REVIEW

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The art of cerebral aneurysm clippology in clip limited setting: A literature review and a perspective experiences in Indonesia

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ABSTRACT

Introduction: Microsurgical clipping for cerebral aneurysms is still the mainstay therapy in developing countries because of its superiority in cost-effectivity and durability to control unruptured cerebral aneurysms in reducing residual and recurrence rates by complete total occlusion achieved compared to coiling. However, neurosurgical facilities in Indonesia frequently encounter the challenge of limited clip availability in size and shape variations, besides the problems of limited qualified cerebrovascular experts to perform the microsurgical clipping. Furthermore, unprecise and inefficient closure of the aneurysm's neck due to inadequate clipping could lead to residual and rebleeding.

Methods: A literature review was conducted in this study along with the authors' perspective experiences working in a clip-limited setting hospital to achieve effective aneurysm occlusion.

Literature Review: A brief introduction to clipping history, biomechanicals, types, physics, and utilization of temporary and permanent clipping are required for this limited clip-selection facility, especially for young neurosurgeons. Regarding the limited size and shape of aneurysm clips, several clipping methods can be used alternatively to achieve a good clinical outcome and total aneurysm occlusion.

Conclusion: As most neurosurgery centers in Indonesia face limited clip-selection settings, continuous experience sharing and better knowledge must be improved.

Keywords: aneurysm clipping, cerebral aneurysm, clippology, microneurosurgery.
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INTRODUCTION

Despite the debate over the superiority of microsurgical clipping versus endovascular coiling to treat cerebral aneurysms, the use of microsurgical clipping is still a mainstay in developing countries with considerations in terms of cost-effectiveness and durability to control unruptured cerebral aneurysms (UCAs) in reducing residual and recurrence rates due to its advantages in achieving complete total occlusion of the aneurysm compared to coiling.[1-5] However, some studies have found coiling to result in lower mortality and neurological disability rates.[3,5,6] As a developing country with few neurosurgeons, Indonesia only has a few neurosurgical facilities with infrastructure and qualified cerebrovascular experts to operate on cerebral aneurysm cases. Outside of its facilities that are only concentrated in big cities, one of the most frequently encountered challenges is the limitation in the availability of variations in the size and shape of the microsurgical clips themselves to precisely and efficiently close the neck of the aneurysm to prevent residual regrowth and rebleeding.

Treatment for this varying complexity of cerebral aneurysms requires better knowledge and experience in angioarchitecture, biomechanical, and physics of aneurysm clips, clipping techniques, and surgical corridor approaches. This review aims to share the authors' perspective experiences working in a clip-limited setting hospital to achieve effective aneurysm occlusion, preceded by a brief introduction of clipping history, materials, types, physics, and utilization of temporary and permanent clipping.

Historical development of cerebral aneurysm clipping

The surgical approach to treating intracranial aneurysms begins with applying the concept of Hunterian (proximal) ligation of the parent artery to induce thrombosis within the aneurysmal sac, introduced by John Hunter in 1784. Due to its high morbidity and mortality rate, several other methods were introduced. However, the first successful method to directly treat an aneurysm, the trapping method, was done by Axel Herbert Olivecrona in 1932. Walter Edward Dandy later introduced the first use of an aneurysm clip to ligate the neck of a saccular cerebral aneurysm in 1937 using the Cushing V-shaped malleable silver clip that Harvey Cushing created, which marked the birth of cerebral aneurysm's neck clipping.[7-9]

Of the many versions of clips developed to suit the needs of aneurysm surgery, the most commonly used clips worldwide are the Sugita and Yasargil clips, developed in the 1960s to 1980s. The Yasargil clip is an alpha Greek letter configuration clip with strong closing pressure and a narrow base which optimizes aneurysm neck visualization. It also features an outer ring to prevent uncrossing aneurysm legs.[9-11] The Sugita clip is also an alpha-type but with a long clip with external crossed wire between the blade and body of the clip and a loop on the back to prevent misalignment, uncrossed clip-arm and to create a wide opening of the clip blade that is useful in clipping giant and deep aneurysm.[9,11,12]

Materials, types, and physics of aneurysm clips

The material that makes up the clips is essential because it determines the closing and opening force, weight, radiological visualization, and biological reactions elicited. Initially, sterling silver, consisting of 7.5% copper and 92.5% silver, followed by stainless steel, was used. Still, they are no longer used due to their highly corrosive nature, which causes an excessive inflammatory response and long-term oxygen deprivation.[13-17]

In the development considering corrosion potential, the Yasargil-Phynox and the Sugita-Elgiloy clips, which consisted of high-grade cobalt-chromium, were widely used in cerebral aneurysms.[9,11,13,16] The shift from using clips to titanium materials is due to cobalt-causing magnetic resonance imaging (MRI) interference.[13,16] During its development, Sugita introduced titanium-6A1-4V clips (89.4% titanium, 6.08% aluminum, and 4.06% vanadium) with better strength and occlusion force, with some addition of high biocompatibility, corrosion resistance, and superior imaging properties than pure titanium clips.[9,13,16]

The size of clips is variable, ranging from 3 mm to 40 mm long. Comparative studies by Horiuchi *et al*. showed that both Yasargil Titanium III and Sugita Titanium 2 have a similar closing force, but the shape was significantly different in the forces.[18] The non-straight clips are weaker than the straight ones, and the large clips generate less force than the placement of several short clips.[18,19] The current standard force exerted in the temporary clip is 50 to 85g, and the minimum strength of 25g for a 1.5 mm vessel to arrest the flow.[20-22] The force of temporary clips is weaker than permanent clips, with a range of 70 – 110g compared to 130 – 180g in both Yasargil and Sugita's newest titanium clips.[18,23,24]

Utilization of temporary and permanent clipping

Temporary clips are usually used for precluding occlusion before the aneurysm dissection and permanent clip placement because of their utilization to minimize intraoperative rupture and facilitate control of the aneurysm by the operator by increasing the pliability of the aneurysm which makes it softer, as well as for aneurysm sac remodeling during the suction decompression technique, and atherosclerotic plaque removal. Temporary clips were first used by Jefferson in 1928, and their use is crucial in emergency settings such as intraoperative aneurysm rupture.[13,25,26] However, there are some disadvantages to using temporary clips, namely interfering with a deep dissection process because it occupies the space and field of view, increasing the risk of brain ischemic incidences with prolonged temporary occlusion, and high risk of thrombus formation if the occlusion is taken more than 10 minutes.[17,25,27] The average time of temporary clipping for vascular arrest in the middle cerebral artery (MCA) aneurysm surgery is a total of 13 minutes with the time limit for a single continuous application time limited to 2.4 minutes, and longer duration is related to higher postoperative deficits.[17,23]

Besides its limitations, several methods have been developed to improve the safety limit of temporary clips, including intraoperative electrophysiological monitoring to measure the integrity of the brainstem and spinal cord to prevent permanent neurologic injury by an application of a combination or one bottom-up (spinal cord dorsal columns) monitoring by somatosensory evoked potentials (SSEP) and a top-down (anterior columns) monitoring by motor evoked potentials (MEP); Intraoperative thermal diffusion flowmetry for regional cerebral blood flow (TDF-rCBF) using a real-time and quantitative measurement by microprobe implantation in the brain to evaluate an ischemic incidence during the use of temporary clips and final permanent clips position evaluation during postoperative period; Neuroprotective agents as preconditioning strategies to lower the risk of infarction; and avoid the use of temporary clipping in a severe atherosclerotic vessel and use it carefully in patients with the history of endovascular treatments or indwelling stents as the incidences of clip slippages, persistent refilling, and thrombo-embolic strokes are increase.[27-34]

The permanent clip placement is the final step to occlude the aneurysm. There are several considerations of the permanent clip placement depends on the aneurysm location which include the bifurcation aneurysm of MCA and basilar artery (BA) which is the branching site of the patent artery, should be clipped perpendicularly to the afferent artery and parallel to the efferent branches; Sidewall aneurysm such as ophthalmic artery aneurysm where hemodynamic stress as a more significant turnover and with the curve in the outer wall vessel, should be clipped parallel to the patent artery; The anterior communicating artery (ACA) and BA bifurcation aneurysm that associated with perforating arteries which needed to be preserved should be clipped parallel to the line of perforating arteries across an aneurysm; and the giant aneurysm should be clipped with the tandem technique developed by Drake to decrease the risk regrowth, by using the straight fenestrated clip as the first clip to close a distal aneurysm neck and a shorter clip as the second one to close the fenestration contour and preserve efferent arteries near the neck. Modifying tandem clipping with an angled fenestrated clip can also be performed at the aneurysm neck, with each blade overlapping to prevent refilling. The blade tips can be aligned in the opposite direction while facing each other (toe-toe placement) or crosswise (heel-heel arrangement).[13,25] Clipping a large aneurysm can be simplified by completely transecting the neck. However, this method requires a complicated reconstruction using clips that should be stacked perpendicular to the aneurysm neck, with the procedures of an incomplete proximal-distal control with back-bleeding, moved branch arteries adherence, and reconstructing the neck and atherosclerotic tissue at the aneurysm neck.[25]

Perspective experience on clip-limited settings in Indonesia: The art of clippology

The main discussion of this article is to present the condition of most neurosurgical settings in Indonesia, represented by our perspective experience in one of the neurosurgery centers in the capital city of Jakarta. Most cerebral aneurysm cases in our daily practice are ruptured aneurysms, reflecting the inadequate screening, early detection, and prevention of rupture in most unruptured aneurysm patients. Unfortunately, most hospitals in Indonesia have short clip variation availability, including ours. Some hospitals are averagely equipped with a container of more or less than 20 aneurysm clips with a random shape and size (Figure 1). It becomes a new challenge when dealing with emergency cases because the clips' availability in the vendors is also often in short supply. However, this condition is not the reason to stop our service, as life-saving is the main priority. Therefore, a good experience and knowledge of clips' aneurysm angioarchitecture and physics are essential.

Usually, we utilize the proximal control with or without distal control using the brief clip(s) with its placement on a parent and main branch artery before the aneurysm neck and dome dissection to provide a well-controlled dissection (Figure 2). This procedure softens the aneurysm, which allows a safe mobilization of its dome and offers better visualization of surrounding structures. The duration of a temporary clipping usually takes between 2 – 3 minutes to prevent the risk of cerebral ischemia. Still, in several complex cases, intermittent temporary clipping of the parent or branch artery is usually needed up to three times with several minutes in between. This strategy is essential since a premature or intraoperative aneurysm rupture increases the risk of unfavorable neurological outcomes. After the neck of the aneurysm is well identified, a pilot clip is placed around its neck, and the temporary clip(s) are removed, then the dissection of the aneurysm dome can be performed. In a condition with limited clip variation availability, a multiple clip reconstruction is required to close the aneurysm neck perfectly. During the application of the permanent clip, a complete visualization has to be established. The microscope viewing angle and patient's position must be adjusted so both sides of the aneurysm's necks, clip blades, and surrounding structures of the aneurysm should be in one view. The working clip appliers are held around 30 degrees off the line of sight, ensuring minimal hindrance in the visual field and visual blocking by the operator's hand. The operator controls the maneuvers of a permanent clip, considering the pitch (slope of the clip appliers), yaw (side-to-side rotation of the clip appliers in

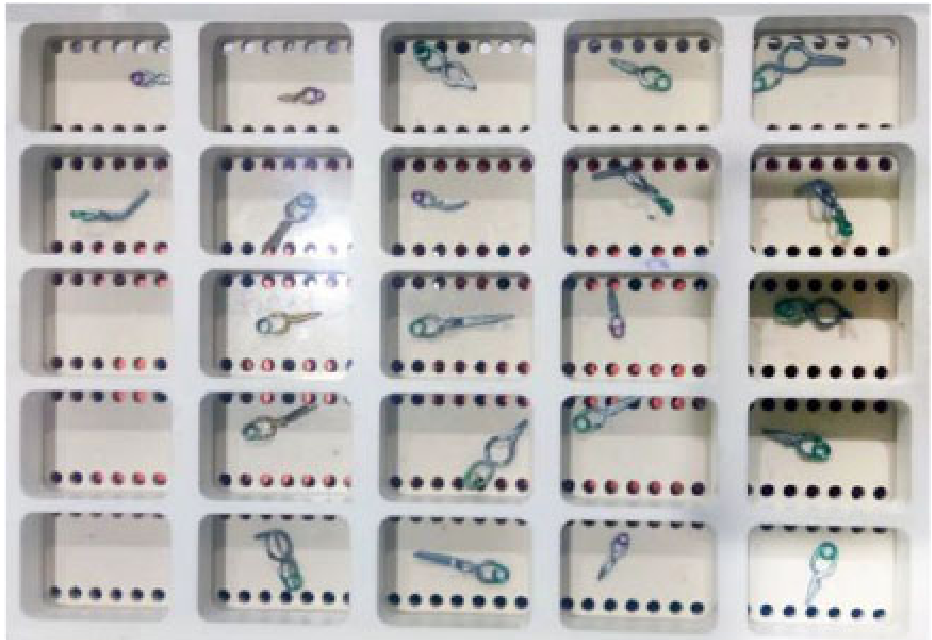

Figure 1. Examples of insufficient aneurysm clip availability in a neurosurgical center in Jakarta. Usually, vendors provide the clips according to the available stocks, or the vendor's staff chooses the clips randomly.

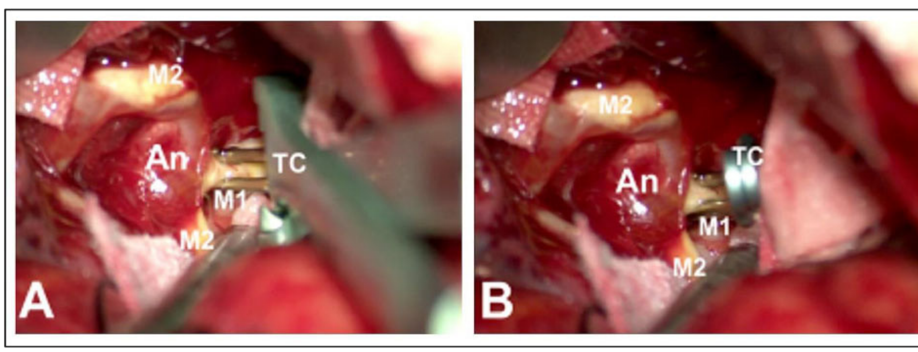

Figure 2. A: The ideal position of the proximal temporary clip is as close as possible to the neck of an aneurysm. A temporary clip placed at the M1 artery, with the microscope working angle during its placement, is essential for more precise visualization. The color code of temporary clipping is usually gold. B: After M1 temporary clip placement shows an adequate space for surgical maneuver and dissection around the neck of the aneurysm. In this case, we did not put the distal temporary clip at bilateral M2 because the aneurysm is softened after proximal temporary clipping.
An: Aneurysm; M1: Middle cerebral artery segment 1; M2: Middle cerebral artery segment 2; TC: Temporary clip.

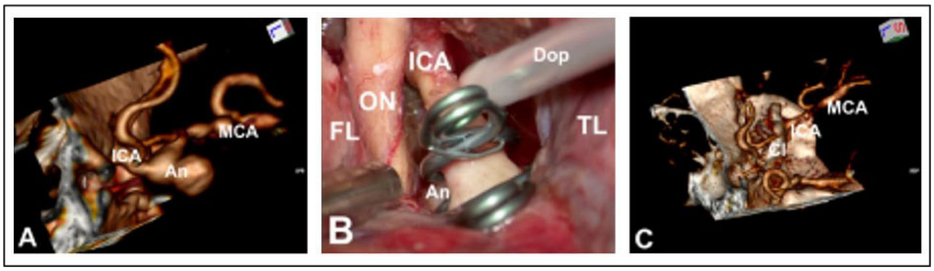

Figure 3. A: Pre-operative CTA showed a giant ICA aneurysm pointed in superoposterior direction. B: The tandem clipping technique (Drake's technique) occludes the aneurysm while preserving the ICA. In this case, we did not have clips with an appropriate ring and blade size. However, the surgery was done well, and the patient achieved an excellent clinical outcome. C: Postoperative CTA showed that the aneurysm is occluded and ICA, MCA, and ACA are well preserved.
ACA: Anterior cerebral artery; An: Aneurysm; CTA: Computed tomography angiogram; Dop: Doppler ultrasound; FL: Frontal lobe; ICA: internal carotid artery; MCA: Middle cerebral artery; ON: Optic nerve; TL: Temporal lobe.

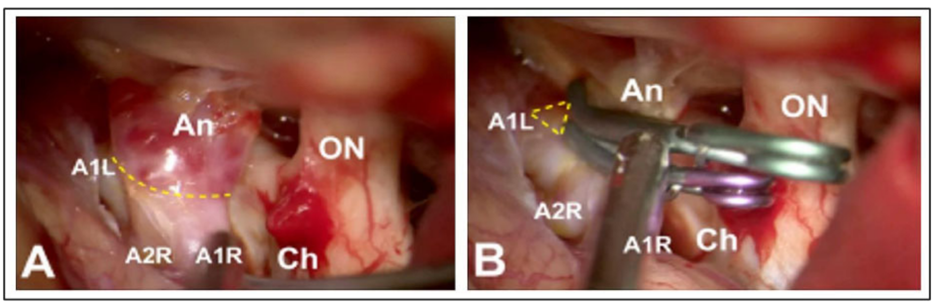

Figure 4. A: An anterior communicating artery aneurysm case after meticulous dissection to expose the aneurysm. The yellow dashed line represents the neck of the aneurysm. B: We did a stacked clipping technique. However, a small residual neck represented in the yellow dashed triangle was left behind due to the limited availability of the clip. The aneurysm could have a perfect occlusion if we had a mini clip with a longer blade. We managed the residual by coagulating the aneurysm.
An: Aneurysm; A1R: Right anterior cerebral artery segment 1; A2R: Right anterior cerebral artery segment 2; A1L: Left anterior cerebral artery segment 1; Ch: Optic chiasm; ON: Optic nerve.

the vertical axis), and roll (side-to-side rotation in the instrument axis).

The essential selection of clip sizing with a blade size around 1.5 times the aneurysm neck size is difficult to achieve when the clip size provided is limited. As a result, an oversized clip is sometimes placed, and when the clip stocks are undersized, a multiple clip stacking method is required to occlude the aneurysm. We usually use numerous clipping techniques if an aneurysm is large with a broad neck and complex anatomy. The clips should be progressively placed from the deepest to the nearest neck. Multiple clipping can be performed in three different ways which include tandem clips with two or more fenestrated clips placed at the neck (Figure 3); Stacked clips by understacking or overstacking parallel clips to each other in tight surgical corridors where the first method is too difficult to perform (Figure 4); and overlapping clips can be done by applying a fenestrated clip that encircles the first straight clip to close an opening below the initial clip.[13,25,26]

CONCLUSION

Microsurgical aneurysm clipping is a strategic option for treating cerebral aneurysms, especially in developing countries. However, the inadequate clip supply, distribution, and availability of neurosurgical centers and neurosurgeons are a challenge that must be solved by multisectoral stakeholders, including hospitals, vendors, medical societies, and the government. In addition, as most of the neurosurgery centers in Indonesia face limited clip-selection settings, continuous experience sharing and better knowledge on aneurysm clippology are essential.

CONFLICT OF INTEREST

The authors declare no conflict of interest to disclose regarding the materials or the methods used.

AUTHOR CONTRIBUTION

The authors contributed equally to the writing of the manuscript. Mardjono Tjahjadi did patient treatment and surgery. All authors discussed and analyzed the findings, collected the data, reviewed the results, and approved the final version of the manuscript.

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