Incidence and prognostic factors related to major adverse cerebrovascular events in patients with complex aortic diseases treated by the chimney technique

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ABSTRACT

Objective: Endovascular aneurysm repair (EVAR) with the chimney technique (ch-EVAR) has been used for the treatment of aortic aneurysms as an alternative approach to fenestrated endografting or open repair. Nonetheless, the need for an upper extremity arterial access may contribute to a higher risk for periprocedural cerebrovascular events. This study reports on the perioperative cerebral and major adverse cardiac and cerebrovascular events (MACCE) after ch-EVAR.

Methods: The PERICLES registry (PERformance of the chImney technique for the treatment of Complex aortic pathoLogiES) is an international, retrospective multicenter study evaluating the performance of ch-EVAR for the treatment of complex aortic pathologies. For the purpose of the current analysis, 425 patients treated by ch-EVAR between 2008 and 2014 were included. The primary outcome of this analysis was the incidence of procedure related cerebrovascular events defined as transient ischemic attack or stroke. The secondary end point was in-hospital MACCE, including acute coronary syndrome, stroke, and death of any cause.

Results: The incidence of clinical relevant cerebrovascular events was 1.9% (8/425). A postoperative transient ischemic attack was observed in four patients (0.95%) and a stroke in additional four (0.95%). Three patients died during the hospital stay secondary to sequelae from postoperative stroke. A prior history of stroke/transient ischemic attack, atrial fibrillation, previous carotid revascularization, or known carotid artery disease did not significantly increase the risk for adverse neurologic events. The overall MACCE rate amounted to 8.5% (36/425). Logistic regression analysis revealed that the use of bilateral upper extremity access (odds ratio [OR], 2.79; 95% confidence interval [CI], 1.04-7.45]), aneurysm rupture (OR, 5.33; 95% CI, 1.74-16.33), and a prolonged operation time (>290 minutes; OR, 1.005; 95% CI, 1.001-1.008) were associated with a significantly increased risk for MACCE.

Conclusions: This analysis demonstrates that ch-EVAR is associated with a relatively low rate of cerebrovascular events. However, a postoperative stroke is associated with increased mortality. Ruptured aneurysms, bilateral upper extremity access as in case of multiple chimney graft placement, and longer operative times were identified as independent risk factors for MACCE. (J Vasc Surg 2017;■:1-8.)

The chimney (or snorkel) endovascular aneurysm repair (ch-EVAR) is an alternative approach to fenestrated/branched endovascular or surgical repair for the treatment of aortic aneurysms. Previous studies and more recently the PERICLES registry presented the world wide collected experience including 517 patients with pararenal pathologies.[1-8]

Chimney EVAR requires upper extremity access. Theoretically, the need for upper extremity access may contribute to a higher risk for ischemic cerebrovascular events. Single-center studies reported a remarkable variety regarding the incidence of perioperative strokes between 3% and 10%, and no robust conclusion concerning the safety of this procedure could be made.[5,9-11] Upper extremity access is a favored approach in the treatment of coronary and mesenteric disease, and represents a viable alternative to transfemoral approach in a variety of peripheral procedures. Nonetheless, in these interventions, only one sheath is needed, and manipulation of the sheath is limited once a stabile position is acquired.[12-14] Concerning complex aneurysm treatment, few studies report on the incidence, type, location, or severity of postoperative stroke and its association with upper extremity access.[15-18] The aim of the current analysis was to evaluate the incidence and risk factors associated with cerebrovascular events after

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ch-EVAR analyzing the data of the PERICLES registry (PERformance of the chImney technique for the treatment of Complex aortic pathoLogiES).

METHODS

The PERICLES registry is an international, retrospective, multicenter study that complied with the principles of the Declaration of Helsinki. The local ethics committees and respective institutional review boards from the participating centers approved data acquisition. Patient informed consent was obtained for this study. Participating centers were required to have performed ≥10 ch-EVAR in complex aortic pathologies. The clinical records of all patients who underwent endovascular ch-EVAR at 9 centers between 2008 and 2014 were retrospectively reviewed. Clinic charts were reviewed for patient demographic data, comorbidity, history and physical examination findings, and radiologic and procedural details. These data were accordingly analyzed. As reported, all commercially available abdominal endografts in different combinations with chimney grafts were included in the present study. Patients with thoracic aneurysms, aortic dissections, or extensive thoracoabdominal aneurysms with involvement of the supradiaphragmatic thoracic segment were excluded.[8]

To evaluate the risk factors and incidence of cerebrovascular events, a separate database with inclusion of several factors, which could potentially lead to cerebrovascular events, was also completed from the participating centers. Nine departments could provide all additional information needed, for a total cohort of 425 patients. All centers collected additional information such as time to stroke, location of stroke, type of aortic arch, and previous cerebrovascular revascularization. A neurologist at every institution made the diagnosis of stroke and/or transient ischemic attack (TIA). A cranial computed tomography (CT) scan or magnetic resonance imaging was performed for every patient presenting with clinical symptoms of stroke/TIA. No core laboratory or clinical events committee adjudicated end points or clinical events.

Chimney technique. The chimney technique has been previously described in detail.[19] Briefly, a surgical exposure of the left axillary or brachial artery is performed in case of a single chimney graft deployment. Although a left upper extremity catheterization is preferred, because it prevents wire manipulation at the origin of the carotid arteries reducing the potential risk of cerebral embolization, in some patients a right axillary access was used. When a second chimney graft is required, the axillary or brachial artery could be punctured twice, with a distance of ≥1 cm. A bilateral upper extremity access might be mandatory in patients with multiple chimney reconstructions and small diameter of the access vessel. The minimum required diameter of the axillary artery should be 6 mm when two sheaths are used. An arterial sheath (6-F, 7-F, or 8-F) is then advanced, and access in the target visceral/renal vessel is obtained. All sheaths should be in place before deployment of the endograft. The arterial sheaths used were selected according to the diameter of the bridging stent deployed. No conduit was used.

Transfemoral access is obtained by percutaneous access or by surgical exposure of the groin vessels. A standard endograft is then advanced at the level of the new aortic neck. After the deployment of the endograft, a balloon-expandable or self-expandable stent-graft is advanced through the sheath and deployed in the target visceral vessel. Additional placement of bare metal stents was also used according to surgeon preference and target vessel anatomy. After deployment of the chimney grafts, balloon molding is performed to ensure adequate seal at the proximal neck and to minimize perigraft flow.

Outcomes and definitions. The primary outcome of the current analysis was the incidence of periprocedural cerebrovascular events defined as TIA and stroke. Secondary outcome was the occurrence of major adverse cardiac and cerebrovascular events (MACCE), including myocardial infarction, stroke, and death. Stroke was defined as brain or retinal cell death attributable to ischemia, based on neuropathologic, neuroimaging, and/or clinical evidence of permanent injury.[20] TIA was defined as a transient episode (<24 hours) of neurologic dysfunction caused by focal brain ischemia, without acute infarction.[21] MACCE was defined as the composite end point of death of any cause during the hospital stay, acute coronary syndrome including unstable angina, and stroke. Juxtarenal pathologies were considered any degenerative aneurysms or penetrating atherosclerotic ulcers up to the level of renal arteries, type Ia endoleaks after prior infrarenal EVAR, and para-anastomotic

ARTICLE HIGHLIGHTS

- **Type of Research:** Analysis of the multicenter retrospective PERICLES registry
- **Take Home Message:** The incidence of major cerebrovascular and cardiac events after 425 endovascular aneurysm repair with the chimney technique was 8.5%, with 1.9% having stroke or transient ischemic attack, respectively. These complications were associated with bilateral upper extremity access, aneurysm rupture, and an operation time of >290 minutes.
- **Recommendation:** This study suggests that, after chimney endovascular aneurysm repair, major cerebrovascular and cardiac events are infrequent and associated with bilateral arm access, ruptured aneurysms, and a prolonged operative time.

Table I. Comorbidity factors (neurologic event)

	Cohort (N = 425)	Stroke/TIA (n = 8)	No stroke/TIA (n = 417)	*P*
Age, years	75.6 (44-96)	78.71 (74-86)	75.6 (44-96)	.299
Male	272 (64)	5 (62.5)	267 (64.0)	.929
Coronary disease	264 (62.1)	4 (50.0)	260 (62.3)	.476
Cerebrovascular disease	66 (15.1)	0 (0)	66 (15.8)	.221
Diabetes	83 (19.4)	2 (25.0)	81 (19.4)	.911
Renal insufficiency	184 (43.3)	3 (37.5)	181 (43.3)	.932
ESRD	43 (10.1)	1 (12.5)	42 (10.0)	.822
Hyperlipidemia	281 (66.3)	5 (62.5)	276 (66.2)	.820
Hypertension	379 (89.4)	5 (62.5)	374 (89.7)	.013
Stroke history	46 (10.8)	0 (0)	46 (11.0)	.320
Prior carotid endarterectomy	35 (8.2)	0 (0)	35 (8.4)	.392
Atrial fibrillation	53 (12.5)	1 (12.5)	52 (12.4)	.998
Antiplatelet therapy	333 (78.4)	6 (75.0)	327 (78.4)	.827
Statin therapy	281 (66.1)	5 (62.5)	276 (66.2)	.816

ESRD, End-stage renal disease; *TIA*, transient ischemic attack.
Data are presented as mean (range) or number (%).

aneurysms after previous open aortic repair. Pararenal pathology was defined as aneurysm dilation up to the level of the superior mesenteric artery.

Statistical analysis. Descriptive statistics were used to assess study demographics, comorbidities, and outcome variables as appropriate. Rank-sum and Pearson χ^2 tests were used to analyze relationships between continuous and categorical variables, respectively. Univariate and multivariate logistic regression analysis was performed to identify risk factors associated with MACCE.

$P < .05$ was considered significant for all analyses. Statistical analysis was performed using Stata 12.0 (StataCorp LP, College Station, Tex).

RESULTS

A total of 425 patients (mean age, 75.6 years; range, 44-95) treated by ch-EVAR were analyzed. The majority of patients were treated electively (n = 376 [88.5%]), whereas 49 patients (11.5%) were admitted with symptomatic (n = 24 [5.6%]) or ruptured (n = 25 [5.9%]) aortic aneurysms. A juxtarenal aneurysm was identified in 355 patients (83.5%) and a pararenal aneurysm in 70 (16.5%). A single chimney graft was used in 198 patients (46.6%) and multiple chimney grafts were deployed in 227 patients (53.4%). The mean number of chimney grafts placed was 1.7 per patient. A left high brachial or axillary arterial access was used most commonly (n = 308 [72.5%]), whereas a right-sided access was chosen in 49 patients (11.5%). Bilateral upper extremity access was required in 77 patients (18.1%). The mean operation time was 220 ± 101 minutes. Table I summarizes the comorbidity and the baseline characteristics of this cohort. Data concerning the anatomy and the presence of thrombus or atherosclerotic disease of the aortic arch was available in 169 patients (40%).

Stroke/TIA. The overall incidence of symptomatic perioperative cerebrovascular events was 1.9% (8/425). TIAs were observed in four patients (0.95%), and stroke was diagnosed in additional four subjects (ischemic stroke, n = 3; hemorrhagic stroke, n = 1). Prior history of stroke/TIA ($P = .320$), atrial fibrillation ($P = .998$), previous carotid revascularization or known carotid artery disease ($P = .392$) was not associated with adverse neurologic events. There was a trend toward greater stroke risk when a bilateral upper extremity access was used; however, this did not reach statistical significance (37.5% vs 17.7%; $P = .151$). The use of multiple chimneys grafts ($P = .603$) or the presence of ruptured aneurysm ($P = .475$) was also not associated with increased risk for perioperative cerebral events (Table II). A prolonged operational time was observed among patients with stroke (285 ± 106 minutes vs 219 ± 101 minutes; $P = .045$). A logistic regression analysis did not reveal any predictor for cerebral events whereas hypertension showed a protective effect (odds ratio [OR], 0.19; 95% confidence interval [CI], 0.04-0.85; $P = .030$). The procedural and baseline characteristics of the eight patients who suffered an adverse cerebrovascular event are presented in detail in Table III.

Three patients who suffered a stroke died during the hospital stay. The first patient with ischemic stroke of the right anterior cerebral artery passed away owing to respiratory failure. The cerebral event was diagnosed in the immediate postoperative period in the presence of a left hemiplegia. He underwent a triple chimney reconstruction and had a bilateral upper extremity access using 6-F sheaths. He had a type II arch with mild to

Table II. Anatomic and procedural factors (neurologic event)

	Cohort (N = 425)	Stroke/TIA (n = 8)	No stroke/TIA (n = 417)	*P*
Rupture	25 (5.9)	0 (0)	25 (6.0)	.475
Suprarenal	70 (16.5)	2 (25.0)	68 (16.3)	.511
Old EVAR	41 (9.6)	0 (0)	35 (8.4)	.351
Old open	35 (8.3)	0 (0)	8 (1.9)	.666
Multichimney	227 (53.4)	5 (62.5)	222 (53.2)	.603
Access				
Bilateral	77 (18.1)	3 (37.5)	74 (17.7)	.151
Left only	308 (72.5)	4 (50.0)	304 (72.9)	.151
Right only	49 (11.5)	1 (12.5)	48 (11.5)	.931
Sheath size				
6-F	126 (29.6)	4 (50.0)	122 (29.2)	.203
7-F	249 (58.6)	3 (37.5)	246 (59.0)	.222
8-F	53 (12.5)	1 (12.5)	52 (12.5)	.998
OR time, minutes	220 ± 101	285 ± 106	219 ± 101	**.045**
Arch type (incomplete data)				
I	95	2	93	.800
II	51	1	50	.819
III	23	1	22	.787

EVAR, Endovascular aneurysm repair; *TIA*, transient ischemic attack.
Data are presented as number (%) or mean ± standard deviation. Boldface entries indicate statistical significance.

moderate atherosclerotic disease and without the presence of thrombus. The second patient showed a right-sided hemiparesis, progressing to herniation 3 days after surgery. The patient died the same day. A CT scan revealed a hemorrhagic stroke in the left middle cerebral artery territory. He was treated with double chimney (2 × 7-F sheaths) through a single left upper extremity access. The preoperative CT scan revealed a type II aortic arch with mild atherosclerotic disease. The third patient developed a postoperative multiorgan dysfunction syndrome and died 7 days after surgery. The ischemic event occurred during the procedure. The postoperative CT scan revealed an ischemic stroke in the left middle cerebral artery territory. He underwent a single chimney procedure with a 6-F sheath and had a type III aortic arch with a significant amount of thrombus and atherosclerotic disease. The last stroke patient recovered fully. He had an ischemic stroke direct after surgery in the posterior cerebral artery territory. He underwent single chimney from a left upper extremity access. All TIA patients fully recovered and their symptoms regressed completely within 24 hours. Distribution of TIA can be found in Table III.

MACCE. The incidence of MACCE was 8.5% (36/425) in this study. Eight patients (1.9%) suffered cerebrovascular adverse events and 3 of them died. Nineteen patients (4.5%) suffered an acute coronary syndrome, and 11 (2.6%) died from cardiac events. Finally, 3 patients (0.7%) with bowel ischemia, 4 patients (0.9%) with multiorgan dysfunction syndrome, and 2 patients (0.5%) with acute heart failure also died during the hospital stay. The 30-day mortality rate was 5.4% (n = 23 patients). Tables IV and V summarize relevant comorbidities as well as the anatomic and procedural factors for MACCE. The use of bilateral upper extremity access (OR, 2.79; 95% CI, 1.04-7.45), aneurysm rupture (OR, 5.33; 95% CI, 1.74-16.33), and prolonged operation time (>290 minutes; OR, 1.005; 95% CI, 1.001-1.008) were associated with an increased risk for MACCE. The use of multiple chimneys, age, and type of aneurysm were not found to have an association (Table V).

DISCUSSION

The clinical value of ch-EVAR as an alternative approach has been demonstrated by multiple clinical studies in the treatment of pararenal and juxtarenal aortic disease.[1-8] However, the need for upper extremity arterial access might increase the risk for cerebrovascular events. The present study analyzed the association between upper-extremity access and cerebrovascular events treated by ch-EVAR in the framework of the PERICLES registry. Evaluation of postoperative neurologic clinical status showed low incidence of perioperative strokes and TIA. Consequently, the use of the upper extremity access seems to be safe with acceptable risk for cerebrovascular events for patients with pararenal and juxtarenal aneurysms.

Interestingly prior cerebral events, carotid artery revascularization, atrial fibrillation, or known cerebrovascular

Table III. Patients with stroke or transient ischemic attack (*TIA*)

	Age, years	Gender	ASA class	OR time, minutes	Access	Sheath size, F	No. of chimneys	Time to stroke/TIA	Location of stroke	Stroke type	Arch
Stroke 1	74	Male	IV	447	Bilateral	6	3	Periprocedural	Right ACA	Ischemic	Type II, mild ATS
Stroke 2	78	Male	III	300	Left arm	7	2	72 hours	Left MCA	Hemorrhagic	Type II, mild ATS
Stroke 3	74	Male	IV	270	Left arm	6	1	Periprocedural	Left MCA	Ischemic	Type I, many thrombus and ATS
Stroke 4	77	Male	III	180	Left arm	7	1	Periprocedural	Left PCA	Ischemic	Type II, mild ATS
TIA 1	81	Male	IV	195	Left arm	8	2	12 hours	Left MCA		Type II, few thrombus and mild ATS
TIA 2	79	Female	IV	440	Bilateral	6	3	Periprocedural	Left MCA		Type II, mild ATS
TIA 3	80	Female	IV	240	Bilateral	7	2	Periprocedural	Left MCA		Type II, mild ATS
TIA 4	86	Female	IV	205	Right arm	6	1	Periprocedural	Right MCA		Type I, mild ATS

ACA, Anterior cerebral artery; *ASA*, American Society of Anesthesiologists; *ATS*, atherosclerotic disease; *MCA*, middle cerebral artery; *OR*, operating room; *PCS*, posterior cerebral artery.

Table IV. Comorbidity factors (major adverse cardiac and cerebrovascular events [*MACCE*])

	Cohort (N = 425)	MACCE (n = 36)	No MACCE (n = 389)	*P*
Age, years	75.6 (44-96)	77.6 (55-96)	75.4 (44-95)	.148
Male	272 (64)	26 (72.2)	246 (63.2)	.283
Coronary disease	264 (62.1)	23 (63.9)	241 (62.0)	.819
Cerebrovascular disease	66 (15.1)	5 (13.9)	61 (15.7)	.776
Diabetes	83 (19.4)	5 (13.9)	78 (20.1)	.372
Renal insufficiency	184 (43.3)	17 (47.2)	167 (42.9)	.619
ESRD	43 (10.1)	4 (11.1)	39 (10.0)	.836
Hyperlipidemia	281 (66.3)	22 (61.1)	259 (66.6)	.493
Hypertension	379 (89.4)	30 (83.3)	349 (89.7)	.461
Stroke history	46 (10.8)	2 (5.6)	44 (11.3)	.288
Prior carotid endarterectomy	35 (8.2)	3 (8.3)	32 (8.2)	.982
Atrial fibrillation	53 (12.5)	4 (11.1)	49 (12.6)	.796
Antiplatelet therapy	333 (78.4)	22 (61.1)	259 (66.6)	.507
Statin therapy	281 (66.1)	27 (75.0)	306 (78.7)	.610

ESRD, End-stage renal disease.
Data are presented as mean (range) or number (%).

disease did not increase the risk in this cohort for a perioperative adverse neurologic event. Additionally, no association was found between bilateral upper extremity access and arterial sheath size used and cerebral events. The only factor that contributed to a higher risk for adverse neurologic events was prolonged procedural time. Paradoxically, hypertension was found to have a protective effect for in-hospital stroke/TIA. This finding is difficult to explain, given the opposite is well-known to be true for spontaneous strokes.[22] We assume that, in hypertensive subjects, the cerebral blood perfusion remained in narrow limits despite the intraoperative hypoperfusion.

In a recent review of the chimney technique, Lindblad et al[23] reported a postoperative stroke incidence of 1% to 2%. In contrast, Katsargyris et al,[11] in a systematic review of the literature, observed a higher ischemic stroke incidence of 3.2% after ch-EVAR. This group reported higher stroke rates after ch-EVAR compared with open surgery ($P = .002$) and fenestrated EVAR ($P = .012$), and concluded that upper extremity access (brachial/axillary artery) along with possible hostile arch anatomy create an additional risk for iatrogenic stroke.[11] Of note, the authors did not include in this review the largest ch-EVAR series and analyzed heterogeneous cohorts including also patients who were treated for thoracic pathologies or atherosclerotic occlusive disease.[24]

Regarding fenestrated/branched EVAR, Haulon et al[15] reported an ischemic stroke incidence of 2.5%. In the GLOBAL collaborators on advanced Stent-graft

Table V. Anatomic and procedural factors (major adverse cardiac and cerebrovascular events [*MACCE*])

	Cohort (N = 425)	MACCE (n = 36)	No MACCE (n = 389)	*P*
Rupture	25 (5.9)	7 (19.4)	18 (4.6)	**<.001**
Suprarenal	70 (16.5)	10 (27.8)	60 (15.4)	.056
Old EVAR	41 (9.6)	4 (11.1)	27 (6.9)	.756
Old open	35 (8.3)	5 (13.9)	30 (7.7)	.250
Multichimney	227 (53.4)	23 (63.9)	204 (52.4)	.188
Access				
Bilateral	77 (18.1)	12 (33.3)	65 (16.7)	**.013**
Left only	308 (72.5)	23 (63.9)	285 (73.3)	.228
Right only	49 (11.5)	5 (13.9)	44 (11.3)	.643
Sheath size				
6-F	126 (29.6)	13 (36.1)	113 (29.0)	.375
7-F	249 (58.6)	17 (47.2)	232 (59.6)	.248
8-F	53 (12.5)	6 (16.7)	47 (12.1)	.426
OR time, minutes	220 ± 101	292 ± 139	213 ± 95	**.045**
Arch type (incomplete data)				
I	95	12 (33.3)	83 (21.3)	.517
II	51	4 (11.1)	47 (12.1)	.358
III	23	3 (8.3)	20 (5.1)	.899

EVAR, Endovascular aneurysm repair; *OR*, operating room.
Data are presented as number (%) or mean ± standard deviation. Boldface entries indicate statistical significance.

Techniques for Aneurysm Repair (GLOBALSTAR) registry, 3 patients (0.9%) developed a TIA after fenestrated EVAR; no strokes were reported.[16] In the WINDOWS trial (Medical & Economical Evaluation of Fenestrated & Branched Stent-grafts to Treat Complex Aortic Aneurysms), the treatment of pararenal and suprarenal aortic pathologies with branched/fenestrated endografts was associated with a perioperative stroke risk of 1.6% and 2.4%, respectively. Of note, patients with ruptured aneurysms were excluded from this trial.[17] Additionally, Knowles et al[18] observed a 2% ischemic stroke rate after fenestrated EVAR performed exclusively through transfemoral access. In this cohort, upper extremity access for fenestrated EVAR compared with transfemoral only did not increase the risk for cerebral complications.[18]

Although a head-to-head comparison of ch-EVAR and fenestrated/branched endografting is confounded from different selection criteria, it seems that the need for adjunctive upper extremity access does not significantly increase the risk for ischemic cerebral events compared with the other treatment modalities, at least in the treatment of juxtarenal and pararenal aneurysms. However, it should be noted that the number of patients treated with multiple chimneys grafts, requiring multiple cannulations of the upper extremity arteries, was limited and robust conclusions concerning ≥three chimney grafts cannot be made.

Despite the current concerns that central neurologic complications can compromise the performance of upper extremity access, there are no robust data supporting that this approach for vascular interventions significantly increases the risk for ischemic events.[14] Ratib et al[25] reported comparable stroke rates after transradial and transfemoral percutaneous coronary interventions.[25] Furthermore, Hoffman et al[26] did not observe any difference in terms of ischemic stroke rates after transradial and transfemoral percutaneous coronary intervention (0.57% vs 0.34%; $P = .32$). Kwok et al[27] performed a stroke analysis of the British Cardiovascular Intervention Society database for patients undergoing percutaneous coronary intervention between 2007 and 2012. They observed a stroke rate of 0.13% (543 of 426,046 patients); however, a radial approach was not identified as an independent risk factor for cerebral events. Interestingly, an ischemic stroke was associated with a ninefold increase in odds of 30-day mortality (OR, 9.27; 95% CI, 7.18-11.99) expressing the gravity of this complication.[27] Similarly, despite the low cerebral event rates observed in our cohort, stroke was in all but one patient a fatal postoperative complication. In contrast, TIA was associated with a benign clinical course.

In this context and to reduce the risk for perioperative cerebral adverse events, we suggest a preoperative duplex scan of the supra-aortic vessels before elective cases to exclude a significant stenosis of the internal carotid artery. Additionally, a double puncture of the axillary artery instead of bilateral upper extremity access may be preferable in cases of multiple chimneys, although no advantage could be found in this study. In contrast, published single-center experiences suggested that bilateral access could increase the risk for

stroke, especially in aortic arches containing mural thrombus.[10,11] This finding could not be confirmed in the PERICLES registry. Finally, transfemoral access and placement of a flexible self-expanding covered stent (Viabahn) by means of the lift technique may also be an option to reduce the risk of stroke in high-risk patients.[28] Evaluating the results regarding MACCE, anatomic and procedural factors such as bilateral access, prolonged operation time, and ruptured aneurysms were all independently predictive risk factors for an adverse events. Similarly, in the WINDOWS trial, prolonged procedural time increased the risk for perioperative morbidity.[17]

Limitations. Several aspects of the present analysis warrant comment. Notwithstanding on the well-known limitations of registries, the retrospective nature of PERICLES study remains a major limitation. The registry also contains self-reported data and no core laboratory or clinical events committee adjudicated end points or clinical events. Moreover, the limited number of patients treated by >one and >two chimney grafts does not allow us to draw robust conclusions concerning the impact of multiple upper extremity cannulations. As described, in the PERICLES registry the average amount of chimney grafts used per patient was 1.7. Thus, profound assumptions and conclusions for >two chimney grafts cannot be drawn. Similar to other reports, postprocedural cerebrovascular imaging was performed in all participating centers based on clinical suspicion. Only when clinical symptoms presented, further neurologic examination and CT/magnetic resonance imaging scans were initiated. Thus, this study cannot provide any data concerning clinically silent microembolization. Also, we could not provide data for all patients regarding the type and the calcification or mural thrombus burden of the aortic arch, which could lead to an even better understanding of risk factors for stroke.

CONCLUSIONS

The collected experience regarding ch-EVAR demonstrated that the incidence of cerebrovascular neurologic events related to the chimney technique is low and <2%. Despite the rarity of cerebral events, postoperative stroke is still associated with high in-hospital mortality. Ruptured aneurysms, the need for bilateral upper extremity access as in case of multiple chimneys, and longer operation times are significant risk factors for MACCE. These findings stress the importance of patient selection on overall outcomes after ch-EVAR, and show that reducing operation times may be beneficial to reducing the risk of MACCE.

AUTHOR CONTRIBUTIONS

Conception and design: MB, JL, KD, FV, KS
Analysis and interpretation: MB, KT, GT, FP, KS
Data collection: MB, KT, KS
Writing the article: MB, KS
Critical revision of the article: MB, KT, JL, KD, FV, GT, FP, KS
Final approval of the article: MB, KT, JL, KD, FV, GT, FP, KS
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APPENDIX.

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