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Intradural versus Extradural Location of Paraclinoid Aneurysms: Preoperative Red Flag Markers

Abstract

Background: Exact preoperative confirmation of the distal dural ring and intradural location of a paraclinoid internal carotid aneurysm has been an age old dilemma. This study was aimed at identifying anatomical landmarks in cases of paraclinoid aneurysms, which were relatively consistent, and would help in predicting the possibility of an extradural inaccessible location of these aneurysms for surgical clipping. **Methods:** Ninety surgically managed unruptured paraclinoid aneurysms were retrospectively analyzed with preoperative computerized tomography. Axial relation of the aneurysm neck to the ophthalmic artery (OA), optic strut (OS), and anterior clinoid process (ACP) in terms of vertical distance and the direction of projection were analyzed and tabulated for all 90 cases. Intradural and extradural (inaccessible) aneurysms were compared. **Results:** Seven out of the 8 inaccessible necks were medially directed and 1 was ventrally placed ($P = 0.053$). The OA level when compared to the neck had a positive correlation with inaccessible aneurysms for clipping ($P = 0.002$) The OS location above the level of the neck had significant correlation with inaccessibility of clipping and extradural location ($P < 0.001$). The tip of the ACP had no statistical significance with inaccessibility ($P = 0.351$). **Conclusions:** Medially projecting aneurysms with necks below the level of the OS and origin of the OA should be managed with a high index of suspicion and an alternate method of treatment should be sought. The relation of the neck to the ACP does not seem to have significant statistical bearing with decision making.

Keywords: *Anterior clinoid process, distal dural ring, extradural aneurysm, ophthalmic artery, optic strut, paraclinoid aneurysm*

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Introduction

The management priorities in case of paraclinoid aneurysms change as per their location. It is thus extremely important to gauge the exact location of these aneursyms, to achieve the best possible results. Till date, however, the localization of these aneurysms purely on imaging has remained challenging. The distal dural ring (DDR) is the boundary between the intradural and extradural internal carotid artery (ICA) segments. Several studies have attempted to predict the location of an ICA aneurysm based on the imaging of the DDR, but, unfortunately, these studies have lacked surgical confirmation.[1,2] We hereby present a retrospective analysis of paraclinoid aneurysms treated surgically in a single institute. In our study, we sought to determine the feasibility of clipping these aneurysms based on a few anatomical landmarks in the paraclinoid region, studied on preoperative radiology. The landmarks analyzed were the ophthalmic artery (OA) origin, the optic strut (OS), anterior clinoid process (ACP) tip, and the direction of projection of the aneurysm.

Objectives

This study aimed to analyze the exact location of paraclinoid aneurysms radiologically and to compare these radiological observations with those made intraoperatively. The study was designed so as to help the surgeon to predict the type of aneurysm, preoperatively using these fixed radiological landmarks. This study would also help the surgeon preempt the possibility of encountering an unusual aneurysm located extra-durally, based on the radiological landmarks studied preoperatively. This is extremely important as it would help the surgeon

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take a call regarding the feasibility of surgical clipping for this select group of patients.

Materials and Methods

A case record of Paraclinoid Aneurysms treated between January 2015 and July 2019 at the Fujita Health University, Banbuntane Hotokukai Hospital, Nagoya, Japan, were retrospectively analyzed. Preoperative Computerized tomography (CT) angiography was analyzed and the three-dimensional-CT (3D-CT) reconstruction data were viewed. All cases with CT angiography (CTA) suggesting: (1) aneurysms distal to or near the takeoff of the OA, (2) superior and/or medial to the ACP or (3) after the cavernous ICA were considered surgical candidates.

Patients' demographic data, site of the aneurysm, operation notes, and postoperative morbidities or mortalities were reviewed and recorded. Institutional ethical clearance and patients' consent for publication were taken. According to our departmental protocol, all patients diagnosed with un-ruptured paraclinoid ICA aneurysms who were candidates for treatment were discussed with the neurointervention team. If not considered a good candidate for intervention, the patients were offered surgery. We use reconstructed computed tomography angiography routinely for surgical planning, and in case of any ambiguity, request a digital subtraction angiography. All the surgeries were performed by a chief operating surgeon and assisted by two senior surgeons. Intraoperative decisions were made by the mutual agreement of all the three surgeons. All neurovascular surgeries are performed with OPMI® Pentero® Microscope (Carl Zeiss, Oberkochen, Germany) with infrared 800 camera equipped with FLOW 800 software (Carl Zeiss, Oberkochen, Germany). On exposure of aneurysm, we perform indocyanine green (ICG) video angiography to delineate the aneurysm and its relation to all the surrounding vessels. Furthermore, to evaluate any perforating artery or other structures hidden behind the aneurysm, we introduce a rigid endoscope (Machida, Japan) under microscopic guidance. With this technique, we check for the estimated final location of the aneurysm clip tips ensuring they are away from the critical structures.

Surgical approach

All paraclinoid aneurysms were treated using an ipsilateral pterional approach with an extradural, ACP removal. The craniotomy was made with high-speed cutting drill. The sphenoid ridge was flattened first to make a wide space for exposure. The meningo-orbital and ororbito-temporal periosteal fold was exposed at the temporal side, lateral to the ACP. The dural groove was taken as the landmark for the junction of the periorbital and temporal dura [Figure 1]. Following this, the removal of ACP using a micro-rongeur was done in a piecemeal fashion. The correlation between the direction of the aneurysm and the tip of ACP should be considered because we can punctiliously avoid a premature

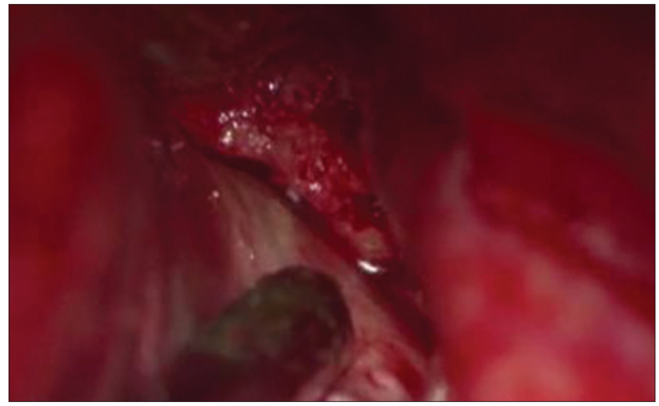

Figure 1: The extradural part of the anterior clinoid process (triangular shaped) before being nibbled off completely

rupture of the aneurysm, especially the medial direction of the aneurysmal dome. Removal of the cortical bone of the ACP allows for improved exposure of the ICA (ophthalmic and clinoid parts), aneurysm, optic nerve, and oculomotor nerve. The DDR was observed and the OS was seen in the area of the Dolenc or clinoidal triangle. The bone in this area must be removed with micro-forceps. The dura was incised from the Sylvian area for the exposure of the Sylvian fissure and through the distal part of the ICA. The aim of opening the dura in this step is inspection and confirmation of the location of the aneurysmal sac before the tip of the ACP is removed. An "L-"shaped dural incision was performed along the Sylvian fissure and the frontal base. The dural incision extended anteriorly over the third cranial nerve and toward the opening of the oculomotor foramen. The DDR was completely or partially released to allow for mobilization of the ICA segment in order to improve access to the aneurysm for clipping [Figure 2]. Aneurysms in the paraclinoid region were visualized after the above exposure and a check endoscopy was done in all cases to identify the exact relation of the neck to the dome and the surrounding vessels before clipping. An ICG fluorescence angiography was performed in all cases before and after clipping. Cases in which the aneurysm dome or neck could not be clearly visualized even after the complete exposure were documented. The clipping strategies and postoperative evaluations were not included in this study and hence not discussed.

Tabulations

Intraoperative findings were compared with the preoperative 3D-CT reconstructions. The location of the DDR based on the imaging and operative findings were compared. Imaging of cases in which the aneurysm was found to be extradural were reviewed and compared with the intradural aneurysms. Cases in which clipping was not feasible due to inaccessibility of the neck were identified. Preoperative CTA images (128 slices, Toshiba Inc., Japan) were re-evaluated by two separate observers. Both these observers analyzing the CTA and the DSA findings were

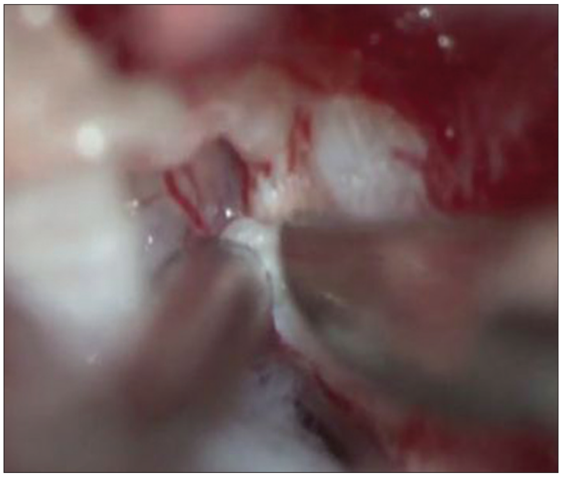

Figure 2: The step of cutting of distal dural ring with the anterior clinoid process base on the right side (with bone wax applied over it), fronto-lateral parenchyma seen on the left side and the "V" shaped dural incision in the center

blinded to the intraoperative findings. The scanner is equipped to give CT cuts of 0.5 mm thickness. The origin of the neck of the aneurysm was identified. This was labeled as station zero. The axial level of the maximum thickness of the OS, origin of the OA and the tip of the ACP (highest and posterior most point) were identified. The OS, although a small structure can be identified at the inferior wall of the optic canal after tracing the ACP to its base. The slice numbers of these structures were used to calculate the vertical distance between the necks of the aneurysms and these structures. The differences in relation to the OA, OS, ACP, direction of projection (classified. into dorsal, ventral, medial and lateral) and location of aneurysm in relation to the long axis and direction in cross sections of the ICA were analyzed and tabulated.[3] Since exact analysis of these structures in axial CT scan can sometimes have inter-observer variations, the observations in which there was discrepancy between the two observers were evaluated with coronal cuts and 3D reconstructions to confirm the analysis or a mean value was assigned to those observations which remained ambiguous.

Observations and Results

Ninety patients were operated for paraclinoid aneurysms from January 2015 to July 2019. Demographic details of all these patients, maximum size of the sac in millimeters, projection of the aneurysms, and relation of the neck in millimeters to the OS, OA origin and ACP tip were recorded. All cases were operated using the technique described above. Cases which were treated by endovascular techniques have not been included in the statistical analysis. Ten aneurysms out of the 90 cases were found to be inaccessible for surgical clipping. Figures 3-8 describe three cases which were thought to be inradural aneurysms, but turned out to be extradural and hence inaccessible for surgical clipping intra-operatively. Eight

Table 1: Intra-operative location analysis of aneurysm in study population

Group	Frequency (%)
Intradural	82 (91.1)
Extradural	8 (8.9)

were inaccessible and/or not visible and hence deemed to be extradural, while 2 aneurysms were not clipped because of precarious perforator vessels in the vicinity [Table 1] (e.g., Case 1, 2, 3). One case out of the intradural patients arm was not investigated with CTA preoperatively and hence was not included in further statistical analysis. The mean age of presentation was 54.17 ± 13.35 for the intradural group and 57 ± 14.21 for the extradural group (statistically insignificant). There were 8 (8.9%) male and 82 (91.1%) female patients (statistically insignificant). One case had a double paraclinoid aneurysm and 4 cases had contra lateral aneurysms at different locations (1 middle cerebral artery, 2 anterior communicating artery, and 1 posterior communicating artery origin). Six cases had a bi-lobed aneurysm. The maximum diameter of the aneurysm had a mean of 5.24 ± 2.25 mm for the intadural group and 4.5 ± 2.08 mm for the extradural group (statistically insignificant). Most aneurysms were medially directed (46.7%), superior/dorsal (35.6%), posterior/ventral (6.7%) and lateral projection (11.1%). In all 10 cases which were deemed unsuitable for surgical clipping, intraoperatively, the sac was coated using a flattened muscle flap and these cases were then reconsidered for further angiography with/without interventional treatment. The clip obliteration rate was complete in the rest of the cases and confirmed with postoperative angiography.

Statistical analysis

The vertical distance of the neck of all aneurysms was analyzed with the OS, tip of ACP and the origin of OA. The findings were analyzed using SPSS software version 17 (IBM Corp., Armonk, N.Y., USA) using Chi square and paired t tests wherever applicable. Seven out of the 8 inaccessible necks were medially directed and 1 was ventrally placed (P = 0.05) [Table 2]. The difference between intra- and extra-dural aneurysms with relation to the direction of the aneurysm is thus statistically significant. The OS serves as an effective landmark for distinguishing an extradural aneurysm and thus determining the surgical inaccessibility for clipping of an aneurysm (P = 0.001) [Table 3]. The difference in the ACP between intra and extradural aneurysms was not statistically significant and it thus cannot be used a reliable predictor for determining the accessibility of surgical clipping (P = 0.351) [Table 4]. The difference in the proportion of the OA between intra- and extra-dural aneurysms was statistically significant and it thus can be used as a reliable predictor for determining the feasibility of surgical clipping (P = 0.002) [Table 5].

Table 2: Comparison of site of aneurysm with group (n=90)

Site of aneurysm	Group		Total
	Intradural	Extradural	
Lateral (%)	10 (12.2)	0 (0)	10 (11.1)
Medial (%)	35 (42.7)	7 (87.5)	42 (46.7)
Posterior (%)	5 (6.1)	1 (12.5)	6 (6.7)
Superior (%)	32 (39)	0 (0)	32 (35.6)
Total	82	8	89
χ^2		7.68	
P		0.05	

The difference in the proportion of site of aneurysm between intradural and extradural group was statistically significant (P=0.053)

Table 3: Comparison of optic strut with group (n=89)

OS	Group		Total
	Intradural	Extradural	
Below level of neck (-) (%)	76 (93.8)	5 (62.5)	81 (91)
Level of neck (at 0) (%)	3 (3.7)	0 (0)	3 (3.4)
Above the neck (+) (%)	2 (2.5)	3 (37.5)	5 (5.6)
Total	81	8	89
χ^2		16.985	
P		<0.001	

The difference in the proportion of OS between intradural and extradural group was statistically significant (P<0.001). OS – Optic strut

Table 4: Comparison of anterior clinoid process with group (n=89)

ACP	Group		Total
	Intradural	Extradural	
Below level of neck (-) (%)	17 (21)	0 (0)	17 (19.1)
Level of neck (at 0) (%)	9 (11.1)	1 (12.5)	10 (11.2)
Above the neck (+) (%)	55 (67.9)	7 (87.5)	62 (69.7)
Total	81	8	89
χ^2		2.093	
P		0.351	

The difference in the proportion of as between intradural and extradural group was statistically not significant (P=0.351). ACP – Anterior clinoid process

Table 5: Comparison of ophthalmic artery with group (n=89)

OA	Group		Total
	Intradural	Extradural	
Below level of neck (-) (%)	59 (72.8)	1 (12.5)	60 (67.4)
Level of neck (at 0) (%)	18 (22.2)	6 (75)	24 (27)
Above the neck (+)(%)	4 (4.9)	1 (12.5)	5 (5.6)
Total	81	8	89
χ^2		12.19	
P	0.002		

The difference in the proportion of OA between intradural and extradural group was statistically significant (P=0.002). OA – Ophthalmic artery

95% of the extradural aneurysms were found to lie between −2.47 and 0.97 mm and 95% intradurals were found to lie between −6.11 and −4.68 mm. The range of OA for extradural aneurysms is found to be −0.57–0.82 mm and those for intradural is found to be −2.27 and −1.34 mm (95% confidence interval). The OS, OA, and the direction of the aneurysm neck are thus good predictors for accessibility of surgical clipping.

Discussion

Bouthillier *et al*. described 7 segments of the ICA, where C4 = intracavernous, C5 = clinoidal and C6 = ophthalmic. However, exact differentiation between the intradural and extradural segments was not defined.[4] These two segments are separated by the DDR which is bound by the OS anteriorly, ACP laterally, continues as the dura over the tuberculum sellae medially, the diaphragm sellae posteromedially and the dura over the posterior clinoid process posteriorly.[5]

It is extremely important that these two aneurysms be classified preoperatively on imaging as it would alter the surgical treatment and have a significant bearing on the patient prognosis.[2,6] In addition, cases in which the unruptured aneurysm is deemed to lie below the DDR have a significantly less chance of development of a subarachnoid hemorrhage.[2,7,8] Identification of the location of the intradural segment of the carotid artery has been attempted by various studies using various landmarks such as: (1) OA, (2) ACP, (3) OS, (4) tuberculum sellae + ACP, (5) subarachnoid space, and (6) carotid concavity on 3D-CTA.[1,2,3,5,9-12] Many previous studies have also attempted to delineate the exact location of sssssethe DDR on preoperative imaging. Punt *et al*.[9] proposed that the intradural aneurysms arise distal to the OA, however it is now known that about 10% of OA arise in the extradural segment.[2] Taptas *et al*. defined the ACP as the landmark for differentiating the two segments.[3] However, Oikawa *et al*. demonstrated that the DDR is not an exactly horizontal structure and that it slants posteromedially from the superior border of the base of the ACP toward the tuberculum sellae (TS), and that aneurysms proximal to the DDR are extadural and those distal to the DDR are Intradural.[5] Kyoshima and Kobayashi *et al*. classified these juxta dural ring aneurysms and also defined the concepts of the carotid cave (CC) and carotid groove. They classified these aneurysms into: (1) paraclinoid intradural, (2) CC aneurysms, and (3) infraclinoid extradural aneurysms.[13] The CC is an out-pouching of the subarachnoid space medial to the ICA below the DDR. Hence, theoretically some aneurysms below the DDR may also cause subarachnoid hemorrhage (SAH). As per their observations, the CC aneurysms are anatomically intradural even though they might be arising proximal to the origin of the OA at the angiographic genu or the anterior siphon knee of the ICA. They also classified the aneurysms based on the direction of projection into dorsal, ventral, medial and lateral.[13,14]

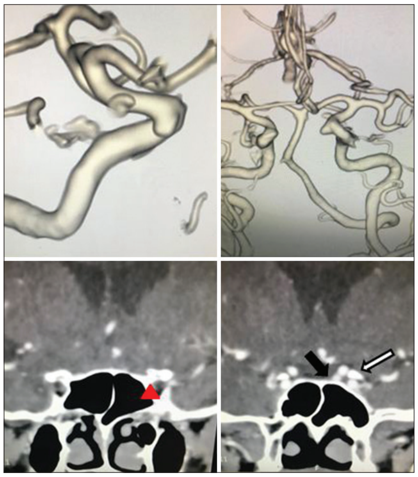

Figure 3: Case 1: Antero-posterior and medio-lateral three dimensional CT reconstruction images of a left paraclinoidal internal carotid artery aneurysm directed medially (top left and top right respectively). The bottom left image shows the optic strut (red arrow head superior angle) on a coronal CT image and the image on the bottom right shows the anterior clinoid process (black and white arrow) with the aneurysm sac (black arrow)

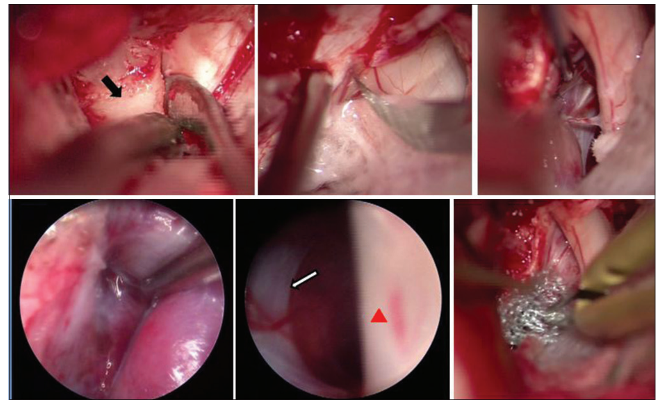

Figure 4: Case 1: The intraoperative microscopic images on the top showing from left to right the steps of anterior clinoidectomy (anterior clinoid = black arrow), opening of the distal dural ring and the evaluation of the medial wall of the internal carotid artery. The bottom figures from left to right show the intraoperative endoscopic images which fail to localize the aneurysm, and the area close to the extradural part is coated using an artificial matrix ([Neoveil; Gunze, Kyoto, Japan])

Figure 5: Case 2: Another similar case of a left paraclinoid aneurysm with antero-posterior and lateral three-dimensional CT angiography images on the top and the axial CT images showing the level of the optic strut (black arrow), aneurysm sac (black arrow head) in the bottom left and the anterior clinoid tip in the bottom right (black and white arrow)

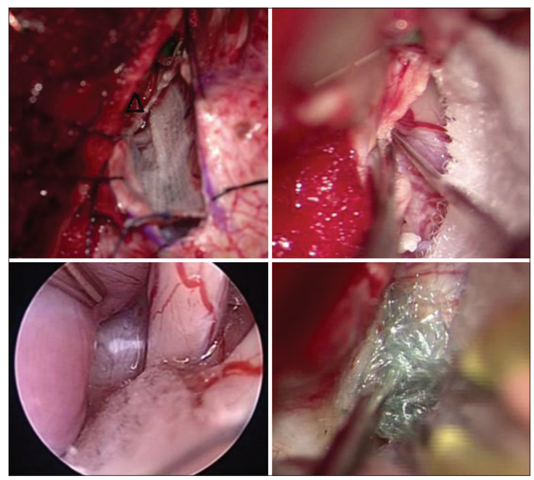

Figure 6: Case 2: The intraoperative findings with the top left image showing the clinoidectomy (black triangle) and the top right image showing the opening of the dural ring. The bottom left image of the intraopertive endoscopy clearly shows the inability to identify the aneurysm sac medial to the internal carotid artery and hence the area was coated similar to case 1 (bottom right)

Murayama *et al*. identified a clinoidal segment concavity, not much unlike the carotid waist, in the carotid segment between the ACP and the TS. They proposed this concavity to be a landmark of the DDR.[12] Several researchers have attempted to delineate the intradural carotid segment using magnetic resonance (MR) imaging whether in the form of Fast Spin 3D T2-weighted analysis or by combining MR angiography with 3D-MR cisternography. These studies were based on the cerebro-spinal fluid borders adjoining the DDR and the roof of the cavernous sinus without actually visualizing the dura and lacked surgical confirmation in all cases.[2,10] More recently, Chih-Hsiang *et al*. have identified the OS as an important landmark for the DDR and have concluded that the DDR is supposed to be located 2 mm above the base of the OS in axial planes.[1]

Paraclinoid aneurysms in relation to the DDR have been described as intradural, transitional/CC and extradural.[1,3] Identification of the exact location is therefore vital as aneurysms located extradurally can be managed without surgery. In our case review we analyzed 90 cases of paraclinoid aneurysms managed surgically and found that the; (1) axial level of the maximum thickness of OS, and (2) axial level of the OA correlated well with the axial level of the aneurysm neck, helping us to identify it as an intradural aneurysm and thus being able to offer surgical clipping for these patients. Most studies performed earlier however have lacked the surgical correlation, as patients in whom the aneurysm is assumed to be extradural could not be operated for ethical reasons. Since this study was a retrospective one, we could gather a significant sample size for definitive conclusions. The tip of the ACP had

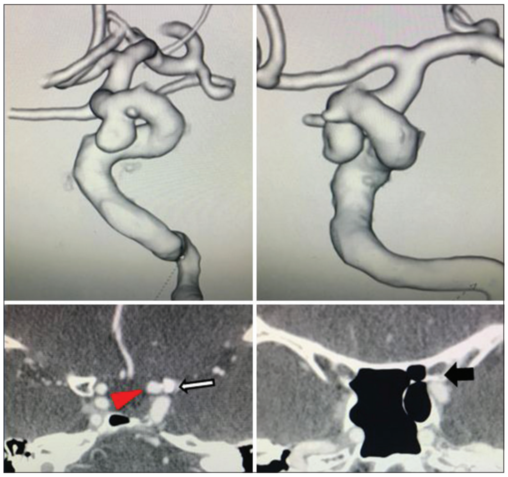

Figure 7: Case 3: Another similar case of left paraclinoid internal carotid artery aneurysm directed medially, anteroposterior and lateral three-dimensional CT images on the top with the CT scan analysis for the level of the anterior clinoid process (black and white arrow), the optic strut (black arrow). The red arrow head indicates the aneurysm sac, however, the landmark used for calculation in the study is the aneurysm neck)

no statistical correlation with the aneurysm location. This corroborates with the currently available literature about how the ACP tip is highly variable in its location, and is a poor predictor for determining the location of the aneurysms. Seven out of our 8 extradural cases were medially directed, and the direction of the neck was found to be a reliable predictor of the type of aneurysm and the feasibility of surgical clipping (P = 0.05). Thus, the medially directed cases need to be managed with caution. The OS is a fixed landmark which forms the inferior border of the optic canal. This landmark can be identified on axial scans by tracing the ACP to its medial base. As proven by our results, aneurismal necks which are above the OS should be amenable to surgical clipping (i.e., 95% of the aneurysms found to be extradural in our surgical series lie between −2.27 and +0.97 mm). The OS thus serves as a reliable predictor for deciding which patients are unlikely to benefit from surgery and should be offered alternative treatments. Although literature suggests that 8%–10% OA originate extradurally, our study compared only the axial levels of the OA and not the distance of the aneurysm necks along the long axis of the ICA. This may be the fallacy of the study. However, from our calculations there still appears to be a statistically significant correlation (P = 0.002) and thus axial CT scan analysis for the OA and neck origin can be vital in surgical decision making even if the necks are distal to the OA origin along the ICA long axis.

Conclusions

The analysis of the preoperative CTA is vital in the decision making for surgical management of paraclinoid aneurysms. In the present study, we have combined various methods of identification of the DDR and the extradural location of the paraclinoid aneurysms namely OS, OA, ACP, and the projection of sac, using preoperative imaging and compared them with the intraoperative findings. We recommend that the aneurysm necks arising below the level of the OS and below the origin of the OA should be managed with a high index of suspicion and an alternate method of treatment should be sought. The ACP does not seem to have significant statistical bearing on the location of the aneurysm or the feasibility of surgical clipping. While, the OA, OS, direction of the aneurysm neck serve as reliable predictors for determining the feasibility of surgical clipping and in selecting patients who can be managed without surgery. Based on our results, we thus can reliably determine the patients who were likely to be benefited from a surgery and those who were not. The latter, should thus be offered alternative treatments upfront.

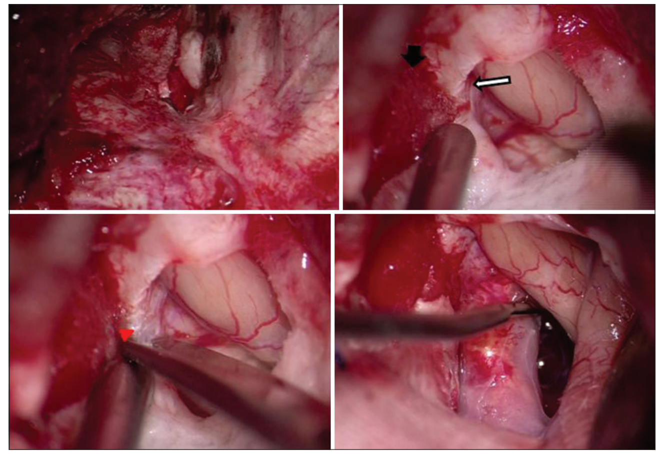

Figure 8: Case 3: The intraoperative findings similar to above cases showing the clinoidectomy (top left), the distal dural ring opening (black and white arrow, red arrow head) and the inability to visualize the aneurysm on the medial side of the internal carotid artery

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Conflicts of interest

There are no conflicts of interest.

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