Direct carotid puncture for mechanical thrombectomy in acute ischemic stroke patients with prohibitive vascular access

*Branden J. Cord, MD,¹ Sreeja Kodali, BS,² Sumita Strander, BA,² Andrew Silverman, ScB,² Anson Wang, BS,² Fouad Chouairi, BS,¹ Andrew B. Koo, BS,¹ Cindy Khanh Nguyen, BS,² Krithika Peshwe, MBBS,² Alexandra Kimmel, BA,² Carl M. Porto,¹ Ryan M. Hebert, MD,¹ Guido J. Falcone, MD,² Kevin N. Sheth, MD,² Lauren H. Sansing, MD,² Joseph L. Schindler, MD,² Charles C. Matouk, MD,¹ and Nils H. Petersen, MD²

Departments of ¹Neurosurgery and ²Neurology, Yale University School of Medicine, New Haven, Connecticut

OBJECTIVE While the benefit of mechanical thrombectomy (MT) for patients with anterior circulation acute ischemic stroke with large-vessel occlusion (AIS-LVO) has been clearly established, difficult vascular access may make the intervention impossible or unduly prolonged. In this study, the authors 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 The authors retrospectively studied patients from their prospective AIS-LVO database who underwent attempted MT between 2015 and 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 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 [$\pm$ SD] 82 ± 11 years, mean National Institutes of Health Stroke Scale [NIHSS] score 17 ± 5 , with females accounting for 75% of the patients). There were 20 patients in the DCP group and 17 in the abMT group. The two groups were well matched for the known predictors of clinical outcome: age, sex, and admission NIHSS score. Direct carotid access was successfully obtained in 19 of 20 patients. Successful reperfusion (thrombolysis in cerebral infarction score 2b or 3) was achieved in 16 (84%) of 19 patients in the DCP group. Carotid access complications included an inability to catheterize the carotid artery in 1 patient, neck hematomas in 4 patients, non-flow-limiting common carotid artery (CCA) dissections in 2 patients, and a delayed, fatal carotid blowout in 1 patient. The neck hematomas and non-flow-limiting CCA dissections did not require any subsequent interventions and remained clinically silent. Compared with the abMT group, patients in the DCP group had smaller infarct volumes (11 vs 48 ml, $p = 0.04$), a greater reduction in NIHSS score (-4 vs $+2.9$, $p = 0.03$), and better functional outcome (shift analysis for 3-month modified Rankin Scale score: adjusted OR 5.2, 95% CI 1.02–24.5; $p = 0.048$).

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

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KEYWORDS difficult vascular access; direct carotid puncture; large-vessel occlusion; mechanical thrombectomy; acute ischemic stroke; vascular disorders

FIVE major randomized controlled clinical trials have established mechanical thrombectomy (MT) as a new standard of care in patients with anterior circulation acute ischemic stroke 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 ac-

ABBREVIATIONS abMT = aborted MT; AIS-LVO = acute ischemic stroke with large-vessel occlusion; CCA = common carotid artery; DCP = direct carotid puncture; mRS = modified Rankin Scale; MT = mechanical thrombectomy; NIHSS = National Institutes of Health Stroke Scale; TICI = thrombolysis in cerebral infarction.

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* C.C.M. and N.H.P. contributed equally to this work.

cess, often leading to abandonment of the procedure with attendant worse radiographic and clinical outcomes.²⁻⁴

Although alternative access routes, including transradial and transcarotid approaches, have been described as either 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 with those who 2) underwent attempted MT via direct carotid puncture (DCP).

Methods

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

Study Design and Patients

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, were made by the patients' attending providers and clinical care team in accordance with current American Heart Association guidelines.¹¹ Two of 3 neurointerventionalists at our institution (C.C.M. and R.M.H.) started using DCP as a secondary approach for transfemoral access failure in June 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 (Fig. 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 2 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.

MT was then performed in the usual fashion with a stent retriever (Medtronic Solitaire Revascularization Device) used alone or in conjunction with a distal aspiration catheter (ACE 68 or JET-7, Penumbra), the so-called Solumbra technique. The catheters were looped on the chest

to facilitate handling. During each removal of the stent retriever with or without the aspiration catheter, the sheath's hemostatic valve was removed to prevent dislodgment of clot within the sheath and distal embolization. After the MT procedure was completed, the sheath was removed by manual compression or with the off-label use of a 6F Angio-Seal vascular closure device (Terumo Medical). Patients were routinely kept intubated until the following day to prevent neck movement in the immediate postprocedural period. A postprocedure imaging protocol (carotid ultrasound × 3 days and day 3 neck CTA) to assess for occult vascular injury or pseudoaneurysm formation was implemented later in our experience (last 8 cases).

Statistical Analysis

Baseline characteristics are summarized by mean and SD for normally distributed continuous variables, by median and IQR for skewed continuous variables, and by number (%) for categorical variables. We used chi-square, *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 score. All statistics were performed in IBM 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 preintervention 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, $p < 0.001$), were more likely to be female (76% vs 54%, $p = 0.01$), and had more comorbidities, including a history of prior stroke or transient ischemic attack, when compared with patients with a successful transfemoral approach from our overall AIS-LVO cohort. Patients with prohibitive vascular access were also less frequently treated with intravenous alteplase 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 1).

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

FIG. 1. Percutaneous transcarotid access for MT. **A:** Fluoroscopic image showing tortuous arch anatomy preventing a transfemoral approach. **B:** DCP is performed under ultrasound guidance (arrow indicates micropuncture needle). **C:** Anteroposterior digital subtraction angiogram showing that a 5.5-cm 6F Brite Tip sheath is inserted into the CCA. **D:** Anteroposterior-projection digital subtraction angiogram demonstrating large-vessel occlusion (arrow indicates right M₁ occlusion). **E:** Corked clot (inset demonstrates how the clot can be sheared off and trapped in the sheath valve upon removal; the cap must be popped off before withdrawing the aspiration catheter). **F:** Anteroposterior-projection digital subtraction angiogram showing TICI grade 3 revascularization from a transcarotid approach. **G:** Overview of setup showing looping of long catheters outside the body; the inset shows the catheter in the carotid artery. **H:** Angio-Seal closure. **I:** Ultrasound study demonstrating the Angio-Seal footplate within the vessel without dissection or pseudoaneurysm. Figure is available in color online only.

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 international normalized ratio (warfarin). The neck hematoma remained stable in size and did not cause

airway compromise. No surgical intervention was necessary. The remaining 3 cases had small-neck hematomas that were successfully managed by 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 blowout on

TABLE 1. Demographics and baseline characteristics

	abMT Group	DCP Group	p Value*
Total no. of patients	17	19	
Outcomes assessed at 90 days, n (%)	17 (100)	19 (100)	
Age in yrs, mean $\pm$ SD	83 $\pm$ 10	81 $\pm$ 11	0.677
Female sex, n (%)	13 (76)	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 (76)	13 (68)	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
Lt	10 (59)	10 (53)	
Rt	7 (41)	9 (47)	
Location of occlusion, n (%)			0.166
M1 segment	7 (41)	11 (58)	
M2 segment	6 (35)	3 (16)	
tICA	2 (12)	5 (26)	
Tandem	2 (12)	0 (0)	
Admission NIHSS score, median (IQR)	17 (13.5–21.5)	18 (14–21)	0.693
ASPECTS, median (IQR)	8.5 (7–10)	9.5 (8–10)	0.313
Preadmission mRS score, median (IQR)	1 (0–2)	0 (0–1)	0.162
Treated w/ alteplase, n (%)	6 (35)	7 (37)	0.923
Onset to MT in mins, mean $\pm$ SD	396 $\pm$ 291	623 $\pm$ 578	0.021
MT to reperfusion in mins, mean $\pm$ SD	NA	Primary: 40 $\pm$ 29; secondary: 130 $\pm$ 66	
Successful recanalization, n (%)	0 (0)	16 (84)	<0.001
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

ASPECTS = Alberta Stroke Program Early CT Score; NA = not applicable; TIA = transient ischemic attack; tICA = terminal internal carotid artery.

* Comparison between the abMT group and DCP group (significance set at $p < 0.05$).

† There were 3 patients without smoking usage data in the abMT group and 2 patients without smoking usage data in the DCP group.

FIG. 2. Non-flow-limiting carotid dissection. **A and B:** Sequential frames of the right CCA angiogram. The arrows denote the tip of the carotid sheath buried into the back wall of the vessel and associated small dissection. **C:** Postprocedure CT angiogram showing new back wall vessel irregularity at the area of the sheath tip (arrow), with only mild narrowing of the vessel. **D:** Postprocedure transverse ultrasound study showing thrombus in the small dissection flap (arrow).

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 (Fig. 2). No additional interventions were required. Clinical and procedural data for each patient can be found in Tables 2 and 3.

Successful reperfusion (TICI score 2b or 3) was achieved in 16 (84%) of 19 transcarotid MTs compared with 0 of 17 abMTs. The time from MT start to revascularization for patients undergoing primary DCP was on average shorter (40 ± 29 minutes) than that for patients receiving traditional MT via femoral access puncture at our center (69 ± 48 minutes). Patients receiving secondary DCP after failed femoral access had a longer average revascularization time of 130 ± 66 minutes, as expected from the multistep 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 $+2.9$, $p = 0.034$; Fig. 3). After adjusting for age and admission NIHSS score, performing DCP in patients with prohibitive vascular access was associated with an increased likelihood of shifting toward a lower (i.e., better) mRS score at 3 months (adjusted OR 5.2, 95% CI 1.02–24.5; $p = 0.048$; Fig. 4).

Discussion

A significant subset of patients with anterior circulation AIS-LVOs 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 who underwent MT, we showed that use of a transcarotid approach compared with procedure abandonment was associated with significantly increased rates of reperfusion, greater improvement in NIHSS scores, decreased infarct volumes, and improved 3-month functional outcomes. The overall high incidence of in-hospital and 90-day mortality in both groups is likely related to the advanced patient age when compared with 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 and 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 older than 80 years, 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

TABLE 2. Clinical and procedural details of all patients who underwent DCP

Pt No.	Age (yrs)	NIHSS Score	ASPECTS	Side of Occ	Site of IV Alt	Carotid Access Complications	Femoral Access Complications	SCP	Anesth (fentanyl)	TICI Score	mRS Score at Discharge	90-Day mRS Score	Interval:			Closure Method
													Femoral Puncture to Carotid Puncture (mins)	Carotid Puncture to RPF (mins)	Total Procedure Time (mins)	
1	79	21	9	Rt	M ₁	No	None	Yes	CS, LA (fentanyl)	2b	4	3	42	58	100	Closure device
2	81	14	9	Lt	M ₂	No	None	Yes	GA	3	3	1	72	28	100	Closure device
3	86	22	7	Lt	tICA	No	None	Yes	GA	3	5	6	81	66	147	Closure device
4	88	18	10	Rt	M ₁	No	None	Yes	GA	2b	5	6	NA	37	37	Closure device
5	66	21	10	Lt	M ₂	No	None	Yes	GA	2a	5	5	186	131	317	Closure device
6	87	20	7	Rt	M ₁	No	None	Yes	GA	2b	4	3	57	64	121	Closure device
7	58	27	8	Lt	tICA	No	Small-neck hematoma; monitored; no surgical intervention required	Yes	GA	2b	5	4	41	21	62	Closure device
8	82	9	10	Rt	M ₁	Yes	Small-neck hematoma; monitored; no surgical intervention required	Yes	GA	2b	5	1	65	55	120	Closure device + manual compression
9	>89	19	No CT	Lt	M _s	No	Small-neck hematoma; monitored; no surgical intervention required	Yes	GA	2b	6	6	79	87	166	Manual compression
10	>89	21	8	Rt	M ₁	No	None	Yes	GA	3	6	6	105	25	130	Closure device + manual compression
11	88	18	9	Rt	M ₁	No	None	Yes	GA	2b	4	6	51	18	69	Closure device
12	79	11	9	Lt	M ₁	No	Non-flow-limiting dissection of CCA; monitored closely; no intervention required	Yes	GA	2b	6	6	NA	35	35	Closure device
13	>89	25	9	Lt	M ₁	No	None	Yes	GA	3	4	5	NA	23	23	Closure device
14	87	18	10	Rt	tICA	Yes	None	Yes	GA	3	5	6	NA	14	14	Closure device
15	>89	15	10	Rt	tICA	No	Fatal carotid blowout on postop day 4	Yes	GA	3	6	6	26	36	62	Closure device

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TABLE 2. Clinical and procedural details of all patients who underwent DCP

Pt No.	Age (yrs)	NIHSS Score	ASPECTS	Side of Occ	Site of Occ	IV Alt	Carotid Access Complications	Femoral Access Complications	SCP	Anesth	TICI Score	mRS Score at Discharge	Interval:				Total Procedure Time (mins)	Closure Method
													90-Day mRS Score	Femoral Puncture to Carotid Puncture (mins)	Carotid Puncture to RPF (mins)			
16	78	26	10	Rt	M _i	Yes	Non-flow-limiting dissection of CCA; monitored closely; no intervention required	None	Yes	GA	2a	5	6	50	98		148	Closure device
17	58	11	10	Lt	M _i	None	None	None	Yes	GA	2b	3	1	NA	97		97	Closure device
18	89	18	10	Lt	tICA	Yes	Moderate-size neck hematoma; INR normalized; hematoma monitored; no surgical intervention required	None	Yes	GA	2b	6	6	NA	34		34	Manual compression
19	67	11	6	Lt	M _i	No	None	None	Yes	GA	0	4	4	80	74		154	Manual compression
20	85	19	4	Rt	M _i	No	Unable to catheterize	None	No	GA	0	6	6	20	NA		71	Manual compression

Alt = Alteplase; Anesth = anesthesia; CS = conscious sedation; GA = general anesthesia; INR = international normalized ratio; IV = intravenous; LA = local anesthesia; Occ = occlusion; pt = patient; RPF = reperfusion; SCP = successful carotid puncture.

TABLE 3. Clinical and procedural details of all patients with an abMT

Pt No.	Age (yrs)	NIHSS Score	ASPECTS	Side of Occ	Site of Occ	IV Alt	Femoral Access Complications	Anesth	TICI	mRS Score at Discharge	90-Day mRS Score	Total Procedure Time (mins)	Closure Method
1	87	14	9	Rt	M ₁	Yes	None	LA, CS (fentanyl, propofol)	0	5	4	142	Closure device + manual compression
2	>89	4	6	Rt	M ₁	No	None	LA, CS (fentanyl, midazolam)	0	5	6	55	Manual compression
3	89	18	7	Rt	M ₁	Yes	None	LA, CS (fentanyl, midazolam)	0	6	6	52	Manual compression
4	83	23	9	Lt	M ₂	No	None	LA, CS (fentanyl)	0	5	6	51	Closure device
5	80	8	7	Lt	M ₂	No	None	LA, CS (fentanyl)	0	4	2	136	Closure device
6	86	13	8	Rt	M ₁	No	None	LA	0	6	6	32	Closure device
7	88	22	7	Lt	M ₁	No	Focal groin hematoma; sandbag applied	LA (fentanyl, propofol)	0	4	6	164	Closure device + manual compression
8	>89	16	6	Lt	tICA	Yes	None	LA	0	6	6	28	Closure device
9	60	18	8	Lt	Tandem occlusion, ICA, M ₁	Yes	None	GA	0	5	5	128	Closure device + manual compression
10	88	15	10	Rt	M ₁	No	None	LA, CS (fentanyl, midazolam)	0	6	6	46	Closure device
11	79	23	10	Lt	M ₂	No	None	GA	0	6	6	141	Closure device + manual compression
12	73	12	No CT	Lt	M ₂	No	None	GA	0	3	6	63	Manual compression
13	>89	17	10	Lt	M ₂	No	None	LA, CS (fentanyl)	0	5	6	89	Closure device + manual compression
14	62	24	10	Lt	M ₂	No	None	GA	0	4	5	117	Closure device + manual compression
15	89	19	8	Rt	M ₁	Yes	None	LA, CS (fentanyl)	0	6	6	116	Closure device
16	80	17	10	Rt	Tandem occlusion, ICA, M ₁	Yes	None	LA, CS (fentanyl, midazolam)	0	5	6	141	Closure device
17	85	21	10	Lt	tICA	No	None	LA, CS (fentanyl)	0	5	6	164	Closure device

TABLE 4. Procedural time intervals for all patients

	Onset to EVT In-Room	EVT In-Room to Femoral Puncture	Femoral Puncture to Carotid Puncture	EVT In-Room to Carotid Puncture	Carotid Puncture to Recanalization	Groin Puncture to Recanalization
abMT (control)	374 ± 289	22 ± 11	NA	NA	NA	NA
Primary DCP	426 ± 403	NA	NA	37 ± 11	40 ± 29	NA
Secondary DCP	683 ± 644	19 ± 7	68 ± 41	87 ± 37	58 ± 33	130 ± 66
MT via femoral access	429 ± 371	26 ± 15	NA	NA	NA	69 ± 48

EVT = endovascular therapy.

Times are reported as mean ± SD in minutes.

nuances. Most of our transcrotid punctures were closed with an Angio-Seal device, but we have also used manual compression without major complications, even in patients who have received intravenous alteplase. Four patients developed nonsurgical neck hematomas during manual pressure hold or closure device deployment immediately after sheath removal, which were monitored. These predominantly 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 blowout following successful transcrotid MT. During deployment of the vascular closure device in this latter case, puckering of the skin and soft tissue overlying the carotid artery 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 a request for autopsy. Following this event, all patients treated via the transcrotid approach underwent serial daily carotid ultrasound imaging and CTA on postprocedure day 3. Note was made of non-flow-limiting dissections on the back wall of the CCA in 2 patients (this is remote from the carotid puncture site), likely due to rubbing of the tip of the 6F sheath during the thrombectomy procedure (Fig. 1). No additional interventions were required. In our experience, increased ease of use and safety, as well as improved closure methods, could likely be obtained by the development of carotid-specific sheaths and access systems.

While a transcrotid 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 improv-

ing revascularization times and outcomes. Given its relative safety and efficacy, transcrotid access for revascularization may be indicated for a larger cohort of patients with AIS-LVO. 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 compared with 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 findings.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 MT will likely reduce the need for a transcrotid 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

FIG. 3. Radiographic and short-term clinical outcomes. **Left:** Final infarct volume given in milliliters at 24 hours postprocedure. Bars and error bars represent the median and IQR, respectively. **Right:** Change in NIHSS score between admission and 24 hours postprocedure. Bars and error bars represent the mean and SEM, respectively. **p < 0.05. Figure is available in color online only.

FIG. 4. Three-month functional outcomes following direct carotid puncture versus abMT; $p < 0.05$ between groups. aOR = adjusted OR. Figure is available in color online only.

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 helps to overcome this limitation. Second, although larger than a case series, the analysis is retrospective.

Conclusions

A significant proportion of patients with AIS-LVO have anatomy prohibitive for transfemoral MT. This retrospective cohort study demonstrates that the use of transcarotid MT in these patients is associated with higher revascularization rates, smaller final stroke volumes, improved NIHSS scores, and improved functional outcome compared with the standard of care after failed transfemoral MT alone. This study supports the use of transcarotid puncture for MT.

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Disclosures

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Author Contributions

Conception and design: Petersen, Cord, Matouk. Acquisition of data: Cord, Kodali, Strander, Silverman, Wang, Chouairi, Koo, Nguyen, Peshwe, Porto. Analysis and interpretation of data: Petersen, Cord, Matouk. Drafting the article: Cord, Strander. Critically revising the article: Petersen, Kodali, Silverman, Wang, Nguyen, Peshwe, Kimmel, Hebert, Falcone, Sheth, Sansing, Schindler, Matouk. Approved the final version of the manuscript on behalf of all authors: Petersen. Statistical analysis: Petersen, Kodali, Strander, Silverman, Wang. Study supervision: Petersen.

Supplemental Information

Online-Only Content

Supplemental material is available with the online version of the article.

Supplemental Table 1. <https://thejns.org/doi/suppl/10.3171/2020.5.JNS192737>.

Previous Presentations

Portions of this work were previously presented at the 2019 CNS

Annual Meeting, San Francisco, California, October 19–23, 2019; Cord BJ, Wang A, Chouairi F, et al. Percutaneous trans-carotid puncture for mechanical thrombectomy in acute ischemic stroke patients is safe and effective: a large, single-center case series. *Neurosurgery*. 2019;66(suppl 1):50. http://doi.org/10.1093/neuros/nyz310_167; and the International Stroke Conference 2019, Honolulu, Hawaii, February 6–8, 2019; Wang A, Cord BJ, Chouairi F, et al. Abstract TP15: Percutaneous transcarotid puncture is a viable alternative for thrombectomy in acute ischemic stroke patients with difficult vascular access. *Stroke*. 2019;50(suppl 1):ATP15. http://doi.org/10.1161/str.50.suppl_1.TP15.

Correspondence

Nils H. Petersen: Yale Medical School, New Haven, CT. nils.petersen@yale.edu.