MICROSURGICAL APPROACH FOR CLIPPING OF DISTAL ANTERIOR CEREBRAL ARTERY ANEURYSMS AND FACTORS AFFECTING THEIR CLINICAL OUTCOMES: A RETROSPECTIVE STUDY

Submitted for M.Ch Neurosurgery

By

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Submitted by : Dr. Bimal Kumar Sahoo

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CERTIFICATE

This is to certify that the thesis entitled "*Microsurgical approach for clipping of distal anterior cerebral artery aneurysms and factors affecting their clinical outcomes: A retrospective study* " is a bona fide work of Dr.Bimal Kumar Sahoo and was conducted in the Department of Neurosurgery, Sree Chitra Tirunal Institute for Medical Sciences & Technology, Thiruvananthapuram (SCTIMST), under my guidance and supervision.

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DECLARATION

This thesis titled entitled "*Microsurgical approach for clipping of distal anterior cerebral artery aneurysms and factors affecting their clinical outcomes: A retrospective study* " is a consolidated report based on a bonafide study of the period from January 2007 to January 2017, done by me under the Department of Neurosurgery, Sree Chitra Tirunal Institute for Medical Sciences and Technology (SCTIMST), Thiruvananthapuram.

This thesis is submitted to SCTIMST in partial fulfilment of rules and regulations of MCh Neurosurgery examination.

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INTRODUCTION

Distal anterior cerebral artery aneurysms (DACA aneurysms) are relatively uncommon and constitute 2-6% of all aneurysms(1). The aneurysm arises from anterior cerebral artery distal to the anterior communicating artery. DACA aneurysms similar to other intracranial aneurysms are usually saccular and flow related. Relative small size at the time of presentation, frequent association with other aneurysms and vascular anomalies such as azygous, bihemispheric, triplicated pericallosal arteries makes the aneurysm unique. Difficult location of the aneurysm deep in the anterior inter hemispheric space needs different microsurgical approaches. These aneurysms are fragile and have a high tendency to rupture during exposure itself. They are associated with higher morbidity and mortality than predicted from the angiogram(1)

Most series reports fewer than 30 patients. Largest series consists of 501 patients has been reported by Lehecka et al. This study was based on all DACA aneurysms from two neurosurgical centres in Finland from 1980 to 2005(2). In India the data about DACA a. are meagre. Two large studies in India are by Chhabra et al who studied 67 patients(3) and Shukla et al studied 132 patients(4). In this study we have included 40 consecutive operated cases of DACA aneurysms in Department of Neurosurgery, SCTIMST operated between 1st January 2007 to 1st January 2017. The different parameters included demographic distribution of the aneurysm, spectrum of presentations,

associated aneurysms, vascular anomalies, aneurysm characteristics, surgical management and outcome.

AIMS & OBJECTIVES

The aim and objective of present study includes

1. Study the demographic distribution, natural history and clinical presentations of DACA aneurysms.
2. Study the imaging and intra operative characteristics of DACA aneurysms.
3. Study the associated anomalies.
4. Study the pre-operative, intra-operative and post-operative factors influencing surgical outcome.
5. Study the complications related to DACA aneurysms.

Following key questions would be answered:

1. Is the outcome comparable to previous studies in the literature?
2. Are the factors affecting outcome significant enough and if they can be taken care of meticulously to improvise the outcome?

MATERIALS & METHODS

During the period from January 2007 to January 2017 we operated 40 DACA aneurysms in the Department of Neurosurgery, SCTIMST, Trivandrum .These patients were the subject of the study.

This study was a retrospective one, and the data were collected by reviewing patients case records. The details of clinical presentation, associated features, radiographic findings and surgical outcome were analysed by examining the case records.

Inclusion criteria

- Patients operated for DACA aneurysm

Exclusion criteria

- Patients with DACA aneurysm managed conservatively.

Patients were graded preoperatively using WFNS system based on

Glasgow Coma Scale.

- Grade I - GCS 15.
- Grade II - GCS 13-14; no deficits.
- Grade III - GCS 13-14; with neurological deficits.
- Grade IV GCS 8-12; with or without deficits.

- Grade V - GCS 3-7; with or without deficits.

The surgical outcome results were analysed using modified Rankin scale

- 0-no symptoms at all
- 1- No significant disability despite symptoms: able to carry out all usual duties & activities
- 2 - Slight disability: unable to carry out all previous activities. Able to look after own affairs without assistance
- 3- Moderate disability: requiring some help, but able to walk without assistance
- 4- Moderately severe disability: unable to walk without assistance, and unable to attend to own bodily needs without assistance
- 5- Severe disability: bedridden, incontinent, and requiring constant nursing care and attention.
- 6- Dead

MRS score 0-2 were considered as good outcome while 3-6 were considered as poor outcome.(5)

REVIEW OF LITERATURE

Anatomy of Anterior Cerebral Artery (ACA)

The knowledge of microanatomy of ACA is essential before studying DACA aneurysm. The ACA is traditionally divided into five segments. A1 segment or pre-communicating segment starts from the origin of ACA to Anterior communicating artery (Acom A). The A2 segment otherwise called post-communicating or Infracallosal segment, begins at the Acom A and follows the rostrum of the corpus callosum, the A3 segment, or precallosal segment, curves around the genu until the artery assumes a posterior course; the A4 segment or supracallosal segment and A5 segment or postcallosal segment run over the body of corpus callosum. The division between A4 and A5 is done by the vertical plane passing through the coronal suture. A2 and A3 constitute the ascending segment while A4 and A5 constitute the horizontal segment. The ACA divides into Callosomarginal (Cma A.) and Pericallosal arteries (Pca A.)(6). The Cma A. runs over the cingulate gyrus while Pca A. runs on the corpus callosum. As much as 20% patients lack Cma A. The prominent cortical branches include Orbitofrontal A., Frontopolar A. , Internal frontal A (divided into anterior, middle, and posterior branches), Paracentral A, and Parietal A.(divided into superior and inferior branches).

Anomalies of ACA are grossly divided into median ACA, bihemispheric ACA and azygous ACA. When bilateral A2 segment fuse to form a single A2 is known as azygous ACA. If one of the A2 segments is hypoplastic or

terminates early, the opposite ACA can divide and supply both hemispheres is known as bihemispheric ACA. A third ACA branch that supply the medial surface of either one or both hemispheres, is referred to as a median ACA(7)

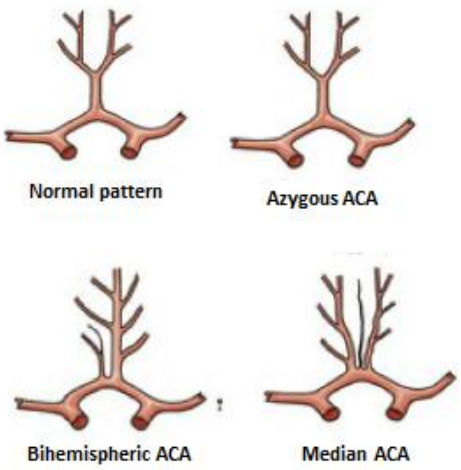


Figure-1: Showing variation of ACA.

- ACA aneurysms are divided into five groups(8)

1. A1 or proximal ACA aneurysms
2. Anterior communicating aneurysm
3. A2 segment and its frontobasal branch aneurysms or proximal pericallosal aneurysms
4. A3 segment, curving around genu of corpus callosum
5. A4 and A5 segment and it's distal cortical branch aneurysms or distal pericallosal aneurysms
6. Last three groups are included in DACA aneurysms.

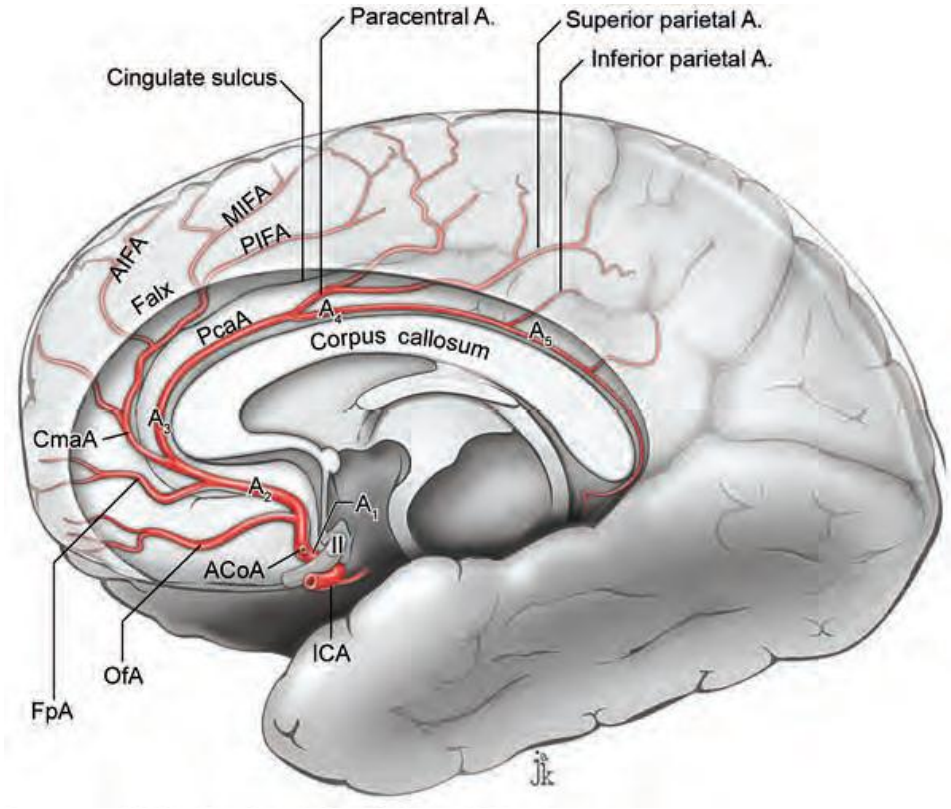


Figure 2: Microsurgical anatomy of ACA, pericallosal artery (PcaA), and callosomarginal artery (CmaA) (lateral view). The ACA is divided into five segments: A1, precommunicating or horizontal segment; A2, postcommunicating or infracallosal segment;A3, precallosal segment; A4, supracallosal segment; and A5, postcallosal segment(9).

- Predisposing factors for intra cranial aneurysms-

The exact pathophysiology of intra cranial aneurysms is unknown. Thin tunica media and adventitia layer are characteristics of intra cranial blood vessels. Large cerebral blood vessels lie in the sub arachnoid space with minimal connective tissue support. These factors may predispose these vessels for saccular aneurysms(10). As Rhoton described the aneurysms tend to occur at branching points, with dome projecting away from the convex surface of

arterial curve due to alteration of internal haemodynamic. These aneurysms are constantly surrounded by perforators(11).

Multiple factors are involved in the formation and growth of intra cranial aneurysm which includes trauma , hemodynamic stress acting on the vessel wall (12,13) infection, inflammation processes (14,15),arterial wall remodelling and degeneration(16,17), extrinsic risk factors such as smoking, hypertension, alcohol consumption and genetic predisposition(18). In a study by Gabriel et al about 2% of patient was found to have aneurysms without any risk factors of SAH. Women had aneurysms more often than men and their aneurysms had a greater risk of rupture. There was increased prevalence with age, atherosclerosis, familial predisposition, autosomal dominant polycystic kidney disease (ADPKD) (19). Cigarette smoking, alcohol consumption, hypertension(20–22), history of SAH(23) has been suggested to increase the risk of rupture of a previously known unruptured aneurysm.

- Prevalence of intracranial aneurysms

Intra cranial aneurysms constitute about 2% of adult general population (19). Incidence varies widely in both western countries(24,25) and various regions of India(26). In racial differences whites are twice more prone to having aneurysms than the black population(27).

- Prevalence of DACA aneurysms

DACA aneurysms otherwise known as pericallosal artery aneurysm present on anterior cerebral artery distal to Acom A. This aneurysm is relatively rare and constitutes about 1.5 to 9% of all intra cranial aneurysms(1). Indian studies also found similar incidence of 6.2% by Shukla et al (4)and 7.46% by Chhabra et al(3). DACA aneurysms are frequently found to be associated with other intracranial aneurysms(28). The incidence of intra cranial aneurysms associated with DACA aneurysm can be as high as 44%(1).

- Presentations
    - Clinical presentations of intra cranial aneurysm are variable. While a ruptured aneurysm may present dramatically with thunderclap headache, an unruptured aneurysm may present with vague symptom like dizziness. The common symptoms of ruptured aneurysm are(29).
    - Typical
        - Thunderclap headache (sudden, severe with maximum intensity peak within seconds/minutes)
        - Nausea/vomiting – nuchal rigidity – photophobia
        - Transient or persistent or delayed altered mental status/loss of consciousness
        - Other signs of increased ICP
        - Less frequent

- Mild intensity headache
- Seizures
- Focal neurological symptoms (dysarthria, lateralized sensory/motor symptoms)
- EKG abnormalities mimicking myocardial infarction
- Agitation, confusion, obtundation mimicking psychiatric disorders

- Common presentation of unruptured intracranial aneurysms

  - Headache: due to minimal leakage of blood which irritates the meninges experiencing a sentinel headache in the 2 months preceding the rupture

  - Symptoms due to mass effect (may be a warning sign of an impending rupture. Third cranial nerve palsy (from a posterior communicating artery aneurysm) bitemporal hemianopsia (from an anterior communication artery aneurysm impinging on the optic chiasm), ischemic cerebrovascular disease poorly defined spells, and seizures.

- Specific presentations of DACA aneurysms(30)

  - Akinetic mutism

  - Bilateral leg weakness

- Behavioural changes, and cognitive deficits

These typical presentations are due to involvement of bilateral cingulate gyri and the supplementary motor areas either because of intracerebral hemorrhage (ICH) or infarction.

- Clinical Grading Systems

Two clinical scales and one computed tomography based grading system most often used are

- Hunt and Hess grading and
- World Federation of Neurological Surgeons (WFNS) grading.
- Fischer scale, classifies subarachnoid hemorrhage (SAH) based on appearance and quantification intracranial blood on CT scan.

The Hunt and Hess grading system is as follows

Grade 1 – Asymptomatic or mild headache

Grade 2 – Moderate to severe headache, nuchal rigidity, and no neurologic deficit other than possible cranial nerve palsy

Grade 3 – Mild alteration in mental status (confusion, lethargy), mild focal neurologic deficit

Grade 4 – Stupor and/or hemiparesis

Grade 5 – Comatose and/or decerebrate rigidity

The WFNS scale is as follows:

Grade 1 – Glasgow Coma Score (GCS) of 15, motor deficit absent

Grade 2 – GCS of 13-14, motor deficit absent

Grade 3 – GCS of 13-14, motor deficit present

Grade 4 – GCS of 7-12, motor deficit absent or present

Grade 5 – GCS of 3-6, motor deficit absent or present

Modified WFNS scale differs from the original scale in that patients with GCS scores of 14 and 13 are assigned to grade II and grade III, respectively, regardless of the presence of neurologic deficits, prognostication of patients with SAH was more accurate than the original scale(31).

The Fischer scale (CT scan appearance) is as follows:

- Group 1 – No blood detected
- Group 2 – Diffuse deposition of subarachnoid blood, no clots, and no layers of blood greater than 1 mm
- Group 3 – Localized clots and/or vertical layers of blood 1 mm or greater in thickness
- Group 4 – Diffuse or no subarachnoid blood, but intracerebral or intraventricular clots are present

Differences between the Fisher scale and modified Fisher scale(32)

SAH classification	IVH	Fisher grade	Modified Fisher grade
Diffuse, thick SAH	Present	3	4
	Absent	3	3
Localized, thick SAH	Present	3	4
	Absent	3	3
Diffuse, thin SAH	Present	4	2
	Absent	2	1
Localized, thin SAH	Present	4	2
	Absent	1	1
No SAH	Present	4	2
	Absent	1	0

All these grading systems are important for prognosis assessment and urgency of interventions.

- Diagnosis and Imaging

The intracranial aneurysms usually diagnosed clinically following rupture or appearance of compression symptoms; these are then confirmed by imaging. Aim of imaging is to correctly diagnose the presence of aneurysm, nature of aneurysm, associated anatomical variations, complications and assessment of their treatment (pre-procedural, periprocedural and follow up)

- Computed tomography

Soon after its introduction in 1970 it has been utilised for demonstration of SAH (33) . High density of recently clotted blood makes it suitable tool for diagnosing acute intracranial haemorrhage. Being the faster imaging method with need for minimum patient cooperation it is the first investigation of choice in case of suspected SAH. Again in one of the study by Van der wee et al found sensitivity and specificity rates of 100% and 98% respectively for CT scan performed within 12 hours of ictus(34). CT scan not only confirms diagnosis but also shows the distribution (intracerebral, intraventricular, subarachnoid or subdural) and volume of intracranial haemorrhage. Distribution of SAH helps in predicting the cause of bleed, location of ruptured aneurysm (35) and volume of clot predicts the severity of illness (36–39). Limitations of CT scans include false negative results due to poor quality imaging, artefacts caused by patient movements, inaccurate interpretation by inexperienced radiologists. Haemorrhage in posterior fossa and close to skull base more likely to be missed (40). Again chances of CT detection of haemorrhage reduce with time over the first 2 weeks following aneurysm rupture and may be as low as 50% at 7 days(41).

- CT Angiography(CTA)

Angiography by CT scan has an important role in investigating the spontaneous SAH. Benefits of CTA include ability to detect most intracranial aneurysms 3 mm or larger, allows study of the surrounding osseous anatomy

and 3D anatomy of vessels. Vieco et al. reported sensitivity rates for CT angiography of 77%-97% and specificity rates of 87%-100% for the detection of ruptured aneurysm in 30 SAH patients(42).

- Magnetic resonance imaging (MRI)

Three dimensional time of flight (TOF) MRA is the most widely used MRI sequence for evaluation of intra cranial aneurysms.

Advantages(43):

- Provides good spatial resolution
- Relatively insensitive to signal loss caused by turbulent flow
- Performed within a time span that allows anatomic MRI during the same imaging session

Limitations(43):

- The sequences are sensitive to patient motion. A patient with acute SAH is in severe pain which limits the ability to remain relatively motionless. This may limit its use in the setting of acute SAH.
- Artefacts related to spin saturation and flow can simulate cerebral aneurysms.
- The signal intensity of substances that are bright on unenhanced or contrast-enhanced T1-weighted images, such as methemoglobin-

containing (hematomas) and cystic lesions filled with proteinaceous material, can be transmitted onto TOF source images and simulate an aneurysm. Uses accelerated parallel imaging. It is reported to have higher sensitivity than TOF, similar to high-resolution CTA(44).

- Digital Subtraction Angiography

DSA remains to be the reference standard for evaluation of cerebral aneurysms(45,46). Small intimal flaps (i.e., dissecting aneurysms or associated arterial dissections) may be missed on CTA that is why the final analysis should rely on DSA. 3D rotational angiography has increased the diagnostic capability. A study of 350 patients with aneurysms showed that the application of 3D rotational angiography allowed detection of 94 additional aneurysms, most of them smaller than 3 mm (mean size 3.54 mm)(47).

For surgical planning and follow up comparison following features is important

- Neck-to-dome ratio, neck to artery ratio, and maximum dimensions
- The relationship of aneurysms to surrounding structures, including perforating arteries, osseous structures, and the dural ring.

Limitations:

- DSA requires the use of iodinated contrast material (with the attendant risks of nephrotoxicity) and ionizing radiation.

- Also introduces the risk of complications related to the use of an arterial catheter, including stroke

- Ultrasound

Transcranial Doppler(TCD) ultrasound is a well-established tool for measurement of blood flow velocities, detect vasospasm and to image the basilar artery(48,49). Colour coded has also been used to identify intracranial aneurysms after SAH(50,51). Wardlaw et al were able to identify 30 of 33 aneurysms demonstrated by intra-arterial DSA in a group of 35 selected patients by using a modified Doppler ultrasound technique called "colour Doppler energy" to improve the technique's sensitivity for intracranial vascular imaging(52).

- Surgery for DACA aneurysms

  - Indications

Ruptured DACA aneurysms are usually associated with hematomas that require surgical evacuation because of mass effect. The Cooperative study in 1966 showed bled DACA aneurysm carries a mortality rate of 81% on conservative treatment as compared to the 32% mortality rate post-surgery (53). Again rupture rate for unruptured DACA aneurysms is notoriously high. Although International Study of Unruptured Intracranial Aneurysms (ISUIA) showed low rupture rate (about 0·1% per year) for anterior circulation aneurysm of size below 7mm, many studies on DACA aneurysm have reported

otherwise(54). A review found that 67% of ruptured DACA aneurysms were less than 6 mm(55). Bleeding occurs irrespective of size because of lack of arachnoid membranes at the level of pericallosal cisterns(56) and higher aneurysm/parent vessel size ratio. So it is reasonable to consider surgery for unruptured aneurysms irrespective of size, inpatients that are young, have irregular or fusiform aneurysms or have family history of aneurysmal bleed.

- Surgical approaches

Many surgical approaches and techniques have been described in literatures for DACA aneurysm. All these methods have evolved with the aim of getting a proximal control early, minimising brain tissue retraction, easy arrival at the aneurysm and smooth clipping. Aneurysms in the frontobasal or proximal region can be approached through the pterional craniotomy with removal of gyrus rectus or sub frontal approach. Although Laitinen and Snellman first described subfrontal approach Because of difficulty he later shifted to interhemispheric approach(57). De Sousa et al described three different approaches through unilateral triangular bone flap(1). The position of the bone flap varied from frontobasal to parietal depending upon the location of the aneurysm. Interhemispheric approach as described by Yasargil is currently most accepted for DACA aneurysm(58). This surgical approach is recommended for any aneurysm distal to the mid genu of the corpus callosum. Other approaches described are anterior frontal approach by Ohno et al(55), basal interhemispheric approach by Yasui et al(59). Although so many surgical techniques are available most neurosurgeons prefer unilateral (usually right))

frontal paramedian craniotomy with interhemispheric approach. I- ,C- or U-shaped flaps all are used.

- Aneurysm dissection

For A2 and proximal A3 aneurysms patient is positioned supine with head in neutral position. For distal A3 to A5 aneurysms head lateral with operative side down to allow gravity to retract the brain. Skin incision is made behind hairline. For A2 aneurysms a bicoronal or curvilinear incision may be put. If the A2 aneurysm is proximal standard frontotemporal craniotomy or lateral subfrontal approach may be preferred. For A3 to A5 aneurysms a trap door incision may be done ipsilateral to aneurysm. After craniotomy dura is opened based on superior sagittal sinus (sss). Dura is reflected to opposite site with firm tacking sutures. This gives access to subdural plane down the falx from SSS to inferior saggital sinus. This approach may be troubled by presence of bridging veins draining to SSS, veins that fuse to dura before reaching the midline, arachnoid granules and thin adhesions. Arachnoid granules and adhesions may be gently removed but veins need special care. Draining veins attached to dura may be preserved by splitting the dural flap and creating a working corridor between the veins. After opening the interhemispheric fissure, dissection proceeds deeper to reach the roof of the posterior corpus callosum cistern beneath the free edge of the falx. Early removal of haematoma creates more working space. If the hematoma has penetrated the ventricle, its removal collapses the ventricle as well as decompresses the brain. However the haematoma attached to the fundus of

aneurysm should be left untouched till proximal control is achieved to prevent uncontrolled rupture. Sub arachnoid haemorrhage, haematoma and brain swelling may make dissection further difficult. The callosomarginal artery may be confused with pericallosal artery, the rt pericallosal artery may be confused with left and vice versa. Identification of corpus callosum by its white colour signals the arrival of pericallosal artery depth. The pericallosal artery is followed anteriorly to open the interhemispheric fissure till inferior margin of falx. In dissection of ruptured aneurysms distal to proximal approach may be dangerous, in such case once dissection plane established between posterior parts of frontal lobes, dissection shifts anteriorly to get proximal control. Usually surgeon arrives at the dome of DACA aneurysm before getting proximal control. This is more common with proximal aneurysms(60). To reach the A2 segment proximal to the aneurysm some advice gentle retraction while others advice partial resection of genu(61). Delineation of vascular anatomy is essential with the use of sharp instruments. Throughout the dissection liberal use of papaverin solution is needed as these small vessels are vulnerable for vasospasm. Ideally, all four vessels should be visible before safe clipping: two proximal and two distal segments. Indocyanin green (ICG) may be used to identify before clipping. Temporal clip may be needed during final dissection especially in large aneurysms. Mild rise in blood pressure with mean arterial pressure 90-100 may be needed during temporary clipping. Anatomy of DACA aneurysms usually permits clipping with single or multiple stacked clips. Arteries draping the aneurysm, incomplete plane between aneurysm neck

and efferent artery, may demand fenestrated clip(60). After aneurysm clipping residual haematoma may be evacuated. The aneurysm may be punctured with needle or microscissors to verify that the aneurysm is completely excluded. The patency of afferent and efferent arteries is confirmed by ICG fluoroscopic angiography and a micro Doppler probe. Quantitative flow across the vessel may be measured using Transonics flowmeter(61). The dura is usually possible to be closed primarily or with small pericranial patch. Bone flap is fixed with titanium plate and screw. Galea is closed with absorbable sutures and skin is closed with suture or stapler.

- Role neuronavigation system

The accurate localisation of aneurysm preoperatively is important to avoid unnecessary handling and damage to vital structures. Use of neuronavigation with CT angiography and MR angiography help in better localisation of aneurysm and deciding the proper approach. Kim et al. reported 12 patients with DACA aneurysms which were clipped guided by neuronavigation system. The neuronavigation system provided real time presentation of the aneurysm which helped in localising the aneurysm. Additional benefits were small craniotomy and accurate intra operative orientation. The registration precision ranged from 0.5-1.5mm with mean 0.88mm(62). They concluded that the DACA aneurysms are good candidate for use of neuronavigation.

- Avoiding complications(61)

  - Avoid sacrifice of cortical bridging veins by splitting the dural flap attached to cortical veins and creating a working corridor between the veins.

  - Superior sagittal sinus violation may be suture repaired than compression with thrombotic agents which may cause thrombosis of sinus.

  - Proximal and distal segments of aneurysms must be preserved, as DACA provide blood supply to structures like cingulate gyrus, precentral and post central mesial cortex.

- Summary of surgical tips

  - DACA aneurysms are often multiple, small with high incidence of intracerebral and intraventricular haemorrhage. Surgery should be considered in all cases even in aneurysms < 7mm.

  - Image guidance with CTA or MRA is extremely useful for localise and plan for approach of surgery

  - Preparation for a bypass graft and/or DACA to DACA bypass followed by trapping of the aneurysm in case of large or complex aneurysms.

  - Proper positioning of head in order to get the help of gravity retraction of frontal lobe.

- Preservation of cortical bridging veins.
- Violation of superior sagittal sinus to be repaired rather than compression control with thrombotic agents.
- Identification of corpus callosum and pericallosal artery.
- Early evacuation of haematoma except part attached to aneurysm.
- Identification of two afferent and two efferent arteries before clipping.
- Post clipping gentle puncture of fundus of aneurysm to confirm the complete exclusion of aneurysm
- Post op afferent and efferent artery patency assessment by ICG fluoroscopic angiography and quantitative flow assessment by Transonics flowmeter.

- Role of endovascular treatment-

Earlier studies have shown a higher complication rates like arterial dissection, intraprocedural rupture, incomplete occlusion rates for DACA aneurysms (63–66). With evolving technology like soft/ultra-soft coils, micro catheters, stent assisted coiling the complication rates have decreased but are still high when compared to other sites of circle of Willis. Keston et al found higher rates of periprocedural rupture and incomplete obliteration as compared to other circle of Willis aneurysms(63). Sturiale et al found in his study aneurysmal occlusion rate of 86 %, iatrogenic rupture rates of 7%, morbidity

rate of 8% and mortality rate of 9%(67). Huang et al in his study of 41 patients found technical success rate of 97.6% and aneurysm occlusion rate of 90.3%(68). Unique features of DACA aneurysms like small size, broad base with originating branches, presence oh haematoma, associated ACA anomalies and multiple aneurysms prevents it from smooth endovascular coiling. Till now surgical clipping is considered to be treatment of choice for DACA aneurysms while endovascular treatment remains potential alternative.

RESULTS

The present study contains 40 consecutive cases of operated cases of DACA aneurysms between 1st Jan 2007 to 1st January 2017.

- **Sex distribution**

Sex	Frequency	Percent
Male	14	35.0
Female	26	65.0
Total	40	100.0

Table 1

In our study 65 %(n=26) were females.

- **Age distribution**

	N	Median age in years	Minimum age in years	Maximum age in years
Age	40	55	28	84

Table 2

Median age of presentation was 55yrs (ranged from 28 to 84yrs).

- **Distribution according to presence of hypertension**

Presence of hypertension	Frequency	Percent
Yes	13	32.5
No	27	67.5
Total	40	100.0

Table 3

In our study 32.5 %(n=13) patients had hypertension.

- **Distribution according to presence of Diabetes mellitus**

Presence of diabetes mellitus	Frequency	Percent
Yes	8	20.0
No	32	80.0
Total	40	100.0

Table 4

Twenty percent (n=8) of our patients had diabetes mellitus.

- **Distribution according to WFNS grading**

WFNS grading	Frequency	Percent
Grade 1	22	55.0
Grade 2	2	5.0
Grade 3	10	25.0
Grade 4	6	15.0
Total	40	100.0

Table 5

At the time of presentation 55% (n=22) were with WFNS grade 1, 5% (n=2) were with WFNS grade 2, 25 %(n=10) were with WFNS grade 3, 15% (n=6)were with WFNS grade 4.

- **Distribution according to presence of headache during presentation**

Presence of h/o of headache	Frequency	Percent
Yes	35	87.5
No	5	12.5
Total	40	100.0

Table 6

In 87.5% (n=35) patients typical thunder clap headache was the presenting feature.

- **Distribution according to presence of history of loss of consciousness**

Presence of h/o of loss of consciousness	Frequency	Per cent
Yes	21	52.5
No	19	47.5
Total	40	100.0

Table 7

In 52.5% (n=21) patients history of loss of consciousness was present.

- **Distribution according to presence of history of seizure**

Presence of h/o of seizure	Frequency	Percent
Yes	3	7.5
No	37	92.5
Total	40	100.0

Table 8

In 7.5% (n=3) patients history of seizure was present.

- **Distribution according to presence of history of weakness of lower limb**

Presence of h/o of limb weakness	**Frequency**	**Percent**
Yes	12	30.0
No	28	70.0
Total	40	100.0

Table 9

In 30% (n=12) of patients history of limb weakness was present.

- **Distribution according to Fischer grading**

Fischer grade	Frequency	Percent
Grade 1	6	15.0
Grade 2	7	17.5
Grade 3	15	37.5
Grade 4	12	30.0
Total	40	100.0

Table 10

In our study 15% (n=6) had Fischer grade 1, 17.5 %(n= 7) had Fischer grade 2, 37.5%(n=15) had Fischer grade 3 ,30%(n=12)Fischer grade 4 sah.

- **Distribution according to presence of hydrocephalus**

Presence of hydrocephalus	Frequency	Percent
Present	8	20.0
Absent	32	80.0
Total	40	100.0

Table 11

Pre op hydrocephalus was found in 20% (n=8) of cases.

- **Distribution according to presence of infarct**

Presence of h/o of infarct	Frequency	Percent
Present	4	10.0
Absent	36	90.0
Total	40	100.0

Table 12

Pre-operative CT scan was showing infarct in 10 % (n =4) of cases.

- **Distribution according to shape of aneurysm**

Shape of aneurysm	Frequency	Percent
Saccular	40	100%
Fusiform	0	0 %

Table 13

All patients (n=40) in our study had saccular aneurysms

- **Distribution according to direction of projection**

Projection	Frequency	Percent
Anterior	30	75.0
Posterior	10	25.0
Medial	14	35.0
Lateral	17	42.5
Data not available	9	22.5
Superior	32	80.0
Inferior	7	17.5
Data not available	1	2.5

Table 14

In our study 75 %(n=30) patients had anteriorly directed aneurysms, 42.5%(n=17) had laterally directed aneurysms while 80%(n=32) patient had superiorly directed aneurysms.

- **Distribution according to side of aneurysm**

Side of origin of aneurysm	Frequency	Percent
Right	14	35
Left	25	62.5
Bilateral mirror aneurysm at A3 segment	1	2.5
Total	40	100.0

Table 15

Right sided aneurysm was found in 35% (n= 14) of cases, in 62.5% (n=25) cases it was left sided while in one case (2.5%) it was bilateral.

- **Distribution according to segment of ACA giving rise to aneurysm**

Segment of ACA	Frequency	Percent
A2	22	51.16
A3	20	46.52
A4	1	2.32
A5	0	0
Total	43	100.0

Table 16

In our 40 patients total 43 DACA aneurysms were found. Out of which 51.16% (n=22) were at A2 segment, 46.51 %(n=20) were at A3 segment and 2.32%(n=1) was found on A4 segment. No A5 segment aneurysm was found.

- **Distribution according to maximum dome diameter**

Maximum dome diameter	N	Percent
<7mm	28	71.8
≥7mm	11	28.2
Total	39	100.0

Table 17

In our study 71.8 %(n=28) patients had small(<7mm) DACA aneurysms, with maximum dome diameter less than 7mm while 28.2 %(n=11) patients it was ≥7mm. In 1 patient data was not available.

- **Distribution according to Aspect ratio**

	N	Median	Maximum	Minimum
Aspect ratio	39	2.89	6.66	1.06

Table 18

Median Aspect ratio was 2.89 (ranged from 1.06 to 6.66)

- **Distribution according to presence of anomalous circulation**

Presence of anomalous circulation	Frequency	Percent
Present	10	25.0
Absent	30	75.0
Total	40	100.0

Table 19

Anomalous circulations were associated with 25 %(n=10) of DACA aneurysms

- **Distribution according to lobularity of the aneurysm**

Lobularity of the aneurysm	Frequency	Percent
Single	25	62.5
Bilobed	7	17.5
Multilobed	8	20.0
Total	40	100.0

Table 20

This study had 17.5% (n=7) patients with bilobed aneurysms while 20%(n=8) cases had multilobed aneurysms(≥3) rest (62.5%, n= 25) had non lobulated saccular aneurysms

- **Distribution according to presence of multiple aneurysms**

Multiple aneurysms	Frequency	Percent
Present	14	35.0
Absent	26	65.0
Total	40	100.0

Table 21

Thirty five percent (n=14) patients had multiple aneurysms.

- **Distribution according to presence of fullness of brain on dural opening**

Fullness of brain on dural opening	Frequency	Percent
Full	18	45.0
Lax	22	55.0
Total	40	100.0

Table 22

Brain was full on dural opening in 45% (n=18) cases.

- **Distribution according to presence of fullness of brain on dural closure**

Fullness of brain on dural closing	Frequency	Percent
Full	1	2.5
Lax	39	97.5
Total	40	100.0

Table 23

Brain was full on dural closing only in 1 patient (2.5%) who later needed csf diversion.

- **Distribution according to procedure done**

Procedure	Frequency	Percent
Microsurgical clipping only	36	90
Microsurgical clipping with additional wrapping	4	10
Total	40	100.0

Table 24

All DACA aneurysms (n=40) were clipped additional muscle wrapping was done in 10% (n=4) cases for residual aneurysms.

- **Distribution according to occurrence of intra operative rupture**

Intra-operative rupture of aneurysm	Frequency	Percent
Present	5	12.5
Absent	35	87.5
Total	40	100.0

Table 25

Intra operative rupture occurred in 12.5% (n=5) cases.

- **Distribution according to frequency of temporary clipping**

Intra-operative temporary clipping	Frequency	Percent
Present	21	52.5
Absent	19	47.5
Total	40	100.0

Table 26

Intra operative temporary clipping was needed in 52.5 %(n=21) cases

- **Distribution according to duration of temporary clipping**

	N	Median	Maximum	Minimum
Total duration of temporary clipping	21	3mins 40secs	28mins	1min

Table 27

Median duration of temporary clipping was 3mins 40secs (range 1-28 mins)

- **Distribution according to occurrence of symptomatic vasospasm**

Symptomatic post-operative vasospasm	Frequency	Percent
Present	9	22.5
Absent	31	77.5
Total	40	100.0

Table 28

Symptomatic post-operative vasospasm occurred in 22.5 % (n=9) cases.

- **Distribution according to occurrence of cerebral infarct post operatively**

Presence of post-operative infarct	Frequency	Percent
Present	8	18
Absent	32	82
Total	40	100.0

Table 29

Post op infarct was found in 18 %(n=8) cases.

- **Distribution according to occurrence of operative site haematoma**

Presence of operative site haematoma	Frequency	Percent
Present	5	12.5
Absent	35	87.5
Total	40	100.0

Table 30

Operative site haematoma occurred in 12.5 %(n=5) cases.

- **Distribution according to need for post-operative csf diversion**

Postop-CSf diversion	Frequency	Percent
Present	1	2.5
Absent	39	97.5
Total	40	100.0

Table 31

Post-operative csf diversion was needed in only 1(2.5%) patient.

- **Distribution according to re-exploration due to post-operative complications**

Re-exploration	Frequency	Percent
Present	5	12.5
Absent	35	87.5
Total	40	100.0

Table 32

Re-exploration was needed in 12.5% (n=5) cases.

- **Distribution according to presence of post-operative motor deficit.**

On discharge- presence of motor deficit (Includes persistent and new onset cases)	Frequency	Percent
Present	14	35.0
Absent	26	65.0
Total	40	100.0

Table 33

During discharge 35% (n=14) patients had motor deficit which included the persistent motor deficit group along with new onset group.

- **Distribution according to no of hospital stay post-surgery**

	N	Mean	Minimum	Maximum
No of days of hospital stay post-surgery	40	10.0	6	78

Table 34

Median no of hospital stay post-surgery was 10.0 days (ranged from 6-78 days)

- **Distribution according to outcome during discharge**

Discharge outcome	Frequency	Percent
Poor (mRS3-6)	12	30.0
Good (mRS≤2)	28	70.0
Total	40	100.0

Table 35

Good outcome was found in 70% (n=28) of cases at the time of discharge.

- **Distribution according to final outcome.**

Final outcome	Frequency	Percent
Poor (mRS3-6)	9	22.5
Good (mRS≤2)	31	77.5
Total	40	100.0

Table 36

Final outcome (included the condition patients at 6 month follow up and discharge mRS score for patient who didn't come for follow up) was good in 77.5%(n=31) of cases .

- **Comparison of prognostic parameters to the discharge outcome**

Parameters		**Poor outcome %(n)**	**Good outcome %(n)**	**p**
Sex	Male	28.6%(n=4)	71.4(10)	0.885
	Female	30.8%(8)	69.2(18)	
Hypertension	Present	53.8(7)	46.2(6)	*0.022*
	Absent	18.5(5)	81.5(22)	
Diabetes Mellitus	Present	62.5(5)	37.5(3)	*0.025*
	Absent	21.9(7)	78.1(25)	
WFNS grading	Grade 1	13.6(3)	86.4(19)	*0.01*
	Grade 2	50(1)	50(2)	
	Grade 3	30(3)	70(7)	
	Grade 4	83.3(5)	16.7(1)	
Maximum dome diameter	<7mm	25(7)	75(21)	0.478
	≥7mm	36.4(4)	63.6(11)	
Modified Fischer's grade	1 and 2	23.1(3)	76.9(10)	0.5
	3 and4	33.3(9)	66.7(18)	
Hydrocephalus	Present	37.5(3)	62.5(5)	0.605
	Absent	28.1(9)	71.9(23)	
Pre op infarct	Present	25(1)	75(3)	0.818
	Absent	30.6(11)	69.4(25)	
Anomalous circulation	Present	50(5)	50(5)	0.111
	Absent	23.3(7)	76.7(23)	
Other aneurysms	Present	14.3(2)	85.7(12)	0.112
	Absent	38.5(10)	61.5(16)	
Brain on dural opening	Full	38.9(7)	61.1(11)	0.267
	Lax	22.7(5)	77.3(17)	
Segment of aneurysm origin	A2	71.4(15)	28.6(6)	0.776
	A3	64.7(11)	35.3(6)	
	A2 and A3	100(1)	0	
	A3 and A4	100(1)	0	
Intraoperative rupture	Present	0(0)	100(5)	0.118
	Absent	34.3(12)	65.7(23)	
Intraoperative need for temporary clipping	Present	71.4(15)	28.6(6)	0.836
	Absent	68.4(13)	31.6(6)	
Operative site haematoma	Present	60(3)	40(2)	0.118
	Absent	25.7(9)	74.3(26)	
Post-operative vasospasm	Present	66.7(6)	33.3(3)	*0.006*
	Absent	19.4(6)	80.6(25)	
Post-operative infarct	Present	87.5(7)	12.5 (1)	*0.0*
	Absent	15.6(5)	84.4 (27)	

Table 37

CHARTS & GRAPHS

- **Sex distribution**

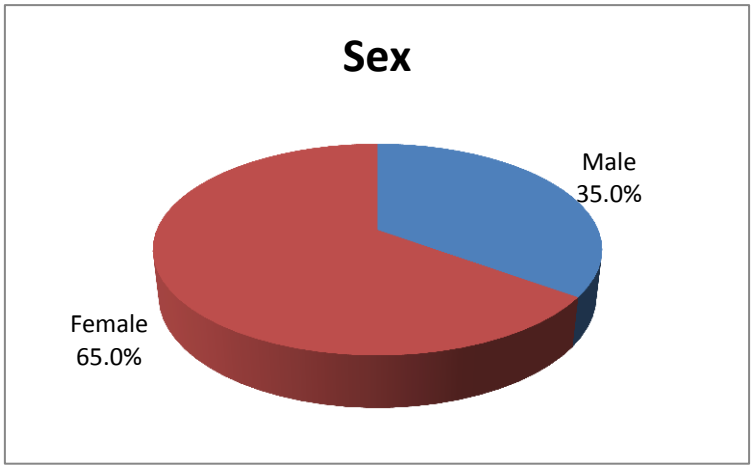


Figure 1

In our study 65 %(n=26) were females.

- **Age distribution**

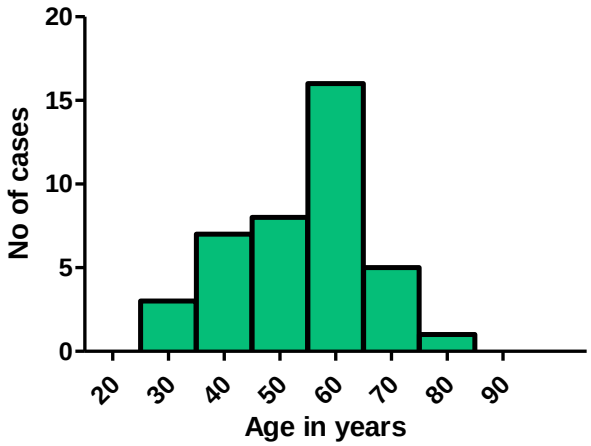


Figure 2

Median age of presentation was 55yrs (ranged from 28 to 84yrs).

- **Distribution according to presence of hypertension**

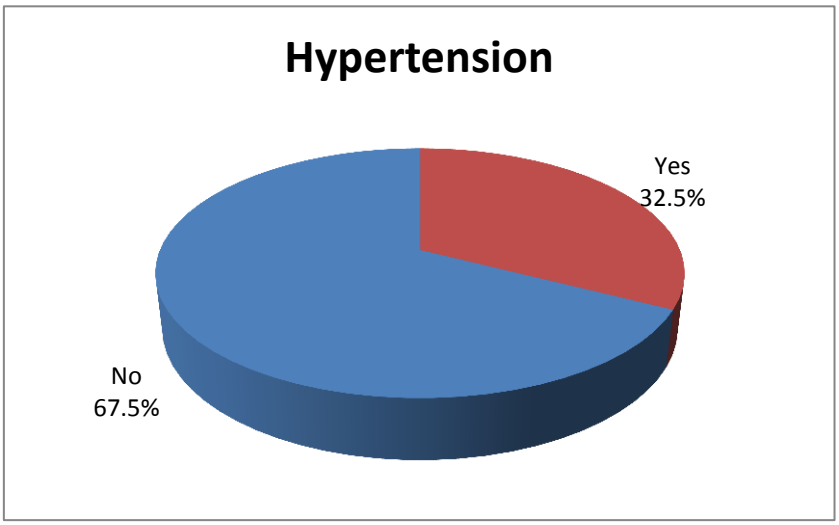


Figure 3

In our study 32.5 %(n=13) patients had hypertension

- **Distribution according to presence of Diabetes mellitus**

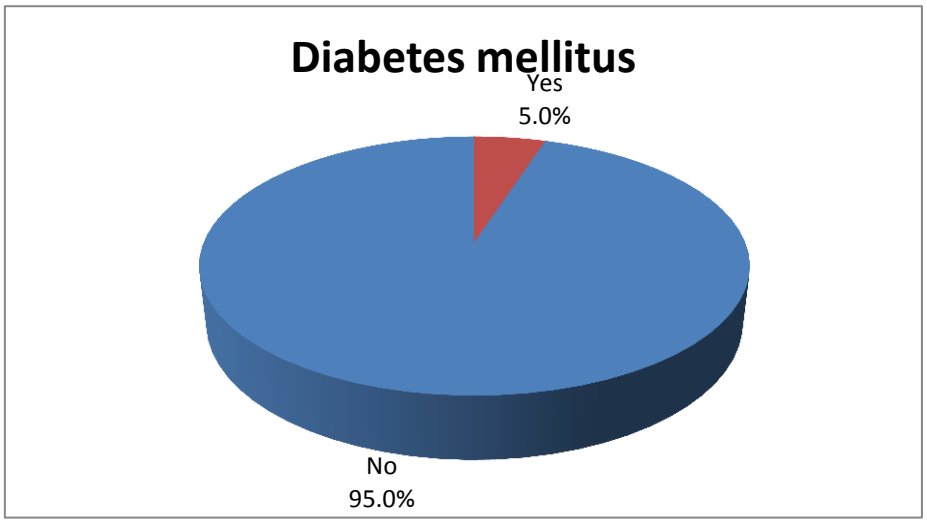


Figure 4

Twenty percent (n=8) of our patients had diabetes mellitus

- **Distribution according to WFNS grading**

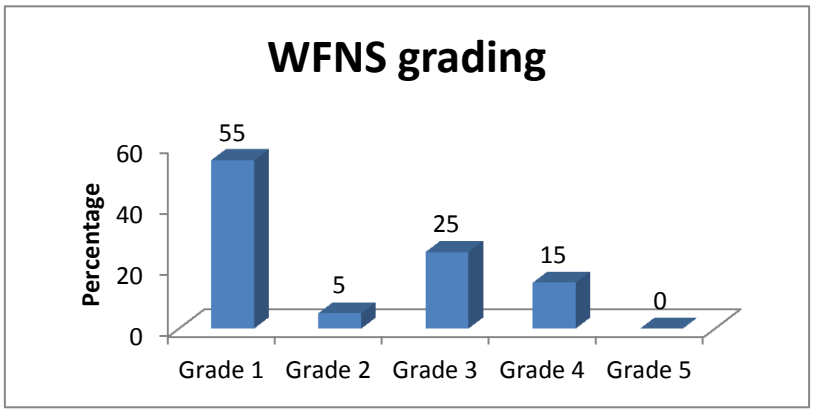


Figure 5

At the time of presentation 55% (n=22) were with WFNS grade 1, 5%(n=2)were with WFNS grade 2, 25%(n=10)were with WFNS grade 3, 15% (n=6)were with WFNS grade 4.

- **Distribution according to presenting complain**

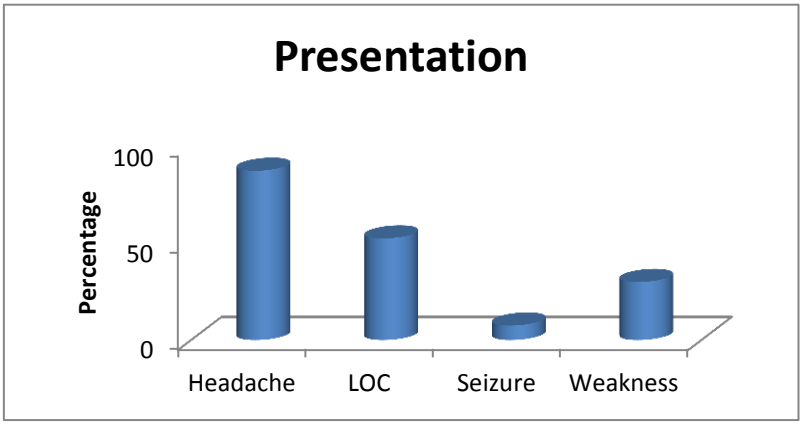


Figure 6

In 87.5% (n=35) patients history of typical thunder clap headache was found, loss of consciousness in 52.5%(n=21), seizure in 7.5%(n=3) and in 30%(n=15) limb weakness.

- **Distribution according to Fischer grading**

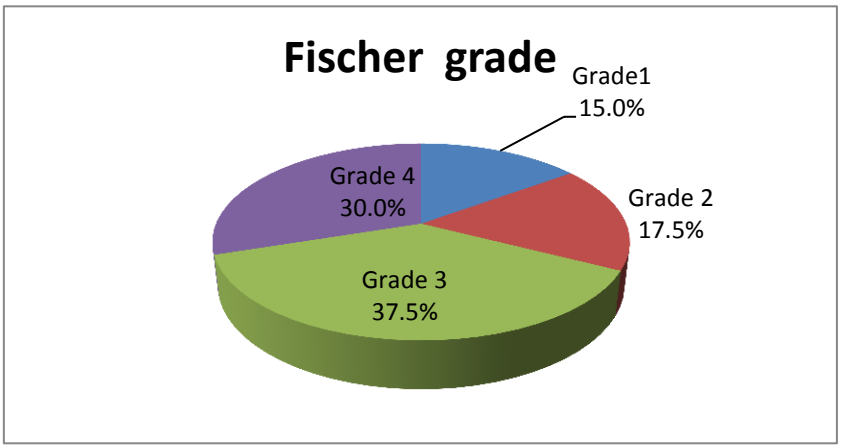


Figure 7

In our study 15% (n=6) had Fischer grade 1, 17.5 %(n= 7) had Fischer grade 2, 37.5%(n=15) had Fischer grade 3 ,30%(n=12)Fischer grade 4 sah.

- **Distribution according to presence of hydrocephalus**

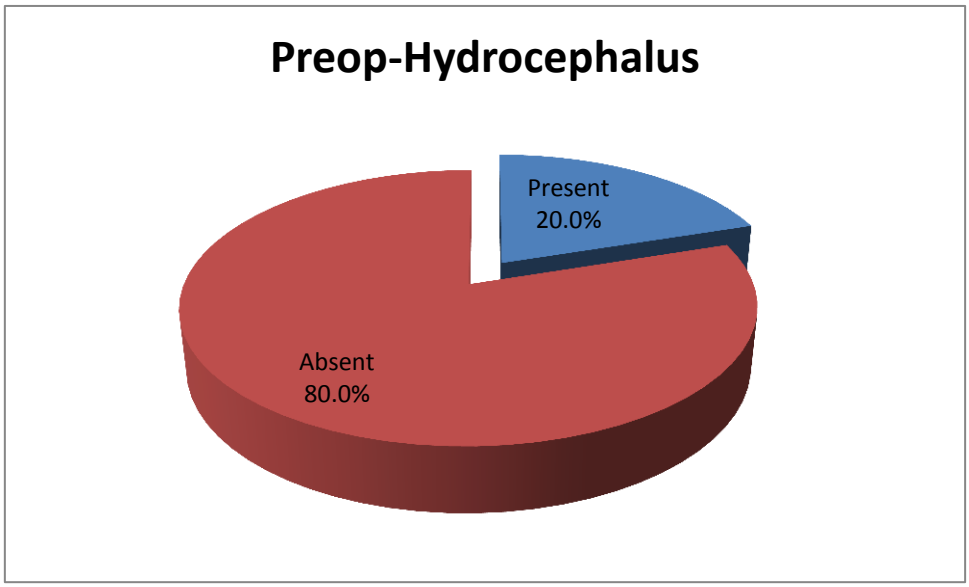


Figure 8

Pre-operative hydrocephalus was present in 20% (n=8) of cases.

- **Distribution according to time since bleed**

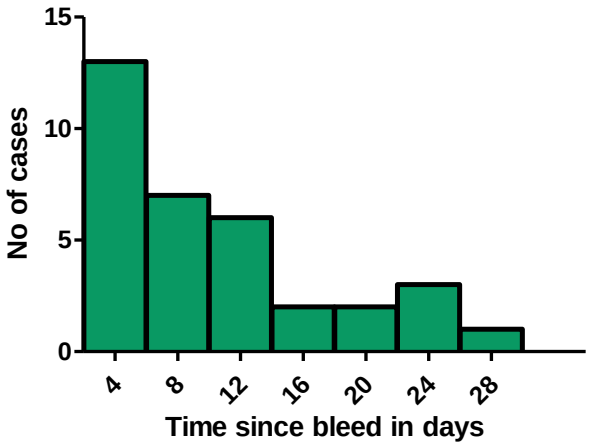


Figure 9

Median duration of time since bleed to surgery was 7days (range 0-28days).

- **Distribution according to direction of projection of aneurysm**

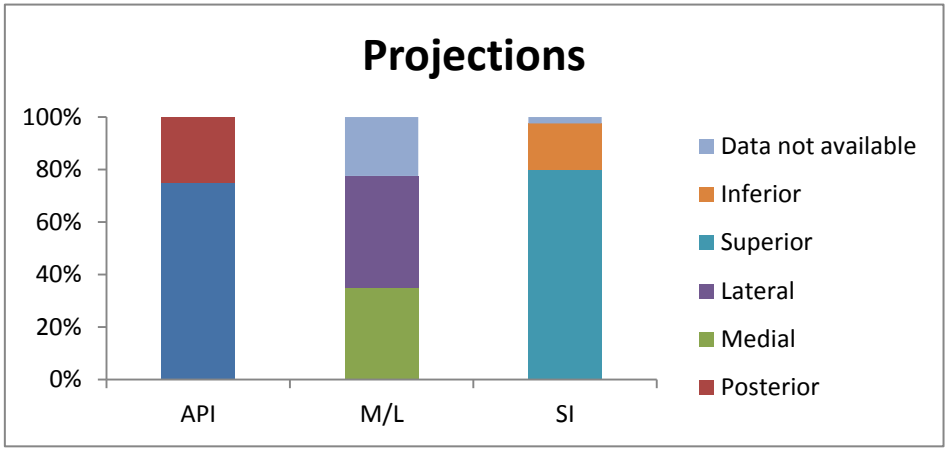


Figure 10

In our study 75% patients had anteriorly directed aneurysms, 42.5% had laterally directed aneurysms while 80% patient had superiorly directed aneurysms

- **Distribution according to side of aneurysm.**

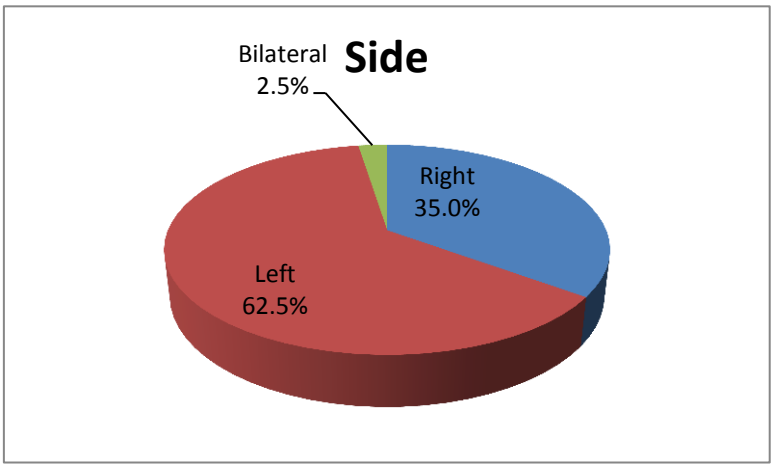


Figure 11

Right sided DACA aneurysm was found in 35% (n= 14) of cases, in 62.5% (n=25) cases it was left sided while in one case (2.5%) it was bilateral mirror aneurysm was found.

- **Distribution according to segment of ACA giving rise to aneurysm**

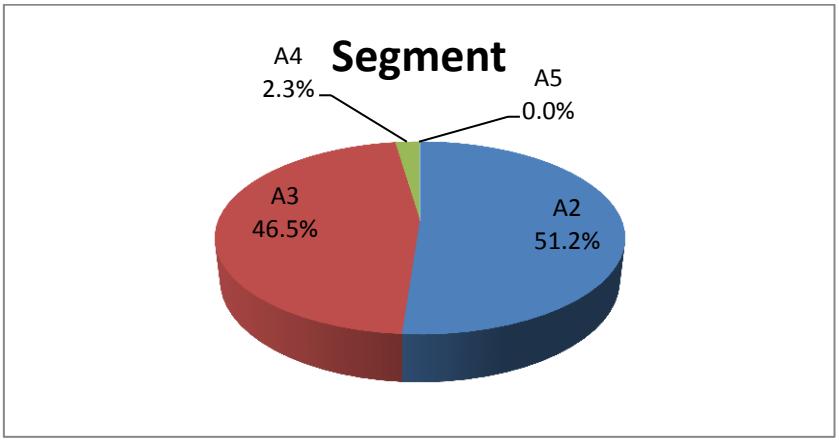


Figure 12

In our 40 patients total 43 DACA aneurysms were found. Out of which 51.16 %(n=22) were at A2 segment, 46.52 %(n=20) were at A3 segment and 2.32%(n=1) was found on A4 segment. No A5 segment aneurysm was found.

- **Distribution according to presence of anomalous circulation.**

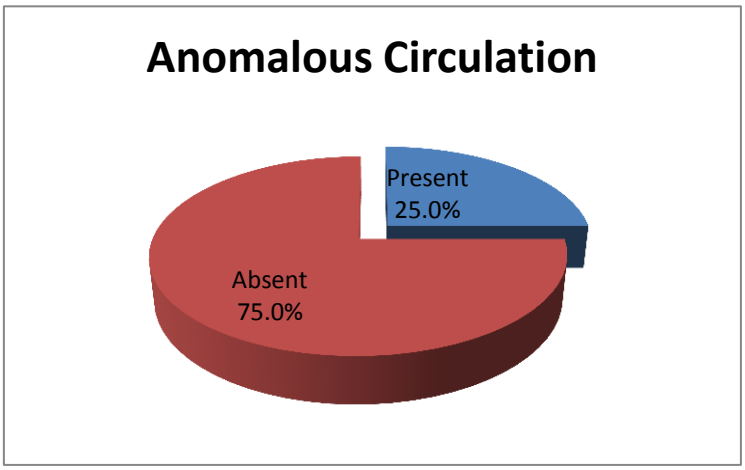


Figure 13

Anomalous circulations were associated with 25 %(n=10) of DACA aneurysms

- **Distribution according to lobularity of aneurysm**

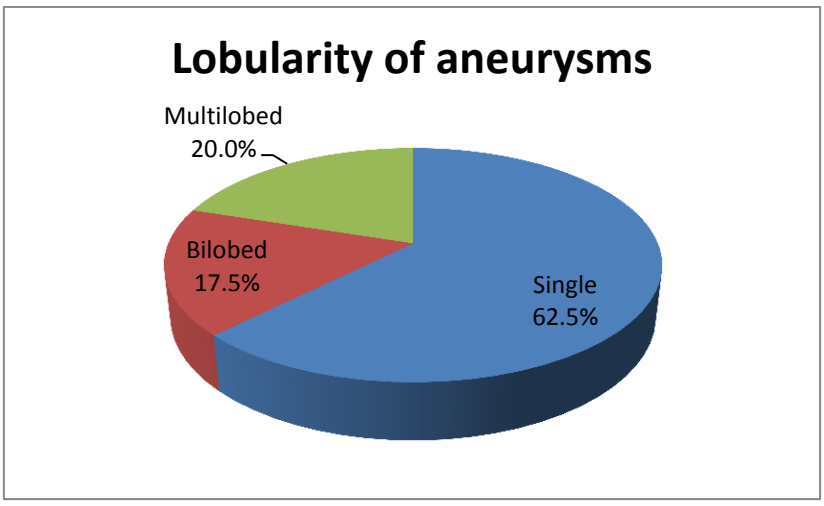


Figure 14

This study had 17.5% (n=7) patients with bilobed aneurysms while 20%(n=8) cases had multilobed aneurysms(≥3) rest (62.5%, n= 25) had non lobulated saccular aneurysms

- **Distribution according to presence of multiple aneurysms**

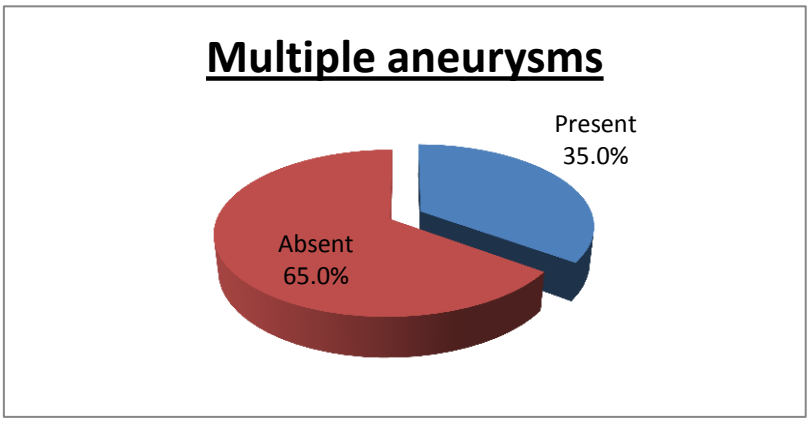


Figure 15

Thirty five percent (n=14) patients had multiple aneurysms.

- **Distribution according to the maximum dome diameter**

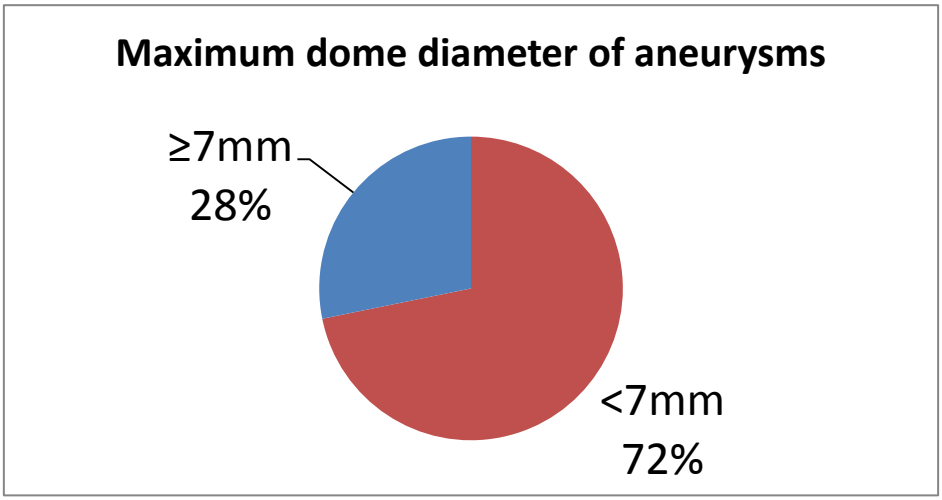


Figure 16

In our study 71.8 %(n=28) patients had small(<7mm) DACA aneurysms, with maximum dome diameter less than 7mm while 28.2 %(n=11) patients it was ≥7mm. In 1 patient data was not available.

- **Distribution according to procedure done**

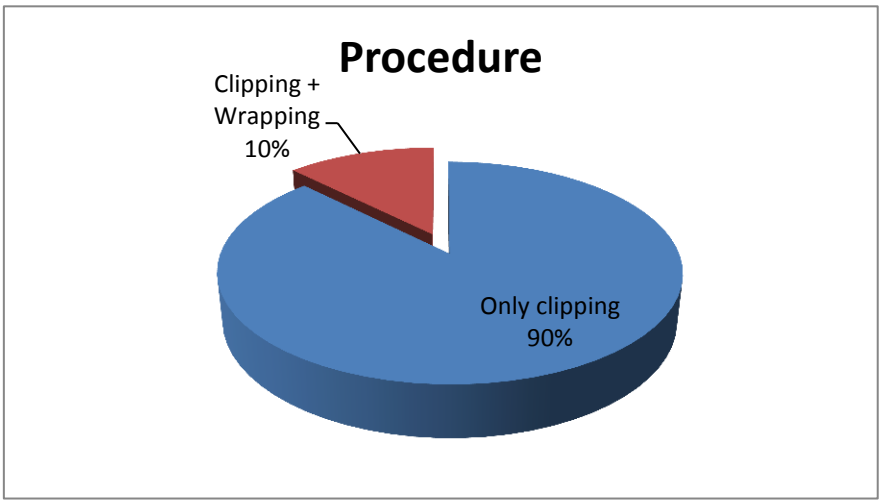


Figure 17

All DACA aneurysms were clipped additional muscle wrapping was done in 10% (n=4) cases.

- **Distribution according to occurrence of intra operative rupture**

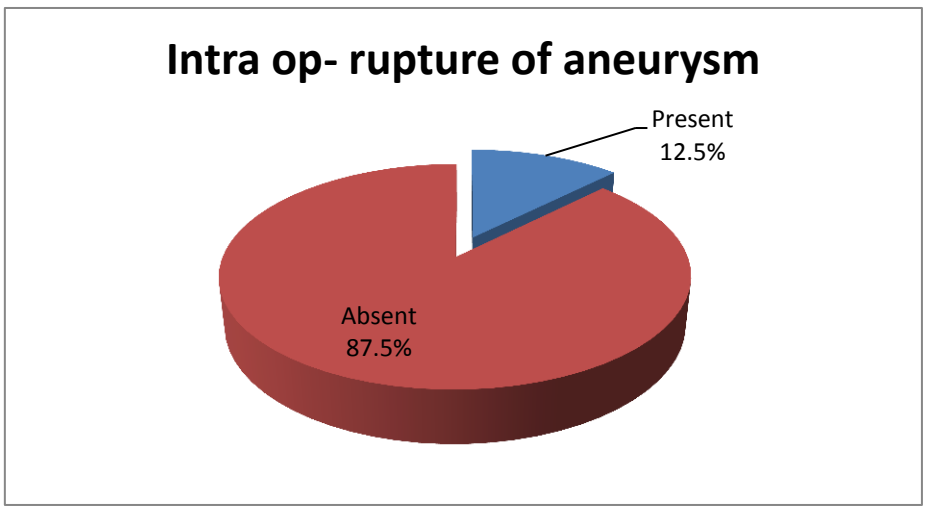


Figure 18

Intra operative rupture of aneurysm occurred in 12.5% (n=5) cases.

- **Distribution according to frequency of temporary clipping.**

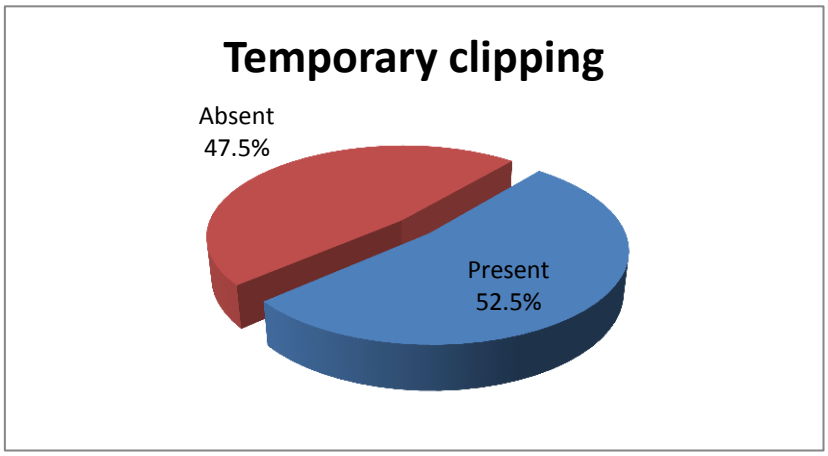


Figure 19

Intra operative temporary clipping was needed in 52.5 %(n=21) cases

- **Distribution according to duration of temporary clipping in seconds**

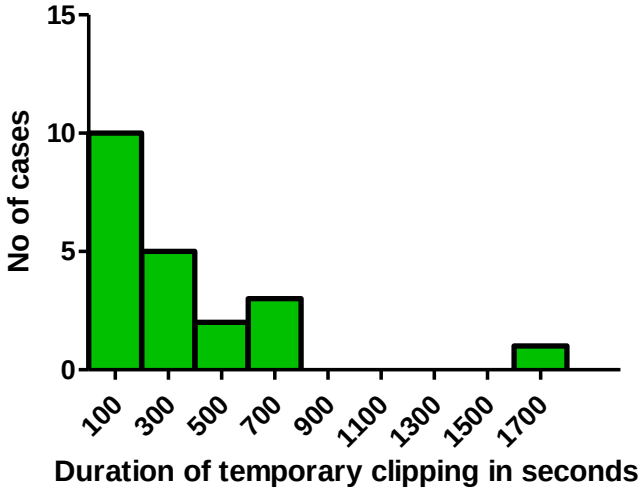


Figure 20

Median duration of temporary clipping was 220sec (range 60-1680secs)

- **Distribution according to occurrence of symptomatic vasospasm**

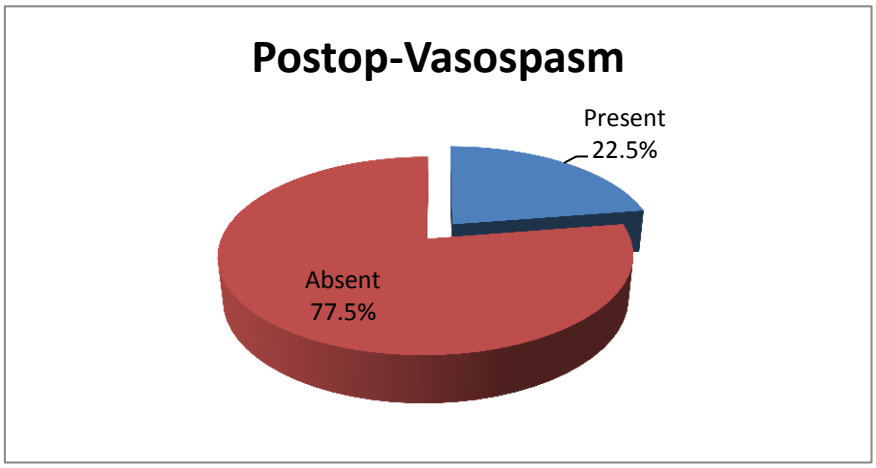


Figure 21

Symptomatic post-operative vasospasm occurred in 22.5 %(n=9) cases.

- **Distribution according to occurrence of infarct post operatively.**

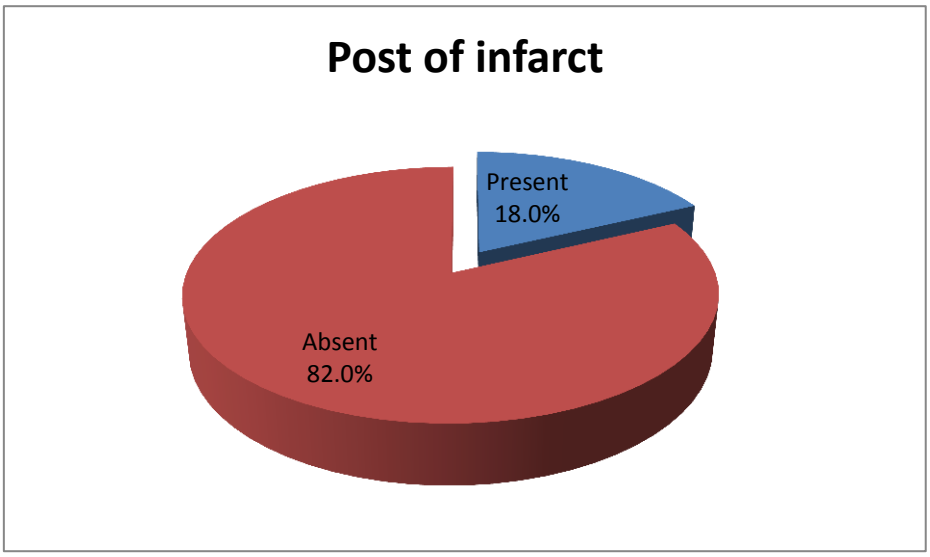


Figure 22

Post-operative infarct was found in 18 %(n=8) cases.

- **Distribution according to occurrence of operative site haematoma**

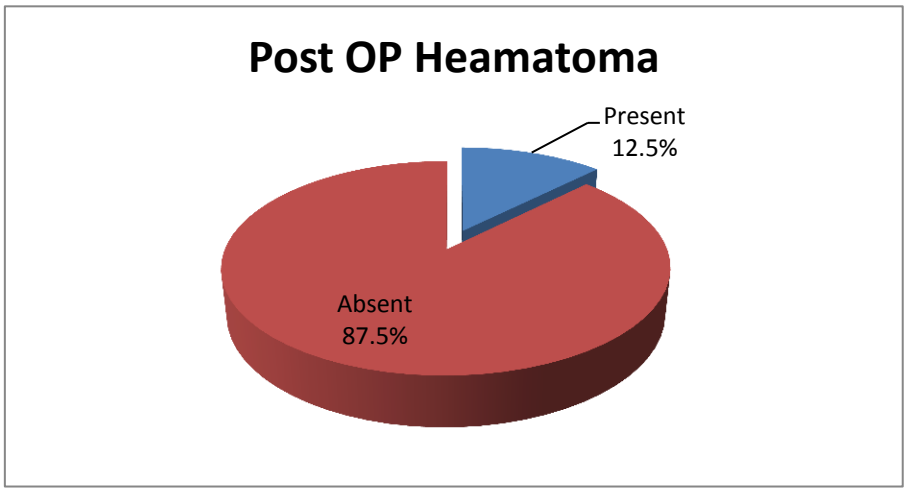


Figure 23

Operative site haematoma occurred in 12.5 %(n=5) cases.

- **Distribution according to need for post-operative csf diversion**

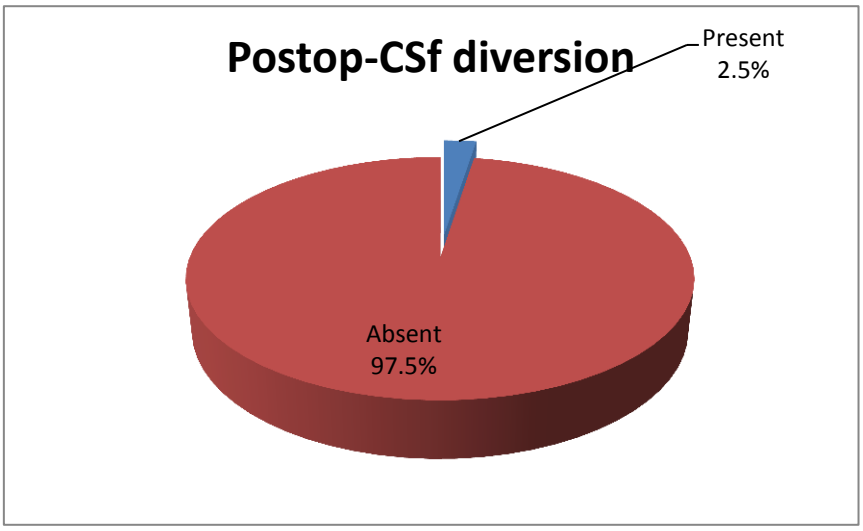


Figure 24

Post-operative csf diversion was needed in only 1(2.5%) patient.

- **Distribution according to re-exploration due to post-operative complications.**

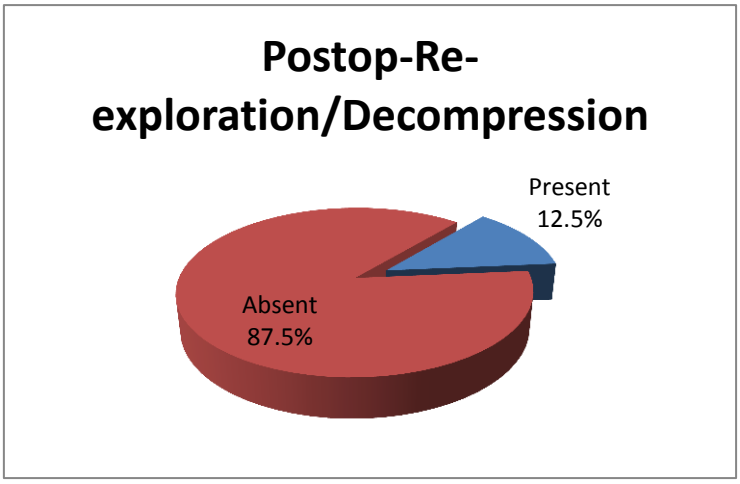


Figure 25

Re-exploration was needed in 12.5% (n=5) cases.

- **Distribution according to no of hospital stay post-surgery**

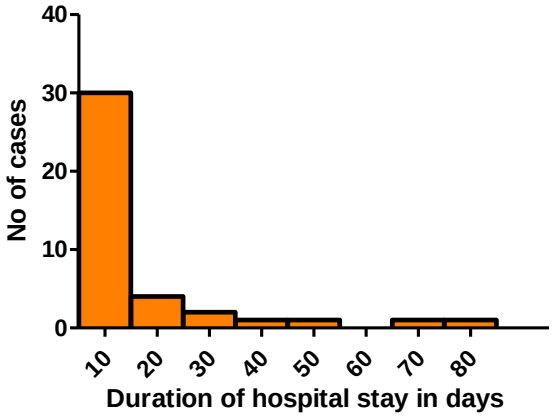


Figure 26

Median number of hospital stay post-surgery was 10.0 days(ranged from 6-78 days)

- **Distribution according to outcome during discharge.**

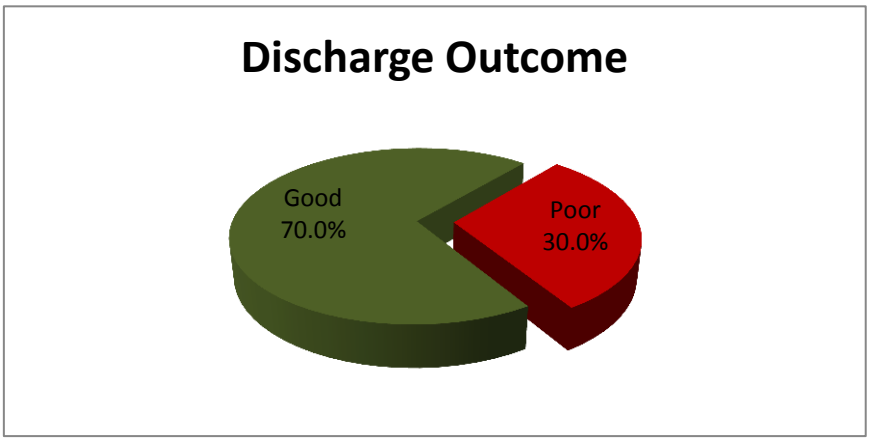


Figure 27

Good outcome (mRS≤2) was found in 70 %(n=28) of cases at the time of discharge.

- **Distribution according to final outcome**

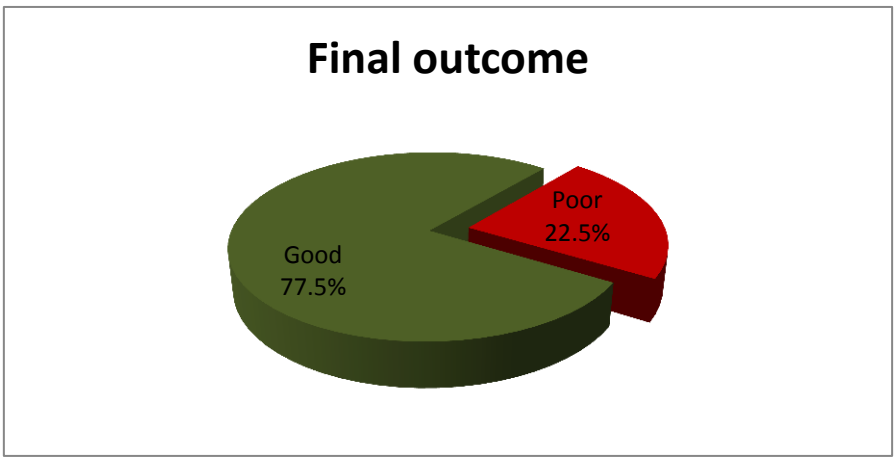
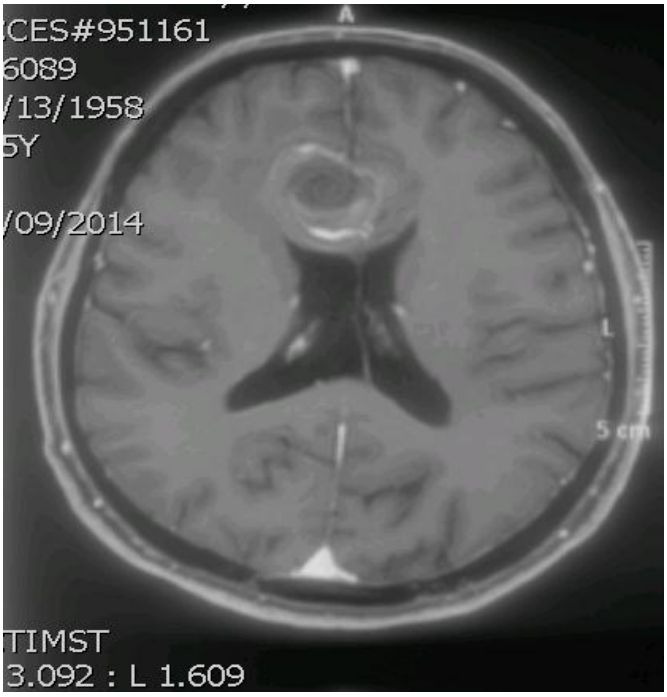


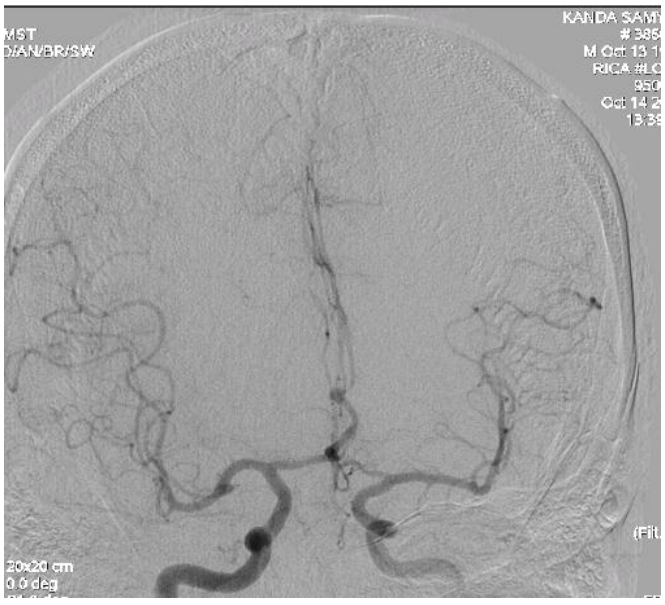
Figure 28

Final outcome (included the condition at 6 month follow up and discharge mRS score for patient who didn't come for follow up) was good in 77.5%(n=31) of cases .

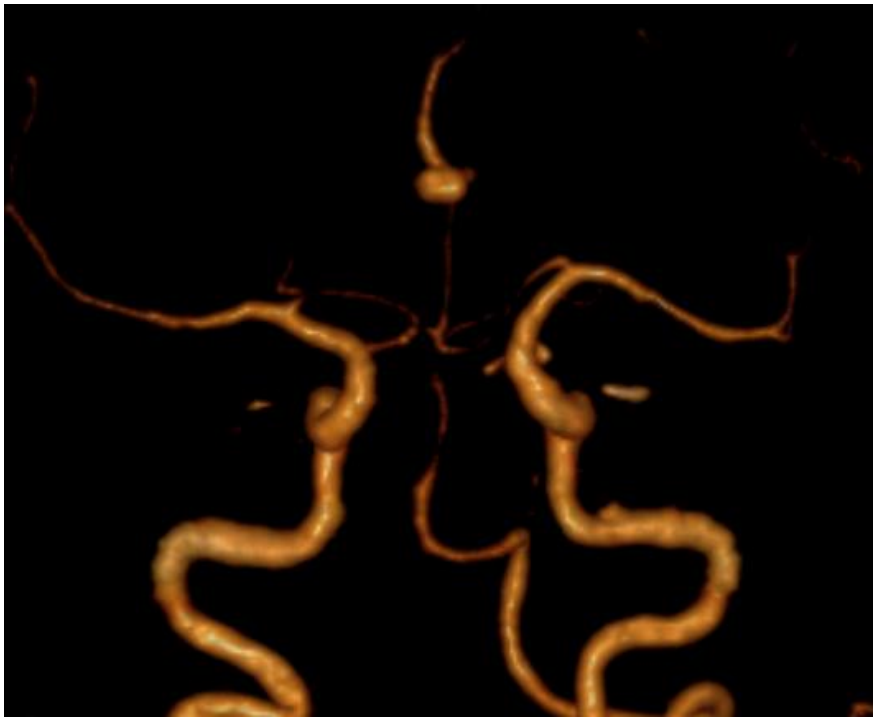
IMAGES



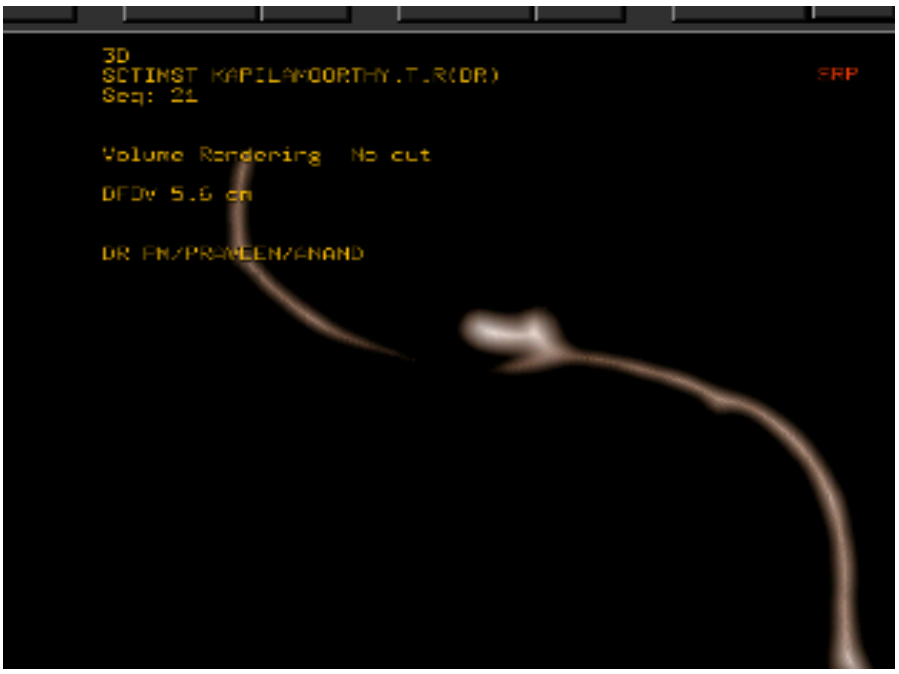
A case of giant DACA aneurysm with intramural thrombus.



Four vessel angiogram of the above mentioned patient not showing the full aneurysm due to presence of thrombus.



A case of DACA aneurysm showing its origin from the azygous ACA.



A case of bilobed DACA aneurysm.

A case of multilobed DACA aneurysm.

DISCUSSION

DACA aneurysms are rare when compared to incidence of other intra cranial aneurysms. We operated 40 DACA aneurysms over 10 years from 1st Jan 2007 to 1st Jan 2017. In our series 65% (n=26) were females. Female sex has always been considered to be a risk factor for intracranial aneurysm. Risk of rupture increases in post-menopausal age group probably due to absence of the protective sex steroids(69). In our study we found no significant positive correlation(p=0.168) between female gender and poor outcome, although many studies does show this positive relation(70). Lehecka et al found similar results with female preponderance without any significant correlation with the outcome(2).

DACA aneurysms more commonly present 5th to 6th decade of life. Median age of presentation in our study was 55yrs (range 28-84yrs). With increased age there was increased association with other comorbidities. Age as per had no significant association with poor outcome but presence of diabetes mellitus and/or hypertension significantly increased the risk of poor outcome ($p \leq 0.05$).

Typical thunderclap headache is the most common presentation of DACA aneurysm with SAH. Spectrum of other presentations varies from lower limb weakness, seizures, behavioural changes, cognitive deficit to akinetic mutism due to mass effect on frontal lobe and cingulate gyrus. In this study 87.5% (n=35) patients presented with thunder clap headache. Lower limb

weakness was found during in 30% (n=12) of patients during admission out of which 20% (n=8) cases weakness was associated with thunderclap headache. Fifty five percent of patients (n=22) had no deficit at the time of presentation and were with GCS15 (WFNS grade I) while 15 % (n=6) had low GCS (WFNS grade IV) at the time of presentation. Preoperative clinical grade has been considered as strong predictor of overall outcome. Various studies have associated poor condition at the time of admission with poorer outcome of surgical treatment(71,72). Our study also replicated similar results with higher the WFNS grade higher was the morbidity (p=0.01).

CT scan brain is the first recommended imaging which shows evidence and extent of sah. Fischer grade and recently modified Fischer grade are best system to assess the severity of aneurysmal bleed on the basis of CT scan. In our study there were 30%(n=12) patients with grade IV sah, 37.5%(n=15) with grade III, 17.5%(n=7) with grade II, 15%(n=6)with grade I. We didn't find a significant relation between the Fischer grading and outcome. Lehecka et al (2) showed favourable outcome in 45% versus 93% in patients with and without ICH or IVH respectively. Higher the Fischer grade higher is the risk of vasospasm and poorer outcome. Presence of hydrocephalus can be seen in one fifth of patients with sah early in the course (acute≤3days, subacute 4-14 days) while 10-15% cases hydrocephalous can be seen later on(73). Twenty percent (n=8) of our patients had hydrocephalous but only in 1 patient hydrocephalus was severe enough to need csf diversion. Pre-operative infarct was found in 10 %(n=4) of cases. Studies have correlated hydrocephalous with unfavourable

outcome(2). In our study we didn't find a significant correlation between pre-operative hydrocephalous, or infarct to outcome probably due to small sample size.

Aneurysm characteristics

Most of the aneurysms were directing anteriorly (75%) and superiorly (80%). In all 37 patients with available data were having saccular aneurysms. Left side DACA aneurysm was found in 62.5 %(n=25) patients, in 32.5 %(n=14) it was from rt side ACA while in one(2.5%) patient it was bilateral DACA aneurysm. In our 40 patients total 43 DACA aneurysms were found. Out of which 51.16 %(n=22) were at A2 segment, 46.51 %(n=20) were at A3 segment and 2.32%(n=1) was found on A4 segment. No A5 segment aneurysm was found. Two patients had tandem double DACA aneurysms while one patient had A3 segment mirror aneurysms. Aneurysms were bilobed in 17.5 % (n=7) patients while multilobed in 20% in cases (n=8). Left sided aneurysms tend to be associated with more morbidity and mortality but in DACA aneurysms results may not be similar. DACA aneurysm bleed are more cortical as compared to other aneurysms where bleed is more centrally located and also inter hemispheric bleed may exert equivalent pressure on both sides. Lobularity of DACA aneurysms have not been described in literature, but lobular aneurysms may need extra precaution during clipping. Literature about the DACA aneurysm morphological characteristics is meagre. Our study didn't show any significant correlation between projections of aneurysm, lobularity, side and segment of origin with outcome.

As well studied in literature DACA aneurysms are notorious to bleed at a very small size(3,47,56,72). Aneurysms which arises from distal ACA experiences more wall tension when compared to aneurysms from other larger arteries as explained by Laplace law(74). Bleeding occurs irrespective of size because of lack of arachnoid membranes at the level of pericallosal cisterns(56). In our study 71.8 %(n=28) patients had aneurysms with maximum dome diameter less than 7mm while 28.2 %(n=11) patients it was ≥7mm. In 1 patient data was not available. There was no significant correlation between dome diameter or aspect ratio with the outcome.

Giant DACA aneurysms (> 25mm in diameter) are extremely rare as DACA aneurysms have a high tendency for early rupture. Gelfenbeyn et al reported 26 cases of DACA aneurysms(75). Kawashima et al reported 7 cases of giant DACA aneurysm(76). Clipping may be difficult in many cases because of large neck diameter associated thrombus and may need a bypass. In our study we found a single case of giant DACA aneurysm with a maximum dome diameter of 35mm. The patient presented with left frontal lobe infarct and opposite side lower limb weakness. Favourable neck allowed successful clipping and didn't need a bypass.

Anomalous circulations are commonly seen to be associated with DACA aneurysms. Different anomalies of ACA have been seen in 7-35% of patients. Presence of azygous ACA is found in 3-22% case while bihemispheric ACA in 0.2-12% patients of DACA aneurysm and triplication of ACA in 3-13% cases(30). Associated anomalous circulation was found in 25 % (n=10) of

our patients. Azygous ACA was found in 2(5%) patients, one patient had ipsilateral hypoplastic A1. Other anomalies were fetal PCA, vertebral artery anomaly. We didn't find any case of bihemispheric ACA. Multiple aneurysms have been found in 25-55% of patients with DACA aneurysm as compared to 28-35% in other aneurysms (30,77). There were 35 % (n=14) cases with multiple aneurysms in our study but it didn't have any significant impact on the outcome. In our study only one patient with multiple aneurysms was operated in two stages rest were operated in single stage. In the former patient left DACA aneurysm was associated with bilateral MCA bifurcation aneurysms.

Intraoperative characteristics

Median time since bleed to surgery in our patients was 7days (ranged from day 0 to day 27). We didn't find a significant correlation between time since bleed and surgical outcome. Adequate sized craniotomy, minimum brain retraction, csf drainage, judged temporary clipping, early proximal control and sharp dissection are crucial for aneurysm surgery. We used precoronal parasagittal craniotomy for isolated DACA aneurysms while large pterional craniotomy crossing the sagittal plane was used for patients with other anterior circulation aneurysms. Interhemispheric approach was used for approaching all DACA aneurysms.

In our group 12.5% (n=5) patients had intraoperative rupture of aneurysm but this didn't affect the outcome. Literature suggests the relation between the intraoperative rupture to outcome depends on the stage at which

the aneurysm ruptures. If an aneurysm ruptures before achievement of proximal control or very early during brain retraction it is definitively associated with poor outcome(78). It is also studied that blunt dissection leading to rupture is associated with unfavourable outcome as compared to sharp dissection(79). In our patients two patients had controlled rupture while others had ruptured during fundus dissection.

Temporary clipping is an important tool for adequate dissection of an aneurysm, for delineating anatomy and in adverse situations like intra op rupture. Temporary clipping transiently compromises blood circulation to brain parenchyma. Literature suggests elective temporary clipping reduces the risk of intra op rupture and overall decreases the need for prolonged temporary clipping. When intermittently applied the duration can safely be extended up to 20 mins (80). In our study 52.5% percent patients needed temporary clipping with a median duration of 3mins 40secs(range 1min to 28mins). No significant relation was found between the temporary clipping and the outcome.

Full brain was found at the time of dural opening in 45 % (n=18) cases which gradually subsided with csf drainage and only in one patient needed post op csf diversion. Microsurgical clipping was done in all cases while additional wrapping was done in 4(10%) cases. Wrapping with muscle releases procoagulant factors without producing any foreign body reaction. This helps in achieving haemostasis and obliterating the residual aneurysm(81).

Post-operative events

Post-operative vasospasm and infarct were an important deciding factor for poor outcome in our study ($p<0.05$). Vasospasm not only deteriorates the patient neurologically but prolongs the ICU stay and decreases mobility of patient which further increases the morbidity. In our study, 22.5 % (n=9) patients developed vasospasm which was documented with transcranial Doppler, 4 vessel angiogram or clinical deterioration which improved with triple H therapy. Both patients in our study with azygous ACA with DACA aneurysm had severe vasospasm and later developed delayed ischemic deficit. In our study 20% patients (n=8) had post op infarct. Dorsh et al showed an incidence of 32.5% of symptomatic vasospasm in post op intracranial aneurysms with 10% mortality due to vasospasm(82) while Shukla et al reported 27.3% incidence of vasospasm in DACA aneurysm(4). Both vasospasm and delayed ischemic deficit were counterproductive for good outcome in our study ($p\leq0.05$).

Post op haematoma was found in 12.5% (n=5) of patients but sample size was too small to significantly correlate with the outcome. Out of 5 patients 3 patients needed re-exploration for haematoma evacuation while rest two were conservatively managed. At the time of discharge disabling motor deficit was found in 35% (n=14) cases which included persistent pre op cases with motor deficit (n=4). Most of the patients showed gradual improvement on follow up. In 12.5 %(n=5) patients re-exploration was needed. Three patients were re-explored for haematoma while rest two needed surgery for post op infarct with

malignant brain edema.

Comparison with other series

Lehecka et al in his largest case series of 501 patients reported a favourable outcome (Glasgow outcome scale≥4) in 74% of patients and mortality in 13% of cases. He correlated the poor outcome of DACA aneurysm surgery to the advanced age, pre-operative Hunt and Hess grade≥III, rebleeding before surgery, intraventricular, intracerebral hematoma and severe pre-operative hydrocephalus(2). De sousa et al found 87.5% favourable outcome and 6.94% mortality. He related the multiple intracranial aneurysms operated in one stage to be the reason for the poor outcome(1).

In India data about DACA aneurysms are meagre. A study conducted by Chhabra et al over 67 DACA aneurysms showed a favourable outcome only in 57.1% cases and mortality rate as high as 28.6%. In this study outcome was influenced by pre-operative clinical grade, presence of multiple aneurysms and presence of post-operative infarct(3). Shukla et al found the favourable outcome in 87.5% cases with an in hospital mortality rate of 4.5%(4).

In our study we found a favourable outcome (mRS ≤2) in 70% of cases at the time of discharge while final follow up outcome improved to 77.5%. One (2.5%) mortality in case of azygous ACA aneurysm who developed delayed bilateral ACA territory infarct and hospital course was further complicated by pulmonary embolism, deranged liver function and uncontrolled blood sugar. We found preoperative clinical grade, associated comorbidities, post op

vasospasm and infarct significantly affecting the outcome. In our study presence of multiple aneurysm didn't affect the outcome although all cases with multiple aneurysms except one were operated in one stage.

Limitations

The main limitation our study was the retrospective nature and relatively smaller sample size. The low incidence of DACA aneurysms makes it difficult to get adequate sample size from a single centre.

SUMMARY AND CONCLUSION

- Distal anterior cerebral arteries are rare.
- The numbers of female patients predominated over male patients.
- Majority of patients presented in the 5^{th} to 6^{th} decade of life.
- Comorbidities like diabetes mellitus and hypertension, presenting WFNS grade significantly influenced the outcome.
- These aneurysms were associated with other aneurysms and vascular anomalies.
- Sub arachnoid haemorrhage was the most common presentation.
- Majority of aneurysms were found in A2 segment.
- Presence of multiple intracranial aneurysms, vascular anomalies, intra operative rupture of aneurysm or need for temporary clipping didn't affect the outcome.
- Post-operative vasospasm and infarct was associated with poor outcome.
- Distal anterior cerebral artery aneurysm has been described as malignant aneurysms because of their poor surgical outcome. However with increased surgical experience and meticulous microsurgical techniques excellent results are possible to achieve.

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ANNEXURE I

PROFORMA

Demographic data

1- Name
2- Hospital registration number
3- Age
4- Sex
5- Associated comorbidities

Preoperative parameters

1- Presenting complain
2- Pre-operative GCS
3- Time since bleed
4- Fischer's grade
5- Presence of hydrocephalus
6- Side of aneurysm
7- Aneurysm size
8- Aneurysm characteristics

Intraoperative parameters

1- Method used for securing aneurysm clipping or wrapping or clipping with wrapping
2- Intraoperative temporary clipping
3- Intra operative rupture of aneurysm

Postoperative parameters

1- Postoperative haematoma
2- Postoperative vasospasm
3- Postoperative infarct
4- Postoperative need for csf diversion
5- Postoperative re-exploration or decompression
6- Postoperative hospital stay
7- On discharge motor deficit
8- On discharge mRS score

Follow up assessment

1- mRS at 6month of follow up

The surgical outcome results were analysed using modified Rankin scale

- 0-no symptoms at all
- 1- No significant disability despite symptoms: able to carry out all usual duties & activities
- 2 - Slight disability: unable to carry out all previous activities. Able to look after own affairs without assistance
- 3- Moderate disability: requiring some help, but able to walk without assistance
- 4- Moderately severe disability: unable to walk without assistance, and unable to attend to own bodily needs without assistance
- 5- Severe disability: bedridden, incontinent, and requiring constant nursing care and attention.

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ANNEXURE II

Originality Report

Plagiarism Checker X Originality Report

Similarity Found: 5%

Date: Wednesday, October 04, 2017

Microsurgical approach for clipping of distal anterior cerebral artery aneurysms and factors affecting their clinical outcomes: A retrospective study

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ANNEXURE III

श्री चित्रा तिरुनाल आयुर्विज्ञान और प्रौद्योगिकी संस्थान, त्रिवेन्द्रम
तिरुवनन्तपुरम - ६९५०११, केरल, इंडिया
SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES AND TECHNOLOGY, TRIVANDRUM
Thiruvananthapuram - 695 011, Kerala, India
(An Institute of National Importance under Govt. of India)
Grams : Chitramet, Phone : +91-471-2443152, Fax : +91-471-2550728 / 2446433, E-mail : sct@sctimst.ac.in, Website : www.sctimst.ac.in

Institutional Ethics Committee
(IEC Regn No. ECR/189/Inst/KL/2013)

SCT/IEC/925/JUNE-2016 12.08.2016

Dr. Mathew Abraham
Professor
Department of Neurosurgery
SCTIMST, Thiruvananthapuram

Dear Dr. Mathew Abraham,

The Institutional Ethics Committee reviewed and discussed your application to conduct the study entitled "MICROSURGICAL APPROACH FOR CLIPPING OF DISTAL ANTERIOR CEREBRAL ARTERY ANEURYSMS AND FACTORS AFFECTING THEIR CLINICAL OUTCOMES: A RETROSPECTIVE STUDY" (IEC/925) on 3rd June, 2016.

The following documents were reviewed:

Original submission

1. *Covering letter addressed to the Chairperson, IEC, SCTIMST, dated 19.03.2016 with check list*
2. *TAC Approval Letter*
3. *IEC Application Form*
4. *Project Proposal*
5. *Proforma*
6. *Declaration Form*
7. *CV of Principal Investigator and Co- Investigators*

Revised submission

1. *Covering letter addressed to the Chairperson, IEC, SCTIMST, dated 03.08.2016 with check list*
2. *IEC Application Form*
3. *TAC Approval Letter*
4. *Project Proposal*
5. *Proforma*
6. *Declaration Form*
7. *CV of Principal Investigator and Co- Investigators*

The following members of the Ethics Committee were present at the meeting held on 3rd June, 2016 at G. Parthasarathi Board Room, AMCHSS, SCTIMST

SL. No.	Member Name	Highest Degree	Gender	Scientific /Non Scientific	Affiliation with Institution(s)
1.	Justice Gopinathan. P.S	BSc. LLB	Male	Legal Expert (Chairperson)	No
2.	Dr. Asha Kishore	MD, DM	Female	Clinician (Neurologist)	Yes
3.	Dr. Prabha D Nair	PhD	Female	Basic Scientist	Yes
4.	Dr. Meenu Hariharan	DM	Female	Clinician (Gastro-Enterologist)	No
5	Dr. Rema M. N	MD	Female	Pharmacologist	No
6	Dr. R V G Menon	PhD	Male	Lay Person	No
7.	Dr. V. Raman Kutty	MPH(Harvard) MPhil, MD	Male	Public Health	Yes
8.	Dr. K R S Krishnan	ME, PhD	Male	Biomedical Scientist/Engineer	No
9.	Dr. Kala Kesavan. P	MD	Female	Pharmacologist	No
10.	Smt. Sathi Nair	MA	Female	Lay Person	No
11.	Dr. Christina George	MD	Female	Psychiatrist	No
12.	Dr. Mala Ramanathan	MSc, PhD, MA	Female	Ethicist/Social Scientist (Member Secretary)	Yes

IEC Decision

The IEC approved the conduct of the study in the present form.

Remarks:
The Institutional Ethics Committee expects to be informed about the progress of the study, any SAE occurring in the course of the study, any changes in the protocol and patient information/informed consent and asks to be provided a copy of the final report.

There was no member of the study team who participated in voting / decision making process. The ethics committee is organized and operated according to the requirements of Good Clinical Practice and the requirements of the Indian Council of Medical Research (ICMR).

Sincerely,

Mala Ramanathan
Member Secretary, IEC

Page 2 of 2

ANNEXURE IV

MASTERCHART ABBREVIATIONS:

- SEX: M= 1 F= 2
- SEGMENT OF ANEURYSM ORIGIN :

  1-Two aneurysms from A2 and A3, 2-from A2 segment, 3-from A3 segment, 4-Two aneurysms from A3 and A4
- UNBLED ANEURYSM - U
- PRE-OP WFNS GRADING: 1-Grade 1, 2-grade 2,3- grade 3, 4-grade 4, 5-grade 5
- FISCHERS GRADING: 1 , 2, 3, 4
- PREOP HCP: Y=1, N=2
- PREOP INFARCT: Y=1 N=2
- INTRAOPERATIVE CLIP/WRAP:

  Clipping = 1, Clipping + wrapping =2, wrapping = 3
- INTRAOP- RUPTURE: Y=1, N=2
- INTRAOP TEMPORARY CLIPPING: Y=1, N=2
- POSTOPERATIVE VASOSPASM : Y=1, N=2
- POSTOP INFARCT : Y=1, N=2
- POSTOP CSF DIVERSION: Y=1, N=2
- POSTOP REEXPLORATION OR DECOMPRESSION : Y=1, N=2
- POST OP VENTILATOR SUPPORT; 0 – 10 DAYS
- ON DISCHARGE MOTOR DEFICIT: Y=1, N=2
- MORTALITY - D
- ON DISCHARGE OUTCOME: Good(mRS≤2) -0, Poor(mR>2) - 1
- ON FOLLOW UP MRS SCALE AT 6 MONTHS OR FINAL AVAILABLE SCORE- Good(mRS≤2):0, Poor(mR>2):1
- Blank space denotes non availability of data.

ANNEXURE V

Serial number	Hosp no	Age in years	sex	Hypertension	Diabetes mellitus	Presentation,Headache	Loss of consciousness	Seizure	Presentation, Weakness	Preop-fischer's grade	Preop-Hydrocephalus	Preop infarct	Side	Segment of origin	Max Dome Diameter	Neck diameter in mm	Shape	Projection,A/P	M/L	Anomalous Circulation	aneurysms	Preoperative time since bleed in days	Approach	Intraop-Clipping/wrapping	Intraop- rupture	Temporary clipping	Postop-Vasospasm	Post of infarct	Post OP Haematoma	Postop-CSf diversion	exploration/Decompression	On Discharge-Motor deficit	Discharge outcome	Final outcome
1	373569	84	2	2	2	1	1	2	2	4	1	2	1	3	4.3	1.5	1	1	1	2	2	1	1	1	2	2	2	2	2	2	2	2	0	0
2	373351	55	2	2	2	1	2	2	1	3	2	2	2	4	4.1	1.4	1	1	1	2	2	20	1	2	2	2	2	2	2	2	2	2	0	0
3	385788	60	2	1	1	1	2	2	2	4	2	1	1	2	6.5	2	1	2		1	2	16	1	1	2	2	1	1	2	2	2	1	1	1
4	386089	56	2	2	1	2	2	2	1	0	2	1	2	2	3.5	2.6	1	2	1	2	2	U	1	1	1	1	2	2	2	2	2	1	0	1
5	387340	34	2	2	2	1	2	2	1	0	2	2	2	3	4.2	1.8	1	1		2	2	6	1	1	2	2	2	2	2	2	2	2	0	0
6	387341	54	1	1	2	1	2	2	2	1	2	2	2	3	35	3	1	1	1	2	2	13	1	1	2	1	2	2	2	2	2	2	0	0
7	389607	58	2	2	2	2	1	2	1	4	2	2	1	2	4.5	1.4	1	1	2	2	2	7	1	1	2	2	2	2	2	2	2	1	1	1
8	392161	31	1	2	2	1	2	2	2	1	2	2	2	3	4	2	1	1	2	2	2	3	1	1	2	1	1	2	2	2	2	1	1	0
9	394668	67	2	1	2	2	1	2	2	0	2	1	1	3	3.6	1.2	1	1	2	2	1	U	1	1	2	1	2	2	2	2	1	2	0	0
10	398378	43	2	1	2	2	2	2	2	4	1	2	1	3	7	1	1	1	2	1	2	0	1	1	2	1	2	1	2	1	2	1	1	0
11	399079	74	2	1	2	1	2	2	2	1	2	2	1	3	3	1.4	1	1		2	1	5	1	1	2	2	2	2	2	2	2	2	0	0
12	406159	61	2	1	2	1	1	2	2	4	1	2	1	1	4.2	2.5	1	2	2	1	1	14	1	1	2	1	2	2	1	2	2	2	0	0
13	407448	72	2	2	1	1	2	2	2	3	2	2	2	3			1	1	2	2	2	4	1	2	2	1	1	1	2	2	2	1	1	1
14	406016	54	2	1	1	2	2	2	1	0	2	2	1	2	7.4	2.9	1	1	2	1	2	U	1	1	2	2	1	1	1	2	1	D	1	1
15	411862	60	2	1	2	1	1	2	2	3	1	2	1	2	6.3	2	1	1	2	2	1	5	1	1	2	1	1	2	2	2	2	2	0	0
16	412047	47	2	2	2	1	1	2	2	0	2	2	2	2	20.6	5	1	1	1	2	2	5	1	1	2	1	2	2	2	2	2	1	0	0
17	372208	55	1	2	1	1	2	2	2	3	2	2	2	3	6.1	2	1	2		2	2	10	1	1	2	2	2	2	2	2	2	2	0	0
18	365426	44	2	2	2	1	1	2	2	3	2	2	2	3	4	2	1	2		2	2	19	1	1	2	1	2	2	2	2	2	2	0	0
19	363690	40	2	2	2	1	1	2	2	4	2	2	2	2	4.3	1.7	1	1	2	2	1	7	1	1	2	2	2	2	2	2	2	2	0	0
20	359093	65	1	2	2	1	1	2	2	3	2	2	2	3	5	3	1	2	2	2	1	13	1	1	2	2	2	2	2	2	2	2	0	0
21	358384	57	2	2	1	1	2	2	1	0	2	2	2	2	6.6	1.3	1	1	2	1	1	5	1	1	2	2	2	2	2	2	2	2	0	0
22	357946	35	2	2	2	1	1	2	1	1	2	1	2	2	4.5	1.4	1	1	2	2	2	27	1	1	2	1	2	2	2	2	2	2	0	0
23	357453	72	1	2	2	1	1	2	1	3	2	2	1	2	8		1	1		2	2	10	1	1	1	2	2	2	2	2	1	2	0	0
24	356306	50	1	1	2	1	2	2	2	3	2	2	2	3	3.5	1.5	1	1	1	1	1	9	1	2	2	2	2	1	1	2	1	1	1	1
25	356095	47	2	2	2	1	1	2	1	1	2	2	2	2	4.2	1.9	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	0	0
26	355762	54	1	2	2	1	1	2	2	3	2	2	2	2	3.4	1.8	1	2		1	2	5	1	1	2	1	1	2	2	2	2	2	0	0
27	349736	56	2	1	2	1	1	1	2	4	1	2	1	2	3.7	2.2	1	2	1	1	2	13	1	1	1	1	2	2	1	2	2	2	0	0
28	344514	52	2	2	2	1	2	2	2	1	2	2	2	2	6	1.4	1	1	1	2	1	3	1	1	2	1	2	2	2	2	2	2	0	0
29	344197	62	2	1	2	1	2	2	2	1	2	2	1	2	5.5	1.9	1	1		2	2	3	1	1	2	1	1	1	2	2	2	1	1	0
30	343836	59	1	1	2	1	1	2	1	4	1	2	1	2	1.7	1.6	1	1	1	1	2	8	1	1	2	2	2	1	1	2	1	1	1	0
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