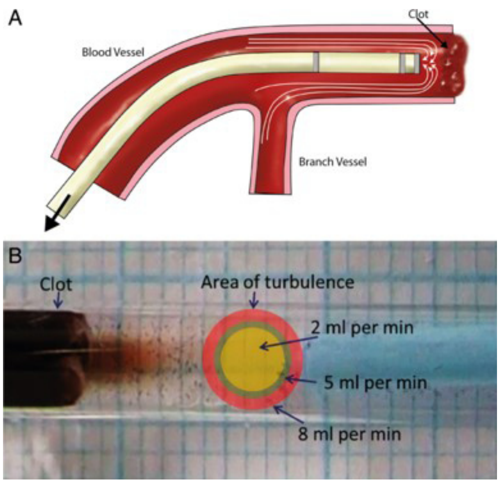

Figure 8: Shows a scenario where there is a gap between the suction catheter and the thrombus causing area of turbulence which results in flow reversal.

Source: Lally et al. J Neurointerv Surg.2016; Sep; 8(9): 969-72.

8. Conclusions

In this initial experience of 48 patients, we have found the ARC™ Intracranial Support Catheter to be a highly navigable and powerful aspirating 6F support catheter. When used as a sole suction device, or combined with the Solitaire™ stent retriever, we have been able to provide a rapid route to successful reperfusion in all cases, with minimal complications related to our endovascular procedures. Our experience with the ARC™ Intracranial Support Catheter for endovascular interventions in acute ischaemic stroke is line with that recently reported by Lozano and co-workers [20]. We can report the ARC™ Intracranial Support Catheter works well when access to thrombi involves navigation through tortuous vessel anatomy, notably when convoluted loops in the cervical internal carotid artery are encountered. We suggest use of the ARC™ catheter in thrombectomy procedures for steep-angle MCA occlusion is appropriate, and for basilar occlusion, where thrombectomy via suction alone proved to be adequate. The ARC™ Intracranial Support Catheter has helped us reduce recanalization times, potentially making it particularly valuable for endovascular thrombectomy in older patients. Our preliminary experience with the ARC™ catheter suggests it may have advantages over the balloon guide catheter technique, reducing the catheter preparation time, the risk of local complications, and the procedure cost.

9. Ethics Declaration

All human and animal studies have been approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

10. References

1. WHO Factsheet: The top 10 causes of death. Updated January 2017. Available at: http://www.who.int/mediacentre/factsheets/fs310/en/ Accessed 02 January 2017.

2. National Stroke Strategy. London: Department of Health, 2001.

3. Evans MRB, White P, Cowley P, et al. Revolution in acute ischaemic stroke care: a practical guide to mechanical thrombectomy. Pract Neurol 2017; 0:252–265. doi 10.1136/practneurol-2017-001685

4. Rodrigues FB, Neves JB, Caldeira D, et al. Endovascular treatment versus medical care alone for ischaemic stroke: systematic review and meta-analysis. BMJ. 2016 Apr 18;353: i1754. doi: 10.1136/bmj.i1754

5. Berkhemer OA, Fransen PS, Beumer D, et al. A randomized trial of intraarterial treatment for acute ischemic stroke. N Engl J Med 2015; 372: 11–20.

6. Jovin TG, Chamorro A, Cobo E, et al. Thrombectomy within 8 hours after symptom onset in ischemic stroke. N Engl J Med 2015;372: 2296–306.

7. Campbell BC, Mitchell PJ, Kleinig TJ, et al. Endovascular therapy for ischemic stroke with perfusion-imaging selection. N Engl J Med 2015;372: 1009–18.

8. Saver JL, Goyal M, Bonafe A, et al. Stent-retriever thrombectomy after intravenous t-PA vs. t-PA alone in stroke. N Engl J Med 2015;372: 2285–95.

9. Goyal M, Demchuk AM, Menon BK, et al. Randomized assessment of rapid endovascular treatment of ischemic stroke. N Engl J Med 2015;372: 1019–30.

10. Bracard S, Ducrocq X, Mas JL, et al. Mechanical thrombectomy after intravenous alteplase versus alteplase alone after stroke (THRACE): a randomised controlled trial. Lancet Neurol 2016; 15: 1138–47.

11. Mocco J, Zaidat OO, von Kummer R, et al. Aspiration thrombectomy after intravenous alteplase versus intravenous alteplase alone. Stroke 2016;47: 2331–8.

12. Muir KW, Ford GA, Messow CM, et al. Endovascular therapy for acute ischaemic stroke: The Pragmatic Ischaemic Stroke Thrombectomy Evaluation (PISTE) randomised, controlled trial. J Neurol Neurosurg Psychiatry 2017;88: 38–44.

13. Khoury NN, Darsaut TE, Ghostine J, et al. Endovascular thrombectomy and medical therapy versus medical therapy alone in acute stroke: a randomized care trial. J Neuroradiol 2017: S01509861pii):30120–1

14. Rha J-H, Saver JL. The impact of recanalization on ischemic stroke outcome: a meta-analysis. Stroke 2007; 38: 967-73.

15. Mazighi M, Serfaty J-M, Labreuche J, et al. Comparison of intravenous alteplase with a combined intravenous-endovascular approach in patients with stroke and confirmed arterial occlusion (RECANALISE study): a prospective cohort study. Lancet Neurol 2009; 8: 802-9 doi: 0.1016/S1474-4422(09)70182-6

16. Khatri P, Yeatts SD, Mazighi M et al. Time to Angiographic Reperfusion and Clinical Outcome after Acute Ischemic Stroke in the Interventional Management of Stroke Phase III (IMS III) Trial: A Validation Study. Lancet Neurol. 2014 June; 13(6): 567–574. doi:10.1016/S1474-4422(14)70066-3

17. Medtronic data on file: ARCTM Catheter Series Competitive Testing report TR-NV12169.

18. V. Leung, A. Sastry, S. Srivastava, et al. Mechanical thrombectomy in acute ischaemic stroke: a review of the different techniques. Clinical Radiology (2017). https://doi.org/10.1016/j.crad.2017.10.022

19. Lally F, Soorani M, Woo T et al. In vitro experiments of cerebral blood flow during aspiration thrombectomy: potential effects on cerebral perfusion pressure and collateral flow. J Neurointerv Surg.2016 Sep; 8(9): 969-72. doi: 10.1136/neurintsurg-2015-011909. Epub 2015 Aug 28.

20. Lozano J, Massari F, Howk M C, et al. (May 21, 2016) Utilization of a New Intracranial Support Catheter as an Intermediate Aspiration Catheter in the Treatment of Acute Ischemic Stroke: Technical Report on Initial Experience. Cureus 8(5): e617. DOI 10.7759/cureus.617

21. Mechanical thrombectomy in basilar artery occlusion: influence of reperfusion on clinical outcome and impact of the first-line strategy (ADAPT vs stent retriever). Gory B, Mazighi M, Blanc R, Labreuche J, Piotin M, Turjman F, Lapergue B; Endovascular Treatment in Ischemic Stroke (ETIS) Research Investigators. J Neurosurg. 2018 Jan 12:1-10. doi: 10.3171/2017.7.JNS171043. [Epub ahead of print]

22. A direct aspiration first pass technique for acute stroke therapy: a systematic review and meta-analysis. Gory B, Armoiry X, Sivan-Hoffmann R, Piotin M, Mazighi M, Lapergue B, Blanc R, Turjman F. Eur J Neurol. 2018 Feb;25(2):284-292. doi: 10.1111/ene.13490. Epub 2017 Nov 24.

23. Contact Aspiration with the New ARC Catheter for Thrombectomy of Acute Ischemic Stroke: Single-Center Results. Gory B, Turjman F. World Neurosurg. 2018 Jan;109:e374-e381. doi: 10.1016/j.wneu.2017.09.180. Epub 2017 Oct 5.

24. Effect of Endovascular Contact Aspiration vs Stent Retriever on Revascularization in Patients With Acute Ischemic Stroke and Large Vessel Occlusion: The ASTER Randomized Clinical Trial. Lapergue B, Blanc R, Gory B, Labreuche J, Duhamel A, Marnat G, Saleme S, Costalat V, Bracard S, Desal H, Mazighi M, Consoli A, Piotin M; ASTER Trial Investigators. JAMA. 2017 Aug 1;318(5):443-452. doi: 10.1001/jama.2017.9644.