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Vascular involvement in anterior clinoidal meningiomas : Biting the 'artery' that feeds

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ABSTRACT

Objectives: Anterior clinoidal (AC) meningiomas often encase internal carotid artery (ICA) and it branches. The aim of this study was to determine the efficacy of preoperative angiogram as a predictor of vessel wall adherence and feeders. Furthermore, defining the dangerous areas would provide insights to decrease vascular injury and achieve maximal safe resection.

Patients and methods: 21 cases of AC Meningiomas were evaluated for feeders, displacement, encasement/ narrowing of ICA and its branches. Intraoperative vascular involvement was noted. The reason and site of vascular injury, if any was evaluated.

Results: Blush from ICA was seen in 15 patients. The ICA in its entirety beyond the bifurcation was encased in 11 patients. The radiological vascular encasement including narrowing didn't corroborate with intra-operative finding of vessel wall adherence. The tumor could be separated along the length of encased narrowed vessel except from ICA bifurcation in 6, where it had infiltrated adventitial layer. The adherent zone extended into anterior cerebral artery in 2 and middle cerebral artery in 2. There was major vessel injury in 2 patients and perforator injury in 2. GTR was achieved in 18 patients.

Conclusion: These tumours are often fed by supraclinoid ICA. It is possible to resect the tumor from vessel wall despite complete encasement/ narrowing on preoperative angiograms. The tumor often lethally embraces the ICA bifurcation making it the most dangerous zone for resection. This is possibly due to an arterial twig that arises close to the bifurcation to irrigate the clinoidal dura and the tumor infiltrates the adventitia at its origin.

1. Introduction

Anterior clinoidal meningiomas form a distinct entity. The close proximity to neurovascular structures pose a significant challenge to their surgical excision [1,2]. Often the major intracranial arteries, occasionally in its entirety may course within the tumor [1]. Though maximal resection is desirable, the risk of injuring such encased/ engulfed arteries makes it formidable [3,4,7]. Additionally, the perforators arising from these major cerebral arteries may also be encased within the meningioma [12]. Morbidity resulting from Injury to such perforators is as bad as injuring the parent artery.

Little has been mentioned about the feeders to these meningiomas. It is presumed that the ethmoidal arteries supply them which may not be true. These tumours possibly receive a great proportion of their blood supply from major cerebral arteries or their connections with the external carotid artery (ECA), making embolization dangerously impossible [11]. The preoperative radiology can help in determining the feeders apart from the extent of major cerebral vessel wrapped by the tumour. Even with the artery completely wrapped and narrowed by the tumour, it is often possible to find a plane between the two [1]. It is not clear if angiogram can predict the infiltration of vessel wall within the tumour. Though the literature on preoperative radiological assessment of encasement of arteries in anterior clinoidal meningiomas is replete, comparison with intraoperative findings is lacking [3.4,6,7].

We studied 21 cases of anterior clinoidal meningiomas where the major intracranial vessels were within the tumor or in close proximity. Attempts were made to identify the feeders from internal carotid artery (ICA) or external carotid artery (ECA) on preoperative angiograms. The extent and pattern of involvement of arteries on preoperative imaging was determined. This was compared with intraoperative findings of vessel wall involvement. The pattern of involvement would help us in identifying the most dangerous zones where tumor is likely to be

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Table 1
Details comparing the radiological and intraoperative findings of vascular involvement in patients with Anterior Clinoidal Meningiomas.

Patient	Blush seen (on angiograms)		Vascular involvement						Extent of resection	clinical outcome
			Radiological finding (Angiograms)			Intra operative				
	ICA	ECA	ICA	ACA	MCA	ICA	ACA	MCA		
SD	+ +	–	*Triad within tumor with rwing of A1			Separable	Separable	Separable	GTR	Delayed vasospasm 10th pod with transient hemiparesis. Recovered fully
BD	+	–	Pushed	Pushed	Pushed	Separable	Separable	Separable	GTR	No added deficits
NI	–	–	Pushed	Pushed	Pushed	Separable	Separable	Separable	GTR	No added deficits
SR	+ +	+	Triad within tumor with narrowing of all 3 vessels			Separable	Separable	Separable	GTR	No added deficits
SB	+	–	Triad within tumor with very thin and stretched A1			Adherent at ventral surface and bifurcation	A1-A2 junction adherent. Injury to A_1	Separable	STR	Expired due to hypothalamic infarcts
VB	+ +	+ +	Pushed	Pushed	Pushed	Separable	Separable	Separable	GTR	No added deficits
RD	–	–	Pushed	Pushed	Pushed	Separable	Separable	Separable	GTR	No deficits
TD	+ +	–	Pushed & stretched	Pushed	Pushed	Separable	Separable	Separable	GTR	No deficits
HK	–	–	Pushed & stretched	Pushed	Pushed & stretched	Separable	Separable	Separable	GTR	No deficits
GD	–	+ +	Proximal ICA	Pushed	Pushed	Separable	Separable	Separable	Cavernous sinus portion left	Ophthalmoplegia
GB	–	–	Pushed & stretched	Pushed	Pushed & stretched	Separable	Separable	Injury to M1 perforator	GTR	Hemiparesis 4/5
JS	+ + +	–	Triad within tumor with narrowing of distal ICA			Adherent at bifurcation	Separable	Separable	GTR	Vasospasm on pod 10 hemiparesis improved. Died after month dur to Steven Johnsons' syndrome
PL	+ + +	–	Triad within tumor with narrowing of all 3 vessels			Adherent at bifurcation	Separable	Adherent,M1 Injury	GTR	Hemiplegia. Conscious
SL	–	–	Pushed	Pushed	Pushed	Separable	Separable	Separable	GTR	No deficits
JK	+	+ + +	Triad within tumour, narrowing of A1			Separable	Separable	Separable	GTR	Transient cavernous sinus syndrome
PR	+ + +	–	Triad within tumour, narrowing of all 3 vessels			Separable	Separable	Separable	GTR	No deficits
SK	+ + MHT	+ +	Triad within tumour, narrowing of all 3 vessels			Stuck ventrally and bifurcation, perforator injury	Separable	Separable	GTR	Delayed onset infarct in internal capsule. Hemiparesis 2/5
DK	–	–	Triad within tumor, narrowing of A1			Struck at bifurcation	Stuck to A1	Separable	GTR	No deficits
GDK	+ +	+	Clinoidal & supraclinoidal ICA within tumor with irregular narrowing	Pushed	Pushed	Separable with intra op spasm	Separable	Separable	GTR	Hemiparesis 3/5 – improved after 6 weeks
SJKl	+ + +	–	Triad within tumour, narrowing of all 3 vessels			Adherent at bifurcation	Separable	M1 couldn't be separated	STR	No deficits
VD	+ +	+	Triad within tumor, regular narrowing of A1			Separable	Separable	Separable	GTR	No deficits

ICA- internal carotid artery; ACA- anterior cerebral artery; MCA- middle cerebral artery; MHT- meningohypophyseal trunk; ECA- external carotid artery. GTR- Gross total resection; STR- subtotal resection; NTR- Near total resection. POD- postoperative day; * Triad – ICA, bicfurcation, A1 and M1.

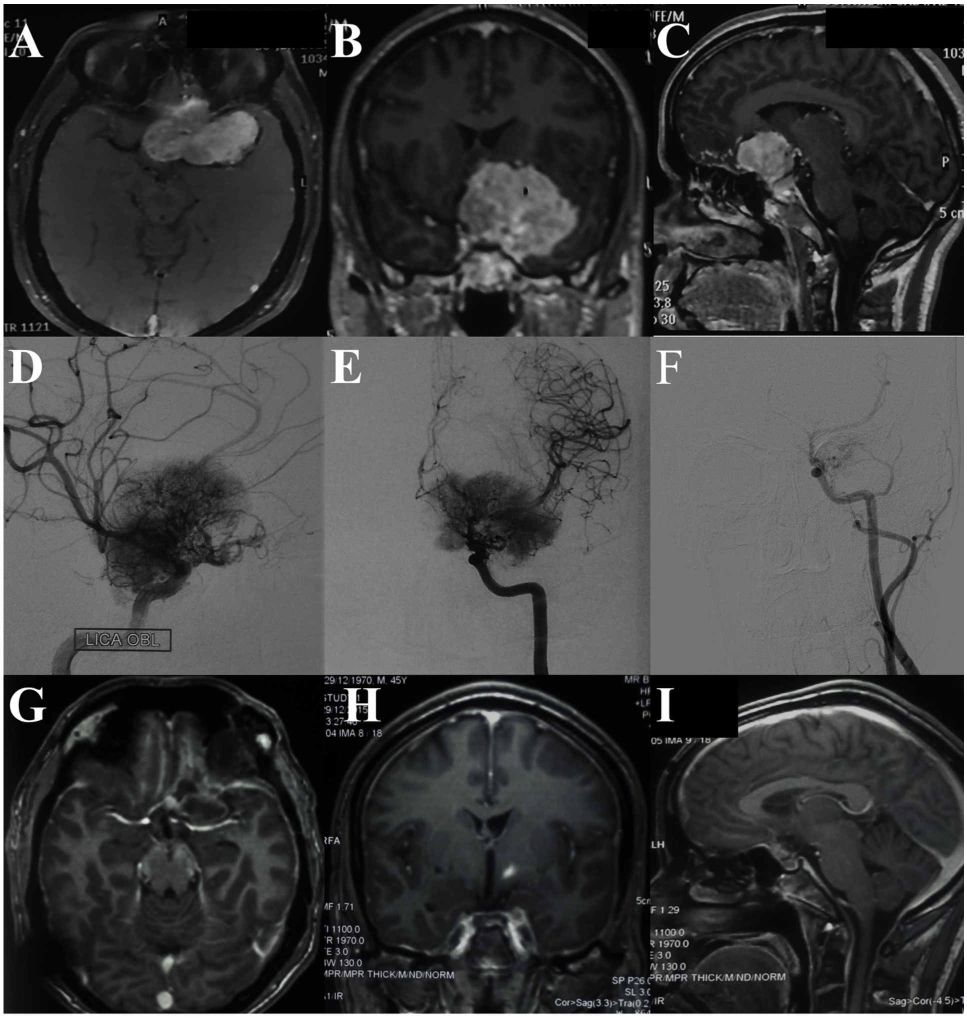

Fig. 1. A–C) Preoperative Contrast MRI in axial, coronal and sagittal plane showing clinoid meningioma with encasement of arteries. D&E) DSA (lateral & oblique) showing intense blush from ipsilateral ICA with irregular narrowing of ICA, A1 and M1 F) DSA with injection from ECA showing no blush G)-I) Follow up MRI at 3 months postoperative period showing good resection.

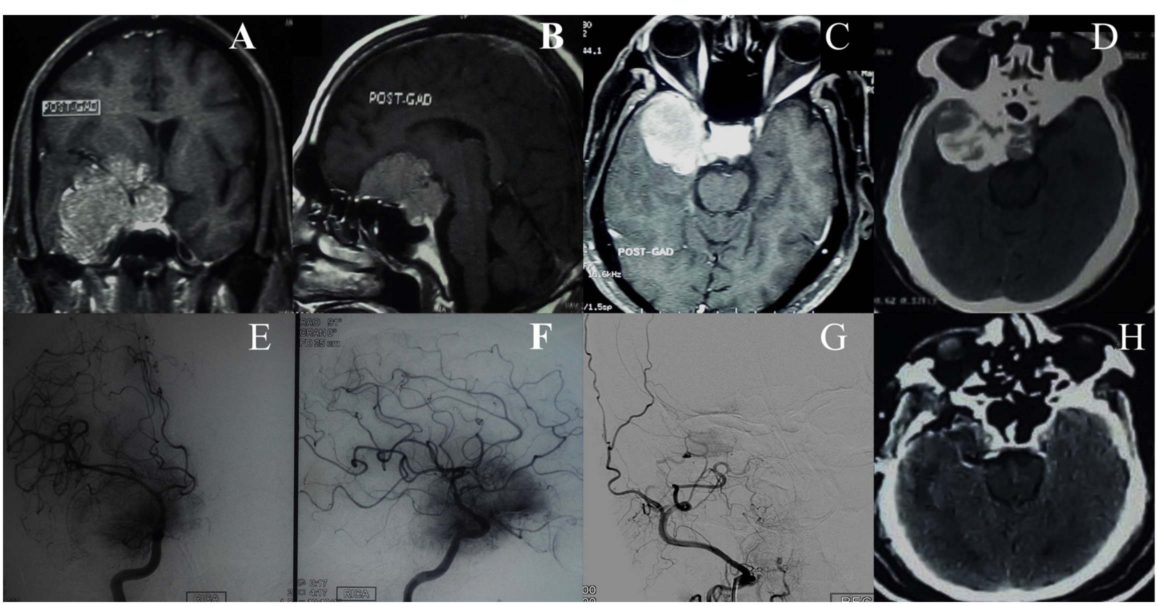

Fig. 2. A–C) Preoperative Contrast MRI demonstrating clinoid meningioma with encasement of ICA as well as A1 and M1 D) Preoperative NCCT scan showing hyperdense lesion E &F) DSA (AP & lateral) showing moderate blush of tumor from ICA with narrowing of ICA at bifurcation G) DSA with ECA injection showing no blush H) postoperative NCCT showing GTR.

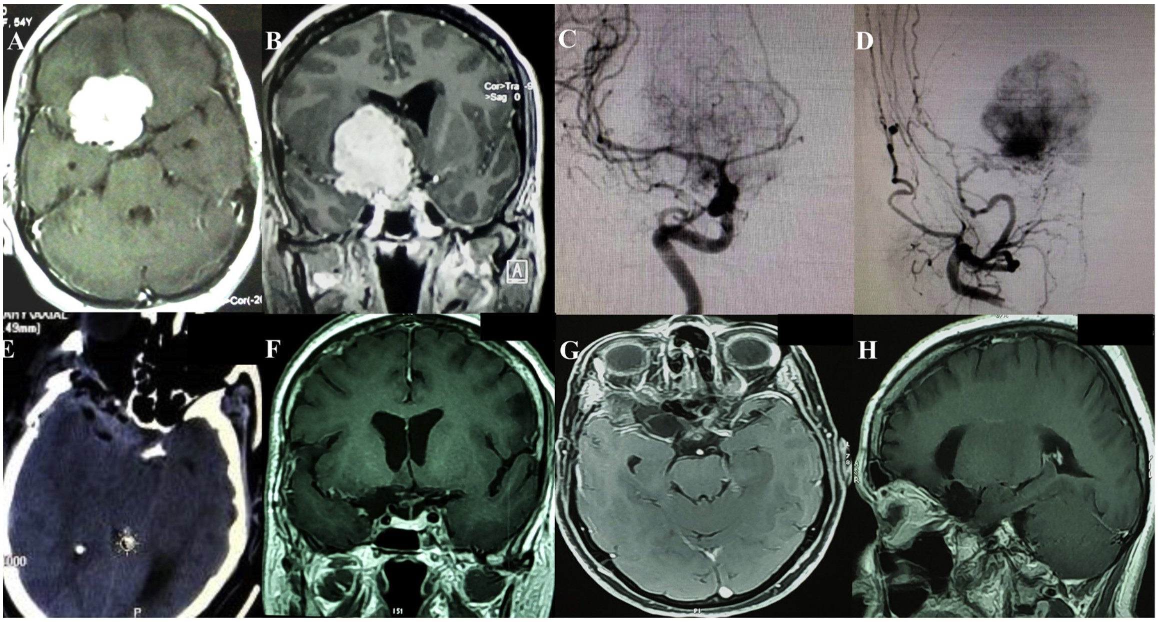

Fig. 3. A &B) Preoperative contrast MRI showing clinoidal meningioma with encased vessels C) &D) DSA Showing thinning of A1 with mild blush from ICA and with intense blush from ECA E) Immediate postoperative NCCCT showing GTR. D–F) 3 month follow up MRI showing no residual lesion.

adherent to vessel wall. The outcome of this study would guide us in better surgical planning.

2. Materials and methods

The study included 21 patients harbouring anterior clinoidal meningiomas in close proximity to ICA and it branches, operated between Jan 2015 and Dec 2018. Informed consent was obtained from all patients prior to surgery (Table 1).

2.1. Preoperative evaluation

Preoperative MRI images were studied to note the size of extent of meningiomas. T2 weighted images showed the relationship of the vessels to the tumour. These patients underwent a digital subtraction angiogram prior to surgery. Bilateral external and internal carotid injections were studied. Vascular blush from ECA, ICA or both was noted suggesting predominant vascular supply to the tumour. A cross compression test was performed in all to assess the contralateral flow and collaterals. Displacement, encasement and narrowing was noted for ICA, anterior cerebral artery (ACA), middle cerebral artery (MCA) and their branches.

2.2. Intra-operative evaluation

Through Frontotemporo orbitozygomatic craniotomy, the clinoid was drilled extradurally and the optic nerve was unroofed. The clinoidal ICA was delineated along with optic nerve and superior orbital fissure, before tumor resection was attempted. The Dural incisions were given in radial fashion in dura parallel to the three structures exposed extradurally i.e. the ICA, Optic Nerve and superior orbital fissure (SOF) [2,8]. The tumor was debulked in a centrifugal manner [8]. The ICA was traced proximal to distal upto the bifurcation as the tumor was gradually removed [8]. The origin of branches and perforators from ICA were traced at their origin and while exiting the tumor [12]. This gave a relative idea about the course of the vessel within the tumor and aided in excision of tumor while preserving the encased vessels. The part of the tumor that was densly adherent to the adventitia was left. Such densly adherent regions in the vessel wall were identified and noted.

3. Results

3.1. Radiological findings

Feeders- The preoperative angiogram revealed tumor blush on ICA injection in 11 (mild blush in 3), on ECA injection in 2 and the blush persisted on both ICA and ECA injection in 4 (Figs. 1–4). The remaining patients had no blush on either arterial injection. Of interest, one patient had additional feeders from meningohypophyseal trunk apart for ICA.

Vascular encasement on angiograms- The ICA was encased along its entire course and beyond the bifurcation (involving variable length of ACA and MCA) in 11 patients. In these patients ICA and branches were stretched and narrowed focally or in their entire length. The narrowing was irregular at places suggesting infiltration of vessel wall. Two patients showed narrowing of clinoidal segment with supraclinoid ICA. Patients without blush from ICA showed no angiographic encasement. However, degree of blush from ICA did not correlate with extent of encasement or narrowing.

3.2. Intraoperative findings

The clinoidal segment of ICA was delineated in all patients. The artery was traced from proximal to distal. The tumor could be resected from the dorsal surface of the ICA in all cases irrespective of the encasement. The tumor was densely adhered to the ICA wall at the bifurcation on the dorsal and superior surface in 6 patients and could not be removed from this zone (Fig. 5). The adherent zone extended to middle cerebral artery (M1 segment) in 2 patients and proximal anterior cerebral artery (A1 segment) in two patient. Beyond this point the tumor could be excised despite encasement of distal segment of arteries. The tumor was difficult to remove from the ventral surface of ICA especially at the branching of posterior communicating artery. This was possibly due to blind location and relative inaccessibility rather than adventitial infiltration.

No separate feeders could be identified even in tumors with predominantly ICA supply.

Vessel injury and outcome - There was injury to M1 segment in one patient and A1-A2 junction in another. The adventitia was infiltrated in both cases. Patient with M1 injury developed MCA territory infarct with

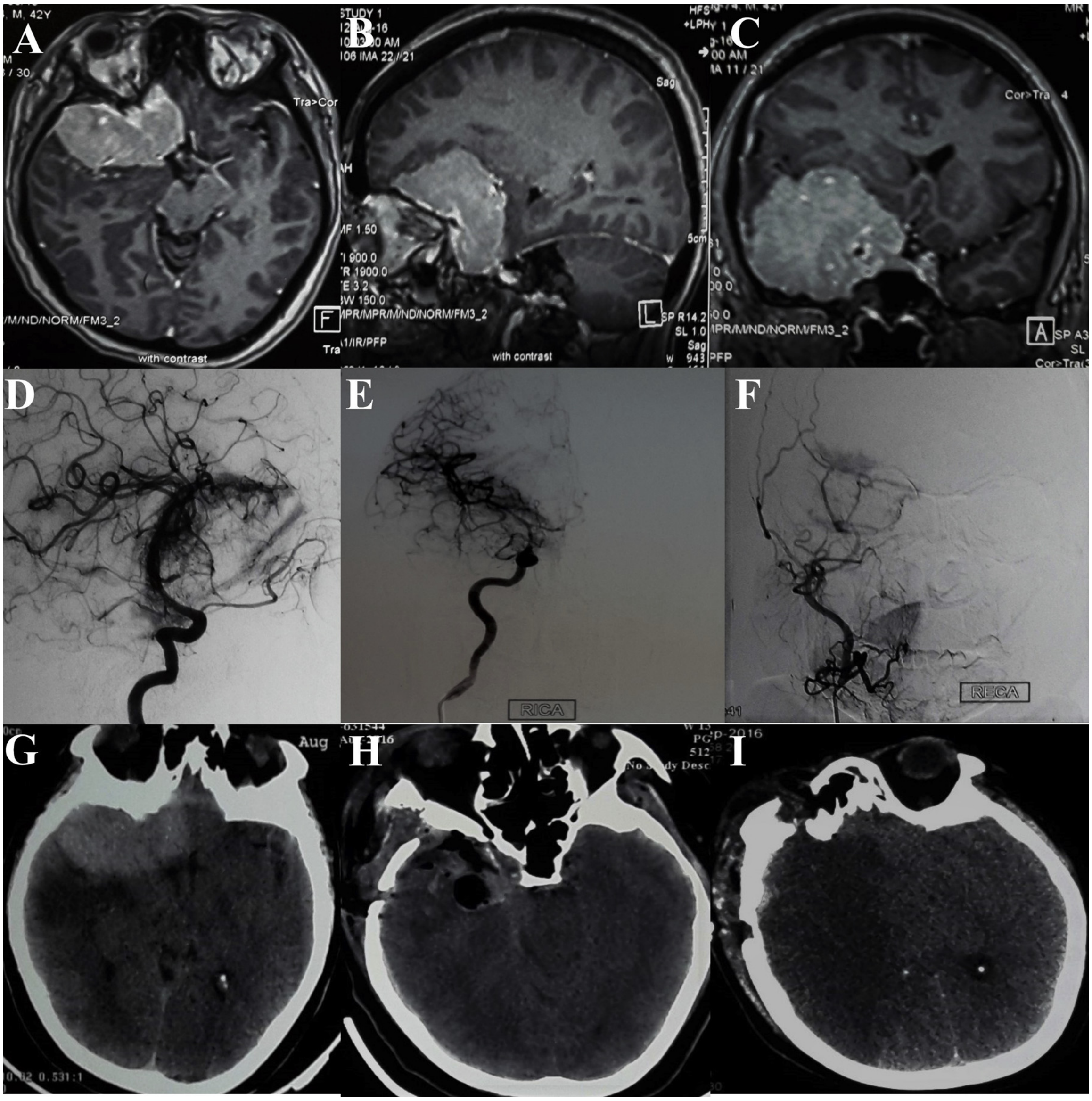

Fig. 4. A–C) Preoperative Contrast MRI in axial, coronal and sagittal planes demonstrating clinoid meningioma encasing ICA bifurcation and origin of both A1and M1 origin D & E) DSA, showing blush from supraclinoid ICA. ICA, M1 and A1 are encased, stretched and narrowed F) DSA with ECA injection showing minimal blush from ECA G) Preoperative NCCT demonstrating hyperdense lesion H) immediate postoperative NCCT showing GTR E)Postoperative scan on day 2 demonstrating MCA infarct on the ipsilateral side.

hemiplegia (Fig. 4) while the other patient with ACA injury succumbed to hypothalamic infarcts.

There was injury to ICA perforator in one patient and M1 perforator in another. Both patients developed hemiparesis. Intraoperative spasm of arteries after tumor resection was seen in 3 patients with ICA encasement. One of them developed transient hemiparesis

In 18 patients the tumor could excised leaving only small specks of tumor densely adherent to vessel wall. In one patient the tumor extended into cavernous sinus and this portion could not be removed. In remaining 2 patients, part of tumor could not be removed as the encased M1 and A1could not be delineated.

There was no intraoperative difference with respect to resection rates, blood loss, tumor vascularity or vascular injury between tumors with predominant ICA tumor supply vs those with predominant ECA tumor supply.

Two patients with encased ICA, developed delayed onset hemiparesis on post of operative day 10. They responded to hydration and possibly had delayed onset vasospasm. One of them died due to Steven –Johnson syndrome a month after successful surgery.

4. Discussion

Al-Mefty classified clinoid meningiomas into three types as per the origin and vascular patterns [1]. Type1 was defined as meningiomas arising from the inferior aspect of the clinoid thus directly invading the ICA with no plane of cleavage of tumor with the vessel pushing the arachnoid as far as MCA. The type 2 meningiomas arise from superior or lateral part of clinoid and has an intact arachnoid between the tumor and ICA making the dissection and separation from ICA easier though the vessels may be totally encased in it. Type 3 meningiomas arise from the optic foramen having again an intact arachnoid membrane between the tumor and ICA [1]. Type 1 remains the most difficult one because of adherence to vessels and chances of vascular injury.

Preoperative knowledge of vascular supply of meningioma helps in planning the surgical attack at the feeders first. In addition, preoperative embolization can reduce the vascularity of the tumor

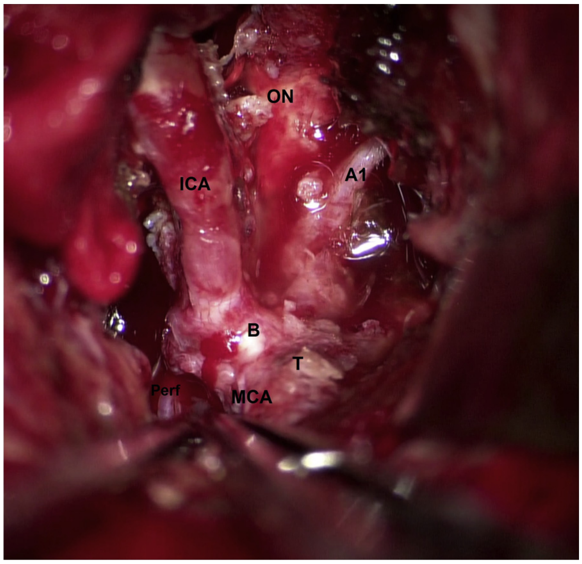

Fig. 5. Intra operative image demonstrating tumor (T) struck to ICA bifurcation while the entire ICA, A1,M1 and perforator from ICA have been bared.

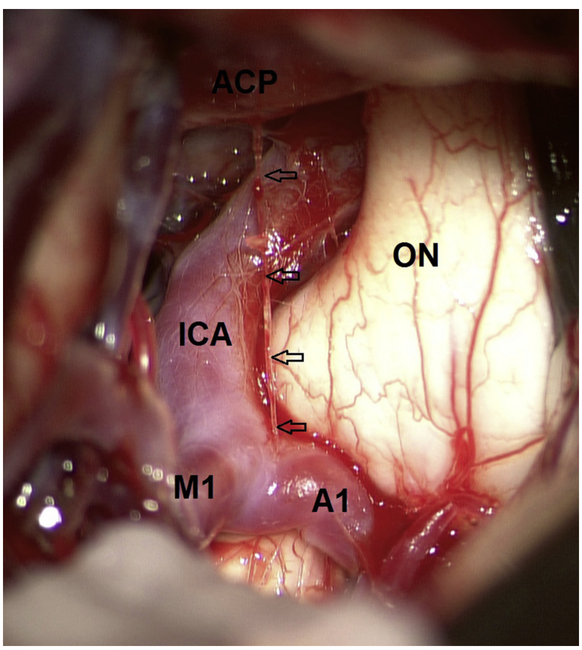

Fig. 6. Intraoperative image of an individual with craniopharyngioma operated through trans-sylvian route where the AC dura (ACP) was normal. Note the arterial twig arising close to the ICA bifurcation from its dorsal surface coursing straight to the clinoidal dura (open arrows). ON is left optic nerve and A1 and M1 are first segment of anterior and middle cerebral arteries respectively.

significantly and aids in resection [11]. The ECA and ICA injections in our study showed not direct feeders. There was indirect evidence in form of arterial blush. In majority, the blush was seen from supraclinoid ICA. This clearly indicated small branches from supraclinoid segment of ICA. A small arterial twig from supraclinoid ICA close to its bifurcation has been observed to supply the dura over AC process [9] (Fig. 6). This twig possibly feeds the clinoidal tumor all along its course to dural base [9]. It is clear that such feeders are not amenable to preoperative embolization.

Preoperative encasement of ICA has been an important factor deciding the extent of resection. Most studies have suggested the extensive length of artery within the tumor and luminal narrowing as a unfavourable marker for safe resection [3–5,10]. Luminal narrowing suggests infiltration into the vessel wall making resection risky [5]. The preoperative MP-RAGE (magnetization-prepared rapid gradient-echo) sequences on MRI, can predict the degree of circumferential encasement of vessels [6]. It varies from zero to grade 5 ranging from no encasement to 360^0 encasements. Such encasement pattern is helpful in predicting the intra operative difficulties and postoperative ischaemic complications. Unfortunately, we did not acquire MP-RAGE sequences in our patients. We could achieve safe maximal resection despite extensive encasement and luminal narrowing.

Our experience suggests that a good plane of dissection exist between the artery and the meningioma despite its encasement and luminal narrowing on preoperative angiogram. This has also been described by Al-Mefty in his work [1]. However, there are areas where the tumor is densely adherent to the vessel wall. The commonest zone has been the ICA bifurcation and it may extend into the proximal A1 or M1. A sliver of tumor is best left around these areas to prevent any inadvertent injury. The encasement of distal ICA, its bifurcation and proximal A1 and M1 has been rightly described as the 'Dangerous triad' [6]. Such focal involvement cannot be explained by lack of arachnoid. The type I Al-Mefty tumor strips the arachnoid and grows along the length of artery and so it should not be possible to resect the tumor form the vessel along its entire length. The type II on the other hand should have an intact arachnoid plane throughout and cannot explain such focal adhesions. In short, our findings defy the simple concept of lack of arachnoid. The most plausible explanation is infiltration along the feeder, the small arterial twig close to ICA bifurcation supplying the AC dura. The tumor grows along this twig right upto its origin, close to the bifurcation. At its origin the tumor infiltrates the adventitia and is adherent. This justifies the title 'tumor bites the artery that feeds it'.

4.1. Limitations

It is possible that the tumor blush would have underestimated the tumor encasement and narrowing of vessels. Another limitation is absence of any angiographic evidence of clinoidal artery. The artery and feeders may be too thin to be detected on angiograms. Intraoperatively, we could not delineate the clinoidal artery in any of the cases with tumors.

5. Conclusion

The clinoidal meningiomas are usually supplied from feeders from supraclinoid ICA and are not amenable for embolisation. Despite the vessel narrowing and encasement within the tumours, there are only focal areas where the tumor infiltrates the vessel wall. Such infiltration is usually seen at ICA bifurcation and proximal A1/M1 and is probably related to the origin of clinoidal artery. It is difficult to determine this focal/ segmental areas of infiltration on preoperative radiology. Narrowing / stenosis of the vessel on preoperative angiography doesn't necessarily means its infiltration. However with vascular encasement of the triad, one should anticipate the focal involvement close to the bifurcation and the surgeon needs to exercise utmost caution while dissecting around this zone. Such encasement can be known from MRI and preoperative angiogram may not be necessary.

Compliance with ethical standards

All procedures performed in study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards."

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Author's contribution

Pravin Salunke; Concept and design, Collection, collation of data, manuscript drafting

Apinderpreet Singh; Collection of data, manuscript drafting

Rajeev Kamble; manuscript drafting,Collection of data

Chirag Ahuja; Collection of data and mansucript drafting

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