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Direct Carotid Puncture for Mechanical Thrombectomy in Acute Ischemic Stroke Patients with Prohibitive Vascular Access

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Abstract

Objective: While the benefit of mechanical thrombectomy (MT) for anterior circulation acute ischemic stroke patients with large vessel occlusion (AIS-LVO) has been clearly established, difficult vascular access may make the intervention impossible or unduly prolonged. In this study, we evaluated safety as well as radiographic and functional outcomes in stroke patients treated with MT via direct carotid puncture (DCP) for prohibitive vascular access.

Methods: We retrospectively studied patients from our prospective AIS-LVO database who underwent attempted MT between 2015–2018. Patients with prohibitive vascular access were divided into two groups: (1) aborted MT (abMT) after failed transfemoral access and (2) attempted MT via DCP. Functional outcome was assessed using the modified Rankin Scale (mRS) at 3 months. Associations with outcome were analyzed using ordinal logistic regression.

Results: Of 352 consecutive patients with anterior circulation AIS-LVO who underwent attempted MT, 37 patients (10.5%) were deemed to have prohibitive vascular access (mean age 82±11, 75% female, mean NIHSS 17±5). These included 20 patients in the DCP group and 17 in the abMT group. The two groups were well matched for known predictors of clinical outcome: age, sex, and admission NIHSS. Direct carotid access was successfully obtained in 19 of 20 patients. Successful reperfusion (TICI 2b-3) was achieved in 16 of 19 (84%) patients in the DCP group. Carotid access complications included: an inability to catheterize the carotid artery in 1 patient; small neck hematomas in 4 patients; non-flow limiting CCA dissections in 2 patients; and a delayed, fatal carotid blow-out in 1 patient. The small neck hematomas and non-flow limiting CCA dissections did not require any subsequent interventions and remained clinically silent. Compared to the abMT group, patients in the DCP group had smaller infarct volumes (11 versus 48 ml, P=0.04), a greater reduction in NIHSS (−4 versus +2.9, P=0.03), and better functional outcome (shift analysis for 3-month mRS OR 5.2, 95% CI 1.02–24.5, P=0.048).

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Conclusions: DCP for emergent MT in patients with anterior circulation AIS-LVO and prohibitive vascular access is safe and effective, and associated with higher recanalization rates, smaller infarct volumes, and improved functional outcome compared to patients with aborted MT after failed transfemoral access. DCP should be considered in this patient population.

Keywords

Difficult Vascular Access; Direct Carotid Puncture; Large Vessel Occlusion; Mechanical Thrombectomy; Acute Ischemic Stroke

Introduction

Five major randomized controlled clinical trials have established mechanical thrombectomy (MT) as a new standard of care in anterior circulation acute ischemic stroke patients with large vessel occlusion (AIS-LVO).[1] MT is typically performed via percutaneous transfemoral access. However, a subset of patients who would benefit from MT present with challenging vascular anatomy, e.g., difficult aortic arch, vessel tortuosity, stenotic vessel ostium, and iliofemoral arterial occlusive disease, that significantly slows or precludes transfemoral access, often leading to abandonment of the procedure with attendant worse radiographic and clinical outcomes.[2–4]

Although alternative access routes including transradial and transcarotid have been described, either as a primary or salvage strategy, clinical series are small and outcome data are limited.[5–10] We sought to compare safety and functional outcome in patients with prohibitive vascular access who (1) had aborted MT (abMT) after failed transfemoral access to those who (2) underwent attempted MT via direct carotid puncture (DCP).

Methods

The authors declare that all supporting data are available within the article and its online supplementary materials.

Study design and subjects

A prospective registry of all MT cases performed at Yale-New Haven Hospital (a certified Comprehensive Stroke Center) over a 3-year period (2015–2018) was retrospectively reviewed for cases of attempted MT via DCP and those who had abMT after failed transfemoral access. Demographics, medical comorbidities, site of occlusion, and presenting National Institutes of Health Stroke Scale (NIHSS) scores were obtained from the electronic medical record. All stroke management decisions including whether or not to proceed with DCP was made by the patients' attending providers and clinical care team in accordance with current American Heart Association (AHA) guidelines.[11] Two out of three neurointerventionalists at our institution (C.M and R.H.) started using DCP as a secondary approach for transfemoral access failure in 6/2016. Thrombolysis in Cerebral Infarction (TICI) scores were assessed from angiograms, while final infarct volumes were calculated from follow-up MR or CT imaging. Functional outcome was assessed using the modified Rankin Scale (mRS) at discharge and 3 months.

Direct carotid puncture technique

For direct carotid artery puncture access the technique described by Mokin et al. was used, with minor modification (Figure 1).[12] The head was turned 30° to the contralateral side and placed in mild extension. Using ultrasound guidance, the common carotid artery (CCA) was punctured approximately 3-cm above the clavicle using a 4F Micropuncture® Access Set (Cook Medical) in the triangle formed by the two heads of the sternocleidomastoid muscle and the clavicle. A 45° angle of approach was favored. Under roadmap guidance, the microsheath was positioned in the external carotid artery. Over an Amplatz Support Wire (80-cm, Cook Medical), a 6F Brite Tip® Sheath Introducer (5.5- or 11-cm, Cordis) was used to cannulate the CCA. An angiographic run was performed to confirm positioning of the sheath tip below the carotid bifurcation. The sheath was secured to the surrounding skin using two-point fixation.

Mechanical thrombectomy was then performed in the usual fashion with a stent retriever (Medtronic Solitaire Revascularization Device) alone or used in conjunction with a distal aspiration catheter (Penumbra ACE 68 or JET-7) (the so-called Solumbra technique). The catheters were looped on the chest to facilitate handling. During each removal of the stent retriever ± aspiration catheter, the sheath's hemostatic valve was removed to prevent dislodgement of clot within the sheath and distal embolization. After the MT procedure was completed, the sheath was removed by manual compression or with off-label use of a 6F Angio-Seal™ Vascular Closure Device (Terumo Medical, USA). Patients were routinely kept intubated until the following day to prevent neck movement in the immediate post-procedural period. A post-procedure imaging protocol (carotid ultrasound × 3 days, and day 3 neck CTA) to assess for occult vascular injury/pseudoaneurysm formation was implemented later in our experience (last 8 cases).

Statistical analysis

Baseline characteristics were summarized by means and standard deviations (SD) for normally distributed continuous variables, by medians and interquartile ranges (IQR) for skewed continuous variables, and by numbers (%) for categorical variables. We used -, *t*- or Mann-Whitney *U* tests as appropriate for unadjusted comparisons. Associations with functional outcome were analyzed using ordinal logistic regression, adjusted for age and admission NIHSS. All statistics were performed in SPSS (Version 24, IBM Corp). Statistical significance was set at $P<0.05$.

Results

Over the study period, 352 MT procedures were attempted, the majority via transfemoral access. In 17 cases (4.8%), attempted MT was aborted due to an inability to reach the clot. In 20 cases (5.7%), DCP was attempted either as a salvage technique following failed transfemoral MT (14/20), or as a primary approach in selected cases (6/20) when the operator believed a transfemoral approach was unlikely to succeed in a timely fashion based on review of a pre-intervention CT angiogram (CTA). In a single early case, we failed to introduce the sheath into the carotid artery following successful micropuncture and wire placement. Manual closure was performed. This problem likely resulted from too steep an angle of approach in a patient with a larger neck circumference (Patient #20). This case was excluded from the subsequent as treated analysis. The two groups (DCP and abMT) were well matched for known clinical predictors of outcome including age, sex, and admission NIHSS; as well as other major medical comorbidities and location of the occlusion, (Table 1). In contrast, patients with prohibitive vascular access (both the DCP and abMT groups) were overall older (82 vs. 71 years, $P<0.001$), more likely to be female (76% vs. 54%, $P=0.01$), and had more comorbidities including a history of prior stroke or TIA when compared to patients with successful transfemoral approach from our overall AIS-LVO cohort. Patients with prohibitive vascular access were also less frequently treated with IV tPA prior to endovascular thrombectomy (35% vs. 57%, $P=0.012$) and showed differences in the distribution of baseline mRS scores ($P=0.019$), (Supplemental Table I).

Most patients undergoing DCP were intubated prior to carotid puncture (18/19). Carotid sheath removal was performed with a vascular closure device (15/19) or manual compression (4/19). Four neck hematomas developed at the time of closure (during manual pressure hold or closure device deployment). One of the cases required treatment with fresh frozen plasma to normalize the patient's elevated INR (warfarin). The neck hematoma remained stable in size and did not cause airway compromise. No surgical intervention was necessary. The remaining three cases had small neck hematomas that were successfully managed with observation only. They did not threaten the airway, change in size over time, or require surgical evacuation or prolonged intubation. A single patient suffered a fatal delayed carotid blow-out on post-DCP Day 4 following successful revascularization. In this patient, carotid sheath removal was performed with an Angio-Seal™ Vascular Closure Device. Two non-flow-limiting dissections on the back wall of the CCA were noted on surveillance imaging correlating with the position of the tip of the carotid sheath (but not the point of access into the carotid artery) during the procedure (Figure 2). No additional interventions were required. Clinical and procedural data for each patient can be found in Tables 2 & 3.

Successful reperfusion (TICI 2b or 3) was achieved in 16/19 (84%) transcarotid mechanical thrombectomies as compared to 0/17 controls. The time from MT start to revascularization for patients receiving primary DCP was on average shorter (40±29 mins) than those of patients receiving traditional MT via femoral access puncture at our center (69±48 mins). Patients receiving secondary DCP after failed femoral access had a longer average revascularization time of 130±66 mins, as expected from the multi-step approach (Table 4). At 24 hours, DCP was associated with smaller infarct volume (median 11 vs. 48 ml, $P=0.041$) and greater reduction in NIHSS (−4 vs +2.9, $P=0.034$; Figure 3). After adjusting for age and admission NIHSS, performing DCP in patients with prohibitive vascular access was associated with an increased likelihood of shifting towards a lower (i.e., better) mRS score at 3 months (adjusted OR 5.2, 95% CI 1.02–24.5, $P=0.048$; Figure 4).

Discussion

A significant subset of patients with anterior circulation AIS-LVO have prohibitive vascular anatomy, precluding timely transfemoral access to the site of intracranial occlusion. Alternative approaches, including transcarotid and transradial access, have been reported in case reports and small case series,[12–15] but data comparing radiographic and clinical outcomes in patients with otherwise prohibitive vascular anatomy are lacking. In this study of 36 patients with anterior circulation AIS-LVO undergoing MT, we showed that use of a transcarotid approach as compared to procedure abandonment was associated with significantly increased rates of reperfusion, greater improvement in NIHSS, decreased infarct volumes, and improved 3-month functional outcome. The overall high incidence of in-hospital and 90-day mortality in both groups is likely related to the advanced patient age when compared to our cohort of AIS-LVO patients and clinical trials of MT (82 vs. 71 and 68 years, respectively).[1] In addition, the analyzed patients had more comorbidities, a higher degree of baseline disability and were less frequently treated with TPA.

In our cohort, transfemoral MT failed in 8.5% of patients, which is slightly higher than rates previously reported and may be a reflection of the large number of nonagenarians treated at our institution. The probability of transfemoral access failure has been shown to increase with age with up to 20% failure in patients over 80 years old, likely due to age-related changes in the vasculature.[2,3]

Sheath removal and hemostasis following percutaneous transcarotid access remains a significant concern and barrier to using the technique for many practitioners, especially given the high rate of perioperative antithrombotic or thrombolytic medication. Examples of open surgical closure, manual pressure, extravascular closure devices, and intraoperative closure devices have been described in the literature.[7,8,10,12,13,16] Off-label use of the Angio-Seal™ Vascular Closure device was chosen as it is the most commonly described method with the fewest described complications.[8,16] It is also our standard transfemoral closure method and therefore the technique with which we have the most familiarity and understanding of procedural nuances. Most of our transcarotid punctures were closed with an Angio-Seal, but we have also used manual compression without major complications, even in patients who received IV tPA. Four patients developed non-surgical neck hematomas during manual pressure hold or closure device deployment immediately after sheath removal which were monitored. These small hematomas did not cause tracheal deviation or airway compromise and remained stable in size over time. A single patient suffered a delayed, fatal carotid blow-out following successful transcarotid mechanical thrombectomy. During deployment of the vascular closure device in this latter case, puckering of the skin and soft tissue overlying the carotid was seen, necessitating extra manipulation of the device. This clinical course is consistent with traumatic pseudoaneurysm formation and rupture, although this could not be confirmed as the patient’s family declined request for autopsy. Following this event, all transcarotid cases underwent serial daily carotid ultrasound imaging and a CTA on post-procedure day 3. Note was made of non-flow-limiting dissections on the back wall of the CCA in 2 cases (this is remote from the carotid puncture site), likely due to rubbing of the tip of the 6F sheath during the thrombectomy procedure (Figure 1). No additional interventions were required. In our experience, increased ease of use and safety could likely be obtained by the development of carotid-specific sheaths and access systems, as well as improved closure methods.

While a transcarotid approach was used as salvage therapy in most cases, it was also the primary access point in 32% of patients, selected with the intention of improving revascularization times and outcomes. Given its relative safety and efficacy, transcarotid access for revascularization may be indicated for a larger cohort of patients with large vessel occlusion ischemic stroke. Expanding indications to reach a wider patient cohort may bring significant functional improvement to patients with fast progressing infarcts and challenging anatomy that, while not ultimately prohibitive, can cause significantly slower transfemoral revascularization times with deleterious impacts on clinical outcomes.[3] Analysis of our data demonstrates that primary DCP in patients with prohibitive anatomy achieves revascularization significantly faster than our entire traditional transfemoral cohort which also includes patients with straightforward anatomy. Indeed, a predictive model for difficult transfemoral thrombectomy has recently been developed to improve patient selection based on the pre-procedure CTA.[4]

Notably, transradial approaches are rapidly becoming the primary access point for neurointerventional procedures due to a lower rate of access site complications and improved ease of access in some patients with tortuous and complex arch anatomy.[17,18] Increased familiarity with a transradial approach for anterior circulation large vessel occlusion mechanical thrombectomy will likely reduce the need for a transcarotid approach. In a subset of stroke patients with difficult anatomy, a transradial first approach found equivalent clinical outcomes and revascularization times to a traditional transfemoral approach, without any major morbidity or mortality.[6] Unfortunately, the small size of the radial artery may limit the consistent use of larger thrombectomy catheter systems.[6] Moreover, early cross-institutional experience demonstrated an 18% failure rate of primary transradial thrombectomies, and a 6.9% conversion to a transfemoral approach.[18] While increased experience and refined, transradial-specific catheter systems will improve these rates, a subset of patients will remain in whom both transfemoral and transradial approaches are suboptimal and the most direct approach to the lesion, a transcarotid approach, may be the most clinically appropriate treatment.

Our study has several important limitations. First, the sample size was small, and while the results were significant, we were not able to adjust for all predictors of poor outcome. The addition of short-term radiographic endpoints as well as a plausible biological mechanism help to overcome this limitation. Second, although larger than a case series, it remains a retrospective analysis.

Conclusions

A significant proportion of patients with acute ischemic stroke and large vessel occlusion have anatomy prohibitive to transfemoral mechanical thrombectomy. This retrospective cohort study demonstrates that the use of transcarotid mechanical thrombectomy in these patients is associated with higher revascularization rates, smaller final stroke volumes, improved NIHSS scores, and improved functional outcome as compared to standard of care after failed transfemoral mechanical thrombectomy alone. This study supports the use of transcarotid puncture for mechanical thrombectomy.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Disclosures

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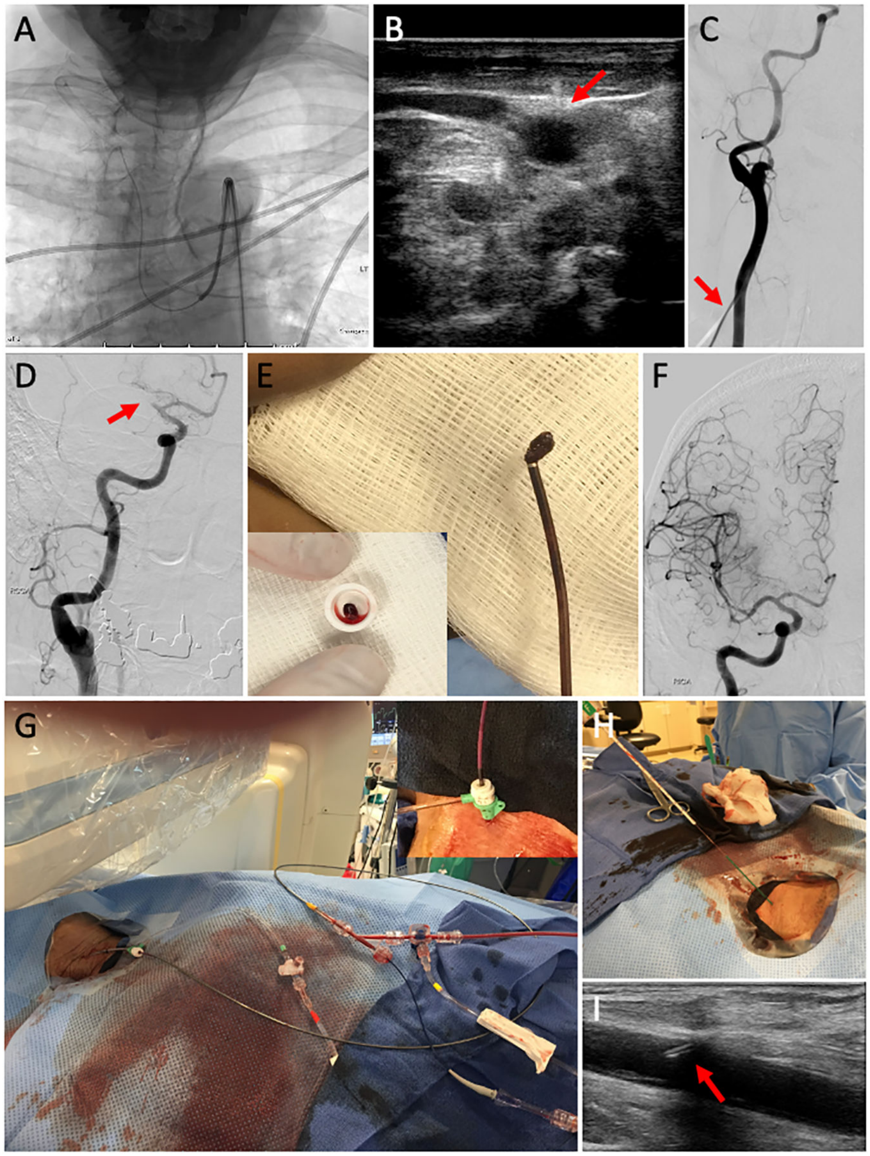

Figure 1. Percutaneous Trans-Carotid Access for Mechanical Thrombectomy.

A. Tortuous arch anatomy preventing trans-femoral approach, B. Direct carotid puncture is performed under ultrasound guidance (arrow indicates micropuncture needle), C. 5.5cm 6F Brite Tip Sheath inserted into CCA, D. AP projection demonstrating LVO (arrow indicates right M1 occlusion), E. Corked clot (inset demonstrates how clot can be sheared off and trapped in the sheath valve upon removal, cap must be popped off before withdrawing the aspiration catheter), F. TICI 3 Revascularization from trans-carotid approach, G. Overview of setup showing looping of long catheters outside body and inset showing the catheter in the carotid, H. Angioseal closure, I. Ultrasound demonstrating Angioseal footplate within the vessel without dissection or pseudoaneurysm.

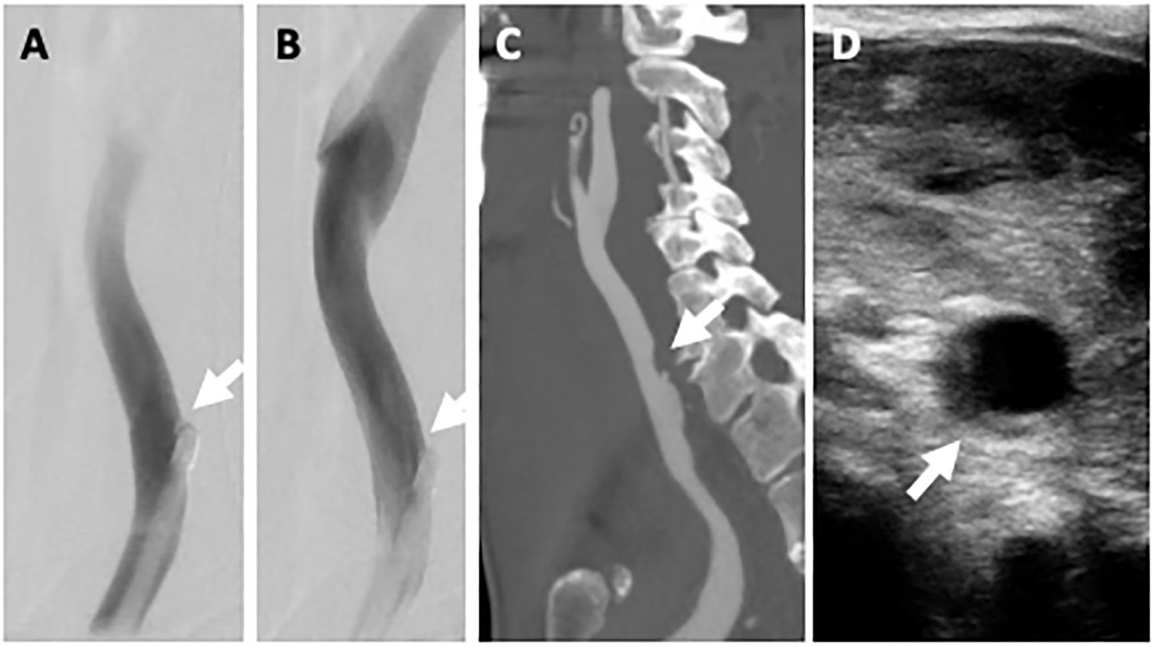

Figure 2: Non-flow limiting carotid dissection.

A/B. Sequential frames of the right common carotid angiogram. Arrow denotes the tip of the carotid sheath buried into the back wall of the vessel and associated small dissection. C. Post-procedure CTA showing new back wall vessel irregularity at the area of the sheath tip (Arrow) with only mild narrowing of the vessel. D. Post-procedure transverse ultrasound showing thrombus in the small dissection flap (Arrow).

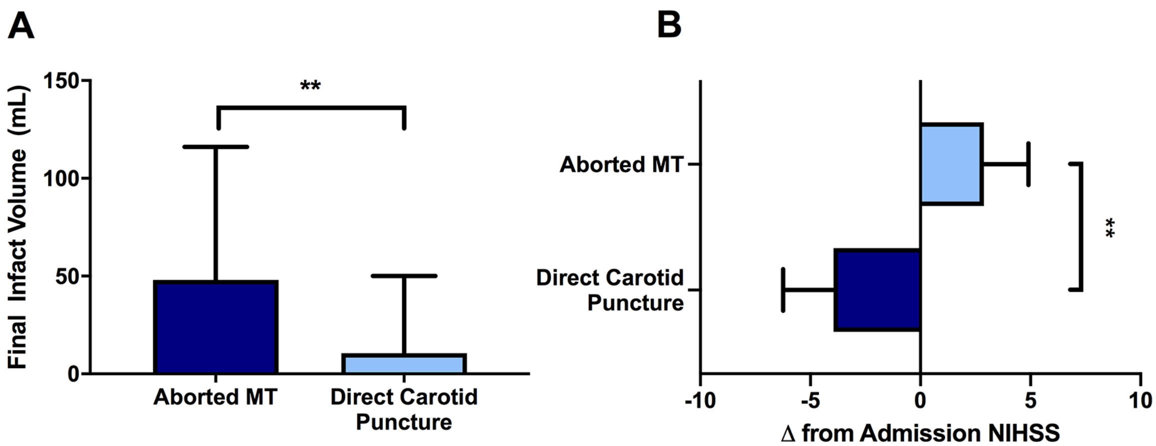

Figure 3: Radiographic and short-term clinical outcomes.

A. Final infarct volume given in mL at 24 hours post-procedure. B. Change in NIHSS between admission and 24 hours post-procedure. **indicates $P<0.05$.

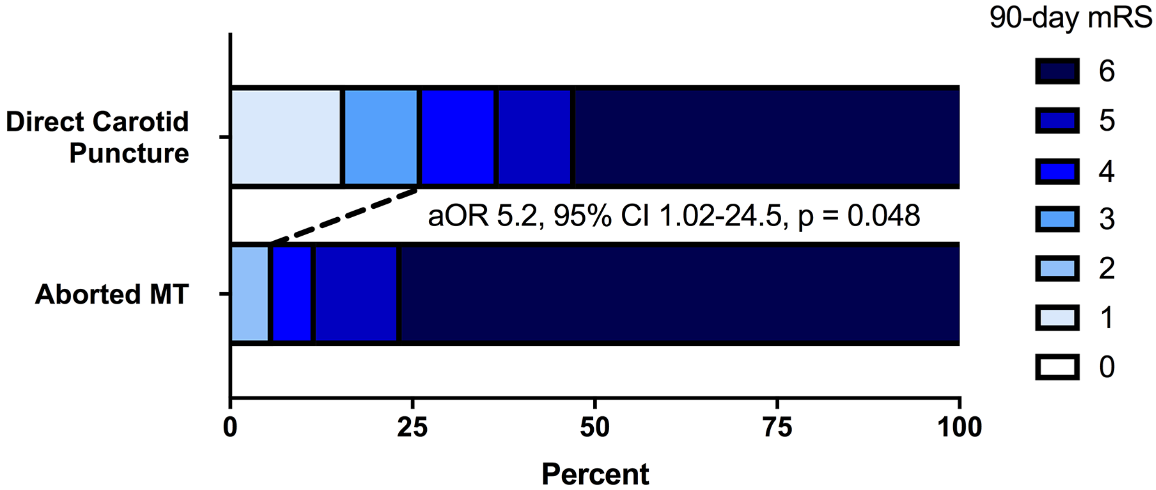

Figure 4: Three-month functional outcomes following direct carotid puncture vs. aborted mechanical thrombectomy.

mRS: modified Rankin score, aOR: adjusted odds ratio, CI: confidence interval. $P<0.05$ between groups.

Table 1.

Patient Characteristics

	Failed Transfemoral Access (abMT)	Transcarotid Access (DCP)	*P Value*
Total patients	17	19	
Outcomes assessed at 90 days, n (%)	17 (100)	19 (100)	
Age, mean ± SD	83 ± 10	81 ± 11	0.677
Gender, F (%)	13 (77)	14 (74)	0.847
Race, n (%)			0.575
White	14 (82)	14 (74)	
Black or African American	1 (6)	3 (16)	
Asian	0 (0)	1 (5)	
Other	1 (6)	1 (5)	
Medical History, n (%)			
Hypertension	13 (77)	13 (69)	0.590
Coronary artery disease	6 (35)	5 (26)	0.559
Myocardial infarction	3 (18)	1 (5)	0.238
Hyperlipidemia	7 (41)	8 (42)	0.955
Chronic heart failure	2 (12)	4 (21)	0.455
Atrial fibrillation	10 (59)	11 (58)	0.955
Diabetes mellitus	3 (18)	2 (11)	0.537
Obesity	3 (18)	4 (21)	0.797
Past ischemic stroke/TIA	6 (35)	4 (21)	0.341
Current/past smoker*	9 (53)	6 (32)	0.229
Side of occlusion, n (%)			0.709
Left	10 (59)	10 (53)	
Right	7 (41)	9 (47)	
Location of Occlusion, n (%)			0.166
M1 MCA	7 (41)	11 (58)	
M2 MCA	6 (35)	3 (16)	
tICA	2 (12)	5 (26)	
Tandem	2 (12)	0 (0)	
Admission NIHSS, median (IQR)	17 (13.5–21.5)	18 (14–21)	0.693
ASPECT Score, median (IQR)	8.5 (7–10)	9.5 (8–10)	0.313
Pre-admit mRS, median (IQR)	1 (0–2)	0 (0–1)	0.162
Treated with tPA, n (%)	6 (35)	7 (37)	0.923
Mean onset to MT, minutes ± SD	396 ± 291	623 ± 578	0.021
Mean MT to reperfusion, minutes ± SD	N/A	Primary: 40 ± 29 Secondary: 130 ± 66	
Successful recanalization, n (%)	0 (0)	16 (84)	< 0.001

	Failed Transfemoral Access (abMT)	Transcarotid Access (DCP)	*P Value*
TICI Score, n (%)			
0	17 (100)	1 (5)	
1	0 (0)	0 (0)	
2a	0 (0)	2 (11)	
2b	0 (0)	10 (53)	
3	0 (0)	6 (32)	
In-hospital mortality, n (%)	6 (35)	5 (26)	0.559
90-day mortality, n (%)	13 (77)	10 (53)	0.137

Table 2.

Clinical and procedural details of all patients with direct common carotid puncture (DCP)

Subject No.	Age	NIHSS	ASPECT	Side of Occlusion	Site of Occlusion	IV tPA	Carotid access complications	Femoral access complications	Successful Carotid puncture	Anesthesia	TICI	Discharge mRS	90 Day mRS	Interval: femoral to carotid puncture (min)	Carotid puncture to reperfusion (min)	Total Procedure time (min)	Closure method
1	79	21	9	R	MCA M1	No	Nil	Nil	Yes	CS, LA (fentanyl)	2b	4	3	42	58	100	Closure device
2	81	14	9	L	MCA M2	No	Nil	Nil	Yes	GA	3	3	1	72	28	100	Closure device
3	86	22	7	L	tICA	No	Nil	Nil	Yes	GA	3	5	6	81	66	147	Closure device
4	88	18	10	R	MCA M1	No	Nil	Nil	Yes	GA	2b	5	6	N/A	37	37	Closure device
5	66	21	10	L	MCA M2	No	Nil	Nil	Yes	GA	2a	5	5	186	131	317	Closure device
6	87	20	7	R	MCA M1	No	Nil	Nil	Yes	GA	2b	4	3	57	64	121	Closure device
7	58	27	8	L	tICA	No	Small neck hematoma; monitored; no surgical intervention required.	Nil	Yes	GA	2b	5	4	41	21	62	Closure device
8	82	9	10	R	MCA M1	Yes	Small neck hematoma; monitored; no surgical intervention required.	Non-flow limiting dissection of the Iliac artery; monitored, no intervention required.	Yes	GA	2b	5	1	65	55	120	Closure device + Manual Compression
9	>89	19	No CT	L	MCA M2	No	Small neck hematoma; monitored; no surgical intervention required.	Non-flow limiting dissection of the Iliac artery; monitored, no intervention required.	Yes	GA	2b	6	6	79	87	166	Manual Compression
10	>89	21	8	R	MCA M1	No	Nil	Perforation of femoral artery;	Yes	GA	3	6	6	105	25	130	Closure device +

Subject No.	Age	NIHSS	ASPECT	Side of Occlusion	Site of Occlusion	IV tPA	Carotid access complications	Femoral access complications	Successful Carotid puncture	Anesthesia	TICI	Discharge mRS	90 Day mRS	Interval: femoral to carotid puncture (min)	Carotid puncture to reperfusion (min)	Total Procedure time (min)	Closure method
								controlled by manual pressure and balloon placement.									Manual Compression
11	88	18	9	R	MCA M1	No	Nil	Nil	Yes	GA	2b	4	6	51	18	69	Closure device
12	79	11	9	L	MCA M1	No	Non-flow limiting dissection of the CCA; monitored closely; no intervention required.	Nil	Yes	GA	2b	6	6	N/A	35	35	Closure device
13	>89	25	9	L	MCA M1	No	Nil	Nil	Yes	GA	3	4	5	N/A	23	23	Closure device
14	87	18	10	R	tICA	Yes	Nil	Nil	Yes	GA	3	5	6	N/A	14	14	Closure device
15	>89	15	10	R	tICA	No	Fatal carotid blow-out on post-op day 4.	Nil	Yes	GA	3	6	6	26	36	62	Closure device
16	78	26	10	R	MCA M1	Yes	Non-flow limiting dissection of the CCA; monitored closely; no intervention required.	Nil	Yes	GA	2a	5	6	50	98	148	Closure device
17	58	11	10	L	MCA M1	No	Nil	Nil	Yes	GA	2b	3	1	N/A	97	97	Closure device
18	89	18	10	L	tICA	Yes	Moderate sized neck hematoma; INR normalized; hematoma monitored; no surgical intervention required.	Nil	Yes	GA	2b	6	6	N/A	34	34	Manual Compression

Subject No.	Age	NIHSS	ASPECT	Side of Occlusion	Site of Occlusion	IV tPA	Carotid access complications	Femoral access complications	Successful Carotid puncture	Anesthesia	TICI	Discharge mRS	90 Day mRS	Interval: femoral to carotid puncture (min)	Carotid puncture to reperfusion (min)	Total Procedure time (min)	Closure method
19	67	11	6	L	MCA M1	No	Nil	Nil	Yes	GA	0	4	4	80	74	154	Manual Compression
20	85	19	4	R	MCA M1	No	Unable to catheterize	Nil	No	GA	0	6	6	20	N/A	71	Manual compression

Table 3.

Clinical and procedural details of all patients with aborted transfemoral approach (abMT)

Subject No.	Age	NIHSS	ASPECT	Side of Occlusion	Site of Occlusion	IV TPA	Femoral access complications	Anesthesia	TICI	Discharge mRS	90-day mRS	Total procedure time (min)	Closure method
1	87	14	9	R	MCA M1	Yes	Nil	LA, CS (Fentanyl, Propofol)	0	5	4	142	Closure device + Manual compression
2	>89	4	6	R	MCA M1	No	Nil	LA, CS (Fentanyl, Midazolam)	0	5	6	55	Manual compression
3	89	18	7	R	MCA M1	Yes	Nil	LA, CS (Fentanyl, Midazolam)	0	6	6	52	Manual compression
4	83	23	9	L	MCA M2	No	Nil	LA, CS (Fentanyl)	0	5	6	51	Closure device
5	80	8	7	L	MCA M2	No	Nil	LA, CS (Fentanyl)	0	4	2	136	Closure device
6	86	13	8	R	MCA M1	No	Nil	LA	0	6	6	32	Closure device
7	88	22	7	L	MCA M1	No	Focal groin hematoma; sandbag applied.	LA, (Fentanyl, Propofol)	0	4	6	164	Closure device + Manual compression
8	>89	16	6	L	tICA	Yes	Nil	LA	0	6	6	28	Closure device
9	60	18	8	L	Tandem occlusion, ICA, MCA M1	Yes	Nil	GA	0	5	5	128	Closure device + Manual compression
10	88	15	10	R	MCA M1	No	Nil	LA, CS (Fentanyl, Midazolam)	0	6	6	46	Closure device
11	79	23	10	L	MCA M2	No	Nil	GA	0	6	6	141	Closure device + Manual compression
12	73	12	No CT	L	MCA M2	No	Nil	GA	0	3	6	63	Manual compression
13	>89	17	10	L	MCA M2	No	Nil	LA, CS (Fentanyl)	0	5	6	89	Closure device + Manual compression
14	62	24	10	L	MCA M2	No	Nil	GA	0	4	5	117	Closure device + Manual compression

Subject No.	Age	NIHSS	ASPECT	Side of Occlusion	Site of Occlusion	IV TPA	Femoral access complications	Anesthesia	TICI	Discharge mRS	90-day mRS	Total procedure time (min)	Closure method
15	89	19	8	R	MCA M1	Yes	Nil	LA, CS (Fentanyl)	0	6	6	116	Closure device
16	80	17	10	R	Tandem Occlusion, ICA, M1	Yes	Nil	LA, CS (Fentanyl, Midazolam)	0	5	6	141	Closure device
17	85	21	10	L	tICA	No	Nil	LA, CS (Fentanyl)	0	5	6	164	Closure device

Table 4.

Procedural time intervals of all patients

	Onset to EVT in-room	EVT in-room to Femoral Puncture	Femoral Punture to Carotid Puncture	EVT in-room to Carotid Puncture	Carotid Puncture to Recanalization	Groin Puncture to Recanalization
Aborted MT (Control)	374 ± 289	22 ± 11	N/A	N/A	N/A	N/A
Primary Direct Carotid Puncture	426 ± 403	N/A	N/A	37 ± 11	40 ± 29	N/A
Secondary Direct Carotid Puncture	683 ± 644	19 ± 7	68 ± 41	87 ± 37	58 ± 33	130 ± 66
MT via Femoral Access	429 ± 371	26 ± 15	N/A	N/A	N/A	69 ± 48