# Surgical and endovascular combined modality of treatment for aneurysms

**Rakeshkumar Luhana, Yoko Kato, Minoru Yoneda, Makoto Negoro, Hirotoshi Sano**

**Abstract**

**Objective**: Most of the aneurysms can be treated successfully with either surgery or endovascular modality alone. But, some complex aneurysms can be better managed with surgical and endovascular combined modality of treatment. This study was done to review combination options, their indications and outcome.

**Material and methods**: Articles in English literature on surgical and endovascular combined modality of treatment for cerebral aneurysms were reviewed and analyzed based on Pubmed search. Following combination options were used:

***Surgery followed endovascular therapy:***

1. Extracranial to intracranial bypass surgery followed by endovascular parent vessel occlusion.
2. Aneurysm clipping assisted by temporary balloon occlusion with / without suction decompression.
3. Intentional partial clipping for neck reconstruction followed by endovascular aneurysm packing.
4. Clipping as the first treatment. Regrown or partially clipped aneurysm obliterated by endovascular packing.

***Endovascular therapy followed by surgery:***

1. Partial coiling to prevent rebleed followed by delayed definitive clipping.
2. Permanent parent vessel occlusion followed by surgery for decompression in giant aneurysm.
3. Coiling as the first treatment, reanalyzed aneurysm treated with clipping.
4. Coiling and clipping of multiple remote aneurysms.

**Results**: In various published series; combined modality of treatment has shown better results in complex aneurysms as compared to either of the modality alone with less morbidity.

**Conclusion**: Surgical and endovascular combined modality is very useful addition to the armamentarium for the management of complex aneurysms and can be applied in various combinations. When used rationally, this approach offers the best outcome with reduction of treatment morbidity.

***Key words**: Cerebral aneurysms, embolization, combined endovascular and surgical management (p9-16)*

## Introduction

Neurosurgery has made remarkable progress in the last four decades. Improvisations in imaging modalities like 3D computerized tomographic angiography (CTA), magnetic resonance angiography (MRA) and 3D digital subtraction angiography (DSA) has made preoperative imaging of the aneurysm and surrounding anatomy much clearer. Skull base approaches with concepts of minimising brain retraction and utilisation of natural corridors for surgery, availability of endoscope assistance and intraoperative Doppler or angiography have resulted in a remarkable progress in aneurysm surgery with resultant significant reduction in morbidity as well as mortality.

Endovascular modality is also advancing rapidly. Availability of a variety of detachable coils, advanced micro catheters with better manoeuvrability, biplane C-arm, plus surgical experience have all resulted in a better outcome. Now, endovascular modality is an important tool in aneurysm management strategy.

Department of Neurosurgery
Fujita Health University Hospital
Dengakugakubo, Aichi-ken
Japan

***Correspondence:***
Dr. Rakeshkumar Luhana
Department of Neurosurgery
Fujita Health University Hospital
1-98 Dengakugakubo
Aichi-ken, 470 1192
Japan
Email: rcluhana@hotmail.com

Although most aneurysms can be clipped microsurgically or coiled endovascularly, a subset of patients may require a combination approach for some complex aneurysms.

***Complex aneurysms*:** There are many factors which make an aneurysm complex. Anatomical factors like large or giant size, size too small for a clip or a coil, fusiform or serpentine shape, presence of a thrombus, aneurysm neck difficult to access, neck is broad, calcified or involving perforating arteries, aneurysm embedded in brain tissue, cerebral oedema or scar from previous surgery. As well as clinical factors like poor neurological grade on presentation, presence of vasospasm, advanced age or significant cardiovascular, pulmonary, renal or endocrine co-morbidity makes an aneurysm complex and difficult to treat by either modality.[16]

Combination modality by combining surgical and endovascular options synergises benefits and minimise side effects and has an important role in the management of such complex aneurysms. It should be used as a planned strategy after discussion among endovascular team, comprising of neurosurgeon and endovascular specialist. It also can be used as a rescue measure, when one modality fails or aneurysm recurs after first treatment.

## Combination options

***Surgery followed by endovascular therapy*:**

1. Extracranial to intracranial bypass surgery followed by endovascular parent vessel occlusion.
2. Aneurysm clipping assisted by temporary balloon occlusion with/ without suction decompression.
3. Intentional partial clipping for neck reconstruction followed by endovascular aneurysm packing.
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***Endovascular therapy followed by surgery*:**

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3. Coiling as the first treatment, reanalysed aneurysm treated with clipping.
4. Coiling and clipping of multiple remote aneurysms.

## Options

***Surgery followed by endovascular therapy*:**

**A)** ***Extracranial to intracranial bypass surgery followed by endovascular parent vessel occlusion*:** Extracranial to intracranial bypass surgery is a valuable tool in surgical armamentarium unsurpassed by endovascular options and is the mainstay of combination therapy. It creates an option beyond clipping or coiling and allows arterial occlusion to be performed without the risk of ischemic stroke and neurological morbidity that would occur without a bypass procedure.

Endovascular balloon test occlusion (BTO) offers a rational approach in patient selection for bypass procedures. Balloon test occlusion performed with hypotensive challenge and cerebral blood flow studies offers a safe and reliable method of predicting tolerance.[46] Alternative approach is universal revascularisation where all the patients undergo bypass procedures in which parent vessel occlusion is planned.[26] Though approach of universal revascularisation eliminates associated risks of BTO like false negative results and delayed ischemic deficits, many patients undergo unnecessary bypass procedure in whom the surgical risks are unjustified. Balloon test occlusion aids in selection of type of bypass and depends on the degree of failure; low flow (superficial temporal artery, occipital or intracranial donor artery), intermediate flow (radial arterial graft) or high flow (saphenous vein graft) bypass is performed.

Staged revascularisation and aneurysm occlusion has important advantages. It allows the bypass graft to mature before it bears full haemodynamic load, at the same time patency of bypass is confirmed angiographically prior to occlusion. Most graft occlusion occurs in first 24 hours and those bypass patent after 24 hours will remain so. Therefore, staged therapy ensures that the graft is patent prior to parent vessel occlusion. The disadvantage of staged procedure is lack of demand on bypass and the risk of aneurysm rupture. In patients with ruptured aneurysms parent vessel occlusion should be combined with the bypass at the same stage.

Endovascular parent vessel occlusion is advantageous as compared to microsurgical occlusion as vessel can be occluded at the desired location and trapped if needed. At the same time, angiographic confirmation of collateral circulation and graft patency can be ensured and this manoeuvre avoids surgical exposure of the vessel.

**B)** ***Aneurysm clipping assisted by temporary aneurysm orifice balloon occlusion with/ without suction decompression*:** Large or giant aneurysm in paraclinoidal region needs proximal control either of the petrous or cervical internal carotid artery (ICA). Petrous ICA exposure is technically difficult while proximal control in neck is at times not effective due to brisk retrograde flow through the ophthalmic artery and cavernous branches.[2] Endovascular balloon can be placed just opposite the aneurysm neck as a temporary proximal control with minimal invasiveness and good efficacy. At the same time, suction decompression may be used to lax the aneurysm which is of help in aneurysm dissection and clipping (Fig. 1). Method of suction decompression by inserting needle through the dome of the aneurysm or cervical ICA is invasive and may

not be effective in a patient with large collateral supply.

**Figure 1 - Endovascular temporary balloon occlusion with suction decompression assisted aneurysm clipping:**

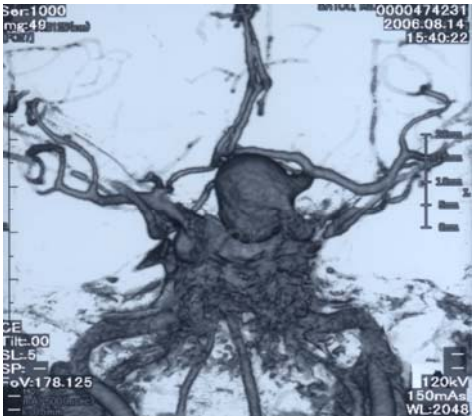



**Figure 1a** - MR angiogram showing a large ICA aneurysm.

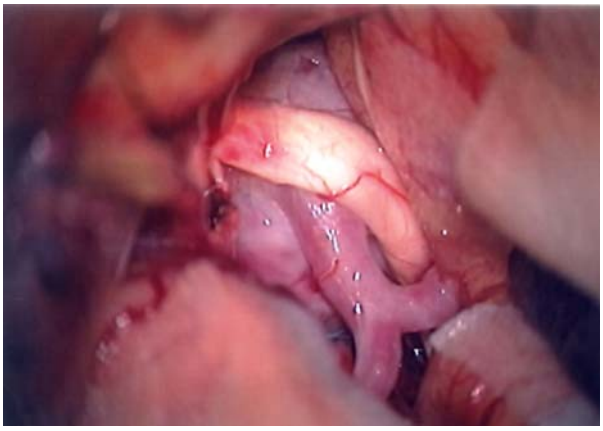


**Figure 1b** - Intraoperative image showing large ICA aneurysm stretching optic nerve.

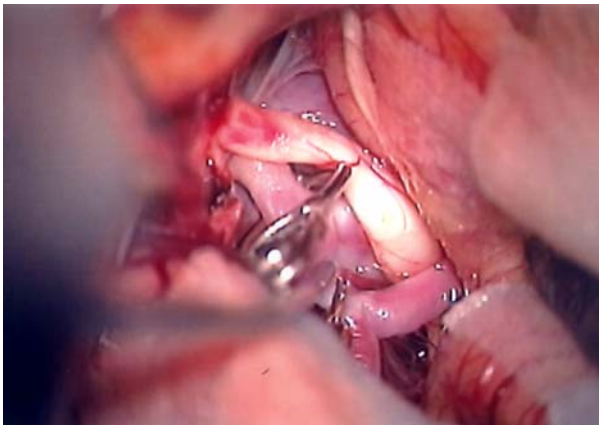


**Figure 1c** - Aneurysm became lax by endovascular suction decompression method and could be clipped with ease.

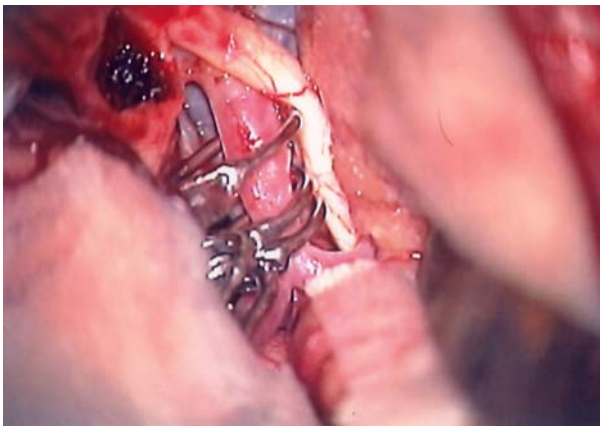


**Figure 1d** - Aneurysm clipped completely.

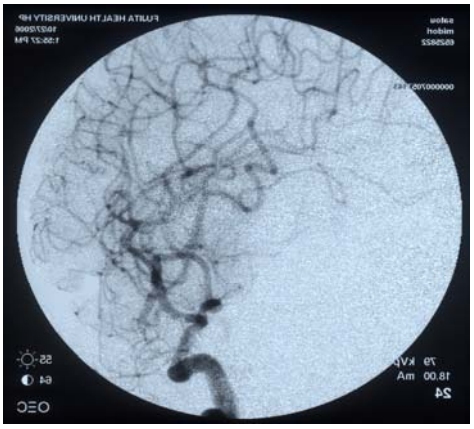


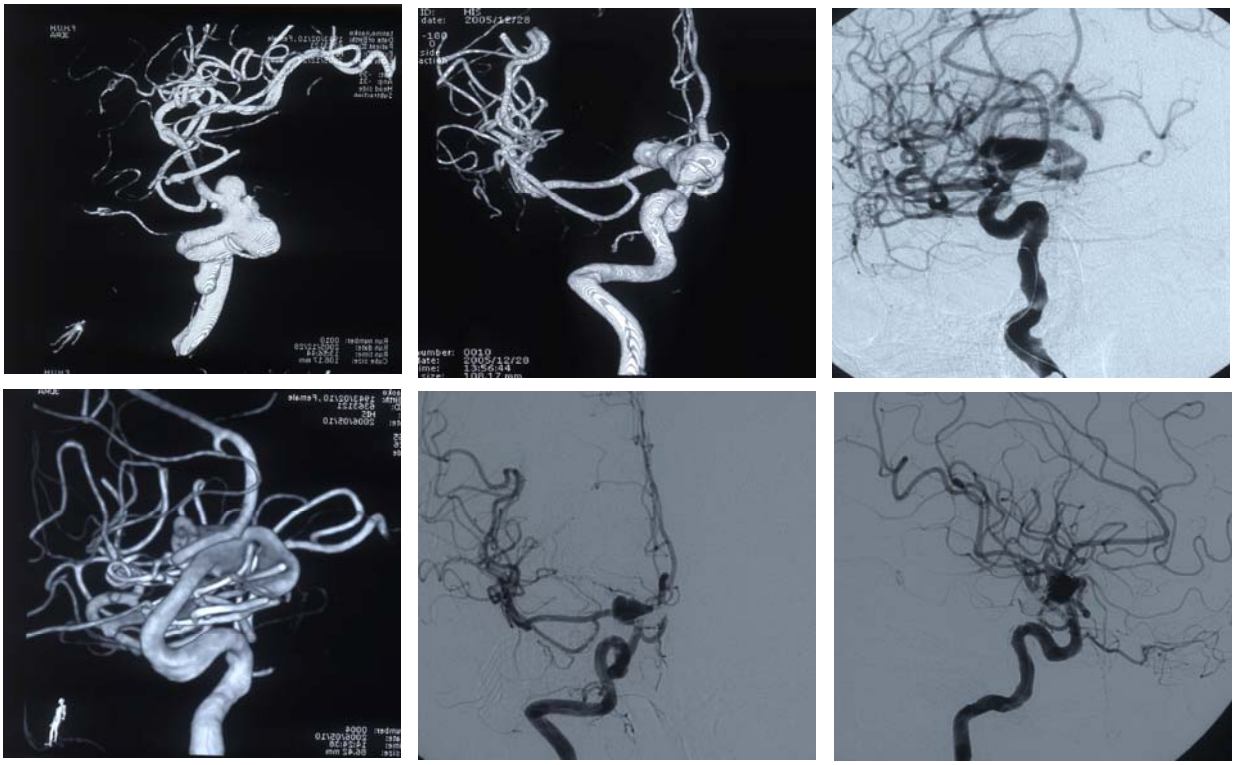
**Figure 1e** - Intraoperative DSA showing complete exclusion of the aneurysm from circulation.

Ability to confirm angiographically determined optimal clip placement, post clipping documentation of aneurysm obliteration and obviation of the need for surgical exposure of the carotid artery in the neck are added advantages of this technique.

**C)** ***Intentional partial clipping for neck reconstruction followed by coiling*****:** Aneurysms with morphology unsuitable for coiling and difficult to access surgically, like cavernous ICA aneurysm with part of it extending intracranially or large, wide necked basilar top aneurysm and; intentional partial clipping is used to reduce the neck size, which makes endovascular packing technically less challenging and safer (Fig. 2). At the same time, it provides information regarding peri-aneurysm environment such as presence of perforators and one gets the opportunity of protecting aneurysm by wrapping.

**D)** ***Clipping as the first treatment. Regrown or partially clipped aneurysm obliterated by coiling*****:** The incidence of aneurysm residual after clipping is approximately 4 to

**Figure 2 - Intentional reconstruction of posterior communicating artery aneurysm neck with clipping followed by coiling:**



**a-b**) Three-D DSA, ICA injection; showing a large, wide necked ICA posterior communicating and anterior choroidal artery aneurysm. Anterior choroidal artery aneurysm was clipped successfully. As posterior communicating artery aneurysm had wide, irregular neck and atherosclerosed wall, intentional neck reconstruction was done. **c-d**) Showing a residual posterior communicating artery aneurysm. As change in aneurysm morphology made coiling easier, coiling was done successfully. Post coiling angiogram: **e)** AP, and **f**) Lateral views showing near complete exclusion of aneurysm with small residue.

7%.[10, 43, 45, 47] In a study of late angiographic follow-up after surgical clipping, there was a 1.5% recurrence rate in patients in whom there was no residual aneurysm after clipping and 25% enlargement in patients in whom there was residual aneurysm. (Mean angiographic follow-up 4.4 +/- 1.6 years; range 2.6 - 9.7 years).[8] The same study found a 1.9% risk of bleeding from aneurysm residual.[8]

Re-operation for this residual or recurrent aneurysm is difficult because of factors such as scarring, adhesions and danger associated with manipulation of previous clip and it is associated with higher risk of morbidity and mortality than the initial operation.[9, 11]

According to Hoh, et al, important factors in selection of modality to treat post clipping residual aneurysms are posterior circulation aneurysm, aneurysm size more than 10 mm and fusiform morphology.[17] Aneurysm with any of these characteristics are treated with either endovascular or combination modality.

Partial clipping might be of help in coiling by changing the aneurysm morphology.

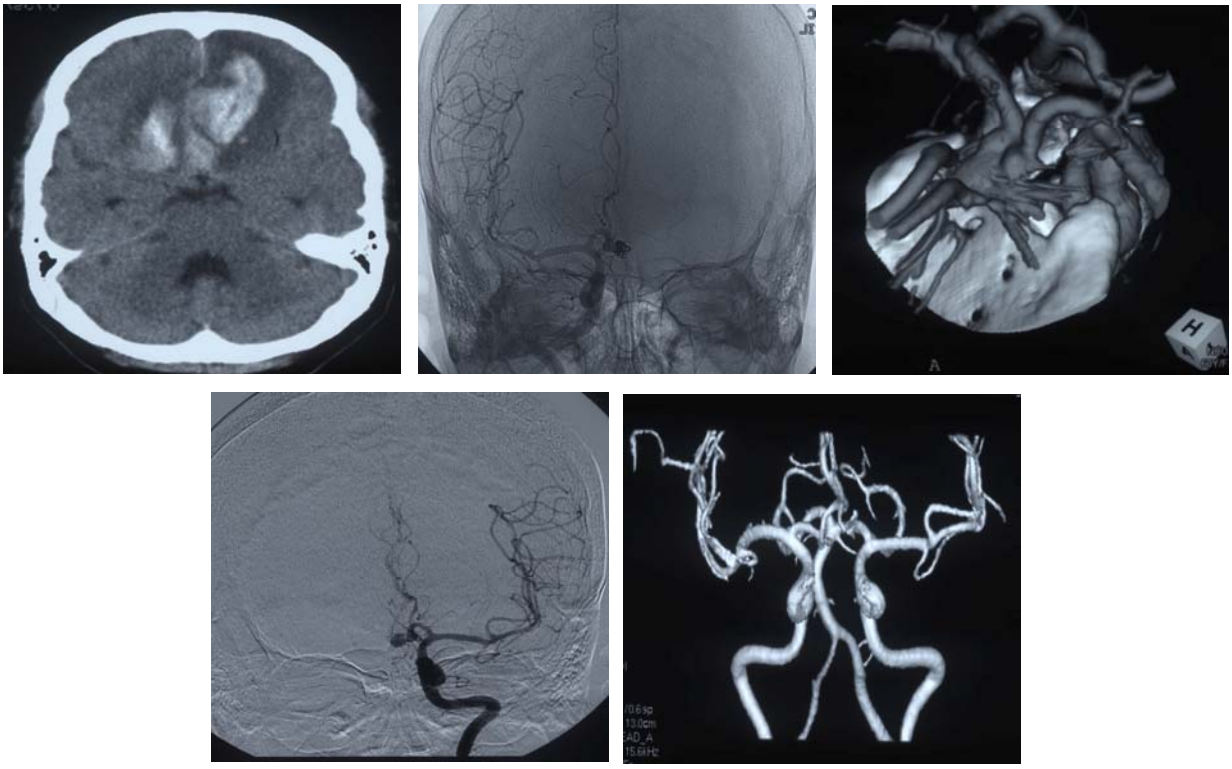
## Endovascular therapy followed by surgery

**A)** ***Partial coiling to prevent rebleed followed by delayed definitive clipping*****:** In situations like poor grade SAH or vasospasm where risk of surgery is high because of temporary risk factors; endovascular modality is of help by obliterating the dome of the aneurysm. It prevents rebleed which is a major cause of morbidity as well as mortality. It also enables one to treat vasospasm more vigorously. Once patient is stable and fit for major operative procedures, clipping can be performed to obliterate the aneurysm completely (Fig. 3).

Several groups have demonstrated the effectiveness of endovascular treatment in protecting patients who are at high risk, from subsequent bleeding.[5,13,30,38,50] Though, the procedural morbidity (9 - 31%) and mortality rates (2 - 9%) were highly variable among groups.[5,13,30,38,50]

**B)** ***Permanent parent vessel occlusion followed by surgery for decompression in giant aneurysm*****:** Untreated giant

**Figure 3 - Partial coiling to prevent rebleeding followed by delayed definitive clipping:**



**a**) CT brain showing subarachnoid haemorrhage with intracerebral haemorrhage. **b**) DSA showing anterior communicating artery aneurysm, as both ACA demonstrated vasospasm, combined modality was planned. Coiling done to reduce the risk of rebleeding by securing fundic part of aneurysm, post clipping angiogram, **c)** and CTA, **d**) Showing residual aneurysm with bleb, clipping done after 4 weeks. **e**) Follow-up MRA showing complete exclusion of the aneurysm.

intracranial aneurysms have a negative natural history as a result of haemorrhage, cerebral compression and thrombo-embolism. The mortality rate associated with surgery alone ranges between 5 and 13%.[12,33,35] Endovascular coil treatment of giant aneurysm can be accomplished with procedure related morbidity and mortality rates comparable or even inferior to those for open surgery.[14] However, as coil strategy appears to be unsatisfactory over a period of time, it has been suggested that aneurysm coiling should currently be reserved for individuals who are considered poor candidates of open surgery. This makes the parent vessel occlusion a better therapeutic option for a definitive treatment.

Occlusion by endovascular balloon provides the ability to occlude the vessel close to the aneurysm which also reduces the possibility of "stump emboli".[16]

When mass effect is the presenting mode, surgical removal of the aneurysm mass to alleviate the compression of the surrounding neural structures is advocated in some instances and preoperative occlusion of the parent vessel by the endovascular approach may ease the surgical removal by suppressing pulsatility and facilitating aneurysm dissection.[33]

**C)** ***Coiling as the first treatment, reanalysed aneurysm treated with clipping*****:** Complete occlusion of aneurysm is difficult to achieve by coiling alone in wide necked, large or giant aneurysm. Recurrence of aneurysm after endovascular treatment is also well documented in literature.[5,7,20,23,25,28,29,31,32,48] Cognard, et al in the long term follow-up series found that the recurrence rate was 14% for totally occluded aneurysm and 33% in subtotally occluded group.[7] Byrne, et al noted a 15% recurrence rate in a 5-year experience and an overall annual rebleeding rate of 1 to 2%, although the rebleeding rate was 8% for lesions that demonstrated progressive growth.[4] Similar reports of late rebleeding rates between 1 to 2% have been reported elsewhere.[15,24] With most endovascular series reporting 60 to 90% of total or near total occlusion rates at the time of treatment and 10 - 20% less at the time of follow-up examinations, clearly there is a large group of patients harbouring potentially dangerous recurrent or residual aneurysms.

Partially treated aneurysm presents an ongoing risk of

haemorrhage and requires definitive treatment. If vascular anatomy or aneurysm configuration is unfavourable for endovascular treatment surgical obliteration is indicated. Whether to treat the aneurysm and which modality is to be used, depends on patients neurological status, general medical condition, location of the aneurysm, aneurysms angioarchitecture, degree of neck occlusion and the elapsed time since last endovascular procedure.

Few authors have described surgical management of previously coiled aneurysms.[5,7,20,25,32,48] Most authors agree that aneurysms without coils in the neck are easier to treat with primary clipping, whereas those with coil mass occupying neck are difficult to clip without coil extraction.[20,48] Large, partially coiled aneurysms are relatively immobile which makes dissection and visualisation in the area around the aneurysm difficult.

Basic principles of clipping are highly relevant in surgical management of these lesions. Maximal exposure with judicious use of cranial base techniques and early acquisition of proximal and distal control are the key to success. Whether to extract coil or not is also controversial. Civit, et al advocated no coil removal, while Thornton, et al used coil extraction in operating on all previously coiled aneurysms, while Horowitz, et al reported coil extraction only when coil mass hampers initial clip trial.[5,20,48]

If aneurysm is truly unclippable vessel occlusion and bypass needs to be considered.

**D)** ***Coiling and clipping of multiple remote aneurysms*:** In patients with multiple aneurysms, when one of the aneurysms is unsuitable by clipping or coiling, a combination modality is used in the same general anaesthesia.

It is also used to avoid an additional craniotomy in patient with remote aneurysms which can not be accessed with single surgical approach. In patients with subarachnoid haemorrhage with multiple aneurysms, when one is not able to decide which aneurysm has bled, all the aneurysms are treated aggressively.

## Results of combined modality

In a series by Hacein-Bey, et al 12 patients with complex aneurysms were treated using following options:[16]

1. ***Endovascular followed by surgery paradigms*:**
   a) Superselective angiography followed by surgical clipping.
   b) Endovascular aneurysm dome packing followed by surgical clipping.
   c) Proximal vessel temporary balloon occlusion followed by aneurysm clipping.
   d) Endovascular permanent vessel occlusion followed by surgical decompression.
2. ***Surgery followed by endovascular paradigms*:**
   a) Surgical exploration followed by endovascular treatment.
   b) Partial surgical clipping followed by endovascular aneurysm obliteration.
   c) EC-IC bypass followed by endovascular parent vessel occlusion.

Out of these 12 aneurysms, 11 (92%) were completely eliminated. Remaining 1 (8%) aneurysm was 90% obliterated and remained quiescent at the 34 months follow-up. No patient experienced rebleeding and there was no death. Eleven patients had excellent outcome (Glasgow Outcome Scale score of I) and 1 patient had fair outcome (Glasgow Outcome Scale of III)

In a series by Lawton, et al, 96 aneurysms in 77 patients were treated with combination modality by 8 different combinations[27]:

1. Selective revascularisation and aneurysm occlusion
2. Endovascular and surgical trapping
3. Clipping of an aneurysm after incomplete coiling
4. Coiling after attempted or incomplete clipping
5. Clipping of recurrent aneurysm after coiling
6. Coiling of recurrent aneurysm after clipping
7. Coiling after previous surgery
8. Clipping and coiling of multiple aneurysms

Seven out of 77 patients died (mortality rate 9%), 6 patients had temporary neurological deficits (7.8%) while permanent treatment related neurological morbidity was seen in 5.2% of patients. At mean follow-up of 9 months, 86% of patients had a good outcome and none of the treated patients experienced rebleeding.

## Advantages

Surgical and endovascular modality are complimentary and not competitive. Aim of combination modality is better efficacy with minimal invasiveness. So, it is advantageous by reducing morbidity as well as mortality and at the same time provides superior results in the complex aneurysms.

At times, combined modality may be the only option available to treat the lesion successfully.

## Requisite

Successful integration of combination modality as a planned strategy requires a dedicated centre with facilities of both cerebrovascular as well as endovascular modality.

There should be understanding and mutual respect for each

other and for the modality in both the teams and decision making should be from neutral standpoint.

## Obstacles

Various obstacles exist to the development of combined approach. Utilisation of both the modalities makes the overall treatment expensive. Apart from the cost; geographic separation of surgical and endovascular facilities in the same centre, lack of proper guidelines for training of intervention specialists and differences in perceived roles among various speciality teams make application of combined approach difficult, at times.

## Conclusion

Cerebrovascular and endovascular combined modality is a very useful addition to the armamentarium for the management of complex aneurysms and can be applied in various combinations. When used rationally, this approach offers the best outcome with reduction of treatment morbidity.

In future, we shall see more variety of combination options and more and more aneurysms being managed successfully by combined modality with resultant decrease in morbidity as well as mortality.

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