

Wrapping Technique in Fusiform Aneurysms

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Abstract

Although the presentation of cerebral aneurysms is variable, those of fusiform configuration in some cases are not possible to resolve through direct clipping. For this aneurysms, there are many surgical options, such as aneurysm trapping or reinforcement of the aneurysm dome. The evolution of the reinforcement technique has undergone many changes, as its origins lie in the pre-microsurgical era until today having non-biological materials. Clipping the neck of an aneurysm is generally considered the best choice of treatment for a ruptured aneurysm. However, most fusiform aneurysms do not have necks arising from the original vessel like saccular aneurysms, for this reason direct clipping is impossible and wrapping constitutes a microsurgical alternative to prevent rerupture of the aneurysm. The goal of wrapping the aneurysm wall is not only for immediate reinforcement, but also to stabilize the vascular wall and adhere to surrounding tissue and finally secure the aneurysm from rupture. We aim to bring to attention a tried-and-true method for surgical control of uncoilable and unclippable aneurysms such as these, and to describe step-by-step the technique of aneurysm wall reinforcement with wrapping and analyze the publications about the technique and results. In the future, experimental studies will be necessary to demonstrate the histological changes in the aneurysm wall with the use of natural cotton, polytetrafluoroethylene sheet or the combination generated on the arterial wall and the neighboring brain structures.

Keywords: Microsurgery; Fusiform Aneurysms; Vascular Disorders; Unclippable Aneurysms

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Introduction

Cerebral aneurysms may present with a myriad of forms. Usually, they have a small neck connecting the body and dome of the aneurysm to the parent artery. These features allow aneurysms to be safely removed from the circulation, either by clipping the neck, or inserting coils into the lumen. The introduction of endovascular techniques has significantly reduced the proportion of intracranial aneurysms treated by surgical clipping. Vascular neurosurgeons deal now with a higher percentage of complicated, blister, dysplasia, fusiform or giant aneurysms that are not amenable to endovascular coiling nor microsurgical clipping [1].

Some aneurysms are deemed unclippable for some reasons: the parent artery may be atherosclerotic, there may be many perforators which make it unsafe, the vessel wall may be very frail and thin, or the configuration of the aneurysm may be unsuitable. In the obliteration of these deadly sacs, many cases were referred to our endovascular colleagues; as for microsurgical techniques, we can perform clipping. Endovascularly, the embolization of such unclippable aneurysms can be done using flow diverters. A systematic review has found that flow diverters are moderately efficient [2], but not significantly better than clipping or coiling [3].

For unclippable aneurysms, there are many options, such as aneurysm trapping by proximal occlusion of the parent artery, with or without adding a vascular bypass or reinforcement of the aneurysm dome. In many cases, aneurysm wall reinforcement is performed spontaneously and we can find intraoperatively that the aneurysm is impossible to clip.

The evolution of the reinforcement technique has undergone many changes, as its origins lie in the pre-microsurgical era, pioneered by Yaşargil, Kempe, Bederson, and many other early neurosurgeons [4,5]. There were more unfavorable outcomes at the beginning, but with the shift from muscle and fascia towards synthetic wrapping materials, and the use of fibrin glue, complication rates and rebleeding rates have steadily decreased, although not statistically significant [5,6].

There is a variety of wrapping materials used to reinforce aneurysms, they range from muslin gauze [7], natural cotton, plastics, cyanoacrylate, muscle or fascia [4], and polytetrafluoroethylene (Gore-Tex) membrane (W. L. Gore & Associates, Inc.) [8]. The goal of wrapping the aneurysm wall is not only for immediate reinforcement, but also for induction of the inflammatory response, so that the resulting fibrotic scar will further stabilize the vascular wall and adhere to surrounding tissue and finally secure the aneurysm from rupture.



In addition, the human fibrin adhesives used to hold the wrapping material in place may also induce an inflammatory response [9]. The fibrotic reaction remains restricted to a small area around the aneurysm, but occasionally the inflammatory response can expand to adjacent structures. Consequently, depending on the anatomical site of the wrapped aneurysm, various neurological complications can occur. There are some possible excessive foreign body induced inflammatory reactions caused by the wrapping material itself; with the possibility of adhesive arachnoiditis, sterile abscess, optic neuropathy, and parent artery narrowing [7]. MR imaging may show perianeurysmal lobulated enhancing masses, referred in some literature as muslinomas [7,10], this may occur postoperatively or several months after the procedure. The vessel wall of adjacent arteries can be infiltrated likewise and occluded; in angiography imaging, 25-40% of patients show severe stenosis or segmental luminal narrowing of the parent vessel, resulting in cerebral infarction in some [7,10]. Parent artery narrowing has been reported after wrapping procedures with cotton gauze and plastic human fibrin adhesives in single cases or small case series [7,10 and 11]. Yoon MA, et al. (2010) [7], used cotton gauze and human fibrin adhesives and described neuroimaging findings in 5 cases with muslinoma, and found parent artery narrowing in 2, which was associated with an ischemic stroke in 1 of their 5 patients. Beitzke M, et al. (2013) [10], used the same materials and found parent artery narrowing in 5 cases, 4 of them associated ischemic stroke; and 2 granuloma formation. The development of ischemic strokes is likely dependent on the rate of progression of a vascular stenosis of the parent artery and on the rate of collateral perfusion [10]. The time course of the hemodynamic changes may play a crucial role. Intraoperatively, assessment of parent artery flow using Indocyanine green (ICG) is recommended to ensure patency [12].

Objectives

In recent years, the advent of new endovascular techniques and devices have reduced the number of aneurysms treated surgically. Conversely, the difficulty of surgical aneurysm cases has increased, as aneurysms deemed unsuitable for endovascular treatment are referred to neurosurgeons; fusiform aneurysms and blister aneurysms among them. We aim to bring to attention a tried-and-true method for surgical control of uncoilable and unclippable aneurysms such as these, and to describe step-by-step our technique of aneurysm wall reinforcement with wrapping and analyze the publications about the technique and results.

Operative Technique

It is very important to achieve 360° dissection of the aneurysm, parent vessel, and its surroundings. After dissection is complete, we must examine the aneurysm for any weak points, and any perforators arising from the vessel wall (Figure 1).

The wrapping material is then maneuvered around the body of the aneurysm. In same case we use duramater as it is tough and retains tensile strength, although we know that with the passage of months it can suffer necrosis and resorption. We prefer the use of non-biological materials such as Gore-Tex (polytetrafluoroethylene), cotton is also appropriate, as it can elicit a fibrotic response. This technique to give strength to fusiform aneurysms allows us to adapt the natural cotton or the Gore-Tex in the case that there are collateral branches arising from the aneurysm. When we have positioned the wrapping around the aneurysm, we will then use an aneurysm clip to secure the wrap, and also put some tension on the vessel to achieve remodeling. We will then use fibrin glue to hold the position of the wrap (Figure 2).

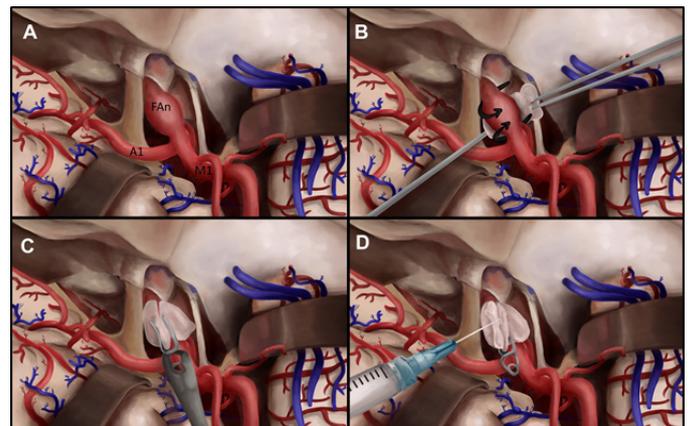


Figure 1: Original drawings of right carotid fusiform aneurysm wrapping with Gore-tex and clipping. A: Right Pterionaltransylvian approach exposing fusiform dilatation of internal carotid artery is performed. B: The dissection in 360° is done in order to separate the aneurysm to the neural structures, a small sheet of Gore-Tex is placed covering the aneurysm. C: The two ends of the Goretex sheet are joined and an angled clip at 90° is placed with the purpose of leaving it fixed covering the dilatation. D: Finally, fibrin glue is placed over the wrapping to help to keep it fixed. Legend: CA: Carotid artery. A1: anterior cerebral artery segment. M1: middle cerebral artery segment. FAn: fusiform aneurysm.

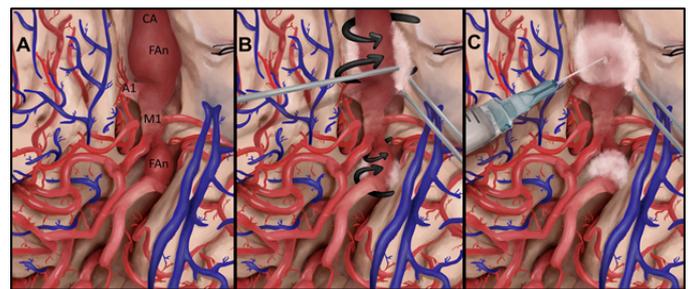


Figure 2: Original drawings of right carotid fusiform aneurysm wrapping with natural cotton. A: Righthtransylvian anterolateral approach, showing a long fusiform aneurysm in the internal carotid artery and right middle cerebral artery. B: The 360-degree dissection is shown on black arrows and complete coverage of the aneurysm with natural cotton. C: Once the cotton wrapping of the two aneurysms is done, fibrin glue is placed to help fix it to the arterial wall. Legend: A1: anterior cerebral artery segment. M1: middle cerebral artery segment. FAn: fusiform aneurysm.

Case Discussion

In our case, the patient presented with severe headache. Imaging studies show an aneurysm of the carotid-ophthalmic artery segment. After discussion, the neurosurgical team elected to have surgery instead of the endovascular option. A left pterional approach was performed. After removing the anterior clinoid process, the optic nerve can be slightly mobilized, and we can visualize the aneurysm. As the vessel wall was very sclerotic, it was decided to wrap the aneurysm. We used duramater for this case, and a right-angled aneurysm clip, with Beriplast® to seal the operation site (Figure 3).

In the second case, the patient presented with severe headache. Imaging studies show an aneurysm of the communicating and choroidal segment of the right carotid artery. A right sidepterional approach was performed. After removing the anterior clinoid process, the optic nerve can be slightly mobilized, and we can visualize the aneurysm. As the vessel wall was very sclerotic, it was decided to wrap the aneurysm. We used Teflon for this case, with Beriplast® to seal the operation site (Figure 4).

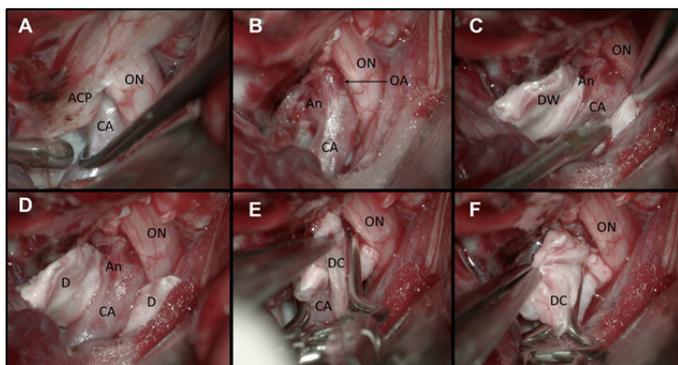


Figure 3: A: Left pterionaltransylvian to expose the carotid cistern. B: Optic foraminotomy and intradural clinoidectomy were performed to expose the clinoid segment of the carotid artery with a fusiform dilatation. C-D: After dissecting the aneurysm in 360°, wrapping with duramater is performed to cover the entire dilatation. E-F: In order to maintain the wrapping, an angled clip is placed on the two edges of the dural sheet. Legend: ON: Optic Nerve. CA: Carotid artery. An: aneurysm. D: Duramater. ACP: anterior clinoid process.

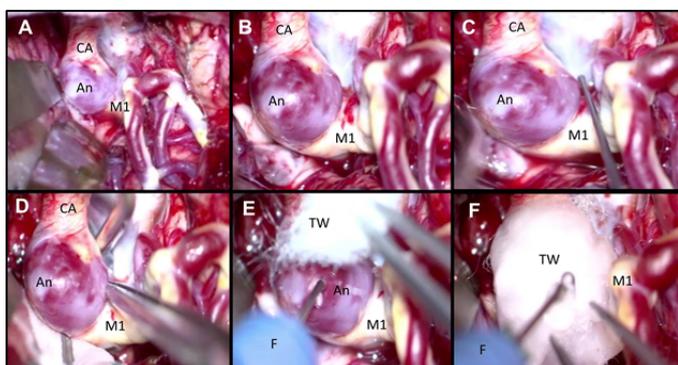


Figure 4: A: Right pterionaltransylvian to expose the carotid and sylvian cistern. A-B: With the extensive dissection of the sylvian fissure it was possible to expose two aneurysms with fusiform characteristics. One of them in the internal carotid artery and another one in the middle cerebral artery in the M2 segment. C-D: Prior to treatment, both aneurysms are dissected from neighboring neural structures in 360°. E-F: Aneurysmal dilatation with Teflon is completely covered and fibrin glue is placed to keep it fixed. Legend: CA: Carotid artery. M1: middle cerebral artery segment. An: aneurysm, F: fibrin glue, TW: Teflon Wrapping.

Discussion

Clipping of the neck of an aneurysm is generally considered the best choice of treatment for a ruptured aneurysm. However, most fusiform aneurysms do not have necks arising from the original vessel like saccular aneurysms, for this reason direct clipping is impossible and wrapping constitute a microsurgical alternative to prevent rerupture of the aneurysm. Fusiform aneurysms cause symptoms by rupture, ischemia or compression of the surrounding neural structures [13]. These aneurysms require different surgical approaches because the neurosurgeon has to achieve 360° dissection and identify small branches arising from the aneurysm wall besides decompressing the brain structures. In such cases, clipping is not safe, and endovascular occlusion cannot be accomplished without sacrificing the parent artery [4]. Preoperative studies must include complete angiography.

The wrapping technique has not been only used in fusiform aneurysms, when an aneurysm is unfavorable for clipping alone or its neck cannot be clipped completely, reinforcement with circumferential wrapping is a well-established neurosurgical procedure [4,14-16] (Table 1).

In 1933, Dott N (1933) performed the first direct treatment of an

intracranial aneurysm, when he wrapped an aneurysm of the middle cerebral artery with autologous muscle, he repeated this operation 3 times between 1931 and 1932. Harvey Cushing had already described using silver clips for aneurysm obliteration as early as 1911 and Walter Dandy had successfully occluded an aneurysm using a clip in 1937 [18]. The wrapping procedure did not become popular until 1954, when Gillingham advocated this technique for all cases of middle cerebral aneurysms and abandoned other methods of treatment. In 1975, he reported a series of 81 cases with an overall mortality of 4%, the 65% of cases returned to fully normal activities [15]. On those cases treated during the last 10 years, the corresponding mortality was nil and 68% returned to full activity. In the early 1960's, Sugar O (1965) used the technique of wrapping with muslin gauze and stated that this may be the procedure of choice for aneurysms that do not lend themselves to clipping or ligation because of a broad base or brittle arteriosclerotic plaques, or because of their location at a division.

Ever since Dott treated his first aneurysm successfully with muscle wrapping, this method has been controversial. Although some authors reported wrapping to be effective [14,16,19,21, and 22], others reported the rerupture of the aneurysm following this procedure [23,24] (Table 1). Mount LA, et al. (1975) [16] reported 58 ruptured aneurysms treated by wrapping with muscle or muslin gauze and/or coating with selvestone plastic material and only one patient, who was treated by wrapping with muscle piece only, suffered from SAH due to rerupture. Stöwsand D, et al. (1975) [22] reported 15 aneurysms treated by coating with EDH adhesive and only one patient treated with incomplete coating suffered from rerupture. Todd NV, et al. (1989) [25] reported that rerupture occurred in 11 of 60 patients treated by wrapping with muslin gauze. They concluded that wrapping offered some protection from rerupture particularly during the first 6 months, but the late re-bleeding rate following wrapping was unacceptably higher than the natural history itself. Taylor JC, et al. (1977) [14] suggested that wrapping of ruptured middle cerebral artery aneurysms was a safe and effective method of prevention of re-bleeding. Sato K, et al. (1990) [26] in his large series, concluded that wrapping as an adjuvant, offered substantial protection for incompletely clipped aneurysms with neck remnants [26]. Cudlip SA, et al. (1998) [27] concluded that wrapping using microsurgical techniques were more efficacious in preventing re-bleeding compared with the pre-microscope era.

In the initial years, muscle was the most common wrap used. By the 1970s, several studies of re-bleeding following muscle wrapping were published [24,28]. Wraps of autologous tissues like muscle, dura or fascia tended to become necrotic, and then absorbed within 2 months [29]. In histological as well as clinical studies, cotton has been found to be the most effective reinforcement material [24,29, and 30]. Cotton-evoked chronic inflammation, fibrosis, and granuloma formation of the adventitia may even be desired in select cases, such as in the treatment of fusiform aneurysmal dilatations and aneurysm segments that cannot be completely clipped [8].

Many studies have assessed the efficacy and long-term follow up of the wrapping technique. However, the majority of publications described the results of muscle-wrapping in the pre-microsurgical era, and little is known about the results of muscle-wrapped aneurysms in the modern microsurgical era. Moreover, in some reports, surgery has been performed in both pre- and post-microsurgical era, without a clear separation of the specific results [1]. Fujiwara S, et al. (1990) [6] concluded that aneurysm wrapping alone of ruptured aneurysms is insufficient and not a safe alternative, as rebleed rates were quite high (17%). More recently, Safavi-Abbasi S, et al. (2016) [8] described the



Table 1: MW=muscle wrapping, MGW=muslin gauze wrapping, Clip. M=clipping muscle, WPVC-EP=wrapping with PVC+EP resine, EMM=encasement in methyl methacrylate, SC=silverstone coating, CB=coating Biobond, PC=partial coating, PR=partial reinforcement, VW=vasospasm wrapped, Clip.MW=clipping+muslin wrapping, OA=optochiasmatic arachnoiditis, GSW=gauze sponge wrapping, Clip.W=clipping and wrapping, Vs=Vasospasm, M=meningitis, MGS=muscle gelatin sponge, OCB=oxydizedcellulose+Biobond, H=histoacryl, WC=wrapping cotton, WCG=Wrapping clipping with PTFE strips (Goretex), Mus=Muslinoma, Ara=arachnoiditis, AN=artery narrowing, G=Granuloma, WCC=wrapping clipping cotton.

Authors & Year	N° Aneurysms	Aneurysm treatment	Rebleeding	Growth	Other Complications
Dutton J (1959) [21]	17	Wrapping with acrylic	No	No	No
Selverstone B (1962) [36]	13	Coating with plastics	No	No	No
Drake CG, et al.(1967) [28]	23	6/MW, 3/ MGW, 14/CM	3/MW	4	No
Stepien L(1968) [37]	35	WPVC-EP	No	No	Meningeal
Hammon W (1968) [38]	102	EMM	2	No	No
Mount LA, et al.(1975) [16]	72	8/MW, 28/MGW, 20/SC	1/MW	1/MW	2 meningitis
Stöwsand D, et al.(1975) [22]	15	Coating biobond	1	No	NO
Gillingham FJ(1975) [15]	81				
Taylor JC, et al. (1977) [14]	35	Gauze wrapping	1	NA	No
Mimakawa T, et al.(1987) [23]	467	9/CB, 13/PC, & /PR	6	2	No
Todd NV, et al.(1989) [25]	181	60/wrapping	11	NA	32% VW
Fujiwara S, et al.(1990) [6]	29	Muscle or gauze	5	No	No
Sato K, et al.(1990) [26]	1903	52/MW	2	No	No
McFadzean RM, et al.(1991) [39]	9	5/Clip. M, 3/MW	No	No	5/OA
Morioka M, et al.(1991) [40]	349	24/GSW, 52/Clip.W	3/Clip.W	No	17/Vs, 4/M
Bederson JB, et al.(1992) [4]	4	Clip-cotton	No	No	No
Cossu M, et al.(1993) [5]	47	7/MGS, 28/OCB, 10/H	8	----	No
Fujitsu K, et al. (1994) [41]	5	Wrap-clipping Dacron	No	No	No
Anson JA, et al.(1996) [13]	3	Muslin/cotton	No	No	No
Drake CG, et al.(1997) [42]	120	5/Wrapping cotton	1	1	1 infarction
Cudlip SA, et al.(1998) [27]	15	15/Muslin Wrap.	No	No	1 infection
David CA, et al.(1999) [31]	160	147/clipping, 8/WC	1	No	No
Nakano S, et al. (2000) [43]	7	7/Clip.W	No	No	No
Ohkuma H, et al.(2002) [44]	18	7/wrapping	2	1	1 Infarction
Choudhari KA, et al.(2004) [45]	225	3/wrapping	3		
Deshmukh VR, et al.(2006) [46]	74	7/Clip.W, 61/WC	1	No	2 infection
Kubo Y, et al.(2006) [47]	6	6/WCG	No	No	1 remnant
Yoon MA, et al. (2010) [7]	147	54/Clipping-wrapping	No	No	5/Mus. 5/Ara
Germanò A, et al.(2013) [1]	8	8/MW	1	No	No
Beitzke M, et al. (2013) [10]	567	11/WC, 10/CW	No	No	5/AN, 2/G
Perrini P, et al.(2015) [48]	290	15/WC	1		2/AN, 1/G
Safavi-Abbasi S, et al.(2016) [8]	60	23/WCC, 37/WC	1	2	No
Safavi-Abbasi S, et al. (2017) [49]	48	18/WCG		2	1 Stroke

long-term outcomes of fusiform aneurysm wall reinforcement. The annual rebleeding risk of cotton-augmented, incompletely clipped aneurysms was 1.03% in this study, which is lower than the previously reported 0.93%, 1.5-17% [5,8 and 31]. A variant of this maneuver is the cotton-clipping technique, used in the management of intraoperative rupture of aneurysm neck, in which a piece of cotton is placed on the aneurysm rupture site, and the aneurysm is clipped over the cotton [12,32].

There is a real and urgent need for a surgical model which could mimic the actual aneurysm microsurgery conditions. Animal models such as rats and rabbits have been used to simulate such cases [33]. Avery MB, et al. (2018) [34] described a method of creating fusiform aneurysm model in rabbits, artificially inducing arterial dilation using elastase and CaCl₂. This method can create fusiform aneurysm models with mean vessel dilation of 88%. De De Oliveira MMR, et al. (2018) [35] has also discussed the possibility of using a human placenta model as a training platform for aneurysm clipping microsurgery.

We agree with some authors that natural cotton could generate an inflammatory reaction in the vascular wall and the use of Gore-Tex provides direct mechanical resistance. This inflammatory response generated by the cotton reported in some analyzes, may be

eliminated or diminished by covering the cotton on the outside with a polytetrafluoroethylene sheet.

Conclusions

We believe that this is a useful technique for those uncoilable and unclippable aneurysms, which have a fusiform configuration. For aneurysms that have a neck, the dissection technique is simpler, needing to dissect it proximally and distally prior to placing the clip. Different is the situation to perform the wrapping of fusiform aneurysms where the 360° dissection and the separation of neural structures is a fundamental step. In our opinion, natural cotton may generate an inflammatory reaction in the vascular wall and the use of Gore-Tex provides direct mechanical resistance. This inflammatory response generated by the cotton may be eliminated or diminished by covering the cotton on the outside with a polytetrafluoroethylene sheet. In the future, experimental studies will be necessary to demonstrate the histological changes that the use of natural cotton, Gore-Tex or the combination generates on the arterial wall and the neighboring structures.

Conflict of Interest

None.



Disclosure of Funding

None.

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

Abbreviations

MW: muscle wrapping

MGW: muslin gauze wrapping

Clip. M: clipping muscle

WPVC-EP: wrapping with PVC+EP resine

EMM: encasement in methyl methacrylate

SC: selverstone coating

CB: coating Biobond

PC: parcial coating

PR: parcial reinforcement

VW: vasospasm wrapped

Clip. MW: clipping and muslime wrapping

OA: optochiasmatic arachnoiditis

GSW: gauze sponge wrapping

Clip.W: clipping and wrapping

Vs: Vasospasm

M: meningitis

MGS: muscle gelatin sponge

OCB: oxydized cellulose+Biobond

H: histoacryl

WC: wrapping cotton

WCG: Wrapping clipping with Goretex

Mus: Muslinoma

Ara: arachnoiditis

AN: artery narrowing

G: Granuloma

WCC: wrapping clipping cotton.

References

- Germanó A, Priola S, Angileri FF, Conti A, La Torre D, et al. (2013) Long-term follow-up of ruptured intracranial aneurysms treated by microsurgical wrapping with autologous muscle. *Neurosurg Rev* 36:123-132.<https://doi.org/10.1007/s10143-012-0408-z>
- Kisser A, Kirisits A (2015) Endovascular embolization of unruptured intracranial aneurysms with flow diverters. Ludwig Boltzmann Institute for Health Technology Assessment, Austria.
- Barletta EA, Ricci RL, Silva RDG, Gaspar RHML, Araújo JFM, et al. (2018) Fusiform aneurysms: A review from its pathogenesis to treatment options. *Surg Neurol Int* 9: 189. https://dx.doi.org/10.4103/sni.sni_133_18
- Bederson JB, Zabramski JM, Spetzler RF (1992) Treatment of fusiform intracranial aneurysms by circumferential wrapping with clip reinforcement. *J Neurosurg* 77:478-480.<https://doi.org/10.3171/jns.1992.77.3.0478>
- Cossu M, Pau A, Turtas S, Viola C, Viale G (1993) Subsequent bleeding from ruptured intracranial aneurysms treated by wrapping or coating: a review of the long-term results in 47 cases. *Neurosurgery* 32:344-346.<https://doi.org/10.1227/00006123-199303000-00002>
- Fujiwara S, Fujii K, Nishio S, Fukui M (1990) Long term results of wrapping of intracranial ruptured aneurysms. *Acta Neurochir* 103:27-29.<https://doi.org/10.1007/BF01420188>
- Yoon MA, Kim E, Kwon B-J, Kim JE, Kang H-S, et al. (2010) Muslinoma and muslin-induced foreign body inflammatory reactions after surgical clipping and wrapping for intracranial aneurysms: imaging findings and clinical features. *J Neurosurg* 112:640-647.<https://doi.org/10.3171/2009.7.JNS081625>
- Safavi-Abbasi S, Moron F, Sun H, Oppenlander ME, Kalani MYS, et al. (2016) Techniques and long-term outcomes of cotton-clipping and cotton-augmentation strategies for management of cerebral aneurysms. *J Neurosurg* 125:1-10.<https://doi.org/10.3171/2015.7.JNS151165>
- Yasuda H, Kuroda S, Nanba R, Ishikawa T, Shinya N, et al. (2005) A novel coating biomaterial for intracranial aneurysms: Effects and safety in extra- and intracranial carotid artery. *Neuropathology* 25: 66-76.<https://doi.org/10.1111/j.1440-1789.2004.00590.x>
- Beitzke M, Leber KA, Deutschmann H, Gattringer T, Poltrum B, et al. (2013) Cerebrovascular complications and granuloma formation after wrapping or coating of intracranial aneurysms with cotton gauze and human fibrin adhesives: Results from a single-center patient series over a 5-year period. *J Neurosurg* 119:1009-1014.<https://doi.org/10.3171/2013.6.JNS1373>
- Kawamura S, Hadeishi H, Suzuki A, Yasui N (1998) Arterial occlusive lesions following wrapping and coating of unruptured aneurysms. *Neurol Med Chir* 38:12-19. <https://doi.org/10.2176/nmc.38.12>
- Barrow DL, Spetzler RF (2011) Cotton-clipping technique to repair intraoperative aneurysm neck tear: a technical note. *Oper Neurosurg* 68:6.<https://doi.org/10.1227/NEU.0b013e31821343c6>
- Anson JA, Lawton MT, Spetzler RF (1996) Characteristics and surgical treatment of dolichoectatic and fusiform aneurysms. *J Neurosurg* 84:185-193.<https://doi.org/10.3171/jns.1996.84.2.0185>
- Taylor JC, Choudhury AR (1977) Reinforcement with gauze wrapping for ruptured aneurysms of the middle cerebral artery. *J Neurosurg* 47:828-832.<https://doi.org/10.3171/jns.1977.47.6.0828>
- Gillingham FJ (1975) Ruptured intracranial aneurysms-what now?. XVth Latin-American Neurosurgical Congress, Caracas, Venezuela.
- Mount LA, Antunes JL (1975) Results of treatment of intracranial aneurysms by wrapping and coating. *J Neurosurg* 42:189-193.<https://doi.org/10.3171/jns.1975.42.2.0189>
- Dott N (1933) Intracranial aneurysms: cerebral arterio-radiography: Surgical treatment. *Edinb Med J* 40: T219-T240.
- Dandy WE (1938) Intracranial aneurysm of the internal carotid artery. Cured by operation. *Ann Surg* 107:654-659.<https://dx.doi.org/10.1097/0000658-193805000-00003>
- Gillingham FJ (1958) The management of ruptured intracranial aneurysm. Hunterian Lecture. *Ann R Coll Surg Eng* 23:89-117.
- Sugar O (1965) Aneurysms and arteriovenous anomalies of the brain: Diagnosis and treatment. *JAMA* 193: 1065-1066.<https://doi.org/10.1001/jama.1965.03090120073035>
- Dutton J (1959) Acrylic investment of intracranial aneurysms. *Br Med J* 2: 597-602. <https://dx.doi.org/10.1136/bmj.2.5152.597>
- Stöwsand D, Buhl K (1975) Early and late results after coating intracranial aneurysms with biobond. *Acta Neurochir* 32:73-82.<https://doi.org/10.1007/bf01405904>
- Minakawa T, Koike T, Fujii Y, Ishii R, Tanaka R, et al. (1987) Long-term results of ruptured aneurysms treated by coating. *Neurosurg* 21:660-663.<https://doi.org/10.1227/00006123-198711000-00010>
- Sacks E (1972) The fate of muscle and cotton wrapped about intracranial carotid arteries and aneurysms. *Acta Neurochir* 26:121-137.
- Todd NV, Tocher JL, Jones PA, Miller JD (1989) Outcome following aneurysm wrapping: a 10-year follow up review of clipped and wrapped aneurysms. *J Neurosurg* 70:841-846.<https://doi.org/10.3171/jns.1989.70.6.0841>
- Sato K, Fujiwara S, Kameyama M, Ogawa A, Yoshimoto T, et al. (1990) Follow-up



- study on ruptured aneurysms treated by wrapping. *Neurol Med Chir* 30:734-737.<https://doi.org/10.2176/nmc.30.734>
27. Cudlip SA, Kitchen ND, McKhahn GM, Bell BA (1998) Wrapping of solitary ruptured intracranial aneurysms, outcome at five years. *Acta Neurochir* 140:1167-1171.<https://doi.org/10.1007/s007010050232>
 28. Drake CG, Vanderlinden RG (1967) The late consequences of incomplete surgical treatment of cerebral aneurysms. *J Neurosurg* 27:226-238.<https://doi.org/10.3171/jns.1967.27.3.0226>
 29. Ebina K, Iwabuchi T, Suzuki S (1984) A clinico-experimental study on various wrapping materials of cerebral aneurysms. *Acta Neurochir* 72:61-71.<https://doi.org/10.1007/BF01406814>
 30. Herrera O, Kawamura S, Yasui N, Yoshida Y (1999) Histological changes in the rat common carotid artery induced by aneurysmal wrapping and coating materials. *Neurol Med Chir* 39:134-140.<https://doi.org/10.2176/nmc.39.134>
 31. David CA, Vishteh AG, Spetzler RF, Lemole M, Lawton MT, et al. (1999) Late angiographic follow-up review of surgically treated aneurysms. *J Neurosurg* 91: 396-401.<https://doi.org/10.3171/jns.1999.91.3.0396>
 32. Safavi-Abbasi S, Sun H, Oppenlander ME, Nakaji P, Kalani MYS, et al. (2015) Repair of intraoperative aneurysm neck tear utilizing the cotton-clipping technique. *J Neurosurg* 38: Video14.<https://doi.org/10.3171/2015.V1.FOCUS14556>
 33. Yokoi T, Isono T, Saitoh M, Yoshimura Y, Nozaki K (2014) Suppression of cerebral aneurysm formation in rats by a tumor necrosis factor- α inhibitor. *J Neurosurg* 120: 1193-1200.<https://doi.org/10.3171/2014.1.JNS13818>
 34. Avery MB, Alaqeel A, Bromley AB, Chen Y-X, Wong JH, et al. (2018) A refined experimental model of fusiform aneurysms in a rabbit carotid artery. *J Neurosurg* 131: 88-95.<https://doi.org/10.3171/2018.2.JNS173168>
 35. De Oliveira MMR, Ferrarez CE, Ramos TM, Malheiros JA, Nicolato A, et al. (2018) Learning brain aneurysm microsurgical skills in a human placenta model: predictive validity. *J Neurosurg* 128:846-852.<https://doi.org/10.3171/2016.10.JNS162083>
 36. Selverstone B (1962) Aneurysms at middle cerebral "trifurcation" treatment with adherent plastics. *J Neurosurg* 19:884-888.<https://doi.org/10.3171/jns.1962.19.10.0884>
 37. Stepien L (1968) Reinforcement of intracranial aneurysms with adherent plastics: Selverstone Method. *Prog Brain Res* 30: 361-365.[https://doi.org/10.1016/S0079-6123\(08\)61483-1](https://doi.org/10.1016/S0079-6123(08)61483-1)
 38. Hammon W (1968) Intracranial aneurysm encasement. *J Neurol Neurosurg Psychiatry* 31:524-527.<https://dx.doi.org/10.1136/jnnp.31.5.524>
 39. Mc Fadzean RM, Hadley DM, Mcllwaine GG (1991) Optochiasmal arachnoiditis following muslin wrapping of ruptured anterior communicating artery aneurysms. *J Neurosurg* 75: 393-396.<https://doi.org/10.3171/jns.1991.75.3.0393>
 40. Morioka M, Marubayashi T, Masumitsu T, Hori T, Ushio Y (1991) Wrapping of intracranial aneurysms with gauze sponge. *Neurol Med Chir* 31:135-140.<https://doi.org/10.2176/nmc.31.135>
 41. Fujitsu K, Ishiwata Y, Gondo G, Fujii S, Feng DD (1994) Wrap-clipping with a Dacron mesh silastic sheet. Technical note. *J Neurosurg* 80:336-337.<https://doi.org/10.3171/jns.1994.80.2.0336>
 42. Drake CG, Peerless SJ (1997) Giant fusiform intracranial aneurysms: a review of 120 patients treated surgically from 1965 to 1992. *J Neurosurg* 87:141-162.<https://doi.org/10.3171/jns.1997.87.2.0141>
 43. Nakano S, Iseda T, Yoneyama T, Ikeda T, Goya T, et al. (2000) A combination of wrapping and clipping using a collagen-impregnated Dacron fabric (Hemashield). *Surg Neurol* 53:330-333.[https://doi.org/10.1016/S0090-3019\(00\)00177-4](https://doi.org/10.1016/S0090-3019(00)00177-4)
 44. Ohkuma H, Nakano T, Manabe H, Suzuki S (2002) Subarachnoid hemorrhage caused by a dissecting aneurysm of the internal carotid artery. *J Neurosurg* 97:576-583.<https://doi.org/10.3171/jns.2002.97.3.0576>
 45. Choudhari KA (2004) Wrapping and coating of cerebral aneurysms: history, evolution and surgical management after re-bleed. *Br J Neurosurg* 18:259-267.<https://doi.org/10.1080/026886690410001732706>
 46. Deshmukh VR, Kakarla UK, Figueiredo EG, Zabramski JM, Spetzler RF (2006) Long-term clinical and angiographic follow-up of unclippable wrapped intracranial aneurysms. *Neurosurgery* 58: 434-442.<https://doi.org/10.1227/01.NEU.0000199158.02619.99>
 47. Kubo Y, Ogasawara K, Tomitsuka N, Otawara Y, Watanabe M, et al. (2006) Wrap-clipping with polytetrafluoroethylene for ruptured blisterlike aneurysms of the internal carotid artery. *J Neurosurg* 105:785-787.<https://doi.org/10.3171/jns.2006.105.5.785>
 48. Perrini P, Montemurro N, Caniglia M, Lazzarotti G, Benedetto N (2015) Wrapping of intracranial aneurysms: single-center series and systematic review of the literature. *Br J Neurosurg* 29: 1-7.<https://doi.org/10.3109/02688697.2015.1071320>
 49. Safavi-Abbasi S, Kalani MY, Frock B, Sun H, Yagmurlu K, et al. (2017) Techniques and outcomes of microsurgical management of ruptured and unruptured fusiform cerebral aneurysms. *J Neurosurg* 127:1353-1360.<https://doi.org/10.3171/2016.9.JNS161165>