Neurosurgical Review (2019) 42:877–884
https://doi.org/10.1007/s10143-018-01063-3

ORIGINAL ARTICLE

A literature review concerning contralateral approaches to paraclinoid internal carotid artery aneurysms

Lucas Ezequiel Serrano [1] · Ali Ayyad [1] · Eleftherios Archavlis [1] · Eike Schwandt [1] · Amr Nimer [2] · Florian Ringel [1] · Sven Rainer Kantelhardt [1]

Received: 4 October 2018 / Revised: 12 November 2018 / Accepted: 23 November 2018 / Published online: 6 December 2018

Abstract

Ipsilateral approaches remain the standard technique for clipping paraclinoid aneurysms. Surgeons must however be prepared to deal with bony and neural structures restricting accessibility. The application of a contralateral approach has been proposed claiming that some structures in the region can be better exposed from this side. Yet, only few case series have been published evaluating this approach, and there is a lack of systematic reviews assessing its specific advantages and disadvantages. We performed a structured literature search and identified 19 relevant publications summarizing 138 paraclinoid aneurysms operated via a contralateral approach. Patient's age ranged from 19 to 79 years. Aneurysm size mainly varied between 2 and 10 mm and only three articles reported larger aneurysms. Most aneurysms were located at the origin of the ophthalmic artery, followed by the superior hypophyseal artery and carotid cave. All aneurysm protruded from the medial aspect of the carotid artery. Interestingly, minimal or even no optic nerve mobilization was required during exposure from the contralateral side. Strategies to achieve proximal control of the carotid artery were balloon occlusion and clinoid segment or cervical carotid exposure. Successful aneurysm occlusion was achieved in 135 cases, while 3 ophthalmic aneurysms had to be wrapped only. Complications including visual deterioration, CSF fistula, wound infection, vasospasm, artery dissection, infarction, and anosmia occurred in a low percentage of cases. We conclude that a contralateral approach can be effective and should be considered for clipping carefully selected cases of unruptured aneurysms arising from medial aspects of the above listed vessels.

Keywords Contralateral approach · Paraclinoid aneurysm

Introduction

Paraclinoid aneurysms still constitute a complex challenge for cerebrovascular surgeons. The complex vascular anatomy of clinoid and ophthalmic segments of the internal carotid artery (oICA) and its branches and its close relation to the optic nerves, the cavernous sinus, and the anterior clinoid process make it difficult to completely expose these aneurysms and to achieve adequate proximal control. All this contributes to the high morbidity rates reported in literature when treating these aneurysms [9, 11, 14, 18, 27, 29, 30].

In the last decades, the great advances achieved in the field of endovascular treatment have allowed to effectively treat paraclinoid aneurysms sparing the risks of cranial surgery [11, 20, 21, 38, 40, 47]. However, endovascular techniques have their own limitations. Complex aneurysm and/or vessel configurations can prevent complete occlusion which increases the risk of aneurysm regrowth and (re-) bleeding [21]. In addition, the occlusion of small, not angiographically visible, perforating branches can lead to ischemic complications affecting the optic apparatus, hypothalamus, internal capsule, or the basal ganglia, with potential devastating consequences [6, 38, 43]. Furthermore, the use of stents or flow-diverting devices implies the need of lifelong platelet antiaggregant therapy with its associated bleeding risk [45].

Lucas Ezequiel Serrano and Ali Ayyad are joint first authors.

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s10143-018-01063-3) contains supplementary material, which is available to authorized users.

✉ Lucas Ezequiel Serrano
lucas.serrano@unimedizin-mainz.de

1 Department of Neurosurgery, Mainz University Hospital, Langenbeckstraße 1, 55131 Mainz, Germany

2 Department of Neurosurgery, Charing Cross Hospital, Imperial College Healthcare, Fulham Palace Rd, London W6 8RF, UK

Finally, endovascular techniques are unable to solve the problem of mass effect of aneurysms compressing highly sensible neural structures, such as the optic nerve.

In this context, the role of surgery is far from having been replaced and has turned into an even more demanding challenge. Neurosurgeons must nowadays deal with aneurysms that cannot be treated by endovascular means due to anatomical limitations or where it failed, and those aneurysms which compress important structures. Additionally, it is important to remember that in many undeveloped countries, endovascular techniques are not available in a vast majority of centers and surgery remains the only treatment option for patients presenting with this pathology.

Even though ipsilateral approaches are the standard for clipping paraclinoid aneurysms, some experienced neurosurgeons have advocated the contralateral approach, asserting that the anatomy of the paraclinoid region is best exposed from the contralateral side [9, 13, 28, 39, 44, 46]. Furthermore, the high incidence of multiplicity shown by paraclinoid aneurysms encourages neurosurgeons to be able to approach both sides through a single one-sided craniotomy [13, 28, 37, 44].

Small case series report on contralateral approaches in selected patients. However, to date, there is a lack of cross-comparative analysis assessing epidemiological, clinical, anatomical, and surgical characteristics; pitfalls; limitations; and complications of contralateral approaches in a structured way.

Methods

Relevant articles were first identified in a PubMed search by the following Boolean search terms: "aneurysm" AND ("approach" OR "approaches") AND ("contralateral" OR "unilateral" OR "bilateral") on August 2018. All works referring to extracranial aneurysms (aortic, renal, etc.) were excluded in a first step.

In a second step, we included articles referring to intracranial aneurysms in this work only if all the following criteria were fulfilled:

- The article described explicitly the surgical treatment of any paraclinoid aneurysm (understood as carotid-ophthalmic, superior hypophyseal, or carotid cave's aneurysm) from the contralateral side.
- Clinical, epidemiological, surgical, and postoperative data was available from those patients treated specifically on paraclinoid aneurysms using a contralateral approach.

We excluded all works if any of these criteria was fulfilled:

- The work did not explicitly report the treatment of any paraclinoid aneurysm.
- Paraclinoid aneurysms had not been approached contralaterally, or the information regarding to the approach side specifically to the paraclinoid aneurysms reported was irretrievable.
- Patient's clinical, epidemiological, surgical, and postoperative data were not available, or in series reporting different aneurysm types and approaches, the data corresponding specifically to patient presenting paraclinoid aneurysms clipped from the contralateral side could not be retrieved (i.e., data were referred to the general patient population with no discrimination of specific data from those patients presenting paraclinoid aneurysms clipped through a contralateral craniotomy).

The search and review process of the articles was performed by the corresponding author of this work, and only articles published in the English language were included. After identification of relevant works, additional articles were identified by crossing references.

We analyzed in each particular publication all data provided by the authors regarding epidemiological patient data (i.e., age and gender), aneurysm distribution, size, localization, shape and projection, surgical approach used and intraoperative manipulations required (optic nerve mobilization, removal of the planum sphenoidale and tuberculum sellae, etc.), and clinical outcome and complications.

Results

Applying the abovementioned Boolean search terms, the PubMed search retrieved 639 articles, which were then screened by the corresponding author of this work. After excluding articles concerning extracranial locations, 359 articles were left. Finally, we identified 19 case reports and series published between 1981 and 2018, reporting clinical and surgical data of patients presenting with paraclinoid aneurysms and who had undergone surgical treatment through a contralateral approach (see Table 1).

These publications report on 138 paraclinoid aneurysms operated via a contralateral approach. The largest series by Andrade-Barazarte et al. comprises 30 patients with aneurysms of the oICA [2]. Other further series comprised 13 and 23 patients; most other reports are single cases [33, 44] (Table 1). Patient's age at the time of surgery variated from 19 up to 79 years, and the number of women exceeded men in the majority of these series (Table 1).

One hundred twenty-six aneurysms approached from the contralateral side were unruptured. In these cases, 47 patients presented with subarachnoid hemorrhage from other aneurysms. In these reports, the ruptured aneurysm was generally approached first and from the ipsilateral side. The authors then proceeded to clipping contralateral

Table 1 A survey of published studies using contralateral approaches to treat paraclinoid aneurysms. *M*, male; *F*, female; *NS*, not specified; *OA*, ophthalmic artery; *SHA*, superior hypophyseal artery; *CC*, carotid cave

Ref.	*N*	Median (min/max) age	Sex (%)		Aneurysm distribution (%)		Aneurysm size	Aneurysm localization	Projection	Approach	Complete occlusion?	Contralateral optic nerve mobilization	Way to achieve proximal control	Complications	Outcome
			M	F	Unilateral	Bilateral									
Nakao 1981	2	40.5 (36/45)	0	100	50	50	NS	OA	Posteromedial	Pterional	Yes	Not required	NS	None	Good
Milenkovic 1982	1	48	0	100	0	100	NS	OA	NS	Pterional	Yes	NS	NS	Intraoperative bleeding from other aneurysms	Good
Yamada 1984	4	51.5 (32/57)	0	100	75	25	NS	OA	Medial	Pterional	Yes	Not required	NS	Vasospasm 25%	Good 50%
														Mild hemiparesis 25%	Fair 50%
Nishio 1985	1	55	0	100	0	100	10 mm	OA	Inferomedial	Pterional	Yes	Not required	NS	None	Good
Shiokawa 1988	1	44	0	100	0	100	NS	OA	Medial	Bifrontal	Yes	NS	NS	None	Good
Vajda 1988	23	NS	NS	NS	50	50	4–35 mm	OA	NS	Pterional	NS	Slight mobilization if aneurysm > 15 mm	NS	NS	NS
Oshiro 1997	1	NS	NS	NS	0	100	NS	OA	NS	Pterional	Yes	NS	NS	None	NS
Fries 1997	10	53.5 (33/64)	20	80	90	10	< 10 mm 60%	OA 60%	Medial 60%	Supraorbital	Yes 80%	NS	Balloon occlusion + clinoid segment exposure	Visual deficits 10%	Good 70%
							10–24 mm 40%	SHA 40%	Superomedial 20%		Wrapping 20%				Fair 10%
									Anteromedial 10% Superior 10%						Poor 10% Dead 10%
Kakizawa 2000	11	60 (55/76)	18	82	37	63	< 5 mm	OA	Superomedial 45% Inferomedial 55%	Pterional	Yes	Not required 73% Slight mobilization 27%	Cervical exposure	None	NS
Sheick 2000b	4	55.5 (48/60)	50	50	100	0	< 5 mm	CC	Inferomedial 25% Medial 75%	Pterional/bifrontal	Yes	Slight mobilization	Balloon occlusion	None	Good
Hongo 2001	1	69	0	100	0	100	25 mm	OA	Superomedial-posterior	Pterional	Yes	Not required	Clinoid segment exposure	None	Good
McMahon 2001	9	44 (38/60)	22	78	0	100	NS	OA 77% SHA 23%	NS	Pterional	Yes	Not required	NS	Visual deficits 11% Artery dissection 11% *N. caudatus* infection 11%	Good 78% Fair 11% Dead 11%
Pereira 2006	13	NS	NS	NS	0	100	NS	OA 84% SHA 16%	NS	Pterional		NS	NS	Visual deficits 23%	Good
Park 2009	2	44 (25/63)	0	100	0	100	NS	OA 50% SHA 50%	NS			NS	NS	Anosmia 50%	Good
Chandela 2011	1	37	0	100	0	100	NS	OA	Medial	Pterional	Yes	NS	Cervical exposure	None	NS
Chen 2013	8	60.5 (28/77)	25	75	100	0	< 5 mm	SHA	Inferomedial 75%	Pterional	Yes	Not required 62%	Balloon occlusion	None	NS
									Superomedial 25%			Slight mobilization 25% Significant mobilization 13%			
Nacar 2014	11	47 (24/62)	11	89	0	100	< 6 mm	OA	Superior 64% Medial 18%	Pterional	Yes 91% Wrapping 9%	Not required 82% Slight mobilization 18%	NS	Pneumonia 9% Visual deficits 9%	Good 91% Dead 11%
									Superomedial 9%						

Table 1 (continued)

Ref.	N	Median (min/max) age	Sex (%) M	Sex (%) F	Aneurysm distribution (%) Unilateral	Aneurysm distribution (%) Bilateral	Aneurysm size	Aneurysm localization	Projection	Approach	Complete occlusion?	Contralateral optic nerve mobilization	Way to achieve proximal control	Complications	Outcome
Andrade-Barazarte 2015	30	45 (19/79)	17	83	15	85	<7 mm 96% 7–14 mm 4%	OA	Anteromedial 9% Superomedial 76% Medial 13%	Supraorbital	Yes	NS	NS	CSF leakage 7% Wound infection 7% Visual deficits 3%	Good 93% Poor 7%
Yu 2017	5	54 (47/65)	NS	NS	0	100	2–14 mm	OA	Superior 10% Medial	Pterional	NS	NS	NS	NS	Good

innocent aneurysms, through the same craniotomy in the same surgical session [2, 23, 27–29, 31, 32, 37, 39, 44, 48, 50]. An exception was the case of a 48-year-old woman who was treated for a ruptured left middle cerebral artery aneurysm whose contralateral previously incidental carotid-ophthalmic aneurysm ruptured intraoperatively and was consequently clipped first [25]. Vajda et al. approached primarily 12 ruptured carotid-ophthalmic aneurysms contralaterally, being 50% of these single and 50% associated to other unruptured aneurysms [44]. In 79 cases in which no subarachnoid hemorrhage occurred, aneurysms were either diagnosed incidentally through MRI performed for other reasons or had manifested with visual deficits caused by direct compression of the optic nerve [23]. Ninety-six paraclinoid aneurysms treated through a contralateral approach were associated with aneurysms on the craniotomy side. Like in the 47 SAH cases mentioned above, contralateral approaches were employed in order to spare a second craniotomy.

Most paraclinoid aneurysms approached contralaterally were ophthalmic artery aneurysms. Only four works reported contralateral approaches to both ophthalmic and superior hypophyseal artery aneurysms [13, 23, 32, 33]. Chen et al. conducted a study of contralateral approaches specifically to superior hypophyseal artery aneurysms, and Sheick et al. specifically described contralateral approaches to carotid cave aneurysms [5, 37]. Most aneurysms treated contralaterally were small with maximum diameter of 2 to 10 mm. Only three authors reported successful clipping of exceptional large or giant aneurysms [13, 15, 44]. Aneurysm projection was always medial, with the dome directed either superiorly, inferiorly, anteriorly, or posteriorly (Table 1).

Most surgeons choose a pterional approach for contralateral clipping of paraclinoid aneurysm. Some used modifications, such as combining it with semi-sitting position in order to reduce the venous pressure in the cavernous sinus [37]. Two works however emphasized the effectiveness of the supraorbital approach to attempt clipping of contralateral paraclinoid aneurysms [2, 13]. Sheick et al. used in a bifrontal craniotomy in one patient to treat a contralateral carotid cave aneurysm associated to a tuberculum sellae meningioma [37]. The same approach was applied by Shiokawa et al. in a single case of a contralateral approach to a medially pointing ophthalmic artery aneurysm [39].

Intraoperatively, contralateral approaches were reported to require no or only minimal optic nerve mobilization. Only three articles specified the need of drilling the tuberculum sellae and/or planum sphenoidale [16, 29, 37]. Most articles did not explicitly describe how proximal vessel control was achieved. In general, the strategies proposed were balloon occlusion of the internal carotid artery [5, 13, 37], clinoid segment exposure [13, 15], and cervical carotid exposure [4, 16].

Complete aneurysm occlusion was reported for all but three ophthalmic aneurysms which needed to be wrapped, since clipping was technically not possible due to aneurysm size and configuration [13, 27]. Of 19 studies reviewed, only 2 did not provide detailed descriptions to allow us to assess whether specifically the patients with carotid-ophthalmic aneurysms presented complications after surgery (although an overall analysis among all patients with different contralateral aneurysm localizations was provided) [44, 50]. Of the remaining 17 publications, only 5 reported sporadic cases of postsurgical visual deterioration [2, 13, 23, 27, 33]. The percentage of this complication ranged between 3% (1 out of 30 patients) and 23% (3 out of 13 patients) [2, 33]. The other 3 articles reported visual deterioration in about 10% of the patients (altogether 3 out of 30 patients) [13, 23, 27]. Olfactory deficits were not specifically reported in the majority of the studies (18 of 19 publications). Only Park et al. reported a single case of anosmia [32]. Cerebrospinal fluid leak and wound infection were reported in the work of Andrade-Barazarte with a rate of 2 cases out of 30 patients (7%) [2]. In the report of 4 patients from Yamada et al., one patient suffered from vasospasm and other was discharged with a mild hemiparesis due to the hemorrhage [48]. Other postoperative complications such as artery dissection and infarction of the caudate nucleus were described in only one study in one single case out of 9 patients (11%) [23].

Good patient performance was reported between 70 and 93% (corresponding the last to the largest and one of the most recent series published [2]). Just one small 4-patient series from 1984 (including 2 patients with subarachnoid hemorrhage) reported a worse rate with one patient with good and one with mild performance status (50% each) [48]. In all single-patient reports, the clinical outcome was reported to be good. Poor outcome and death rates ranged from 7 to 11% throughout all case series, compromising subarachnoid hemorrhage only.

Discussion

Paraclinoid aneurysms tend to arise from the median aspect of the oICA and commonly point in the same direction. This is mainly an effect of its anatomy, namely the fact that the ophthalmic and the superior hypophyseal arteries arise usually from its medial aspect and that the lateral aspect is in direct contact to the anterior clinoid process. These anatomical characteristics, added to the close relationship to the optic nerve, likewise limit the surgical approach from the ipsilateral side. Since the medial wall of the oICA can be exposed from the contralateral side through the interoptic space, contralateral approaches might offer a better solution. Aneurysm domes projecting medially, superiorly, superomedially, or inferomedially could thus be accessed contralaterally [8, 9, 27, 29]. Aneurysms arising from the lateral wall of the ophthalmic segment and projecting superolaterally or laterally in contrast can be better approached via an ipsilateral craniotomy, limiting the risk of optic nerve damage and poor visualization [2]. Additionally, most works agree that the aneurysm size should be less than 10 to 15 mm for safe clipping via the interoptic space [2, 13, 16, 23, 49]. Larger aneurysms may require complex surgical techniques that would require excessive mobilization of the contralateral optic nerve. Nevertheless, occlusion of a giant aneurysm through a contralateral approach has been reported [15]. In this single case, the medial projection and narrow neck favored contralateral approach, which highlights another important factor: the aneurysm's shape. According to most authors, only saccular aneurysms with simple configurations make their clipping straightforward using the contralateral approach [2, 8, 9].

Of course, the individual size of the interoptic space has to be considered, and most authors point out that a larger window favors contralateral approaches [2, 13, 23]. In cases where the interoptic space is reduced or the chiasm is prefixed, the contralateral approaches are rendered more difficult and dangerous [5, 29, 31, 49]. Andrade-Barazarte et al. consider a median prechiasmatic distance (distance between the anterior borders of the chiasm to the tuberculum sellae) of 5.7 mm and a median interoptic distance (distance between the medial aspects of both optic nerves at the entrance to the optic channel) of 10.5 mm sufficient for contralateral approaches [2]. Kakizawa et al. report corresponding values of a prechiasmatic distance of at least 5.4 mm and an interoptic distance of 10.4 mm [16].

According to literature, contralateral approaches to the oICA are thus feasible in 97% of the cases [2, 13, 31, 44]. This fact is illustrated in by our illustrative case (Figs. 1 and 2 and Video 1). As observed in this case, wide anatomical exposure and successful clipping of a medially pointing paraclinoid aneurysm could be achieved using a contralateral approach, having obtained proximal carotid control by placing angiographically a catheter into the contralateral ICA prior to surgery, which enabled balloon occlusion of the ICA if necessary. In this case, we applied a "keyhole" craniotomy propagated by Perneczky and co-workers. However, the case was selected as it illustrates the view and visualization of the ICA from the contralateral side rather well and is not intended to propagate the size of the craniotomy, since the discussion the "keyhole concept" is beyond the scope of this work and has been led elsewhere [12, 34, 35, 41, 46].

Anterior clinoidectomy, essential for the ipsilateral approaches, is not routinely required during contralateral approaches, and aneurysm exposure can be achieved with minimal optic nerve mobilization. This does help not only to reduce surgical time [16] but also to reduce the risk of visual deterioration, a main concern in conventional ipsilateral clipping of paraclinoid aneurysms [11, 19, 36, 40]. However,

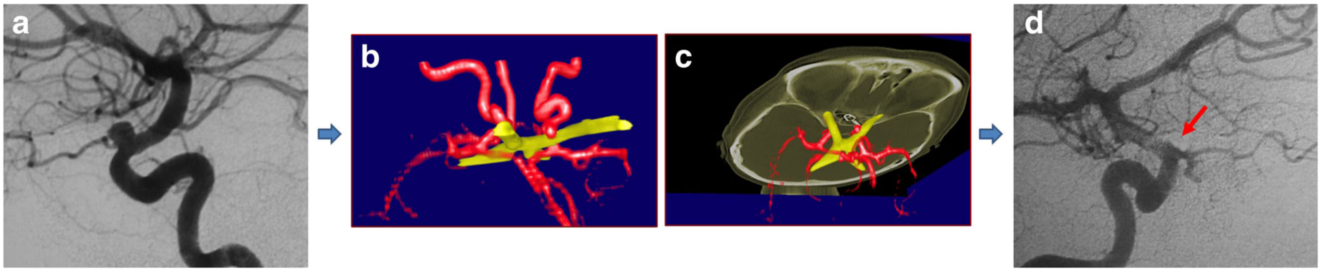

Fig. 1 An illustrative surgical case of a 41-year-old woman presenting in our department with a scotoma of the right visual field caused by a medially pointing left paraclinoid aneurysm, as demonstrated in preoperative angiograms (**a**). Since in this case, we decided to operate via a "keyhole" craniotomy (which is however not the point to be illustrated or discussed); we preoperatively performed a 3D anatomical reconstruction of the aneurysm and its relationships to the optic apparatus (**b**) and bony structures (**c**) in a virtual workspace. This allowed optimal positioning of the "keyhole" craniotomy. Postoperative angiograms showed a complete aneurysm occlusion (**d**), and the patient recovered without adding neurological deficits or other complications

given the heterogeneity of data, a definitive statement comparing visual function and neurological outcome following ipsi- and contralateral approaches cannot be provided. For that aim, systematic clinical trials are still needed.

Limitations of contra- compared to ipsilateral approaches to the oICA include the need for mobilization of the olfactory nerve (with potentially severe consequences for the quality of life if both olfactoric nerves are damaged [3, 10, 26, 42]), the longer working distance, and the difficulty to achieve proximal vessel control.

While it remains unclear how much mobilization of the olfactory nerve can tolerate, it has a remarkable capacity for neural regeneration and recovery if the nerve's continuity is respected [17]. Therefore, great care should be taken to preserve the nerve's continuity. For unilateral approaches to bilateral aneurysms of the middle cerebral artery (MCA), rates

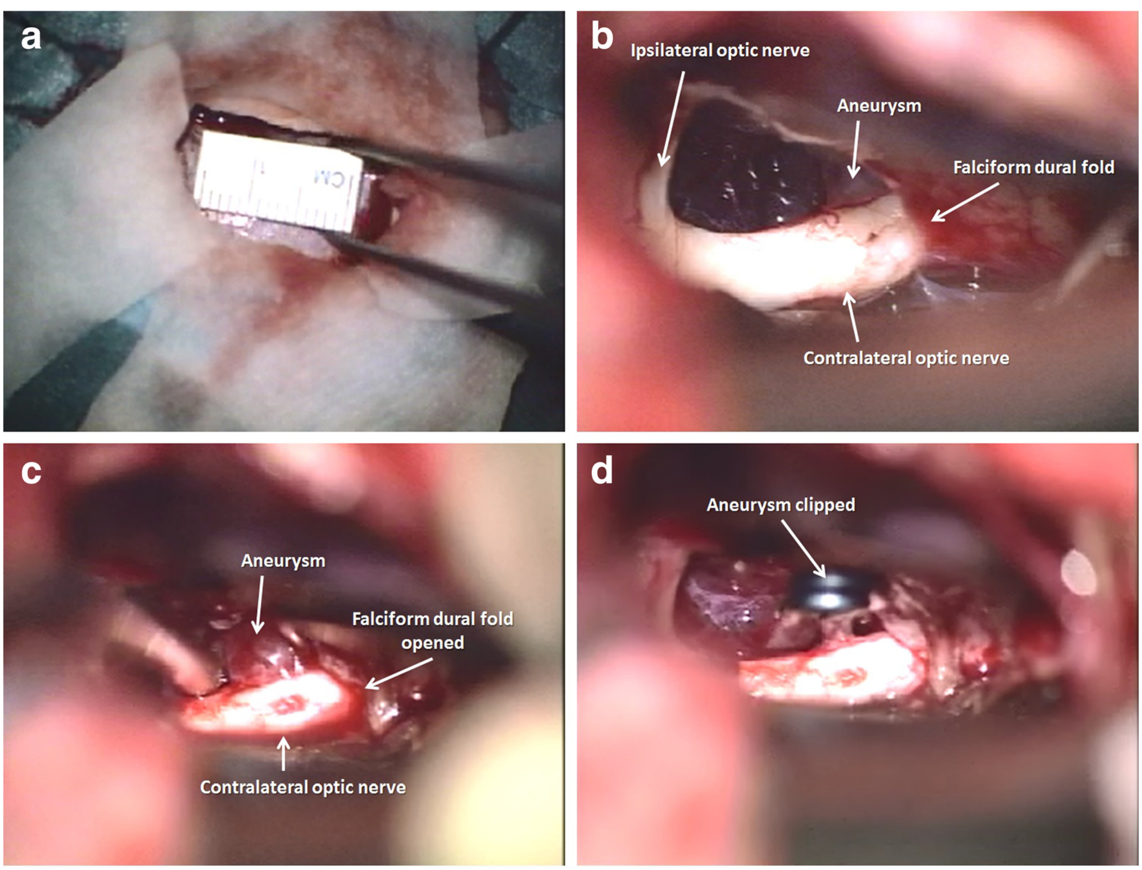

Fig. 2 Intraoperative captures showing contralateral clipping of a paraclinoid carotid aneurysm in our illustrative case. A supraorbital craniotomy was performed (**a**) and dissection proceeded straightforward towards the optic apparatus. The aneurysm dome could be fully exposed through the space between both optic nerves (**b**, **c**), and clipping could be performed successfully needing minimal optic nerve mobilization (**d**)

of hyposmia and anosmia of 8 and 13% have been reported [2, 7]. In the series of Yu et al. [50], the rate of hyposmia for contralateral approaches was 6.3%. Park et al. report hyposmia and anosmia rates of 17 and 42% in 12 patients operated from the contralateral side [32]. This however includes 10 patients with aneurysms located more distally (ICA bifurcation or MCA) which require the placement of a self-retaining retractor on the inferior surface of both frontal lobes, submitting both olfactory nerves to higher injury risk [7, 32].

The difficulty to achieve proximal vessel control during contralateral approaches to the oICA has been mentioned by several authors [2, 5, 13, 37]. Due to patient's positioning, cervical portion of the ICA is pointing away from the surgical field, rendering cervical ICA compression or ligation difficult. The same applies to exposure of ICA's petrous segment. Achieving proximal control therefore requires application of other techniques. For aneurysms arising distally to the clinoid ICA, the resection of the distal dural ring of the ICA can be performed without causing major bleeding from the cavernous sinus, exposing about 3 additional mm of the ICA which might be just enough for placement of a temporary clip [13]. For more proximally located aneurysms, balloon occlusion of the ICA can be performed [5, 13, 37]. Other surgeons use adenosine-induced transitory cardiac arrest, a method which has been demonstrated to be safe and effective in aneurysm microsurgery if correctly applied [1, 2, 22, 24]. Finally, the application of a radiolucent Sugita head frame, which enables head rotation, to enable contralateral cervical ICA exposure has been suggested [4]. Fortunately, since contralateral approaches are generally recommended for unruptured aneurysms and a careful patient selection is required, intraoperative rupture of aneurysms approached contralaterally remains a rare event [2, 9, 13, 16, 23].

Conclusion

Contralateral approach can be effective to clip medially pointing, unruptured, preferably small paraclinoid ICA aneurysms. The contralateral approach seems to reduce the need of optic nerve mobilization and anterior clinoidectomy associated with the risk of visual deterioration. Even though surgical trials comparing ipsi- vs. contralateral approaches in a systematic fashion are still needed, published cases show that if patients are correctly selected and the individual anatomy is carefully considered, excellent results can be achieved.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval Ethical committee approval was not required as presented data corresponds to a review of published literature. The data corresponding to our exemplary surgical case (see "Discussion") are anonymized, and there is no risk of identification.

Informed consent Consent was not obtained given that presented data corresponding to our exemplary surgical case (see "Discussion") are anonymized and there is no risk of identification.

References

1. Alaa A-M, Bose G, Hunt K, Toma AK (2017) Adenosine-assisted neurovascular surgery: initial case series and review of literature. Neurosurg Rev 1–8
2. Andrade-Barazarte H, Kivelev J, Goehre F, Jahromi BR, Hijazy F, Moliz N, Gauthier A, Kivisaari R, Jaaskelainen JE, Lehto H, Hernesniemi JA (2015) Contralateral approach to internal carotid artery ophthalmic segment aneurysms: angiographic analysis and surgical results for 30 patients. Neurosurgery 77:104–112; discussion 112. https://doi.org/10.1227/NEU.0000000000000742
3. Blomqvist EH, Bramerson A, Stjarne P, Nordin S (2004) Consequences of olfactory loss and adopted coping strategies. Rhinology 42:189–194
4. Chandela S, Chakraborty S, Ghobrial GM, Jeddis A, Sen C, Langer DJ (2011) Contralateral mini-craniotomy for clipping of bilateral ophthalmic artery aneurysms using unilateral proximal carotid control and Sugita head frame. World Neurosurg 75:78–82; discussion 41–72. https://doi.org/10.1016/j.wneu.2010.06.028
5. Chen S, Kato Y, Kumar A, Sinha R, Oguri D, Oda J, Watabe T, Imizu S, Sano H, Hirose Y (2013) Contralateral approach to unruptured superior hypophyseal artery aneurysms. J Neurol Surg A Cent Eur Neurosurg 74:18–24. https://doi.org/10.1055/s-0032-1326944
6. Chen Z, Yang Y, Miao H, Li F, Zhang J, Feng H, Zhu G (2013) Experiences and complications in endovascular treatment of paraclinoid aneurysms. J Clin Neurosci 20:1259–1263. https://doi.org/10.1016/j.jocn.2012.09.043
7. Cho MJ, Oh CW, Kwon O-K, Byoun HS, Lee SU, Kim T, Chung YS, Ban SP, Bang JS (2017) Comparison of unilateral and bilateral craniotomy for the treatment of bilateral middle cerebral artery aneurysms: anatomic and clinical parameters and surgical outcomes. World neurosurgery 108:627–635
8. Clatterbuck RE, Tamargo RJ (2005) Contralateral approaches to multiple cerebral aneurysms. Neurosurgery 57:160–163 discussion 160–163
9. de Oliveira E, Tedeschi H, Siqueira MG, Ono M, Fretes C, Rhoton AL Jr, Peace DA (1996) Anatomical and technical aspects of the contralateral approach for multiple aneurysms. Acta Neurochir 138: 1–11 discussion 11
10. Deems DA, Doty RL, Settle RG, Moore-Gillon V, Shaman P, Mester AF, Kimmelman CP, Brightman VJ, Snow JB Jr (1991) Smell and taste disorders, a study of 750 patients from the University of Pennsylvania Smell and Taste Center. Arch Otolaryngol Head Neck Surg 117:519–528
11. Figueiredo EG, Tavares WM, Rhoton AL, De Oliveira E (2010) Surgical nuances of giant paraclinoid aneurysms. Neurosurg Rev 33:27–36
12. Fischer G, Stadie A, Reisch R, Hopf NJ, Fries G, Böcher-Schwarz H, van Lindert E, Ungersböck K, Knosp E, Oertel J (2011) The keyhole concept in aneurysm surgery: results of the past 20 years. Oper Neurosurg 68:ons45–ons51
13. Fries G, Perneczky A, van Lindert E, Bahadori-Mortasawi F (1997) Contralateral and ipsilateral microsurgical approaches to carotid-

ophthalmic aneurysms. Neurosurgery 41:333–342 discussion 342–333
14. Gibo H, Lenkey C, Rhoton AL Jr (1981) Microsurgical anatomy of the supraclinoid portion of the internal carotid artery. J Neurosurg 55:560–574. https://doi.org/10.3171/jns.1981.55.4.0560
15. Hongo K, Watanabe N, Matsushima N, Kobayashi S (2001) Contralateral pterional approach to a giant internal carotid-ophthalmic artery aneurysm: technical case report. Neurosurgery 48:955–959
16. Kakizawa Y, Tanaka Y, Orz Y, Iwashita T, Hongo K, Kobayashi S (2000) Parameters for contralateral approach to ophthalmic segment aneurysms of the internal carotid artery. Neurosurgery 47:1130–1137
17. Kobayashi M, Costanzo RM (2009) Olfactory nerve recovery following mild and severe injury and the efficacy of dexamethasone treatment. Chem Senses 34:573–580. https://doi.org/10.1093/chemse/bjp038
18. Kobayashi S, Kyoshima K, Gibo H, Hegde SA, Takemae T, Sugita K (1989) Carotid cave aneurysms of the internal carotid artery. J Neurosurg 70:216–221. https://doi.org/10.3171/jns.1989.70.2.0216
19. Kumon Y, Sakaki S, Kohno K, Ohta S, Ohue S, Oka Y (1997) Asymptomatic, unruptured carotid-ophthalmic artery aneurysms: angiographical differentiation of each type, operative results, and indications. Surg Neurol 48:465–472
20. Lanzino G, Crobeddu E, Cloft HJ, Hanel R, Kallmes DF (2012) Efficacy and safety of flow diversion for paraclinoid aneurysms: a matched-pair analysis compared with standard endovascular approaches. AJNR Am J Neuroradiol 33:2158–2161. https://doi.org/10.3174/ajnr.A3207
21. Loumiotis I, D'Urso PI, Tawk R, Cloft HJ, Kallmes DF, Kairouz V, Hanel R, Lanzino G (2012) Endovascular treatment of ruptured paraclinoid aneurysms: results, complications, and follow-up. AJNR Am J Neuroradiol 33:632–637. https://doi.org/10.3174/ajnr.A2825
22. Luostarinen T, Takala RS, Niemi TT, Katila AJ, Niemela M, Hernesniemi J, Randell T (2010) Adenosine-induced cardiac arrest during intraoperative cerebral aneurysm rupture. World Neurosurg 73:79–83; discussion e79. https://doi.org/10.1016/j.surneu.2009.06.018
23. McMahon JH, Morgan MK, Dexter MA (2001) The surgical management of contralateral anterior circulation intracranial aneurysms. J Clin Neurosci 8:319–324
24. Meling TR, Romundstad L, Niemi G, Narum J, Eide PK, Sorteberg AG, Sorteberg WA (2018) Adenosine-assisted clipping of intracranial aneurysms. Neurosurg Rev 41:585–592
25. Milenković Z, Gopić H, Antović P, Jovičić V, Petrović B (1982) Contralateral pterional approach to a carotid-ophthalmic aneurysm ruptured at surgery: case report. J Neurosurg 57:823–825
26. Miwa T, Furukawa M, Tsukatani T, Costanzo RM, DiNardo LJ, Reiter ER (2001) Impact of olfactory impairment on quality of life and disability. Arch Otolaryngol Head Neck Surg 127:497–503
27. Nacar OA, Rodriguez-Hernandez A, Ulu MO, Rodriguez-Mena R, Lawton MT (2014) Bilateral ophthalmic segment aneurysm clipping with one craniotomy: operative technique and results. Turk Neurosurg 24:937–945. https://doi.org/10.5137/1019-5149.JTN.12586-14.1
28. Nakao S, Kikuchi H, Takahashi N (1981) Successful clipping of carotid-ophthalmic aneurysms through a contralateral pterional approach: report of two cases. J Neurosurg 54:532–536
29. Nishio S, Matsushima T, Fukui M, Sawada K, Kitamura K (1985) Microsurgical anatomy around the origin of the ophthalmic artery with reference to contralateral pterional surgical approach to the carotid-ophthalmic aneurysm. Acta Neurochir 76:82–89
30. Oikawa S, Kyoshima K, Kobayashi S (1998) Surgical anatomy of the juxta-dural ring area. J Neurosurg 89:250–254. https://doi.org/10.3171/jns.1998.89.2.0250
31. Oshiro EM, Rini DA, Tamargo RJ (1997) Contralateral approaches to bilateral cerebral aneurysms: a microsurgical anatomical study. J Neurosurg 87:163–169. https://doi.org/10.3171/jns.1997.87.2.0163
32. Park J, Lee SH, Kang DH, Kim JS (2009) Olfactory dysfunction after ipsilateral and contralateral pterional approaches for cerebral aneurysms. Neurosurgery 65:727–732; discussion 732. https://doi.org/10.1227/01.NEU.0000350225.36099.0B
33. Pereira RS, Casulari L (2006) Surgical treatment of bilateral multiple intracranial aneurysms: review of a personal experience in 69 cases. J Neurosurg Sci 50:1
34. Reisch R, Perneczky A (2005) Ten-year experience with the supraorbital subfrontal approach through an eyebrow skin incision. Oper Neurosurg 57:242–255
35. Reisch R, Stadie A, Kockro RA, Hopf N (2013) The keyhole concept in neurosurgery. World Neurosurg 79:S17.e9–S17.e13
36. Rizzo JF 3rd (1995) Visual loss after neurosurgical repair of paraclinoid aneurysms. Ophthalmology 102:905–910
37. Sheikh B, Ohata K, El-Naggar A, Hong B, Tsuyuguchi N, Hakuba A (2000) Contralateral approach to carotid cave aneurysms. Acta Neurochir 142:33–37
38. Shimizu K, Imamura H, Mineharu Y, Adachi H, Sakai C, Sakai N (2016) Endovascular treatment of unruptured paraclinoid aneurysms: single-center experience with 400 cases and literature review. AJNR Am J Neuroradiol 37:679–685. https://doi.org/10.3174/ajnr.A4577
39. Shiokawa Y, Aoki N, Saito I, Mizutani H (1988) Combined contralateral pterional and interhemispheric approach to a subchiasmal carotid-ophthalmic aneurysm. Acta Neurochir 93:154–158
40. Sun Y, Li Y, Li AM (2011) Endovascular treatment of paraclinoid aneurysms. Interv Neuroradiol 17:425–430. https://doi.org/10.1177/159101991101700405
41. Taniguchi M, Perneczky A (1997) Subtemporal keyhole approach to the suprasellar and petroclival region: microanatomic considerations and clinical application. Neurosurgery 41:592–601
42. Temmel AF, Quint C, Schickinger-Fischer B, Klimek L, Stoller E, Hummel T (2002) Characteristics of olfactory disorders in relation to major causes of olfactory loss. Arch Otolaryngol Head Neck Surg 128:635–641
43. Thornton J, Aletich VA, Debrun GM, Alazzaz A, Misra M, Charbel F, Ausman JI (2000) Endovascular treatment of paraclinoid aneurysms. Surg Neurol 54:288–299
44. Vajda J, Juhasz J, Pasztor E, Nyary I (1988) Contralateral approach to bilateral and ophthalmic aneurysms. Neurosurgery 22:662–668
45. van den Brand CL, Tolido T, Rambach AH, Hunink MG, Patka P, Jellema K (2017) Systematic review and meta-analysis: is pre-injury antiplatelet therapy associated with traumatic intracranial hemorrhage? J Neurotrauma 34:1–7
46. van Lindert E, Perneczky A, Fries G, Pierangeli E (1998) The supraorbital keyhole approach to supratentorial aneurysms: concept and technique. Surg Neurol 49:481–489 discussion 489–490
47. Wang Y, Li Y, Jiang C, Jiang F, Meng H, Siddiqui AH, Yang X (2013) Endovascular treatment of paraclinoid aneurysms: 142 aneurysms in one centre. J Neurointerv Surg 5:552–556. https://doi.org/10.1136/neurintsurg-2012-010494
48. Yamada K, Hayakawa T, Oku Y, Ushio Y, Yoshimine T, Kawai R (1984) Contralateral pterional approach for carotid-ophthalmic aneurysm: usefulness of high resolution metrizamide or blood computed tomographic cisternography. Neurosurgery 15:5–8
49. Yaşargil MG (1984) Clinical considerations, surgery of the intracranial aneurysms and results, vol 2. Thieme
50. Yu LH, Shang-Guan HC, Chen GR, Zheng SF, Lin YX, Lin ZY, Yao PS, Kang DZ (2017) Monolateral pterional keyhole approaches to bilateral cerebral aneurysms: anatomy and clinical application. World Neurosurg 108:572–580. https://doi.org/10.1016/j.wneu.2017.09.048