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Temporary clipping in intracranial aneurysm surgery. History and development

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ABSTRACT

Background: Neurosurgery's challenging area involves addressing intracranial aneurysms, given the high morbidity and mortality rates associated with them. Safe clipping, a technique that involves the intraoperative temporary occlusion of the arterial supply, is generally used. However, a focused review on the evolution of temporary clipping in intracranial aneurysms hasn't been previously carried out.

Methods: We performed a comprehensive literature search on PubMed Medline and Google Scholar, using the combination of terms: [Temporary clip* AND (Cerebral OR Intracranial) Aneurysm].

Results: From an initial pool of 579 results, we excluded unrelated papers, narrowing it down to 25 relevant studies. These ranged from retrospective and prospective studies on the outcome favorability or radiological evidence, to analyses on potential independent prognostic factors, and articles related to the history and evolution of temporary clipping.

Conclusion: Temporary arterial occlusion in aneurysm surgery has evolved significantly since its inception in the early 20th century, marked by innovations in instruments and temporary clips. Despite these advancements, the utility and safety of temporary clips continue to be topics of discussion, particularly due to concerns regarding possible complications and their influence on long-term results.

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Introduction

Intracranial aneurysms are a health concern affecting roughly 2% of individuals, with their rupture contributing to approximately 3% of all hemorrhagic incidents [9]. A successful therapeutic strategy necessitates not only the comprehensive occlusion of the aneurysm but also the preservation of blood flow in the parent artery, its branches, and the perforating vessels. This is usually achieved through a method known as safe clipping, which is carried out intraoperatively and involves the temporary blockade of the cerebral vasculature both upstream and downstream of the aneurysm [2]. The main purpose of this method is to enable the removal of intramural calcifications and thromboses before definitive clipping in large aneurysms, thereby rendering the aneurysmal wall flexible and adaptable. Moreover, the use of neuroprotective agents, surgical monitoring of cerebral blood flow, and the avoidance of severe and prolonged hypotension can be effective in mitigating cerebral ischemia and extending the safe duration of the temporary clip (TC) application [2].

TC application operates on a principle of safety within a time-limited framework, partly obstructing the nutrient artery, thus enabling back bleeding and retrograde flow through collaterals [6,13]. Although there have been discussions about the repercussions of clipping durations exceeding 20 minutes in terms of vasospasm, the exact impact on the occurrence of delayed cerebral ischemia in patients with aneurysmal subarachnoid hemorrhage remains ambiguous [7,12]. Furthermore, the significance of the clipping duration may be inconsequential given that it can extend up to 90 minutes in intermittent clipping, albeit without a consensus on this aspect as the brain's ischemia tolerance thresholds differ from one individual to another [7,12].

The historical evolution and development of the temporary clipping technique have yet to be fully explored and documented. This review aims to shed light on the journey of temporary clipping from its initial conception and early use to its current day applications.

Methods

To accumulate relevant literature, a comprehensive search was conducted using PubMed Medline and Google Scholar databases. The specific search string employed was: [Temporary clip* AND (Cerebral OR Intracranial) Aneurysm].

Results

The initial search yielded a total of 579 records. Following the removal of irrelevant entries, 25 pertinent studies remained for further examination. These selected studies comprised both retrospective and prospective analyses, focusing on outcomes, radiological evidence, and potential independent prognostic factors. They also encompassed articles that pertained to the historical progression and evolution of temporary clip usage in aneurysm management.

History and development

In the early 1900s, Harvey Cushing pioneered the use of hemostatic clips. He envisioned their broad application in general surgery, highlighting their potential role in arterial procedures to temporarily obstruct smaller collateral vessels. Cushing's unique clip was designed from tantalum wire, forming a diamond shape when one side was opened, which allowed the optimal occlusion of vessels. Despite Cushing's reputation, his clip design did not gain popularity among general surgeons [9].

On 22nd November 1927, Walter Dandy used a method involving temporary vessel occlusion in a patient presenting with progressive hearing loss. An aneurysm was discovered connected to the patient's vertebral artery during surgery, and Dandy temporarily occluded one of the arteries. Postoperative complications led to the patient's unfortunate demise, but this case underscored the concept of temporary vascular occlusion [6].

The notion of preventing intraoperative rupture (IOR) using transient clips for local blood flow control evolved gradually. It was traced back to 1926, when a procedure at the Cushing clinic possibly employed a loose ligature around the carotid artery for transient flow reduction. In 1928, the intracranial use of TCs became attributed to Jefferson, who adapted a clip commonly used in thyroid surgeries [18].

Subsequent innovations included the addition of winged blades to the malleable silver clip by Herbert Olivecrona. However, these clips had a risk of damaging the aneurysm neck [15]. Further advancements included a small, light, and effective artery clamp developed by Black and German, allowing temporary vessel occlusion without

compromising its continuity and patency [3]. Later, Schwartz designed a temporary clip that ended up being permanently implanted in many patients due to the lack of alternatives.

In 1952, Mayfield and Kees slimmed the shank's size and created clips of various lengths, adding serrations to increase grip and minimize slippage. Remarkably, Mayfield managed to convince seven volunteers to undergo surgical exposure and temporary clipping of their temporal arteries, confirming the minimal risk of delayed thrombosis [14].

By 1968, Kenneth Grant Jamieson had modified commonly available curl clips to provide temporary occlusion in aneurysm surgeries, finding them superior to the Scoville spring clips then in use [18]. Around the same time, Suzuki et al. reported the benefits of temporary clamping with mild hypothermia, promoting the concept of intermittent reperfusion [21]. From the late 1970s, reports of temporary arterial occlusion for managing large aneurysms increased, and by 1983, Ljunggren et al. noted that occlusion of the middle cerebral artery (MCA) for up to 20 minutes was well tolerated (Fig 1) [4].

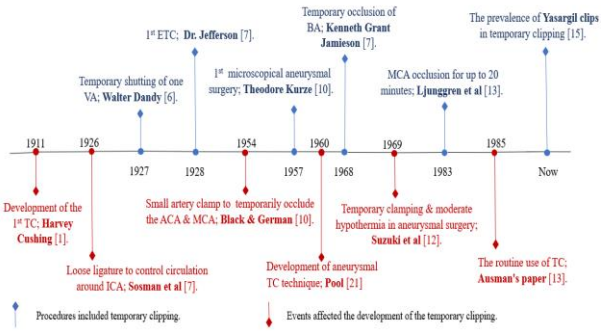

Figure 1. Brief history of the intracranial aneurysmal temporary clipping development.

In the same year, 1968, the first Yasargil aneurysm clip was created, marking a significant advancement in clip design [4]. The current safest temporary clips in use are the Sugita or Yasargil models, which apply varying pressures depending on the size of the artery to be occluded [5]. These clips have undergone numerous modifications over the years, with the standard Yasargil TC now featuring an occlusion force range of (0.88-1.08) N (Fig 2).

Discussion

In the realm of neurosurgery, the act of clipping a ruptured intracranial aneurysm involves a degree of vessel manipulation, which is suspected to induce vasoconstriction. Employing temporary clipping of the parent vessel during surgery is a technique that is either an elective procedure or a rescue measure. TCs, distinguishable by their golden color, possess approximately two-thirds of the closing force of permanent clips (as illustrated in Fig.1). The literature varies on acceptable durations for TC application, with recorded times ranging from immediate to 93 minutes, inclusive of both continuous and sporadic clip application [12].

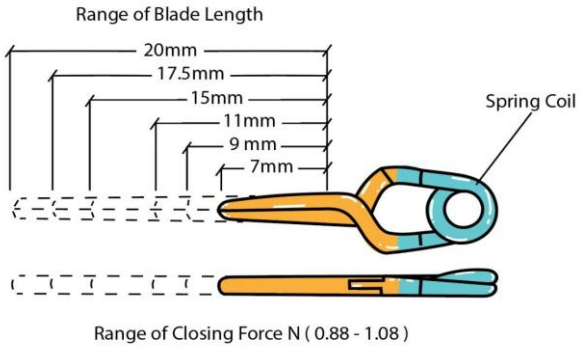

Figure 2. An Illustration of standard Yasargil clip for temporary vessel occlusion.

Elective temporary clip (ETC) application can serve multiple purposes. These include reducing aneurysm pressure before applying a permanent clip, defining the aneurysm's structure while dissecting complex aneurysms, readjusting a permanent clip for aneurysms undergoing multiple clip applications for optimal occlusion, suction decompression technique, sac remodeling, and removal of atherosclerotic plaque from the neck [13]. Rescue temporary clip application, used to control bleeding during IOR and facilitate further dissection and permanent clipping, unfortunately tends to result in unfavorable outcomes, particularly in patients with severe subarachnoid hemorrhage (SAH) [12].

In 1979, Bernd Richling et al conducted a study comparing the effects of four different clip forces and four periods of clipping on the arterial endothelium of rats. They discovered that the duration of clipping had more impact than the clip force itself, while the vessel diameter did not seem to influence the results. Microscopic examination showed alterations in the inner elastic lamina,

implying damage beyond the endothelium. They established a direct relationship between the degree of inner lesion and duration of temporary occlusion. This result was in 1979 using Heifetz clips and long occlusion durations (10-180) mins. [19]. Contrarily, Kuhnel and Muller, through their experimental studies, argued that trauma resulted more from increased occlusion force than extended clipping time [11].

Sivashanmugam and colleagues demonstrated that using ETCs reduced IOR instances and total clipping time, leading to significantly better outcomes. Notably, repeated rescue clipping and total clipping time of at least 20 mins negatively impacted outcomes [7]. Peter Ka-Hung Pang and team endorsed the use of ETCs in IOR prevention [16].

In a study involving 40 consecutive intracranial aneurysm cases, J. Lawrence Pool and team concluded that temporary clip placement on the circle of Willis's segments was a safe approach. These clips did not halt all arterial blood flow, and any bleeding prior to aneurysm rupture could be easily controlled, demonstrating the effectiveness of proximal and distal vessel clipping. However, use beyond 20 minutes led to postoperative issues, including edema and delayed or insufficient recovery [18].

Fady T. Charbel and team showcased the standard strategy for aneurysm clipping surgery. This involves temporary clipping to isolate the proximal and distal vessels to the aneurysm, followed by aneurysm clipping. They highlighted the need to avoid compressing perforating vessels and ensure that vital or collateral channels remain open to maintain local blood flow [5].

According to Akyuz M. and team, temporary clipping could adversely affect cognitive processes and frontal lobe functions. Therefore, preconditioning the brain for temporary vessel occlusion offers a safety layer for ischemia tolerance [1]. Various methods have been developed for this, such as induced hypothermia, adenosine-induced circulation arrest, raising the mean blood pressure, burst suppression with barbiturates, and the use of etomidate and propofol. However, these procedures can also be detrimental [9].

Nitrous oxide uses during aneurysm surgery with TCs, according to a 2009 post hoc analysis, were linked to a higher risk of delayed ischemic neurologic deficits, although long-term neurologic or neuropsychological outcomes didn't show significant harm. This may be due to the TC itself or nitrous oxide, which can augment ischemic insult and increase postexposure vasospasm risk due to elevated homocysteine serum concentrations [17].

Induced hypertension during TC application can encourage collateral perfusion to reach ischemic territories but also makes the aneurysm more prone to rupture. Mild hypothermia (31-34 C) as a protective measure is controversial as it is not thought to significantly impact outcomes and is associated with potential cardiologic and hematologic complications [8,9].

Intraoperative monitoring using parameters like regional brain tissue oxygenation (PBtO2) and electroencephalography has been evaluated [12]. Peter J. Hutchinson et al. discovered that these variables remained stable during straightforward procedures, but adverse events like prolonged temporary clipping led to notable changes in brain metabolism [10]. Silva et al. identified variations in PBtO2 decline following temporary clipping, depending on brain regions, with higher falls noted in temporal lobes [20].

Two circumstances require caution during TC application: when a vessel stented proximal to the aneurysm is present and during endoscopic aneurysm clipping. The first may lead to inappropriate occlusion and thromboembolic stroke due to the stent's irreversible deformation after clipping, particularly for cobalt chromium alloy stents [12]. The second may necessitate alternating between microscope and endoscope but enables optimum orientation of operative anatomy [22].

The safety limit of TC duration should ideally be studied on vessels with minimal collateral circulation, like the M1 segment of MCA [10]. A comprehensive analysis in 2005 involving 1694 aneurysms showed that TCs were more commonly used for ruptured aneurysms compared to unruptured ones and were more likely for internal carotid artery, paraclinoid, and ophthalmic aneurysms. Giant aneurysms with thrombosis or calcifications and irregular fundus shape, especially basilar tip aneurysms, are more likely to be repaired under temporary clipping [20,22].

Conclusion

Temporary occlusion of intracranial arteries during

aneurysm surgery has a long history, starting from the early 20th century with pioneers like Harvey Cushing. Over time, specialized tools and TCs have been developed, enhancing the safety and efficacy of aneurysm treatment. However, despite these advances, the use of TCs remains a topic of debate, particularly concerning potential complications and their impact on long-term patient outcomes.

Abbreviations

ACA; Anterior cerebral artery,
EEG; Electroencephalogram,
ETC; Elective temporary clipping,
IOR; Intra-operative rupture,
PBtO2; Partial pressure of oxygen in brain tissue,
MCA; Middle cerebral artery,
PComA; posterior communicating artery,
TC; Temporary clip.

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