Carotid artery percutaneous access with vessel closure devices in endovascular aortic arch repairs

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ABSTRACT

Objective: To report the use of a percutaneous carotid access with vessel closure devices (VCDs) during complex endovascular aortic arch repair.

Methods: Seven international high-volume centers conducted a retrospective review of all patients receiving percutaneous carotid access with VCD during endovascular aortic arch procedures to investigate its feasibility and safety. The primary end point was the closure success defined according to the modified Valve Academic Research Consortium-2 definition (no need for adjunctive surgical or endovascular procedures to obtain vessel closure and no hemorrhagic/stenotic complications).

Results: A total of 46 patients (27 males [59%]; mean age, 74 years; range, 68-78 years) treated between January 2022 and September 2024 underwent endovascular arch procedures (eight urgent/emergent cases [19%]), all under general anesthesia and ultrasound guidance, using a micropuncture set in 32 cases (70%). The left common carotid artery was punctured in 41 cases (89%). The median introducer sheath inner diameter was 7F (range, 6F-8F). Only 1 VCD was used per access, with 19 cases (41%) using the preclose technique and 27 cases (59%) using the VCD after introduced sheath removal (all but one case treated with PerClose ProGlide [Abbott Vascular]). Closure success was achieved in 44 patients (96%): 1 patient required an intraoperative covered stent placement to cover the puncture site, and 1 patient required an open conversion 2 days after the procedure owing to a pseudoaneurysm diagnosed at the postoperative computed tomography scan. Four patients (9%) required prolonged manual compression after VCD tightening owing to oozing from the puncture site. The prolonged manual compression was correlated to the use of anticoagulants (40 vs 7%; $P = .043$). One case of a non-flow-limiting dissection was left untreated conservatively. Four patients (9%) suffered from postoperative stroke, two ischemic and two hemorrhagic, two on the same side of the carotid puncture and two on the contralateral side. No other complications were reported.

Conclusions: Percutaneous carotid access with a VCD appeared to be feasible and safe, with a high closure success rate. Further investigations are needed to compare open cutdown vs percutaneous access outcomes. (J Vasc Surg 2026;83:656-61.)

Keywords: Carotid artery; Percutaneous access; Vessel closure device; Complex endovascular aortic repair; Aortic arch; Supra-aortic vessel recanalization

Upper extremity access was initially considered the preferential route to connect antegrade branches during thoracoabdominal aortic repair, although it was burdened by relatively high rates of stroke.[1,2] Although there has been a shift to total percutaneous femoral access with steerable sheaths during thoracoabdominal aortic procedures, avoiding upper extremity access,[3,4] the same technique cannot be applied during endovascular aortic arch treatment. Different authors have proposed a total percutaneous approach for arch

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procedures, but it requires either complex manipulation in the arch[5-7] or a retrograde design of one to all branches.[8,9]

During endovascular arch repairs, the carotid access (either for the innominate trunk or for the left common carotid artery) has been commonly performed via a surgical cutdown and vessel exposure. Often, bilateral cervical access is required, which is associated with increased postoperative complications.[10] Percutaneous access to the carotid artery, which would alleviate the burden of those complications, has already been proposed in selected cases during cardiac surgery and carotid artery stenting.[11-14] With regard to endovascular aortic arch procedures, Criado[15] initially proposed this access for parallel graft procedures, and more recently Karelis et al[16] described the use of vessel closure devices (VCD) in the carotid artery.

The aim of this paper was to describe a multicenter experience on the safety and feasibility of the use of a percutaneous carotid artery access with VCD during endovascular aortic arch repairs.

ARTICLE HIGHLIGHTS

- **Type of Research:** Multicenter retrospective nonrandomized cohort study
- **Key Findings:** Percutaneous carotid access performed during aortic arch endovascular repair in 46 patients using 6F to 8F introducers and closed with vessel closure devices resulted in closure success of 96% with no other associated complications.
- **Take Home Message:** Percutaneous carotid access can be performed safely and effectively with a single vessel closure device with acceptable complication rates.

METHODS

Study design. A retrospective review was conducted in seven tertiary aortic centers to include all consecutive patients undergoing endovascular aortic arch repair using custom-made endografts with branches for the innominate artery or the left common carotid artery (Cook Medical), which were accessed percutaneously with the use of VCD in at least one common carotid artery. The study period was from January 2022 to October 2024. The study protocol was approved by the respective ethical committees if so dictated, or ethical approval was waived in accordance with local regulations.

Data collection and end points. Aortic arch endovascular procedure outcomes were defined according to Society for Vascular Surgery reporting standards.[17] Rates of access-related stroke (new neurological deficit with positive neuroimaging) and major/minor vascular/nonvascular complications were reported. Access complications were described according to the Valve Academic Research Consortium-3 reporting standards.[18] Vascular complications included vascular injury (perforation, rupture, dissection, stenosis, ischemia, etc), distal embolization (noncerebral), and closure device failure. Nonvascular complications included damage to the access site, nerve injury, and infection. To be classified as major, the complication had to result in death, Valve Academic Research Consortium type ≥2 bleeding, limb or visceral ischemia, amputation, or irreversible neurological impairment or organ damage. The access status (ie, hemostasis and limb perfusion) at the end of the procedure was assessed by clinical inspection, ultrasound examination, and/or angiography according to standard participant clinical practice. Follow-up included clinical assessment and computed tomography angiography (CTA) at 1 month postoperatively and yearly CTAs thereafter. Experienced observers at each center conducted retrospective image analysis for the study in accordance with the predetermined protocol. The end points were closure technical success, perioperative morbidity, especially related to possible neurological events, and a composite secondary outcome of local and distant access complications.

Percutaneous carotid access patient selection. All access vessels in patients undergoing an aortic arch endovascular procedure were screened both by CTA and duplex ultrasound examination. Patients were screened for the presence of carotid stenosis either at the bifurcation or in the common carotid artery. The presence of anterior calcification, thrombus, or dissection was a contraindication for percutaneous access and would be treated using a surgical carotid exposure. Furthermore, the presence of hypertrophic laterocervical muscles or a short common carotid artery length was considered a relative contraindication.

Operative technique. Procedures were done under general anesthesia in hybrid rooms using fusion imaging. Standard endovascular arch repair technique was used according to local institutional protocol, including carbon-dioxide flushing of the grafts, heparinization with activated clotting times of >250 seconds and cardiac output reduction (rapid pacing or MuVIT maneuver).[19] Cone beam CT scans were used according to local practice. Percutaneous femoral access was used for endograft delivery, and percutaneous carotid artery access was used to cannulate the branches retrogradely and bridge the innominate artery or the left common carotid artery. Carotid access was also used to support an innominate approach to the left carotid inner branch.[20] The choice of bridging stents was done by the operators and was either balloon-expandable (VBX, W. L. Gore & Associates; Bentley BeGraft Plus, Bentley Aortic,

Bentley InnoMed) or self-expanding covered stents (Viabahn, W. L. Gore & Associates; Wrapsody, Merit Medical), iliac limb extension (Cook Medical), or dedicated customized extensions (Cook Medical or Side branch endoprothesis, W. L. Gore & Associates), or a combination of both in a hybrid solution usually with the self-expanding covered stent in the distal part of the target vessel.

Percutaneous carotid artery access was obtained using either a micropuncture or a standard puncture set, according to center preference. The timing of access was determined by physician preference; however, in most cases, it was performed last to minimize the duration that the introducer sheath remained in place. The common carotid artery was usually accessed in its proximal segment, near its bifurcation, possibly in a portion in which the jugular vein was not overlapping to avoid vein puncture or fistula formation and where it was easy to be manually compressed. First, a 6F introducer sheath was inserted and subsequently exchanged for the required introducer sheath size (7F-8F). The VCD was either placed before the sheath exchange or after the sheath removal, according to the operator's preference. After vessel closure is achieved, all cases require a 10-minute manual compression or traction on the VCD sutures to prevent any oozing or hematoma formation at the puncture site, based on physician preference. After access closure, a duplex ultrasound assessment of the access was performed in all cases; if there was uncertainty in the closure success, an angiography was performed according to physician preference. Vessel closure was obtained either before or after the administration of protamine sulfate to return the activated clotting time to a physiological state, according to the physician's preference. The amount of protamine sulfate administered was according to center protocols. All the puncture and closure steps are summarized in the Supplementary Video.

Data analysis. Variables were assessed for normality with the Shapiro-Wilk test. Normal continuous variables are expressed as mean and standard deviation. Non-normal continuous variables were expressed as median, first, and third quartiles (Q1, Q3) or range. Categorical variables were expressed as counts and percentages. The study is observational in nature, and given the single-arm design, neither comparative analysis nor inferential testing was performed. Wizard Statistics (Version 1.9.38, EvanMiller.org) and R-Studio (Version 1.4.1106, RStudio) software for MacOS were used.

RESULTS

A total of 46 patients (27 males [59%],;mean age, 74 years; range, 68-78 years) treated between January 2022 and September 2024 underwent endovascular arch procedures (eight urgent/emergent cases [19%]) with percutaneous access to at least one carotid artery. During the study period, 36 cases were performed with a surgical carotid exposure, with a stroke rate of 11%. All cases in the present series were performed under general anesthesia and ultrasound guidance, using a micropuncture set in 32 cases (70%). The left common carotid artery was punctured in 41 cases (89%) and the right in the remaining 5 cases (11%). The median introducer sheath inner diameter was 7F (range, 6F-8F). Technical success was achieved in 44 patients (96%), with 4 patients (9%) requiring prolonged (>10 minutes) manual compression after VCD tightening owing to oozing from the puncture site. The oozing rate was not related to the heparin reversal timing (before or after VCD closure).

In all but one case, the PerClose ProGlide (Abbott Vascular) was used. One patient (2%) required a covered stent placement to address the puncture site after the VCD failed, necessitating a small surgical exposure of the distal carotid artery. Meanwhile, a second patient (2%) needed an open conversion through a small laterocervical incision at the puncture site 2 days post procedure owing to a pseudoaneurysm identified on the postoperative CT scan, which was not detected during the duplex ultrasound check performed at the end of the procedure and 24 hours afterward. Another patient (2%) had a dissection with no impact on the carotid flow and was thus managed conservatively. The prolonged manual compression owing to oozing was correlated to the use of anticoagulants (40% vs 7%; $P = .043$), two in patients with and two in patients without heparin reversal. Only one VCD was used per access, with 19 cases (41%) using the preclose technique and 27 cases (59%) using the VCD after introducer sheath removal. No significant relationship was found between sheath dwell time and complication rates. Four patients (9%) suffered from postoperative stroke, two ischemic on the same side of the carotid puncture and two hemorrhagic on the contralateral side. Strokes were diagnosed by diffusion-weighted magnetic resonance imaging in all cases, and all cases were intraprocedural and discovered at awakening. The two ipsilateral strokes occurred—one was multiembolic (both sides) with the most clinically prominent lesion in the ipsilateral cerebellar territory with a modified Rankin score of 3; the second one was multiembolic as well and asymptomatic. No other access site complications were reported in the perioperative period or at 6 months. No branch instability or endoleaks were reported for the components delivered through the percutaneous access. All perioperative, intraoperative, and postoperative details for the entire cohort are detailed in the Table.

DISCUSSION

This study highlights an early multicenter retrospective experience from seven tertiary aortic centers using a total percutaneous approach for endovascular aortic arch

Table. Preoperative, intraoperative, and postoperative data for the entire cohort (n = 46)

Characteristics	No. (%) or median (range)
Males	27 (59)
Age, years	74 (68-78)
Age (SVS)	2 (1-2)
BMI	26 (23-29)
>25	24 (52)
>30	9 (20)
Preoperative creatinine	0.96 (0.73-1.21)
Smoking	19 (41)
Previous	5 (11)
Diabetes	3 (7)
Dyslipidemia	22 (48)
Hypertension (SVS)	2 (1-3)
COPD (SVS)	0 (0-0)
CAD (SVS)	0 (0-0)
Renal (SVS)	0 (0-1)
PTCA	3 (7)
CABG	1 (2)
SVS score	6 (4-8)
ASA score	3 (3-4)
Anticoagulant	10 (22)
Antiplatelet	
Single	29 (63)
Double	1 (2)
Puncture side right	5 (11)
Puncture side left	41 (89)
CCA diameter, mm	7.1 (6.8-8.6)
Ipsilateral ICA stenosis	1 (2)
Setting	
Elective	38 (83)
Urgent/emergent	8 (17)
Puncture guidance	
DUS	46 (100)
Micropuncture set use	32 (70)
Preclose technique	19 (41)
Introducer sheath ID	
5F	1 (2)
6F	13 (28)
7F	16 (35)
8F	16 (35)
Time between sheath insertion and removal, minutes	95 (48-120)
Access closure timing	
After stent deployment	12 (26)
After heparin reversal	10 (22)
End of procedure without heparin reversal	24 (52)
Technical success	44 (96)
Method of assessing success	
Clinical	10 (22)
DUS	14 (30)
Angiography	2 (4)
Both DUS and angiography	20 (43)
Need for secondary procedure	2 (5)
Covered stenting	1 (2)
Delayed surgical conversion	1 (2)
Prolonged manual compression	4 (9)
Stroke	4 (9)
Ischemic	2 (50)
Hemorrhagic	2 (50)
Ipsilateral	2 (50)
Contralateral	2 (50)
Hematoma	0 (0)
Length of stay, days	7 (4-10)
Cerebral complications at 30 days	4 (9)
Carotid access complications at 30 days	2 (5)

ASA, Association of Anesthesiologist; *BMI,* body mass index; *CABG,* coronary artery bypass graft; *CAD,* coronary artery disease; *COPD,* chronic obstructive pulmonary disease; *CCA,* common carotid artery; *DUS,* duplex ultrasound; *ICA,* internal carotid artery; *ID,* inner diameter; *PTCA,* percutaneous transcatheter coronary angioplasty; *SAT,* supra-aortic trunks; *SVS,* Society for Vascular Surgery.

procedures. Although the use of a percutaneous carotid artery access was previously described in selected cases during transcatheter aortic valve implantation,[14] the present study is the first multicenter study on the feasibility and safety of the use of a percutaneous carotid artery access with VCD during endovascular aortic arch repair. The technical success of the present study (96%) is in line with the use of VCD in other districts such as the axillary[1,2,21] or the femoral artery,[3,22] thus proving its technical feasibility. Furthermore, given the design of the VCD used in the study and their hydrophilic distal component, no stent disruption was reported when they were deployed after the introducer sheath removal. However, authors suggest placing the VCD under fluoroscopic guidance to avoid this possible complication.

Percutaneous access obviates the need for wound management and dressing care and could thereby decrease risks such as surgical site infection, as well as any possible access site surgical complications. Greenstein et al[23] reported data on 9308 carotid endarterectomies performed by 482 surgeons in 167 hospitals: carotid restenosis or concomitant carotid endarterectomy and cardiac procedures were excluded. Overall, 10% of patients had a minor surgical complication (cranial nerve palsy, 5.5%; hematoma, 5.0%; and wound infection, 0.2%). Moreover, it is unclear at present how many reinterventions will be necessary after endovascular aortic arch procedures owing to the need for redo

carotid access; therefore, preserving native access might be important in the future.

The use of percutaneous carotid access over standard surgical access might not change the position of the operators during the procedure, but the skin introducer retention allows them to work from the right side of the patients without surgical instruments in the field. No need for a learning curve was observed, although all procedures were performed in high-volume tertiary centers with extensive experience with both endovascular aortic arch repairs and percutaneous accesses. Last, it should be noted that the use of VCD for closing carotid access is an off-label procedure and should be done by physicians experienced with their use.

From a neurological perspective, two patients (4%) had an intraoperative stroke on the same side as the carotid artery percutaneous access, and the remaining two on the contralateral side; both findings align with the current literature, proving that using percutaneous access may not increase the stroke rate of these procedures compared with cervical access and vessel dissection.[24] Data on transcatheter aortic valve implantation further validates this finding, showing that a transcarotid approach yielded similar neurological outcomes compared with a transfemoral approach.[25-28] Patient selection remains of the utmost importance, and the same criteria used for femoral and axillary vessels apply. A preoperative duplex ultrasound examination for the absence of plaque is mandatory, as well as to confirm the position of the internal jugular vein to avoid any risk of possible fistula formation. As mentioned, the puncture should always be performed under ultrasound guidance. Last, it is important to note that, during a percutaneous approach, clamping the distal common carotid artery to prevent embolization risk is not possible; however, this practice is often overlooked or deemed unnecessary.

We must acknowledge the limitations of this study. First, the retrospective study design may introduce some selection bias. Second, the centers involved had extensive experience with complex endovascular aortic treatment, which necessitates careful assessment of the generalizability of the results. Third, although the multicenter design facilitated an evaluation of result reproducibility, inherent differences in puncture techniques based on local routines were present. Finally, although the new percutaneous approach shows promising results, the data remain preliminary owing to a limited number of patients, lack of long-term follow-up, and absence of a control surgical group to evaluate the impact of common carotid percutaneous access on overall outcomes.

CONCLUSIONS

The use of percutaneous carotid artery access during endovascular aortic arch procedures and SAT revascularization proved to be safe and feasible, with high rates of technical success and perioperative complications in line with the current literature on other vascular access routes.

AUTHOR CONTRIBUTIONS

Conception and design: ND, LB
Analysis and interpretation: AG, LB
Data collection: AG, ND, SH, TR, GO, MP, GP
Writing the article: AG, LB
Critical revision of the article: ND, SH, TR, GO, MP, GP, LB
Final approval of the article: AG, ND, SH, TR, GO, MP, GP, LB
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Overall responsibility: LB

DATA AVAILABILITY STATEMENT

The data underlying this article will be shared on reasonable request to the corresponding author.

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DISCLOSURES

N.V.D. reports a relationship with Cook Medical and W. L. Gore & Associates; S.H reports a relationship with Cook Medical, Bentley, and GE Healthcare; T.R. reports a relationship with Cook Medical, W. L. Gore & Associates, and Phillips; G.S.O. reports a relationship with Cook Medical and W. L. Gore & Associates; M.P. reports a relationship with Cook Medical and W. L. Gore & Associates; L.B. reports a relationship with Cook Medical and W. L. Gore & Associates.

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