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Multicenter experience of upper extremity access in complex endovascular aortic aneurysm repair

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ABSTRACT

Purpose: Upper extremity access (UEA) for antegrade cannulation of aortic side branches is a relevant part of endovascular treatment of complex aortic aneurysms and can be achieved using several techniques, sites, and sides. The purpose of this study was to evaluate different UEA strategies in a multicenter registry of complex endovascular aortic aneurysm repair (EVAR).

Methods: In six aortic centers in the Netherlands, all endovascular aortic procedures from 2006 to 2019 were retrospectively reviewed. Patients who received UEA during complex EVAR were included. The primary outcome was a composite end point of any access complication, excluding minor hematomas. Secondary outcomes were access characteristics, access complications considered individually, access reinterventions, and incidence of ischemic cerebrovascular events.

Results: A total of 417 patients underwent 437 UEA for 303 fenestrated/branched EVARs and 114 chimney EVARs. Twenty patients had bilateral, 295 left-sided, and 102 right-sided UEA. A total of 413 approaches were performed surgically and 24 percutaneously. Distal brachial access (DBA) was used in 89 cases, medial brachial access (MBA) in 149, proximal brachial access (PBA) in 140, and axillary access (AA) in 59 cases. No significant differences regarding the composite end point of access complications were seen (DBA: 11.3% vs MBA: 6.7% vs PBA: 13.6% vs AA: 10.2%; $P = .29$). Postoperative neuropathy occurred most after PBA (DBA: 1.1% vs MBA: 1.3% vs PBA: 9.3% vs AA: 5.1%; $P = .003$). There were no differences in cerebrovascular complications between access sides (right: 5.9% vs left: 4.1% vs bilateral: 5%; $P = .75$). Significantly more overall access complications were seen after a percutaneous approach (29.2% vs 6.8%; $P = .002$). In multivariate analysis, the risk for access complications after an open approach was decreased by male sex (odds ratio [OR]: 0.27; 95% confidence interval [CI]: 0.10-0.72; $P = .009$), whereas an increase in age per year (OR: 1.08; 95% CI: 1.004-1.179; $P = .039$) and diabetes mellitus type 2 (OR: 3.70; 95% CI: 1.20-11.41; $P = .023$) increased the risk.

Conclusions: Between the four access localizations, there were no differences in overall access complications. Female sex, diabetes mellitus type 2, and aging increased the risk for access complications after a surgical approach. Furthermore, a percutaneous UEA resulted in higher complication rates than a surgical approach. (J Vasc Surg 2022;■:1-10.)

Keywords: Upper extremity access; Brachial artery; Axillary artery; Access complications; Complex aortic aneurysms

As endovascular treatment options for complex aortic aneurysms are continuously expanding and developing, their use increases and becomes more relevant.[1] Treatment of aortic aneurysms by chimney endovascular aortic repair (Ch EVAR), fenestrated endovascular aortic repair (f EVAR), branched endovascular aortic repair (b EVAR), and fenestrated/branched endovascular aortic repair (f/b EVAR) might require upper extremity access (UEA) to cannulate downfacing aortic side branches or to stabilize the graft during the procedure.[2-7]

UEA for complex aortic procedures can be categorized into four general locations: distal brachial artery inside the elbow, brachial artery at the medial upper arm, proximal brachial artery just below the axillary grove, and infraclavicular through axillary access (AA).[3,4,6,8] Whether one of the above-mentioned is preferable over the others has yet to be determined. Infraclavicular percutaneous access through the first segment of the axillary artery is gaining popularity, and results are promising.[9,10] The percutaneous brachial access is used more frequently

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for several different treatments, but also presenting a broad spectrum of access complications.[11-14] Overall percutaneous UEA still plays a menial role in the treatment of complex aortic aneurysms.

A further subject of interest regarding UEA is the debatable influence of the access side on the ischemic cerebrovascular event rates, as prior studies did report an increased cerebrovascular event rate for right and bilateral access.[15] However, there are contradictory publications concerning this topic. One has to consider though that the studies published merely evaluated a small number of patients.[6,15-18]

The aim of this real-world multicenter study was to evaluate the outcome and complications of different UEA strategies used during complex endovascular aortic procedures.

ARTICLE HIGHLIGHTS

- **Type of Research:** Multicenter, retrospective cohort study
- **Key Findings:** Evaluating 417 patients treated for complex aortic aneurysms using four different upper extremity access locations, no significant differences in the composite end point of any access complication were found. However, postoperative neuropathy occurred significantly more often after proximal brachial access. Also, multivariate analysis showed that access complications after an open approach were associated with female sex, diabetes mellitus type 2, and increased age. Finally, access complications were more often seen after a percutaneous approach than after open exposure.
- **Take-Home Messages:** Comparing four upper extremity access sites for complex endovascular aneurysm repair, we found no differences in overall access complications, access reinterventions, or cerebrovascular complications.

METHODS

Study design. This retrospective study was performed at six major aortic centers in the Netherlands. The institutional ethics committees and respective institutional review boards at each of the centers approved data acquisition. Because of the retrospective character of the study, informed consent for inclusion into the data analysis was not necessary. The operating physician chose the access technique. In each center, all endovascular aortic procedures from 2006 to 2019 were reviewed. Consecutive patients who received UEA for elective Ch EVAR, f EVAR, b EVAR, or f/b EVAR were included. The digital medical records were reviewed to collect patient and procedural characteristics and postprocedural clinical outcomes.

Variables and definitions. Patients were divided into four subgroups to analyze the effect of the different access locations, approaches, and access sides. The first group consisted of patients who were approached through the distal brachial artery at the inside of the elbow. The second group contained patients approached through the brachial artery at the medial upper arm. In the third group, patients who were approached through the proximal brachial artery in the axillary grove were included, and the fourth group consisted of patients approached through the first segment of the axillary artery (infraclavicular).

Patient characteristics were made up of demographics, comorbidities, aortic aneurysm configuration, and preoperative use of antithrombotic and cardiovascular medication. Procedural characteristics were the type of EVAR, access side, access location, access strategy, sheath size, procedure time, and used contrast volume. The primary outcome was the incidence of any access complication for each access strategy. This was defined as a composite end point consisting of major hematoma, wound infection, peripheral neuropathy, access vessel dissection, access vessel occlusion, hemorrhage, and pseudoaneurysm. Each patient with the suspected diagnosis of peripheral neuropathy was seen by a neurologist to confirm the diagnosis. The symptoms of the neuropathies were divided into motor, sensory or motor, and sensory deficits. Furthermore, it was assessed whether the symptoms resolved during follow-up in the out-patient clinic. A major hematoma was defined as a hematoma coappearing with another related complication, or an access reintervention. A minor hematoma was a hematoma occurring without any other access complication and which was treated conservatively. Secondary outcomes were the incidence of the different types of access complications, the incidence of ischemic cerebrovascular events, and access reinterventions. An access reintervention was defined as the need for a secondary surgical or percutaneous repair or exploration of the UEA vessel. Ischemic cerebrovascular events had to be diagnosed by a neurologist and were categorized into major (National Institutes of Health Stroke Scale >1), minor (National Institutes of Health Stroke Scale ≤ 1), and transient ischemic attack.[19] General outcomes were spinal cord ischemia, cardiac and respiratory complications, visceral ischemia, and mortality within 30 days after the procedure.

Statistics. Categorical variables were compared using Pearson's χ^2 or Fisher's exact test for analysis. Continuous variables were analyzed by using one-way analysis of variance multicomparison, the Welch *t*-test, or the Student *t*-test. The post hoc analyses were performed using Tukey and Tamhane testing. Multivariate testing was conducted by including all potential covariates ($P < .3$)

Table I. Preoperative characteristics comorbidities and aneurysm configuration, comparing patients receiving a percutaneous or surgical upper extremity access

	All patients (No. of patients = 417) (%)	Surgical approached (No. of patients = 397) (%)	Percutaneous approached (No. of patients = 20 patients) (%)	*P*
Male sex	318 (76.3)	300 (75.6)	17 (85)	.43
Age (SD), years	73 (6.6)	72.9	74.9	.07
BMI(SD), kg/m^2	26.4 (4.7)	26.4 (4.7)	25.8 (3.1)	.42
Height (SD), cm	174.5 (8.3)	174.4 (8.5)	174.7 (5.6)	.63
Weight (SD), kg	80.7 (15.2)	80.5 (15.3)	82.8 (16.7)	.53
No history of smoking	163 (39.1)	160 (40.3)	2 (10)	.23
Current smoker	98 (23.5)	95 (23.9)	3 (15)	.42
Former smoker	155 (37.1)	140 (35.3)	15 (75)	.34
Hypertension	276 (66.2)	266 (67)	10 (50)	.33
Dyslipidemia	201 (48.2)	195 (49.1)	6 (30)	.11
Previous cerebrovascular event	67 (16.1)	62 (16.6)	5 (25)	.12
Diabetes mellitus type 2	50 (12)	50 (12.6)	0	.15
Pulmonary dysfunction	141 (33.8)	136 (34.2)	5 (25)	.47
Creatine (SD)	103 (43)	103 (43)	102.9 (25)	.99
GFR (according to Cockcroft-Gault)				
>60	236 (56.6)	223 (56.2)	12 (60)	.62
30-60	133 (31.9)	126 (31.7)	7 (35)	.45
<30	10 (2.4)	10 (2.5)	0	1
Missing	34 (8.2)	33 (8.3)	1 (5)	1
Prior aortic surgery	165 (39.6)	165 (39.6)	9 (45)	.64
ASA				
1	1 (0.2)	1 (0.3)	0	1
2	107 (25.7)	101 (25.4)	6 (30)	1
3	254 (60.9)	241 (60.7)	13 (65)	.44
4	13 (3.1)	12 (3)	1 (5)	.56
Acetylsalicylic acid	260 (62.4)	246 (62)	260 (70)	.64
Clopidogrel	40 (9.6)	37 (9.2)	3 (15)	.43
Oral anticoagulation (DOAC/vitamin K antagonists)	94 (22.5)	87 (21.9)	7 (35)	.16
Diuretics	148 (35.5)	143 (36)	5 (25)	.47
Statin	298 (71.5)	284 (71.5)	14 (70)	1
Antihypertensives	325 (77.9)	312 (78.5)	13 (65)	.17
Infrarenal AAA	89 (21.3)	81 (20.4)	8 (40)	.79
Juxtarenal AAA	122 (29.3)	114 (28.7)	8 (40)	.79
Suprarenal AAA	31 (7.4)	31 (7.8)	0	1
TAAA	144 (34.5)	143 (36)	1 (5)	.12
TAAA type I	27 (6.6)	26 (6.5)	1 (5)	.7
TAAA type II	30 (7.2)	30 (7.5)	0	.14
TAAA type III	31 (7.4)	31 (7.8)	0	.08
TAAA type IV	35 (8.4)	35 (8.8)	0	.08
TAAA type V	17 (4.1)	17 (4.3)	0	.72
Unknown extension of TAAA	17 (4.1)	17 (4.3)	0	.72
DTAA	21 (5)	19 (4.8)	2 (10)	.12
Unknown aneurysm configuration	10 (2.5)	9 (2.5)	1 (5)	1
Mean aneurysm size (SD), mm	67.5 (13.2)	67.6 (13.2)	71.5 (24.2)	.42

AAA, Abdominal aortic aneurysm; *ASA*, American Society of Anesthesiologists Classification; *BMI*, body mass index; *DOAC*, direct oral anticoagulation; *DTAA*, descending thoracic aortic aneurysm; *GFR*, glomerular filtration rate; *SD*, standard deviation; *TAAA*, thoracic abdominal aortic aneurysm.
Values in parentheses are percentages unless indicated otherwise.

from the univariate analyses into a backward stepwise logistic regression model. Categorical variables are presented as percentages and continuous variables as mean and standard deviation (SD). The significance level was set for P values $<.05$. Data were analyzed using SPSS version 28.0 (IBM).

RESULTS

Patient and procedure characteristics. In total 417 patients were included, who underwent a complex endovascular aortic procedure of an aortic aneurysm using UEA. The mean age was 72.9 years (SD: 6.6 years). Most procedures were performed for abdominal aortic aneurysms (58.0%), followed by 35% thoracoabdominal aortic aneurysms and 5% thoracic aneurysms. The mean aneurysm diameter was 67.5 mm (SD: 13.2 mm). In 73% of the patients, a fenestrated/branched stent graft was implanted. The remaining patients underwent a chimney procedure. No differences between patients receiving percutaneous or surgical access were seen regarding patient characteristics (Table I).

Upper extremity access results. The distal brachial access (DBA) was used in 89, the medial brachial access (MBA) in 149, the proximal brachial access (PBA) in 140, and the AA in 59 patients. There were in total 437 UEA approaches, of which 20 were bilateral, 295 using the left side, and 102 using the right side. A total of 413 access vessels were surgically and 24 were percutaneously approached.

Comparing the characteristics of the percutaneous and surgical UEA procedures, we found that the sheaths used in percutaneous procedures were smaller (percutaneous: 7.0F vs surgical: 9.14F; $P < .001$) and the percutaneous procedures were shorter (percutaneous 208 minutes vs surgical 283 minutes; $P = .019$). The distribution of the performed procedures differed significantly, as percutaneous UEA was mostly used in Ch EVARs. The distribution of the performed procedures differed also between the four access locations, as described in Table II.

In the DBA, the sheaths were the smallest, and in the PBA, the largest (DBA: 7.5F vs MBA: 9.3F vs PBA: 9.7F vs AA: 9.2F; $P < .001$). The post hoc test showed that only the sheaths introduced in DBA were significantly smaller than in all other groups. Comparing the procedure time, significant differences among the four groups were observed (DBA: 223 minutes [SD: 111 minutes] vs MBA: 414 minutes [SD: 126 minutes] vs PBA: 281 minutes [SD: 122 minutes] vs AA: 248 minutes [SD: 98 minutes]; $P < .001$). The post hoc analyses showed that the DBA procedures had a significantly shorter duration compared with the MBA and PBA. Furthermore, the procedures performed through the MBA were significantly longer than all other procedures (Table II).

Primary and secondary outcomes. Comparing the four UEA strategies, no significant differences in the composite end point of access complications were found (DBA: 11.2% vs MBA: 6.7% vs PBA: 13.6% vs AA: 10.2%; $P = .29$). After removing the percutaneous cases, still no significant differences between the groups were found regarding the primary end point (DBA: 5.7% vs MBA: 6.7% vs PBA: 13.1% vs AA: 10.3%; $P = .19$). No significant differences were noted between the four access sites when each type of access complication was analyzed individually, except that the risk of neuropathy was significantly increased after PBA (DBA: 1.1% vs MBA: 1.3% vs PBA: 9.3% vs AA: 5.1%; $P = .003$; Table III). Overall, 19 neuropathies occurred; 9 patients suffered motor and sensory, 8 only motor, and 2 only sensory deficits. In 15 patients, the symptoms resolved completely; in 2 patients, a sensory deficit remained; and in 2 patients, it is unknown if the symptoms persisted.

There was no significant difference for the risk of undergoing an access-related reintervention between the groups (DBA: 6.7% vs MBA: 3.4% vs PBA: 0.7% vs AA: 3.4%; $P = .09$). No patient suffered from acute upper limb ischemia. Nine reinterventions were performed for hemorrhage, three for major hematoma evacuation, two to perform an embolectomy, and in one patient an iatrogenic dissection needed surgical treatment. Comparing surgical and percutaneous approaches, a significantly increased risk for the composite end point access complications (29.2% vs 9.2%; $P = .007$) and access reinterventions (25% vs 1.9%; $P < .001$) was detected in favor of a surgical approach (Fig).

Comparing the patient, procedure, and closure characteristics of patients with and without access complications after percutaneous access, no significant differences were identified (Table IV).

No significant differences in the risk for ischemic cerebrovascular events were found comparing the different access sides (right: 5.9% vs left: 4.1% vs bilateral: 5%; $P = .75$). Overall, 19 (4.6%) ischemic cerebrovascular events occurred, of which 10 were major. Minor ischemic cerebrovascular events took place in eight patients, and one patient had a transient ischemic attack. Ischemic cerebrovascular events were distributed equally among the different procedure types. Five ischemic cerebrovascular events took place after a Ch EVAR (4.4%), seven after an f EVAR (5.1%), five after a b EVAR (4.8%), and two after an f/b EVAR (3.3%) ($P = .94$).

Twenty-nine patients (7.9%) died within 30 days, which was equally distributed between the groups (DBA: 2.4%

Table II. Procedure and access characteristics

	Overall	Surgical	Percutaneous	*P*	Distal brachial	Medial brachial	Proximal brachial	Axillary access	*P*
Procedure					89	149	140	59	
f EVAR	134	129	5		28	59	37	14	
b EVAR	106	106	0		3	41	48	14	
f/b EVAR	62	60	2		8	16	38	1	
Ch EVAR	114	102	12	<.001	50	33	17	30	<.001
Mean procedure time (minutes)	278	283	208	.019	223.1	413.6	280.7	248.3	<.001
Mean contrast (mL)	135	149			125.2	165.4	151.7	121.8	.22
Side									
Left	295	283	10		86	142	51	56	
Right	102	98	9		3	7	89	3	<.001
Bilateral	20	15	5	.71					
Percutaneous	24				19	0	4	1	<.001
Open	413				70	149	136	58	
Conduit	11	11	0		0	0	0	11	<.001
Mean sheath size (F)	9.0	9.14	7.0	<.001	7.5	9.3	9.7	9.2	<.001

b, Branched; *Ch*, chimney; *EVAR*, endovascular aortic repair; *f*, fenestrated; *f/b*, fenestrated/branched.
Values are numeric unless indicated otherwise. Values in parentheses are percentages.

Table III. Safety outcomes comparing access strategies

	Distal brachial (n = 89) (%)	Medial brachial (n = 149) (%)	Proximal brachial (n = 140) (%)	Axillary access (n = 59) (%)	*P*
Access complication	10 (11.2)	10 (6.7)	19 (13.6)	6 (10.2)	.29
Major hematoma	6 (6.7)	5 (3.4)	7 (5)	3 (5.1)	.70
Hemorrhage	3 (3.4)	3 (2)	3 (2.1)	1 (1.7)	.89
Pseudoaneurysm	2 (2.2)	0	1 (0.7)	0	.25
Wound infection	0	3 (2)	0	0	.12
Dissection	2 (2.2)	3 (2)	4 (2.9)	1 (1.7)	.95
Occlusion	0	2 (1.3)	1 (0.7)	0	.58
Neuropathy	1 (1.1)	2 (1.3)	13 (9.3)	3 (5.1)	.003
Access reintervention	6 (6.7)	5 (3.4)	1 (0.7)	2 (3.4)	.094
Minor hematoma	15 (16.8)	13 (8.7)	17 (12.1)	5 (8.5)	.24

vs MBA: 9.0% vs PBA: 9.0% vs AA: 6.3%; *P* = .513). No patient died due to UEA complications (Table V).

Univariate and multivariate analysis for determinants of access complications after surgical access. For this analysis, 38 (9.2%) access complications in 413 punctures were analyzed. In the univariate analysis, no characteristic was an independent risk factor for access complications. Three factors were identified, which showed no significant effect in the univariate analysis but met the inclusion criteria for the multivariate analysis. The multivariate analysis showed that the risk for access complications was decreased by male sex (odds ratio [OR]: 0.27; 95% confidence interval [CI]: 0.10-0.72; *P* = .009), whereas an increase in age per year (OR: 1.08; 95% CI: 1.004-1.179; *P* = .039) and diabetes mellitus type 2 (OR: 3.70; 95% CI: 1.20-11.41; *P* = .023) increased the risk (Table VI).

DISCUSSION

This multicenter, real-world retrospective study at six Dutch hospitals reports on a large cohort of patients who underwent UEA for the endovascular treatment of complex aortic aneurysms. Access locations, access sides, and access techniques were compared. There was no difference between the four access locations (distal brachial, medial brachial, proximal brachial, and axillary artery) in a composite end point of all access complications.

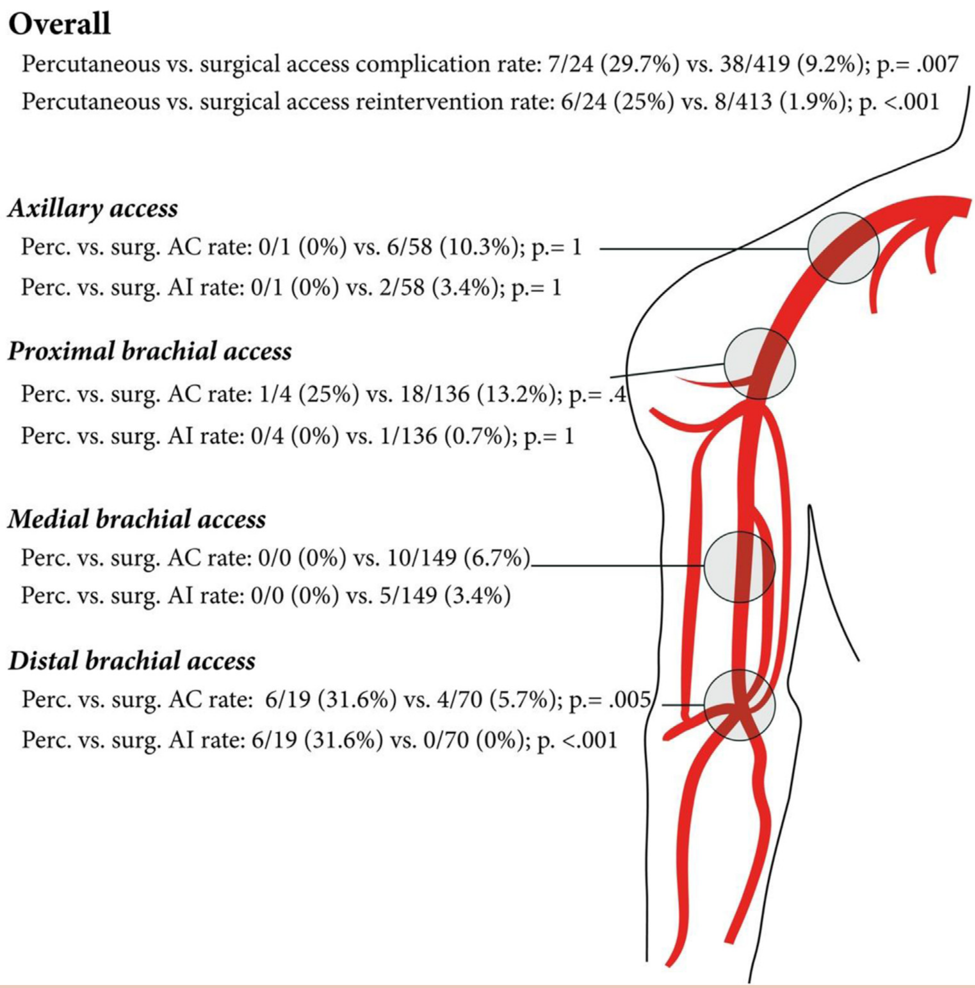

Fig. Access complication and reinterventions per location and comparing percutaneous and surgical access. Values are numeric unless indicated otherwise. Values in parentheses are percentages. *AC*, Access complication; *AI*, access reintervention.

No previous cohort study has been able to compare the different UEA strategies for the treatment of complex aortic aneurysms on a large scale. Previously published UEA complication rates vary between 2% and 14.4%. The rate of overall access complications of 10.2% in our cohort aligns with prior results.[15,17,20,21] In our multicenter cohort, the AA strategy was least frequently used; this might be due to the fact that the surgical approach of the axillary artery can be more challenging and possible access complications include pneumothorax and hemothorax. Although no differences in the overall access complication were seen between the four locations, there were significant more peripheral neuropathies seen after PBA. There are three factors that might have contributed to this finding. The first could be traction on the brachial plexus when dissecting the proximal brachial artery. In addition, larger sheaths were used, which might have increased the mechanical pressure on the brachial plexus during the procedure. Furthermore, the exposed proximal brachial artery, as well as the median and ulnar nerve, lies within the medial brachial fascial compartment, and swelling of the operation field or even a subclinical seroma/hematoma might cause postoperative compression of the nerves.[22]

Despite the high number of peripheral neuropathies after PBA, there were fewer access reinterventions after PBA, because other access complications seen in this group had minor clinical consequences and the peripheral neuropathies could be treated conservatively.

Overall, 24 percutaneous approaches were performed, 19 through the distal brachial artery, 4 through the proximal brachial artery, and 1 through the axillary artery. Despite a smaller mean sheath size compared with a surgical approach, percutaneous access showed an increased rate of access complications and access reinterventions, and six of the seven complications occurred after percutaneous access of the DBA. Overall, not much data has been published comparing percutaneous UEA in the treatment of complex aortic. A meta-analysis comparing percutaneous ($n = 54$) and open ($n = 495$)

Table IV. Comparing percutaneous approached patient and procedure characteristics of patients with and without access complication

	Percutaneous patients with access complication (n = 6)	Percutaneous patients without access complication (n = 14)	*P*
Male sex, n (%)	5 (83.3)	12 (85.7)	1
Age, years	77.9	73.7	.16
BMI, kg/m^2	26	25.7	.87
Height, cm	173	175	.39
Weight, kg	84.3	82.2	.8
Current smoker	1 (17.7)	2 (14.2)	1
Former smoker	1 (17.7)	4 (28.4)	1
Hypertension	1 (17.7)	10 (71.4)	.05
Dyslipidemia	1 (17.7)	5 (35.7)	.61
Previous cerebrovascular event	1 (17.7)	5 (35.7)	.61
Diabetes mellitus type 2	0	0	
	Percutaneous access with access complications (n = 7)	**Percutaneous access without access complications (n = 17)**	***P***
Manual compression	5 (71.4)	12 (70.6)	1
Closure device	2 (28.6)	5 (29.4)	1
Angioseal	0	2 (11.8)	1
ProGlide	1 (14.3)	1 (5.9)	0.51
Mynx	1 (14.3)	2 (11.8)	1
Sheath size (F)	7.29	6.88	0.3

BMI, Body mass index.

Table V. General outcomes

	N = 417
Death	29 (7.9)
UEA-related death	0
Persistent paraplegia/paraparesis	4 (1)
Cardiac complications	40 (9.6)
Myocardial infarction	9 (2.2)
Respiratory complications	35 (8.4)
Visceral ischemia	23 (5.6)

UEA, Upper extremity access.
Values are numeric and values in parentheses are percentages.

UEA in f/b EVAR found an increased risk for access complications after percutaneous access.[17] Besides treatment of complex aortic aneurysms, several publications on percutaneous UEA for other treatments are available. We previously published single-center results of percutaneous DBA and reported access complications in 28% of the patients, but none of these patients are included in this study.[23] In 2016, Kret et al[24] showed that arterial cutdown of the brachial artery (OR: 0.25; 95% CI: 0.07-0.87; *P* = .04) was associated with a significantly decreased risk for access complications. Their finding aligns with a recently published paper by DeCarlo et al,[12] reporting access complications in 7.5% of the percutaneous and 1.6% of the surgical transbrachial procedures. Furthermore, Madden et al[11] reported a need for surgical revision in 15 of 150 patients in whom percutaneous transbrachial procedures were performed. Unfortunately, these three studies did not state where the brachial artery was approached, and most of the procedures were performed for the treatment of peripheral arterial disease.

Compared with the above-described results, our access complication rate after a percutaneous approach of the distal brachial artery is even higher, which may be explained by the aortic nature of the procedures in our study, which are lengthier and require a larger sheath than peripheral procedures. Unfortunately, we were not able to identify risk factors for access complications after a percutaneous approach, due to the low number of patients. But it can be noted that the patients in whom access complications occurred were significantly older and the used sheaths were larger. For percutaneous access, ultrasound-guided punctures reduce the access complication rate.[13] The advantages of ultrasound-guided puncture are clear as it is possible to avoid puncturing in areas prone for complications, such as arterial calcification, occlusive arterial disease, and vulnerable surrounding structures. Furthermore, the puncture should be performed proximally of tortious segments and the sheath vessel ratio should be considered. Summarizing our data and the available literature, percutaneous distal

Table VI. Univariate and multivariate analysis for determinants of access complications after surgical access

	Odds ratio	Lower 95% CI	Upper 95% CI	*P*
Univariate				
Male sex	0.672	0.326	1.386	.282
Increase in age per year	1.030	0.981	1.080	.218
Increase in BMI per kg/m^2	1.062	0.996	1.132	.066
Diabetes mellitus type 2	2.00	0.863	4.637	.106
Increase in GFR	0.988	0.966	1.011	.300
Smoking	0.908	0.411	2.01	.812
Hypertension	0.813	0.406	1.628	.559
Multivariate				
Increase in age per year	1.07	1.01	1.15	.048
Diabetes mellitus type 2	3.74	1.17	11.98	.026
Male sex	0.38	0.15	0.91	.031

BMI, Body mass index; *CI*, confidence interval; *GFR*, glomerular filtration rate.

brachial artery access seems to have a high complication rate and should be avoided. The literature also offers data on percutaneous access of the axillary artery, which has been reported to have a low conversion and reintervention rate, using even larger sheath sizes.[10,20,25-27] However, the above-mentioned meta-analysis by Malgor et al[17] also found percutaneous AA to be inferior to a surgical approach regarding the access complication rate. Percutaneous radial access has shown to have a low complication and reintervention rate in coronary artery procedures. Recently, material has become available to perform also percutaneous radial access for lower extremity, mesenteric, and aneurysm-adjunctive interventions, but still its applicability remains limited by the relatively small lumen of the radial artery.[28,29]

Previous studies described female sex, an increase in body mass index, and age as risk factors for access complications.[24,30-32] Our multivariate regression on the risk to suffer an access complication after surgical access was aligned to these findings as we also found a significant increase of the risk for an access complication by female sex, diabetes mellitus type 2, and increasing age. An explanation for the influence of female sex is probably the smaller vessel size in women and therefore a smaller sheath/vessel ratio, which has been reported to increase the risk for access complications in femoral access.[33] Therefore, it might be beneficial to approach female patients more proximal as the vessel diameter should be larger, nevertheless the individual anatomy has to be evaluated for every patient. Other known risk factors such as hypertension, smoking, renal dysfunction, and an increase in the sheath size did not show a relevant influence in our univariate and multivariate analysis.[34]

It has to be noted that our data were collected retrospectively, and the reasons for choosing one approach over the other were undocumented in most of the cases. Each choice of the surgeon would be affected by own preference, the center's standard approach, the performed procedure, and several access vessel characteristics, and clearly results in some selection bias in our study. Each intervention has its characteristics that influence the access vessel choice, including the sheath diameter or the vessel, which needs to be cannulated.

In summary, it can be postulated that the arterial UEA in women should be obtained as proximally as possible, and in addition, individual and procedural risk factors should be taken into account in every case, especially in women, because access complications occur more frequently in them. Characteristics that could be taken into account are the body mass index, access vessel calibers and course at different levels of the upper extremity, such as tortuosity, upper extremity occlusive disease, and the aortic arch configuration.[35-38] In patients and procedures with a high procedural risk of left subclavian or dominant vertebral artery coverage or a coronary bypass using the left internal mammary artery, left-sided UEA should be performed with caution.[35,36]

Finally, in the current cohort, no significant influence of the access site on the occurrence of ischemic cerebrovascular complications was identified. Traditionally, left UEA has been favored because of the theory that right UEA is more likely to cause ischemic cerebrovascular events as both carotid arteries have to be passed instead of none.[18] This traditional opinion is reflected in our cohort, as most procedures were performed through left-sided UEA. Right-sided access can offer advantages such as ergonomics and lower radiation exposure to the operator.[18,35] In contrast to a previously performed meta-analysis on pooled complex aortic procedures, we found no significant influence of the access side on the occurrence of ischemic cerebrovascular events.[15] Reviewing our results and results published by Plotkin et al[35] and Mirza et al,[18] which also showed comparable ischemic cerebrovascular event rates between different access sides, right-sided UEA seems equally safe as left-sided UEA.

In the past few years, alternatives to UEA have risen, facilitating the possibility to cannulate downward-facing vessels from the femoral arteries.[39,40] The use of steerable sheaths from femoral access to catheterize antegrade branches is an auspicious approach and seems a realistic alternative to UEA. A recently published study by Eilenberg et al[41] demonstrated in a cohort of patients with branched EVAR that ischemic cerebrovascular events solely occurred in patients with UEA whereas none occurred in patients who had only a femoral approach using steerable sheaths. Since the introduction of steerable sheaths for f/b EVAR procedures, we continued to use UEA in approximately 25% of the procedures. In addition, steerable sheaths are not used in chimney procedures or in cases when a through-and-through wire is necessary. Therefore, we believe from today's perspective that there will always be situations in EVAR where a UEA is required.

Limitations of this study include its retrospective design, the heterogeneity of the performed procedures, and interinstitutional reporting measurement. Because we included all patients with UEA from six major aortic centers, different types of complex aortic procedures were included, which differ in their duration, the maximal used sheath size, aortic arch manipulation, and by that in access complication and cerebral ischemic event risk. Some centers might have preferred a percutaneous or surgical approach; therefore, a certain selection bias might have contributed to the negative result of percutaneous access. Because of the above selection biases, a concrete conclusion on a superior access strategy cannot be drawn. However, our study provides a real-world overview of the UEA techniques currently used.

Future studies could be performed prospectively and focus on the influence of the access vessel diameter, the degree of calcification, the intraprocedural anticoagulation, and the sheath to aortic arch retention time on access and cerebrovascular complication rate.

CONCLUSIONS

In this multicenter registry, four different UEA locations (axillary, PBA, MBA, and DBA) were compared in 417 patients and no differences in overall access complications were found. Female sex, diabetes mellitus type 2, and aging increased the risk for access complications after a surgical approach. Percutaneous UEA resulted in higher complication rates than a surgical approach. Finally, the choice of the access side did not influence the occurrence of ischemic cerebrovascular event rate. Selection of an UEA strategy in complex EVAR should be individually based on patient characteristics and risk factors and procedural need.

AUTHOR CONTRIBUTIONS

Conception and design: MM, GS, BM
Analysis and interpretation: MM, JH, JV, HV, ML, MR
Data collection: MM, ML
Writing the article: MM, BM
Critical revision of the article: MM JH, JV, HV, ML, MR, GS, BM
Final approval of the article: MM, JH, JV, HV, ML, MR, GS, BM
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