ISSN 1220-8841 (Print)
ISSN 2344-4959 (Online)

ROMANIAN
NEUROSURGERY

Vol. XXXVII | No. 4 December 2023

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DOI: 10.33962/roneuro-2023-080

Romanian Neurosurgery (2023) XXXVII (4): pp. 460-468
DOI: 10.33962/roneuro-2023-080
www.journals.lapub.co.uk/index.php/roneurosurgery

Dual trained endovascular neurosurgeons. A boon or a necessity?

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Keywords
hybrid neurosurgeon, cerebrovascular surgery, clipping vs coiling, endovascular neurosurgery, aneurysm, A-V malformation

ABSTRACT

Objective: The aim of this research study is to emphasize the necessity to train neurosurgeons in both endovascular procedures as well as microsurgical clipping in the management of intracranial vascular lesions.

Material and methods: In this study, the retrospective data collected from our institution from 2021-2022 is presented. Here we present six cases of intracranial vascular lesions that were initially planned for endovascular procedure and later ended up being managed by microsurgical clipping/ excision. Written informed consent was obtained from relevant individuals for publishing the data.

Results: All six patients recovered well in the postoperative period. Therefore, a neurosurgeon who is adequately trained in vascular neurosurgery along with endovascular tutoring shall have an extensive grasp of cerebral vascular diseases and all the available treatment alternatives. Since we live in a result-oriented scenario - patients shall be best served by a hybrid neurosurgeon in the long run.

Conclusion: This study provides the intra-operative difficulties faced during endovascular management of intracranial vascular lesions. These difficulties require real-time management. Any delay in the process of intra-procedural decision-making making, the non-availability of trained neurosurgeons can have devastating consequences. Hence, this study further fortifies the want for a dual-trained neurosurgeon to handle cerebrovascular lesions.

INTRODUCTION

With the advent of endovascular therapeutic options for the management of cerebrovascular lesions, there has been a radical shift in trend that has been followed by young neurosurgeons. Piazza et al (26) in his study of intracranial aneurysms being managed by microsurgical clip application and endovascular coiling at several teaching medical institutions from 2001 to 2011 found that there was 16% per year decrease in likelihood of residents clipping an aneurysm and 19% increase in likelihood of residents coiling an aneurysm over the study period. This trend was supported by the Barrow Ruptured Aneurysm Trial (25) 6 year results, Rajan Kumar et al (21) and many similar studies.

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ISSN online 2344-4959
© Romanian Society of Neurosurgery

First published
December 2023 by
London Academic Publishing
www.lapub.co.uk

Comparison of microsurgical clipping and endovascular coiling is an ongoing debate with each modality having some advantage and disadvantage over the other. The contest between clipping and coiling in the management of intracranial aneurysmal bleeds has been going on for decades now, as the data supporting both perspectives is pouring in every day. The concluding indicator is however the patient outcome.

The question being addressed in this article is the need for giving equal importance to microsurgical clipping and endovascular coiling in training young neurosurgeons.

We shall enumerate cases of intracranial aneurysm that were planned for endovascular procedures which ended up being managed by microsurgical clipping or combined modality. The technical reasons for abandoning the endovascular procedure, combining the microsurgery and the intra-procedural decision making shall be discussed briefly.

Material and methods

In this study we present the retrospective data collected from our institution from 2018-2022. Criteria for including patients presenting with ruptured intracranial aneurysm / AVM - the ones that were found suitable for endovascular procedures on pre-procedural investigations like DSA and CT - angiography of brain. Who later ended up undergoing microsurgical clipping or combined procedure for various reasons. The team managing the patient has experience in both endovascular procedures as well as microsurgical treatment of these lesions.

Representative cases

Case 1 (Right Posterior Inferior Cerebellar Artery – PICA aneurysm)

A 55-years-old male patient presented with sudden onset severe headache associated with loss of consciousness 20 days prior to presentation. At presentation Glasgow Coma Score (GCS) was E4V4M6, Hunt and Hess grade 2 with no sensory, motor or autonomic neurological deficit. Non-contrast computed tomography (NCCT) Brain showed minimal sub-arachnoid hemorrhage (SAH) in prepontine cistern. CT Angiography and Digital subtraction angiography (DSA) showed right PICA aneurysm (size 7.1mm x 2.1mm x1.4mm). Right vertebral artery was hypoplastic and both PICA were arising from dominant left vertebral artery. (Figure 1A) Right PICA took an 1800 acute turn after its origin from left VA and crossed to opposite side.

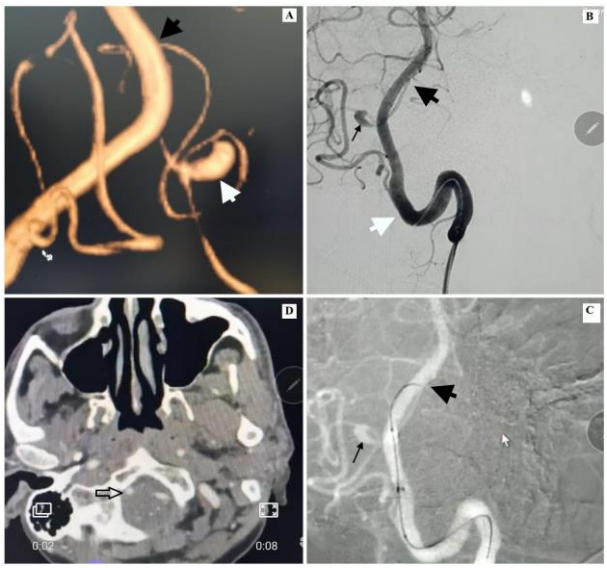


Figure 1(A). clockwise: 3D(A) & DSA image(B) of Left Vertebral angiogram Showing origin of right PICA (Black arrowhead) After origin PICA was taking a U turn and crossing to opposite side. A saccular aneurysm was identified at the junction of first and second loop bifurcation.(white arrowhead) . Micro wire (Syncro-14) tip negotiating the origin of right PICA(C) (Black arrowhead) from the left vertebral artery at acute angle.CT angiography axial image (D) confirms the location of aneurysm (Arrowhead).

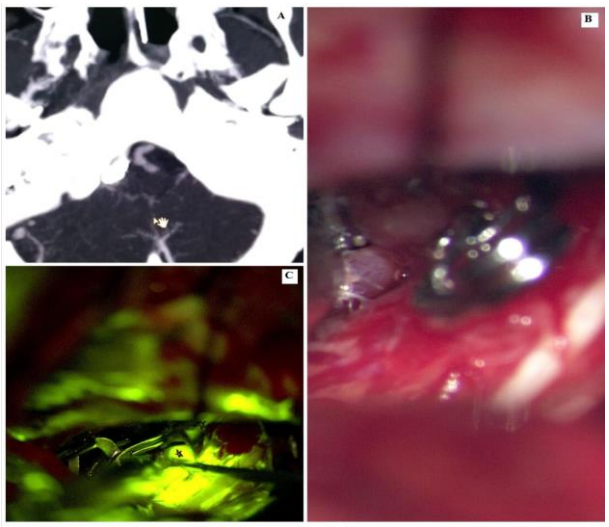


Figure 1(B). clockwise: axial image of right PICA aneurysm post clipping(A); intra-op image of the PICA aneurysm post clipping

with permanent clip in-situ(B) , intra-op fluorescence angiography image(C) post-clipping with permanent clip in-situ and preserved flow in bifurcation branches(star)

A scaccular aneurysm was identified at the junction of first and second loop. Endovascular coiling with neuromonitoring support was attempted. Balloon support was taken to hook the PICA due to acute angle but procedure was abandoned due to fall in EMG reading of facial nerve and heart rate, following cannulation of PICA (Figure 1B). Right extended retromastoid-suboccipital (RMSO) craniotomy with clipping of aneurysm was done on same day. Post op period was uneventful barring grade facial nerve palsy. Patient discharged in a stable condition on postoperative day 11. At the time of discharge patient GCS was E4V5M6 with a modified Rankin Scale (mRS) score of 1.

Case 2 (Basilar top aneurysm)

A 75 years old female patient presented with sudden onset of severe headache along with loss of consciousness and seizure episode 2 days before the presentation. She is known case of systemic hypertension on irregular medication. Patient has a history of ischemic stroke 6 years back which was managed conservatively. At presentation GCS was E3V2M4, Hunt and Hess grade

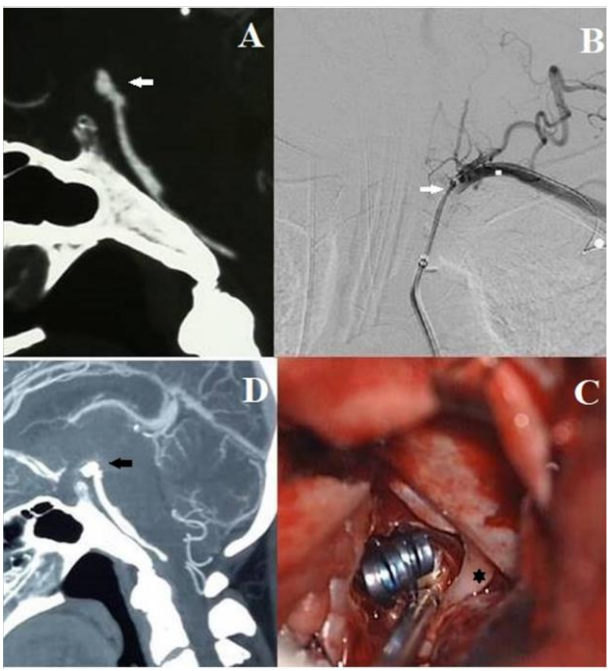


Figure 2. clockwise **-** CT angiography mid sagittal image (A)shows basilar top aneurysm(white arrow); left subclavian artery dissection (Arrow)at the origin of vertebral artery during the endovascular procedure(B) , Aneurysm clipped through trans-sylvian corridor(C), 3rd nerve(star). Post-operative CT angiography mid sagittal image showing successful clip obliteration (arrow) of aneurysm (D).

NCCT Brain showed SAH in prepontine cistern. CT Angiography and DSA showed basilar top aneurysm (size 8.1mm x 5.8mm x 6.9mm). Left vertebral artery was dominant. Endovascular coiling was attempted but procedure was abandoned due to inadvertent dissection into the arterial wall of subclavian artery at the origin of left vertebral artery, owing to its highly tortuous anatomy (Figure2). Right extended pterional craniotomy with zygomatic osteotomy with clipping of aneurysm was done on same day. In post op period patient was put on mechanical ventilation and tracheostomy was done. Low dose ecosprin and atorvastatin combination (75mg+20mg) was started on 4th post-operative day. Patient was gradually weaned off from ventilator and was discharged after three weeks with tracheostomy in-situ. At the time of discharge patient's GCS was E4VtM6. She also has right third nerve paresis. Patient tracheostomy was removed on 2nd follow up visit at 2 months and her mRS score was 3 at 4 months.

Case 3 (Left Middle Cerebral Artery- MCA bifurcation aneurysm)

A 65 years old female presented with sudden onset of severe headache associated with loss of consciousness 10 days before the presentation. At presentation GCS recorded as E3V3M5, Hunt and Hess grade 3. NCCT Brain showed minimal SAH in left sylvian fissure. CT Angiography and DSA showed Left MCA bifurcation aneurysm (size 3.1mm x 1.9mm x1.5mm). Endovascular coiling was attempted but procedure was abandoned due to intra-operative rupture of the aneurysm during the endovascular procedure.(Figure 3) Temporary balloon occlusion (Transform 2*10) was unsuccessfully tried to control aneurysmal leak.

Patient blood pressure was immediately lowered down and heparanization was reversed using protamine sulfate. Immediately left pterional craniotomy and successful clipping of aneurysm done using 6mm straight Yasargil clip (Figure 3). Post-operative period uneventful. Patient discharged after 2 weeks with right hemiparesis (MRS grade 3). Her weakness was completely resolved at 3 month follow up visit.

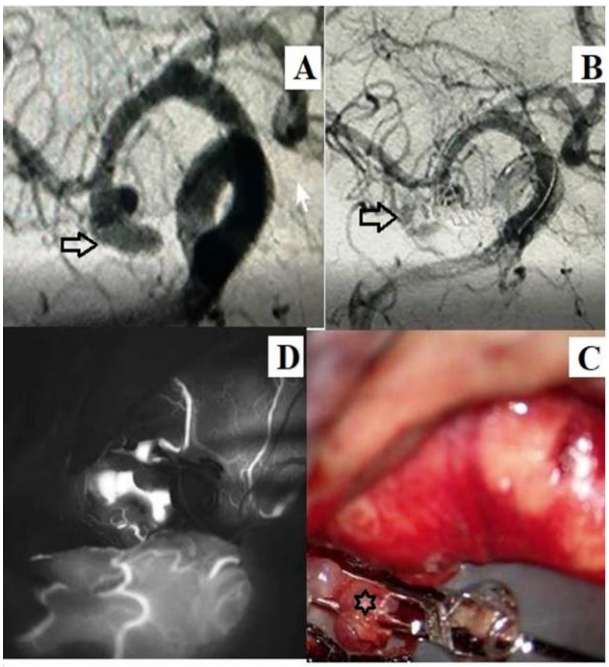


Figure 3. clockwise: Diagnostic angiograpghy (A) showing Left MCA aneurysm(arrow); intra procedural rupture occurred(B) during attempted endovascular coiling, contrast leak is evident(arrow), intra-operative image (C)after successful clipping of Left MCA aneurysm(star); intra-operative ICG image(D) showing preserved distal flow at MCA post-clipping.

Case 4 (Left distal posterior cerebral artery-PCA aneurysm)

A 70 years old male presented with sudden onset severe headache along with vomiting 12days prior to presentation. At presentation GCS recorded as E4V4M6, Hunt and Hess grade 2. There was no sensory/motor/autonomic neurological deficit. NCCT Brain shows minimal SAH in the perimesencephalic cistern. CT Angiography and DSA showed Left distal PCA aneurysm (lateral posterior choroidal artery aneurysm-LPChA) (size 7.2mm x 3.1mm x1.6mm). Endovascular coiling was attempted but procedure was abandoned due to excessive tortuosity of the left vertebral artery and inability to gain the distal access in PCA close to aneurysm (Figure 4A).

In view of vital supply of LPChA, endovascular sacrifice of parent artery was not attempted. Left parietal-occipital craniotomy was done and aneurysm was successfully clipped using Poppens approach (Figure 4B). In the post-operative period patient recovered well. And he was discharged on postoperative day 9. At the time of discharge patients GCS was E4V5M6 and mRS score of 2 without any new neurological deficits.

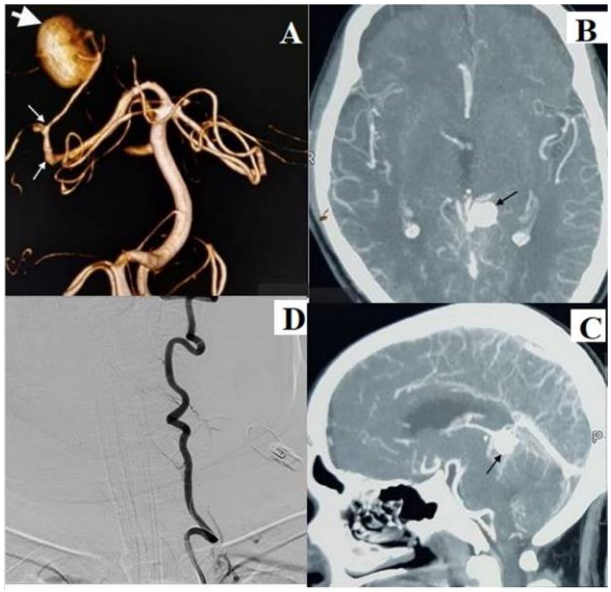
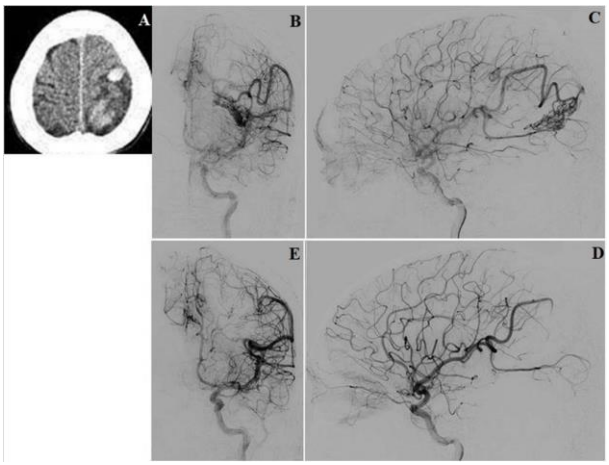


Figure 4. (A) clockwise: 3D-DSA image (A) showing left distal PCA aneurysm (arrow); axial (B) & Sagittal (B) CT angiography images showing the location of LPChA aneurysm in quadrigeminal cistern; DSA image (D) showing narrow caliber of left vertebral artery with tortuous course and several acute bends **(B)** clockwise: Intra-operative microscopic image through occipital transtentorial approach showing aneurysm in quadrigeminal cistern; Post-operative Axial(B), Sagittal (C) and Coronal (D) CT angiography images showing successful clipping.

Case 5 (Left Parietal arterio-venous malformation-AVM)

18 years old male, presented with sudden onset of loss of consciousness with weakness on the right side of the body since one day. At presentation GCS was E4V5M6; with right side hemiparesis (MRC grade 4). NCCT shows small left parietal hematoma. DSA brain revealed left parietal AVM (spetzler martin grade 2) with arterial feeders from MCA (Figure 5A). Endovascular embolisation using onyx-18 was done and complete immediate obliteration of nidus was acheieved. On post-operative day one patient developed seizures with right side hemiplegia and there was sudden deterioration in his consciousness. NCCT brain showed left pareito-occipita hemorrhage with intraventricular extension. Left fronto-temporo-parietal decompressivecraniectomy with evacuation of hematoma was done. Post–operative period was uneventful and patient was discharged on post-op day 14 with GCS E4V5M6 and right hemiparesis (MRC grade 3).His right side weakness was resolved completely at 3 month follow up visit, following

which he was readmitted and cranioplasty was done (Figure 5B).



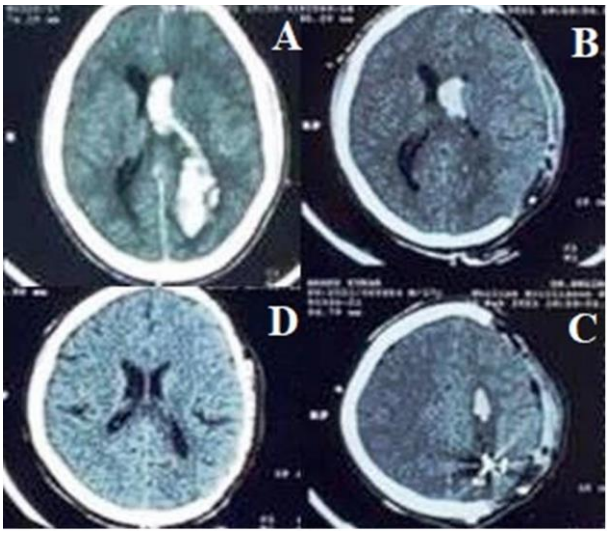
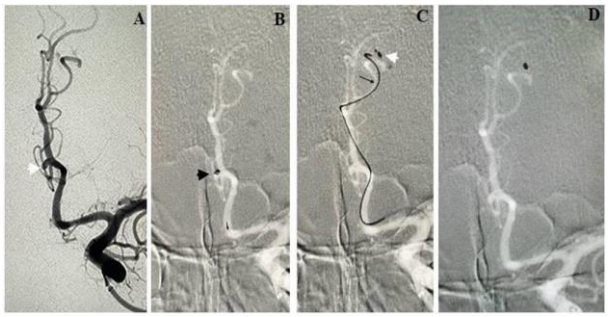


Figure 5. (A) clockwise:NCCT brain (A)showing small left parietal hematoma. DSA image frontal (B) and lateral(C) view showing AVM in left parieto –occipital region with feeers from left MCA. Post-embolisation DSA lateral (D) and Frontal (E) view showing complete angiographic obliteration of nidus.

(B): NCCT brain post-embolisation day one (A) showing increase in size of parieto-occipital hematoma with intraventricular extension. NCCT brain post decompressivecraniectomy(B) and (C) showing hematoma evacuation with onyx cast(C). NCCT brain at three months follow up after cranioplasty (D).

Case 6 (Left distal anterior cerebral artery-DACA aneurysm)

A 48 years old female patient presented with sudden onset of severe headache associated with vomiting 10 days earlier to presentation. At the time of presentation GCS recorded as E2V4M5 with Hunt and Hess grade 2. NCCT Brain S/O SAH in anterior interhemispheric fissure. CT Angiography and DSA showed Left distal ACA aneurysm (size 2.5mm x 2.1mm x1.9mm). Endovascular coiling was attempted. After detachment the coil loop migrated into the parent artery (Figure 6A). All the attempts to retrieve the coil remained unsuccessful. With the help of microcatheter (SL-10, Stryker), the migrated coil was pushed till distal end of left ACA. Right frontal craniotomy with clipping of left DACA aneurysm was done after reversal of heparanisation(Figure 6B). Post-operative course uneventful and she was discharged on 8th day after in GCS 15 without any neurological deficit (MRS gr 2).



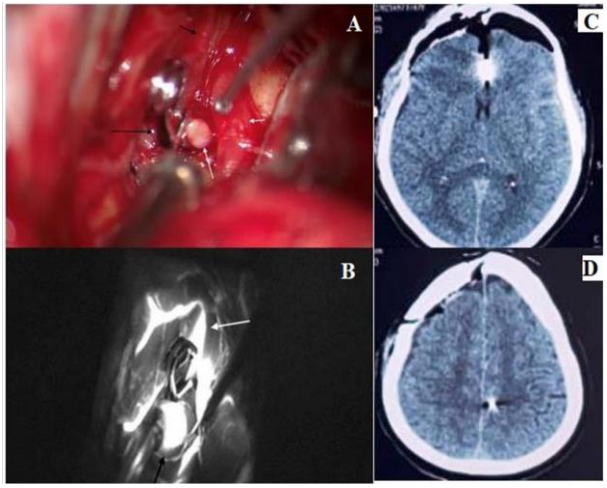


Figure 6. (A): DSA brain image (A) showing left Distal ACA aneurysm (white arrow); coil (Black arrow) inside the aneurysm (B)with microcatheter in parent ACA; After coil migration, microcatheter was used to push the coil(white arrow) distally till terminal end of DACA(C); Final position of coil(D)

(B): intraoperative-image (A) of clipped DACA aneurysm(White arrow), small black arrow - ipsilateral proximal A3 segment, black long arrow- ipsilateral distal A3 segment, white small arrow- right ACA ; intra-operative ICG image(B) showing preserved flow after clip application; Post-operative CT scan(C) showing clip in situ and(D) showing location of distally pushed coil.

Discussion

All the available data currently in the literature regarding Endovascular coiling versus Microsurgical clipping in cerebrovascular lesions-management gives generic data supporting micro surgical clipping / excision over endovascular management and vice versa. In our study we have given the details of intra-procedural difficulties that arise during the endovascular management of intracranial vascular lesions, insight into the decision making as to when to abandon the endovascular procedure and choose microsurgical management of the aneurysm/AVM.

Background

Shift of treatment from open microsurgical clipping to endovascular era

Coiling is currently used to treat more than 50% of ruptured intracranial aneurysms in the western countries, asia including metropolitan regions of India (11) (2)

In a 25 year observational study (starting in 1991) which included 1306 patients who presented with subarachnoid hemorrhage to a major tertiary teaching hospital, progressively increasing percentage of patients were treated by endovascular methods (2). The percentage of patients embolized was 3% from 1991- 1996. And the percentage increased to 42% in the most recent five-year period. This shift was noted to be most dramatic for posterior circulation aneurysms. 71% of posterior circulation aneurysmal conditions are now treated by endovascular methods. Incidentally the majority of MCA aneurysms (78%) continue to be treated by open surgery (2)(4). Endovascular and open surgical treatment are approaching equivalence for ruptured aneurysms along the ICA and ACA (4).

This trend has progressed steadily towards enhancing the endovascular treatment of ruptured aneurysms at major international centers as well (4). In a case series reported on 2411 aneurysm treatments, 62% was in the setting of a SAH, between 1998 and 2009. In general, endovascular treatment as an option progressed from 8% to 28% of interventions. The increase was greatest for basilar apex aneurysms, which increased from 22% endovascular to 88% during that period of study (4)(5)(6)(8). Endovascular interventions have made similar inroads in posterior circulation territory. Payner and colleagues have reported that endovascular treatment of anterior and posterior communicating artery aneurysms increased from 6% and 5% to 38% and 31% respectively by the end of the study period (6)(8). Without giving out specific numerical data. The authors noted that microsurgical clipping was favored for MCA aneurysms throughout the study period.

Microsurgical clipping still remains the mainstay of treatment for ruptured MCA aneurysms, for various reasons like relative accessibility of the MCA superficially within the sylvian cistern (15).Ruptured MCA aneurysm is most likely to present with intraparenchymal hematoma, which can be evacuated during open surgery. The geometry of MCA bifurcation aneurysms, wherein a majority (88%) are broad-necked and nearly half (40%) incorporate a major branch vessel in the dome. These issues pose a challenge to traditional coiling (9)(10). Over a period of time, there have been drastic technological improvements, including three-dimensional CT angiography to visualize. Compliant balloons and self-expanding stents that protect branch vessels, all these have increased the percentage of MCA aneurysms that are amenable to coiling (13)(15).

Endovascular management of ruptured intracranial aneurysms and A-V malformations has steadily increased at major academic institutions. Although endovascular management has assumed a primary role in the treatment of posterior circulation aneurysms, while a majority of ruptured aneurysms arising along the MCA continue to be clipped. Incidentally, coiling and clipping are approaching parity as a management option for treatment of ruptured aneurysm at other locations in the anterior circulation (13).

Difficulties in endovascular management of intracranial aneurysms

Given the existing healthcare system of developing world, the incidence of disease is higher than the resources available to tackle them. A recent survey on neurovascular intervention had 82% of their participants from urban hospitals while only 18% were in the semi-urban or rural hospitals and showed that endovascular management is performed more frequently in private or nonteaching hospitals, than in government or teaching institutes, where clipping is preferred (3).

Another major hurdle with aneurysm coiling is the durability. Inadequate packing of the aneurysm neck

raises the chances of aneurysm recurrence (Raymond and Roy, 1997). The Clinical outcomes of aneurysm coiling are better for small to medium size aneurysms in comparison to giant and fusiform aneurysms (1). In a review of 46 studies encompassing 8,161 coiled aneurysms showed 91% rate of adequate occlusion at initial treatment (Ferns et al., 2009) (12). Recanalization reported in 21% of aneurysms. And retreatment was performed in 10%.

There are other factors like (14)(17)

1. small aneurysms
2. ruptured aneurysms with large hematoma
3. difficult geometry of the aneurysm
4. difficulty to access the aneurysm with the available hardware
5. giant and partially thrombosed aneurysms
6. non-compliant patients
7. Affordability.

Advantages of Microsurgical clipping of intracranial aneurysm

Microsurgical clipping is overall more economical (14). Neurovascular specialists are more concentrated in larger cities at the disposal of that layer of society that can afford the advancements. However, there are more people in the country who belong to the semi-urban and rural demography and have easier access to centers that can manage them by microsurgical clipping rather than higher centers that facilitate coiling (14)(21).

As we stress on the importance of time in the salvation of the brain, the above fact makes it clear that patients, who sometimes travel long distances for treatment, are able to save and so perhaps gain a lot more time, if they are to opt for a center where clipping is offered, as compared to coiling (17). The best possible option is a dually trained neurosurgeon, who is well versed in both the procedures.

Beyond doubt, clipping is more affordable than the cost of the stent or coil. While one may argue that endovascular management is associated with a shorter duration of hospital stay, the time spent outside the hospital in the follow-up period must also be taken into account. Both arms of treatment are associated with the risk of ischaemic stroke, but the coiled patient may require lifelong anti-coagulation and rigorous monitoring of hematological parameters alongside regular consultations, the financial and social burden of which has to be borne for a longer period (7)(22), It has been recorded that overall cost burden at 2-year and 5-year follow-up is significantly higher for patients treated by endovascular coiling as compared to microsurgical clipping, which may be considered natural, considering the cost of anti-platelets alone (7).

It has been observed that complication rates from microsurgical clipping, be it intra-operative or post-operative, are higher than from coiling; however, it has also been observed that the risks for need for reoperation and recurrence are higher in coiling (17). The durability, that is provided by clipping, over coiling, is another major point that favors the practicality of its use in semi-urban and rural world.

Dually trained neurosurgeons

The evolution of neuro-endovascular therapies has led to three versions of task sharing in the management of intracranial aneurysm (1)(16)(18)(19). In a few setups, devoted centers are developed for endovascular management, while others subspecialized in microsurgical management. Most other centers organised themselves into multi-role teams and subspecialized into micro and endovascular surgeons. They consult and consider patients together and recommend treatment strategies based on concurrence on best interest of individual patients. As per this particular prototype, the patient is offered both management options in a single center, but the decision-making will depend on the concurrency of all team members. Reciprocal information about pros and cons of all management options is compulsory. The most important factor is practical experience of the treating doctors in both prototypes.

The third version is the single-doctor with dual capability prototype. It is called as the hybrid neurosurgeon. This version is supposedly cost efficient, wherein both treatments is offered by one treating neurosurgeon. Dually trained neurosurgeons will deliver consistent positive results. Concurrently, several publications from across the globe have proven the better results of hybrid neurosurgeons.

Due to the quick development of neuroendovascular treatment options, there is a incessant transfer of indications for intracranial aneurysm treatment towards endovascular options

over the past decade. This evolutionary phase is probably troublesome for a subgroup of patients who cannot be treated by endovascular therapy alone or complicated by endovascular therapy, those patients that need microsurgical management (very small but bleeding aneurysms, intraprocedural perforations, MCA aneurysms with unfavorable anatomy ,ruptured aneurysms with intraparenchymal hematoma, giant and partial thrombosed aneurysms, young patients who shall perhaps be noncompliant with follow-up imaging, high-grade SAH) in emergency fashion and might also risk the continuity of neurovascular microsurgical dissection skills.

The decision for treatment options will positively be influenced by the hybrid surgeon's capacity to assess and compare the advantages, disadvantages, complications of both therapeutic options in detail. Avoiding wrong decisions because of the "availability of a hammer so let's look at all targets like nails" (20).

The hybrid version offers several advantages: firstly, single-decision maker concept gives freedom to make independent decisions devoid of institutional bias; secondly, equivalent indications lead to selection of tailor-made tools. Finally, preservation of neurovascular microsurgical skills. It is extremely essential to preserve vascular microneurosurgery in the present and future (1)(23)(24) .

Therefore, adequate training in vascular neurosurgery followed by essential endovascular training will result in a broad understanding of cerebrovascular diseases and its management options at the level of treating doctor itself. Patients shall be best served by a hybrid vascular neurosurgeon in the short and long run.

Conclusion

In contrast to developed countries only a substantial number of Indian vascular neurosurgeons work under "hybrid conditions"; at present the majority of neuro-endovascular procedures is performed by neuro-radiologists. As a result of this development, the numbers of microsurgical aneurysm surgical procedures have decreased. As a consequence, experience and skills in aneurysm surgery and cerebrovascular surgical procedures in general are at risk. The results of dually trained- hybrid neurosurgeon, with equal exposure towards surgical and endovascular techniques, are comparable to those reported by mono-therapeutic neurosurgeons and centers with multimodal teams.

With this case series there is promising evidence to prove, that dually trained neurosurgeon is a necessity rather than a luxury who would not only perform surgical and/or endovascular therapeutic procedures effectively, but also switch over safely in need, there are other benefits like - equivalent and specifically suited indication concepts, the continuation of vascular microsurgical skills (as endovascular management therapy has not penetrated deep into semi-urban and rural setups). And also, the availability of both management options in the hands of a neurosurgeon is a significant factor in the overall hospital management.

In the domain of cerebrovascular surgery, endovascular surgery has definitely got several advantages over open surgery. Yet it is common sense to assume that endovascular surgery has its own place and micro surgical clipping of intracranial aneurysms has its own roll in the overall management, and the tendency to get carried away with 'recent advances' should be discouraged.

So far in the literature, comparison of endovascular surgery versus microsurgical clipping of intracranial aneurysms has largely shown data regarding the peri-operative parameters including the geographic and economic variables. This study provides the intra-operative difficulties faced during endovascular management of intracranial vascular lesions. These difficulties require real-time management. Any delay in the process of intra procedural decision making, or non-availability of trained neurosurgeon can have devastating consequences. Hence, this study further fortifies the want of a dual trained neurosurgeon to handle cerebrovascular lesions in most efficient manner.

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