Open Microsurgical Cerebral Aneurysm Treatment After Failed Endovascular Therapy: An Evaluation of Aneurysm Treatment Frequencies in All Neurovascular Centers Across Austria and the Czech Republic Over 20 Years

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BACKGROUND AND OBJECTIVES: Endovascular treatment of cerebral aneurysms has tremendously advanced over the past decades. Nevertheless, aneurysm residual and recurrence remain challenges after embolization. The objective of this study was to elucidate the portion of embolized aneurysms requiring open surgery and evaluate whether newer endovascular treatments have changed the need for open surgery after failed embolization.

METHODS: All 15 cerebrovascular centers in Austria and the Czech Republic provided overall aneurysm treatment frequency data and retrospectively reviewed consecutive cerebral aneurysms treated with open surgical treatment after failure of embolization from 2000 to 2022. All endovascular modalities were included.

RESULTS: On average, 1362 aneurysms were treated annually in the 2 countries. The incidence increased from 0.006% in 2005 to 0.008% in 2020 in the overall population. Open surgery after failed endovascular intervention was necessary in 128 aneurysms (0.8%), a proportion that remained constant over time. Subarachnoid hemorrhage was the initial presentation in 70.3% of aneurysms. The most common location was the anterior communicating artery region (40.6%), followed by the middle cerebral artery (25.0%). The median diameter was 6 mm (2-32). Initial endovascular treatment included coiling (107 aneurysms), balloon-assist (10), stent-assist (4), intrasaccular device (3), flow diversion (2), and others (2). Complete occlusion after initial embolization was recorded in 40.6%. Seventy-one percent of aneurysms were operated within 3 years after embolization. In 7%, the indication for surgery was (re-)rupture and, in 88.3%, reperfusion. Device removal was performed in 16.4%. Symptomatic intraoperative and postoperative complications occurred in 10.2%. Complete aneurysm occlusion after open surgery was achieved in 94%.

CONCLUSION: Open surgery remains a rare indication for cerebral aneurysms after failed endovascular embolization even in the age of novel endovascular technology, such as flow diverters and intrasaccular devices. Regardless, it is mostly performed for ruptured aneurysms initially treated with primary coiling that are in the anterior circulation.

KEY WORDS: Epidemiology, Failed endovascular therapy, Open microvascular surgery, Ruptured aneurysms, Unruptered aneuryms

ABBREVIATION: RR, Raymond Roy.

Cerebrovascular treatment for cerebral aneurysms has evolved tremendously over recent decades. Although open surgery was the only mean to treat cerebral

aneurysms in the dawn of cerebrovascular surgery,[1] endovascular technologies have revolutionized the field since the 1990s. Modern endovascular treatment options for cerebral aneurysms include a variety of devices beyond coil embolization and include flow diversion, intrasaccular devices, and scaffolding technologies at the aneurysm neck to assure adequate obliteration of the aneurysm sac.[2] Along with the development of those technologies, the delivery model of cerebral aneurysm care has changed as well. Patients are regularly treated at centers where interventional radiologists, neurologists, open and hybrid neurosurgeons practice in teams to determine the optional endovascular or open surgical strategy for a particular aneurysm. Despite this integrated approach and a general trend toward more endovascular treatment, open surgery remains the only option to treat an aneurysm if all else fails beside observation. Here, we sought to evaluate the need for open surgery of cerebral aneurysms that failed endovascular treatment in an era of rapid advancements of endovascular technology at all cerebrovascular centers in Austria and the Czech Republic over a 20-year period and put it in context with all aneurysms treated in those countries. To the best of our knowledge, this is the first study of this kind encompassing every neurovascular center in 2 countries.

METHODS

Study Design

All cerebrovascular centers in Austria and the Czech Republic were queried for consecutive cerebral aneurysms that were retreated with open surgery after prior endovascular interventional techniques between 2000 and 2022. For patients to be eligible, at least 1 endovascular device had to be permanently implanted (such as at least 1 coil) with the intent to treat the aneurysm with endovascular means. Patients in whom the initial endovascular attempt was aborted without any endovascular device implantation were not eligible. The indication for treatment with open surgery was the discretion of the treating physician. A data collection sheet containing all relevant variables was distributed to all participating centers. The data collection sheets from each participating center were collated and combined for analysis at the lead center. Centers were furthermore asked to provide the total annual number of aneurysms treated with open or endovascular techniques during the study period. Institutional review board approval was obtained at each individual sites and the study was conducted in accordance with the Declaration of Helsinki. Patient study consent was waived.

Statistical Analysis

Categorical variables were presented as frequencies and percentages, and continuous variables were expressed as medians and ranges. To test different associations and identify significant predictors of symptomatic complications from open surgery, we used logistic regression, and the results were represented as odds ratios (ORs) and 95% CI. All analyses were performed using SPSS© statistical software (IBM© statistics), and a *P*-value <.05 was considered significant.

RESULTS

Countrywide Cerebral Aneurysm Frequencies

Aneurysm treatment frequency data for Austria and the Czech Republic were available from 2005 to 2020. During that period, on average, 1362 cerebral aneurysms were treated annually in the 2 countries. The total population increased from 18.4 Mio. in 2005 to 19.6 Mio. in 2020. Of the overall population, 0.006% of citizens had an aneurysm treated in 2005 which increased to 0.008% in 2020. On average, 0.8% of embolized aneurysms eventually required open surgery, a number that was stable over time (Table 1, Figure 1).

Patient and Aneurysm Characteristics

In total, 128 aneurysms in 126 patients had to be treated with open surgery after failed endovascular intervention from 2000 to 2022. The median age was 47.7 years (range 16-79), and 57.8% were female. Subarachnoid hemorrhage (SAH) was the initial presentation in 70.3% of aneurysms, and 29.7% were unruptured. The most common location was the anterior communicating artery region (40.6%), followed by the middle cerebral artery (25.0%). The median diameter was 6 mm (2-32) (Tables 2 and 3).

Endovascular Treatment Characteristics

Initial endovascular treatment included primary coiling (107 aneurysms), balloon-assist (10), stent-assist (4), intrasaccular device (3), flow diversion (2), and others (2) (Figure 2, Panel A). Complete aneurysm occlusion (Raymond Roy 1 [RR1]) and neck remnant (Raymond Roy 2 [RR2]) after initial embolization were recorded in 52 (40.6%) and 46 (35.9%), respectively. Fifteen percent (20 aneurysms), 3.1% (4), and 0.8% (1) underwent a second, third, and forth endovascular treatment, respectively (Table 4). Among the 46 aneurysms with neck remnant after initial treatment (RR2), 10 (21.7%) received a second and 2

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TABLE 1. Demographics and Cerebral Aneurysm Treatment Statistics[a]

	2005[b]	2006[b]	2007[b]	2008[b]	2009[b]	2010[c]	2011[c]	2012[c]	2013[c]	2014[c]	2015	2016	2017	2018	2019	2020
Population (Mio.)	18.4	18.5	18.6	18.6	18.6	18.9	19.0	19.0	19.0	19.1	19.3	19.3	19.4	19.5	19.5	19.6
Total aneurysms treated	1115	1027	1184	1155	1063	1299	1430	1414	1472	1354	1441	1544	1545	1553	1642	1557
Percent of population	0.006%	0.006%	0.006%	0.006%	0.006%	0.007%	0.008%	0.007%	0.008%	0.007%	0.007%	0.008%	0.008%	0.008%	0.008%	0.008%
Endovascular	727	633	736	681	565	731	846	837	892	822	841	990	925	947	1002	1008
Open surgery	388	394	448	474	498	568	584	577	580	532	600	554	620	606	640	549
Clip after failed embolization	4	8	5	5	8	3	5	4	5	8	5	10	10	12	8	6
Percent open surgery of endovascular procedures	0.6%	1.3%	0.7%	0.7%	1.4%	0.4%	0.6%	0.5%	0.6%	1.0%	0.6%	1.0%	1.1%	1.3%	0.8%	0.6%

[a]Data missing: For the years 2000 to 2004 and 2021 and 2022 aneurysm frequency data were missing.
[b]Data missing: Overall endovascular embolization and open aneurysm surgery frequency data missing from 2 centers.
[c]Data missing: Overall open aneurysm surgery frequency data missing from 1 center.

(20%) a third endovascular treatment attempt. Of the 30 aneurysms with aneurysm remnant (RR3), 3 (10%) were treated endovascularly a second time before surgery.

Comparison of Subarachnoid Hemorrhage Cases With Unruptured Aneurysms

There were 90 aneurysms presenting with SAH. Of these, 88 (97.8%) were in the anterior circulation and 2 (2.2%) in the posterior circulation. After initial endovascular treatment, complete occlusion (RR1) was achieved in 37 (41.1%) while 32 (35.6%) and 21 (23.3%) showed a neck (RR2) and aneurysm residual (RR3), respectively.

Thirty-eight aneurysms were treated elective. Of these, 36 (94.7%) were in the anterior circulation and 2 (5.3%) in the posterior circulation. Occlusion outcome after initial endovascular treatment were as follows: 15 (39.5%) RR1, 14 (36.8%) RR2, and 9 (23.7%) RR3.

Open Surgical Treatment Characteristics and Outcome

The median time between initial endovascular treatment and open surgery was 12 months. Seventy-one percent of aneurysms were treated with open surgery within 36 months of initial embolization (Figure 2, Panel B). In 9 aneurysms (7%), indication for surgery was (re-)rupture and, in 88.3%, reperfusion.

Incomplete initial endovascular treatment (RR2 [n = 46, 35.9%] and RR3 [n = 30, 23.4%]) was present in 76 aneurysms (59.3%) overall. Sixty-six aneurysms (86.8%) showed reperfusion of the neck remnant or residual aneurysm; in 6 aneurysms (7.9%), rerupture occurred; and during initial endovascular treatment of 2 aneurysms (2.6%), a parent vessel was perforated and open surgery was necessary. In the remaining 2 aneurysms, the indication for surgery was (1) mechanical compression of optic chiasm by thrombosed aneurysm sac after flow diverter and (2) aneurysm regrowth after coiling with anaphylactic reaction to contrast material injection during attempted endovascular reintervention.

In 52 aneurysms (40.7%), the initial endovascular treatment resulted in complete occlusion of the aneurysm. Most of these aneurysms presented with reperfusion (n = 47, 90.4%). Rerupture of the aneurysm occurred in 3 cases (5.8%). One aneurysm (1.9%) was treated with open surgery due to concomitant spontaneous intracerebral hematoma after 1 week (no aneurysm rerupture). And in the remaining aneurysm, the reason for open surgical treatment was not stated.

The chosen open treatment strategy included clipping in 93.8%, followed by wrapping (2.4%), bypass (1.6%), and aneurysm sac resection (1.6%). The median diameter of the reperfused aneurysm was 4 mm. Device removal was performed in 16.4%. Symptomatic intraoperative or postoperative complications occurred in 10.9% of aneurysms. The final modified Rankin score was between 0 and 2 in 104 aneurysms (81.3%)

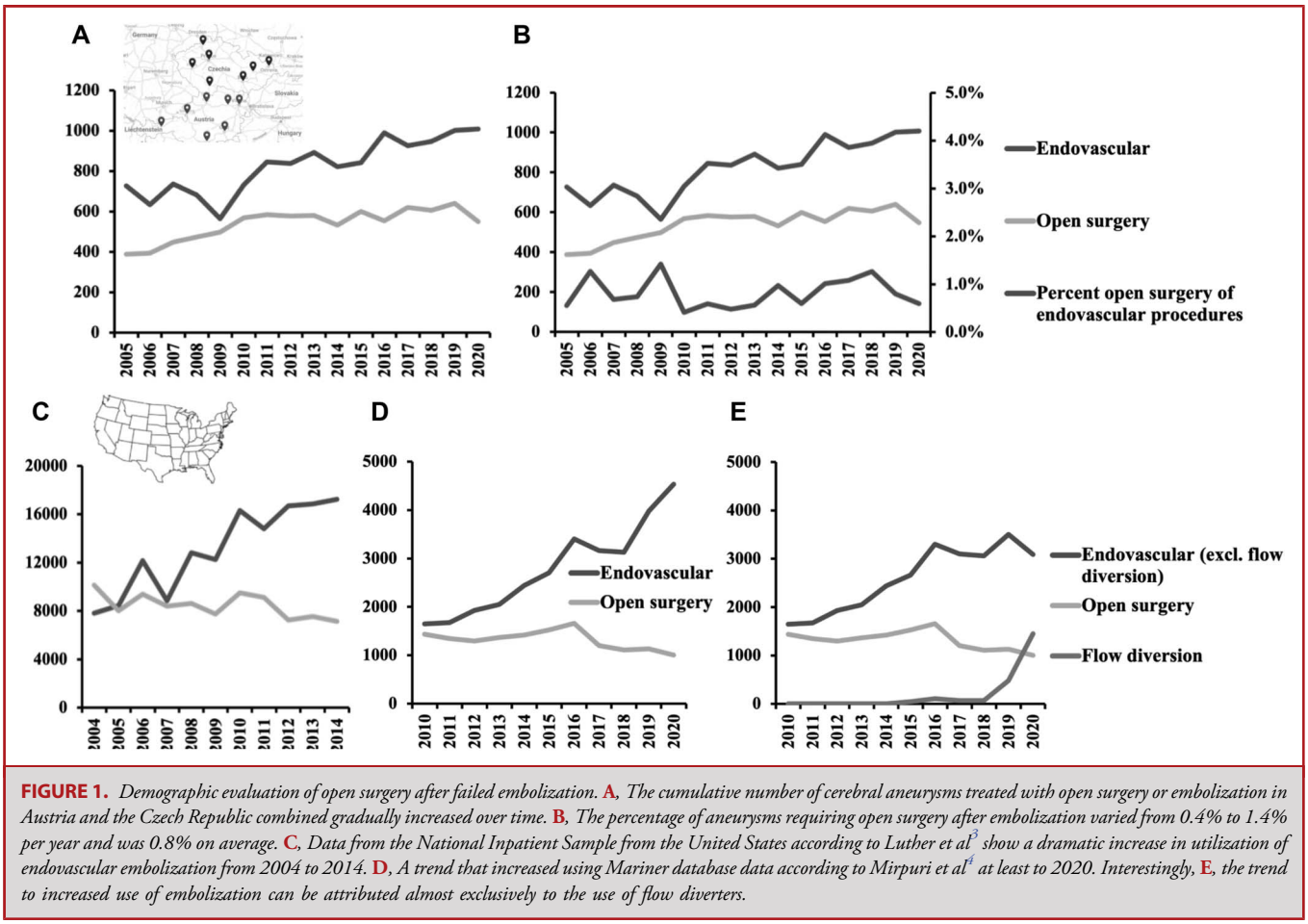

FIGURE 1. *Demographic evaluation of open surgery after failed embolization.* **A**, *The cumulative number of cerebral aneurysms treated with open surgery or embolization in Austria and the Czech Republic combined gradually increased over time.* **B**, *The percentage of aneurysms requiring open surgery after embolization varied from 0.4% to 1.4% per year and was 0.8% on average.* **C**, *Data from the National Inpatient Sample from the United States according to Luther et al*[3] *show a dramatic increase in utilization of endovascular embolization from 2004 to 2014.* **D**, *A trend that increased using Mariner database data according to Mirpuri et al*[4] *at least to 2020. Interestingly,* **E**, *the trend to increased use of embolization can be attributed almost exclusively to the use of flow diverters.*

and 6 (death) in 10 aneurysms (7.8%). Complete aneurysm occlusion after open surgery was achieved in 94% while 3.4% of aneurysms were left with an aneurysm remnant (Tables 5 and 6).

Predictors of Symptomatic Intraoperative or Postoperative Complications from Open Aneurysm Surgery

In the univariable logistic regression, we found that larger size of the initial aneurysm and of the residual/recurrent aneurysm conferred higher odds for developing symptomatic intraoperative or postoperative complications from open surgery (OR 1.13 [95%-CI: 1.02-1.25, P = .022] and OR 1.13 [95%-CI: 1.02-1.26, P = .025]), respectively. Univariable analysis of SAH presentation, temporary occlusion of parent vessel, endovascular device removal, and initial Raymond-Roy scale showed no significant influence. Neither did we find any significant results in the multivariable logistic regression analysis (Table 7).

DISCUSSION

This study represents the first and largest comprehensive evaluation of microsurgical clipping after failed endovascular embolization over a 22-year period for all neurovascular centers across Austria and the Czech Republic encompassing the era of advanced endovascular treatment techniques. Novel is also that this indication is put in context with overall cerebral aneurysm treatment frequencies.

Demographic Evaluation of Open Surgery After Failed Embolization

There is a trend toward increased utilization of endovascular embolization compared with microsurgical clipping in Austria and the Czech Republic. However, also open surgery for cerebral aneurysms was performed more often in 2020 compared with 2005 both in absolute and relative terms. When compared with administrative database data[3,4] from the United States, the United States saw a steep incline at which endovascular treatments were offered and an actual decline in open surgery for cerebral aneurysms. After 2018, the high number of endovascular

TABLE 2. Patient Characteristics

Parameters	n	(%)
No. of patients	126	(100)
No. of aneurysms	128	(100)
No. of ruptured aneurysms	90	(70.3)
No. of incidental aneurysms	38	(29.7)
Sex		
Female	74	(57.8)
Male	54	(42.2)
Median age in years (range)	47.72	(16-79)
Smoking[a]		
Nonsmokers	56	(43.8)
Former smokers	21	(16.4)
Present smokers	43	(33.6)
Arterial hypertension	70	(54.7)
Handedness		
Right	84	(65.6)
Left	1	(0.8)
No data	43	(33.6)
Family history of cerebral aneurysm[b]	7	(5.5)
Baseline mRS of patients with non-SAH	38	(100)
0	17	(44.7)
1	19	(50.0)
2	2	(5.3)
3-5	0	(0)

mRS, modified Rankin Scale; SAH, subarachnoid hemorrhage.
[a]Data missing in 8 aneurysms.
[b]Data missing in 1 aneurysm.

TABLE 3. Aneurysm Characteristics

Parameters	n	(%)
Acute SAH	90	(70.3)
Hunt & Hess Scale		
1	27	(30.0)
2	31	(34.4)
3	16	(17.8)
4	12	(13.3)
5	4	(4.4)
WFNS score[a]		
1	41	(45.6)
2	15	(16.7)
3	12	(13.3)
4	15	(16.7)
5	5	(5.6)
Modified Fisher CT Scale[b]		
0	2	(2.2)
1	16	(17.8)
2	9	(10.0)
3	38	(42.2)
4	24	(25.6)
Nonruptured aneurysm[b]	38	(29.7)
Incidental	31	(81.6)
Symptomatic (potentially)[c]	6	(15.8)
Aneurysm location		
Anterior comm. artery	52	(40.6)
Middle cerebral artery	32	(25)
Posterior comm. artery	16	(11.9)
Pericallosal artery	12	(9.4)
ICA ophthalmic	5	(3.9)
ICA not specified	4	(3.1)
ICA terminus	2	(1.6)
Basilar artery	2	(1.6)
ICA clinoidal	1	(0.8)
PICA	1	(0.8)
SCA	1	(0.8)

procedures performed was mostly driven by frequent utilization of flow diversion.

In this study, the percentage of aneurysms requiring open surgery after embolization varied from 0.4% to 1.4% per year and was 0.8% on average. We did not find an increased need for the open treatment approach although endovascular treatment frequencies increased over time. This is important because endovascular technologies advanced significantly over the past decade and novel endovascular devices such as flow diverters and intrasaccular devices have been introduced into the market earlier in Europe than the United States. Most aneurysms clipped after failed coiling presented with SAH and were initially treated with primary coiling.

TABLE 3. Continued.

Parameters	n	(%)
Side[a]		
Right	39	(30.5)
Left	33	(25.8)
Midline	54	(42.2)
Median size of aneurysm (mm) (range)	6	(2-32)

CT, computed tomography; ICA, internal carotid artery; PICA, posterior cerebellar artery; SAH, subarachnoid hemorrhage; SCA, superior cerebellar artery; WFNS, World Federation of Neurosurgery Score.
[a]Data missing in 2 aneurysms.
[b]Data missing in 1 aneurysm.
[c]Two patients had visual impairment, 2 presented with headaches, 1 patient with a generalized seizure, and 1 patient with a syncope.

Characteristics of Aneurysms Treated With Open Surgery after Failed Embolization

In the previous 2 decades, there has been a significant increase in the number of cerebral aneurysms managed with endovascular interventions (coiling, stent-assisted or balloon-assisted coiling, flow diversion, or intrasaccular devices [ie, WEB and Contour]).[3,4] However, the longevity of some of those techniques remain to be determined, and some endovascular intervention may not result in adequate aneurysm occlusion short-term or long-term and residual and recurrent aneurysms after endovascular treatment may pose a risk of (re)rupture. Although the Cerebral Aneurysm Rerupture After Treatment study found an association between degree of aneurysm occlusion after coiling and (re)rupture risk,[5] no such data are available for newer endovascular devices such as intrasaccular implants.

However, even in an era of stent-assisted coiling, flow diversion, and intrasaccular devices, open surgery for failed embolization is performed primarily in previously ruptured and primarily coiled aneurysms. In this study, only 3 aneurysms (2.3%) had been treated with an intrasaccular device and 2 (1.6%) with flow diversion. Although it is feasible to operate on those aneurysms as reported both after flow diverter[6,7] and intrasaccular treatment,[8-11] those cases are quite rare.

In general, the number of cohort studies looking at microsurgical treatment after failed embolization is limited.[12-14] This is also surprising given that endovascular embolization is frequently criticized for a lack of durability in aneurysm occlusion. Yet, it is mostly case reports that illustrate open surgical approaches for aneurysms where embolization failed. In this context, it is worth mentioning that just as open surgery is occasionally the only solution after failed endovascular treatment, embolization, in particular flow diversion, has also become popular for aneurysms not occluded after microsurgical clipping.[15,16]

The most recent and comprehensive study on clipping after failed embolization was published in 2016 by Daou et al[13] and included 111 patients who were previously coiled. Other endovascular techniques were not included. Seventy-nine percent presented with SAH at initial presentation, compared with 70.3% in this study. The second largest cohort on this topic was published by Dorfer et al who reported on the management of residual and recurrent aneurysms after initial embolization and included 52 cases where open surgery was performed as the ultimate treatment.[14]

Daou et al reported that most aneurysms (97.3%) were in the anterior circulation at the anterior communication (49.5%), posterior communicating (26.1%), or middle cerebral artery locations (8.1%). These data align well with this study where 96.9% were in the anterior circulation and 40.6% at the anterior

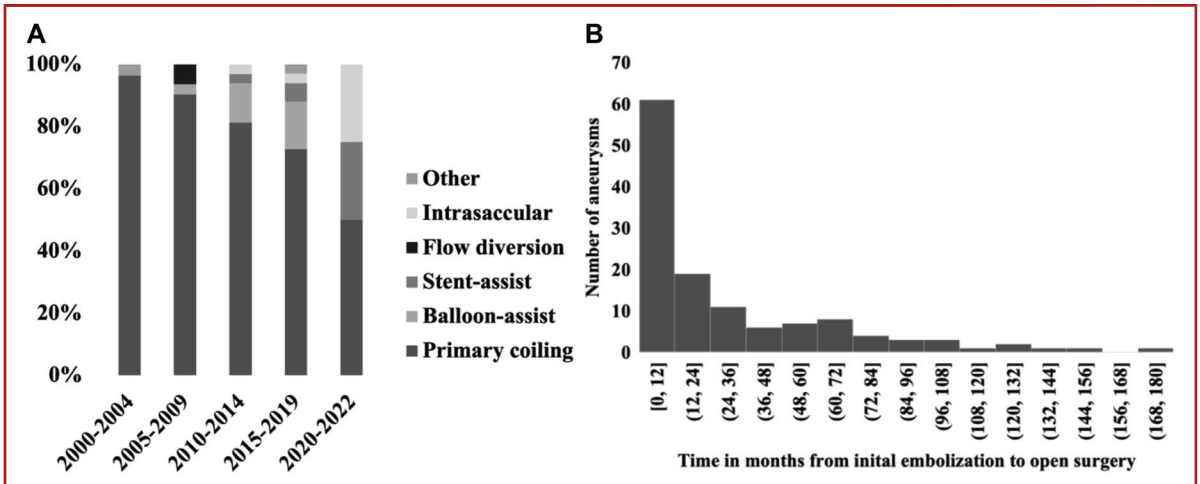

FIGURE 2. A, *Share of initial endovascular embolization modality per 5-year period. Histogram displaying the time from initial embolization to open surgery in months.* B, *Seventy-one percent of aneurysms were treated with open surgery within the first 36 months of initial embolization.*

TABLE 4. Endovascular Treatment Characteristics

Parameters	n	(%)
No. of aneurysms	128	(100)
No. of ruptured aneurysms	90	(70.3)
No. of nonruptured aneurysms	38	(29.7)
Initial endovascular treatment		
Primary coiling	107	(83.6)
Balloon-assisted coiling	10	(7.8)
Stent-assisted coiling	4	(3.1)
Intrasaccular device	3	(2.3)
Flow diversion	2	(1.6)
Stent without coiling	1	(0.8)
Parent artery occlusion	1	(0.8)
Raymond Roy scale		
Complete occlusion (1)	52	(40.6)
Neck remnant (2)	46	(35.9)
Aneurysm residual (3)	30	(23.4)
Symptomatic intraoperative and postoperative complication rate	13	(10.2)
Ischemic only	4	(3.1)
Hemorrhagic only	8	(6.3)
Ischemic/hemorrhagic combined	0	
Other complications[a]	1	(0.8)
Second endovascular treatment	20	(15.6)
Third endovascular treatment	4	(3.1)
Fourth endovascular treatment	1	(0.8)

[a]Aneurysm sac thrombosis after FD stent implantation resulting in optic nerve compression and vision loss; amaurosis in the left eye and temporal hemianopsia in the right eye.

TABLE 5. Open Surgical Treatment

Parameters	n	(%)
Median time between initial endovascular treatment and open surgical treatment (mo) (range)	12	(<1-170)
Indication for open surgery[a]		
Aneurysm residual/reperfusion	113	(88.3)
Aneurysm (re-)rupture	9	(7.0)
Other[b]	5	(3.9)
Method of open surgical treatment		
Clipping	120	(93.8)
Wrapping	3	(2.4)
EC/IC-Bypass	2	(1.6)
Aneurysm sac resection and clip reconstruction	2	(1.6)
Use of temporary artery occlusion[a]	29	(22.7)
Median diameter of residual/recurrent aneurysm area (mm) (range)	4.0	(<1-25)
Intraoperative device removal	21	(16.4)
Symptomatic intraoperative and postoperative complication rate	14	(10.9)
Ischemic only	5	(3.9)
Hemorrhagic only	5	(3.9)
Ischemic/hemorrhagic combined	3	(2.3)
Other[c]	1	(0.8)

EC/IC-Bypass, external carotid to internal carotid bypass.
[a]Data missing in 1 aneurysm.
[b]Other: (1) mechanical compression of optic chiasm by thrombosed aneurysm sac after flow diverter implantation; (2) aneurysm regrowth after coiling with anaphylactic reaction to contrast material injection during attempted endovascular reintervention; (3) intracerebral hematoma from middle cerebral artery aneurysm coiled initially with hematoma evacuation and aneurysm clipping after 1 week (no aneurysm rerupture); (4) 2 patients with intraprocedural parent vessel perforations during embolization requiring open surgery.
[c]Epidural abscess.

communicating, 25% at the middle cerebral, and 11.9% at the posterior communicating artery.

A second or third embolization attempt before clipping was performed in 15% and 1% of aneurysm, respectively, and the mean time from coiling to clipping was 23 months.[13] Here, we found that 15.6%, 3.1%, and 0.8% of aneurysms underwent a second, third, or forth embolization, respectively, and the mean time from initial embolization was only 12 months ranging from less than 1 to 170 months. The shorter time from embolization to open surgery may be explained by the higher rate of aneurysm (re) rupture (7%) compared with Daou et al who reported indication for surgery as aneurysm recurrence in 85.6% and residual in 14.4%, but no (re)rupture. Most instances of (re)rupture after inadequate embolization occur early after treatment and are rare after the first year.[17]

Preferred Open Surgical Solution and Clinical and Radiographic Outcomes

The open neurosurgical treatment options to treat a residual or recurrent aneurysm after embolization include clipping, wrapping, trapping, and bypass. In this study, bypass was required in only 1.6% of aneurysms, and all others were treated with clipping,

TABLE 6. Final Outcomes

Parameters	n	(%)
Outcome in mRS per aneurysm		
0	58	(45.3)
1	30	(23.4)
2	16	(12.5)
3	6	(4.7)
4	7	(5.5)
5	1	(0.8)
6	10	(7.8)
Final angiographic outcome[a]		
Complete occlusion	109	(94.0)
Neck remnant	3	(2.6)
Aneurysm remnant	4	(3.4)
Type of vascular imaging at last[b]		
DSA	65	(56.5)
CTA	32	(27.8)
MRA	17	(14.8)
CTA + MRA	1	(0.9)

CTA, computed tomography angiography; DSA, digital subtraction angiography; MRA, magnetic resonance angiography; mRS, modified Rankin Scale.
[a]Data missing in 12 aneurysms.
[b]Data missing in 13 aneurysms.

wrapping, or a combination thereof. Daou did not report a single bypass case in their series while the rate reported by Dorfer was higher at 9.6%.[13,14] This underlines the fact that a significant number of aneurysms which recur after embolization are managed sufficiently with clipping albeit the treatment approach has to be tailed and individualized to each specific situation, and combination treatments such as bypass combined with parent vessel occlusion are also suitable.[14] As one might expect, complication rates from operating on embolized aneurysms are higher than with treatment-naive aneurysms. In this study, neurologic complications from clipping occurred in 10.2% of aneurysms. Dorfer et al reported a surgical treatment morbidity of 15.6%,[14] whereas Daou et al[13] reported major complications in 8% of patients and mortality in 2.7%. Aneurysm size and location in the posterior circulation were associated with complications, as was coil extraction from the aneurysm. Higher complication rates by Dorfer et al[14] are explained by a higher rate of posterior circulating aneurysms and larger aneurysm sizes in their series. Here, we found initial aneurysm size as well as size of residual and recurrence of the aneurysm associated with symptomatic complications from open surgery. However, no factor was significant in the multivariable analysis, in particular there was no association with endovascular device removal. Nevertheless, the authors recommend against device removal unless it is necessary to maintain parent vessel patency.

Complete occlusion of the aneurysm in the present cohort was achieved in 94% and compared well with Daou et al[13] who reported 97.3% or Dorfer et al with 88.5%.[14]

Limitations

The main limitation of this study is the retrospective character. Retrospective data collection going back more than 20 years is prone to recall bias. In addition, outcome assessment was performed at each center individually and not adjudicated by a blind and independent assessor.

CONCLUSION

Open surgery remains a rare indication for cerebral aneurysms after failed endovascular embolization even in the age of novel

TABLE 7. Predictors of Symptomatic Intraoperative or Postoperative Complications From Open Aneurysm Surgery

	Univariable			Multivariable		
Parameter	OR	95% CI	*P* value	OR	95% CI	*P* value
Subarachnoid hemorrhage presentation	1.06	0.31-3.67	.928	0.94	0.21-4.27	.933
Aneurysm size	1.13	1.02-1.25	**.022**	1.05	0.88-1.25	.598
Raymond Roy scale after initial embolization (RR1/RR2 and RR3)	1.07	0.33-3.45	.914	1.50	0.34-6.74	.595
Temporary occlusion	0.63	0.18-2.20	.464	0.41	0.10-1.71	.218
Endovascular device removal	0.62	0.16-2.47	.497	1.03	0.18-5.88	.976
Diameter of aneurysm residual/recurrence	1.13	1.02-1.26	**.025**	1.11	0.91-1.35	.291

OR, odds ratio; RR, Raymond Roy scale.
Bold indicates statistically significant *P* value.

endovascular technology, such as flow diverters and intrasaccular devices. Regardless, even today, it is mostly performed for ruptured aneurysms initially treated with primary coil embolization that are in the anterior circulation.

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