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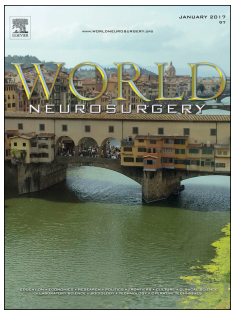

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PII: S1878-8750(17)31201-9

DOI: 10.1016/j.wneu.2017.07.101

Reference: WNEU 6163

To appear in: *World Neurosurgery*

Received Date: 21 April 2017

Revised Date: 16 July 2017

Accepted Date: 17 July 2017

Please cite this article as: Marco C, Flavia D, Eleonora M, Alberto D, Alba S, Maurizio P, Use of Laser in AVM surgery, *World Neurosurgery* (2017), doi: 10.1016/j.wneu.2017.07.101.

Use of Laser in AVM surgery

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Keywords: Arteriovenous malformations; Deep arterial feeders; Laser; Nidus; Small feeders

Abstract

Background

AVM surgery is particularly demanding as for the bleeding control of small deep white matter vessels during and after the removal of the nidus, this representing probably one of the most critical moments of AVMs surgery.

Objective of the present manuscript is to describe a useful technique based on the use of tweezers to temporarily stop the blood flow followed by coagulation with thulium laser.

Methods

Twenty patients with unruptured cerebral AVMs underwent surgical treatment. In each case the superficial feeders were easily coagulated with non-stick bipolar, whereas the finer and deeper feeders were coagulated with this specific technique.

Results

All patients were treated successfully and we achieved an optimal intra-operative hemostasis.

Conclusions

Our results seem to be good and no post-operative complications occurred. This could encourage a more standardized use of the described technique.

Introduction

Surgery for Arteriovenous Malformations (AVMs) is extremely dependent, more than any other surgical fields, on the technical innovation of surgical instruments and devices. AVM surgery is particularly demanding as for the bleeding control of small deep white matter vessels during and after the removal of the nidus, this representing probably one of the most critical moment of AVMs surgery. The disproportion between the thin vessel wall and the relatively large vessel diameter associated with a relevant flow, requires patience and special care in coagulating these small deep white matter feeders. Simple coagulation is difficult and often the surgeon has to follow them in the white matter for several millimeters trying to control the bleeding. Entering in the white matter is a significant cause of postoperative unwanted neurological deficits.

Therefore, in the present work, we discuss our experience with the main bleeding control techniques used in AVM surgery and propose an effective method based on the temporary occlusion of the vessel using tweezers followed by its coagulation with thulium laser (Figure 1A, 1B).

Material and methods

Out of 57 AVMs operated in the last two years at our institution (from January 2015 to December 2016), twenty-five non-consecutive patients underwent surgery using the laser technique. No specific inclusion criteria were applied. Sixteen out of twenty-five were not ruptured AVMs. Patients were 11 males and 14 females; age ranged from 7 to 65.

A large craniotomy was regularly performed in order to widely expose the draining veins along with all the feeders. The latter vessels were followed and dissected using jewelers' tweezers. The most superficial feeders were easily coagulated with non-stick bipolar in a dry field, while the finer and deeper feeders were frequently more difficult to coagulate because of their fragile walls and high blood flow.

Aiming to overcome this limitation, we adopted the following 3-step technique (Figure 2; Video 1):

1) Blunt isolation of the small vessel from the white matter
2) Temporary occlusion of the vessel using tweezers to stop the flow
3) Coagulation of the vessel using the thulium laser without touching it

Blunt isolation avoided white matter damages and postoperative neurological deficits.

Temporary occlusion of the vessel allowed the blood flow to stop for few seconds and permitted the coagulation of blood proteins in the vessel, together with those of the vessel wall.

The laser didn't need to touch the thin and fragile vessel wall, permitting a rapid coagulation, and reducing the risk of rupture and subsequent bleeding. We used the thulium laser from LISA Laser USA, model Revolix Jr 15 Watt (Figure 1B). Average watts ranged between 0.5 to 2.

Thulium laser was also useful to achieve a shrinkage of the malformation, once the major arterial feeders have been isolated and coagulated. Large and dilated veins could be shrunk with efficacy keeping the laser tip distant from the wall (Video 2).

The described technique was integrated with the normal use of non-stick bipolar, at low voltage in a dry field, to control larger vessels.

An immediately post-operative angiography (AGF) was then performed. If there was no residual AVM, the patient was taken to the intensive care for a protected awaking. A clinical and angiographic 6-month follow-up was routinely performed.

Results

Twenty-five patients were successfully treated with the combined use of non-stick bipolar and thulium laser with tweezers. Two patients had a small AVM residual documented in the post-operative AGF and required an immediate second surgical procedure to complete the removal. No intra-operative nor post-operative complications were reported. At the 6-month follow-up the clinical outcome was comparable between the two populations (with and without the use of laser).

Discussion

The surgery of AVMs is complex, still very discussed, and not easy to resolve. The general principles about AVM surgery as pre-operative selective embolization when required and estimated useful, large craniotomy, dural opening under microscope, and circumferential dissection of the nidus are commonly established.

Contrarily, the bleeding control of small deep white matter vessels may be challenging and requires further discussion.

Bipolar coagulation

Spetzler's bipolar forceps technique consists of intermittent coagulation for 1–2 seconds under constant irrigation while avoiding complete closure of the forceps to prevent adherence of the cauterized vessel to the bipolar tips. Furthermore, he continuously maintains cleanliness of the bipolar tips, which prevents sticking.[1,2]

Hashimoto first described non-stick bipolar forceps used at low electrical current which reduces the risk of wall rupture of these tiny vessels.[3] Use of non-stick bipolar forceps in a dry field, rather than with irrigation as with traditional forceps, requires a lower intensity, but it permits a coagulation that is more effective and constant, being not influenced by an excessive (where the coagulation is not effective) nor insufficient irrigation (where the bipolar sticks to the tissue).

Hernesniemi uses Malis bipolar forceps kept clean and cold to prevent scarring and sticking with a setting of 20-25. He proposes to take a small amount of white matter between the tips of bipolar forceps and coagulate it together with the small vessels. He called this technique "dirty coagulation".[4] Forceps used are blunt and large in relation to the vessels. However, using the dirty coagulation technique, the surgeon has to coagulate part of the surrounding white matter.

Small white matter vessels clipping

Coagulation and sectioning of the small fragile subependymal or perforating feeding arteries in the deep white matter can be very challenging. Once injured, these deep vessels have a tendency to retract, and occasionally bipolar coagulation is hardly effective. Following these vessels deeply in the white matter can be one of the main causes of postoperative neurological damage.

Although preoperative embolization could be very helpful, small thin-walled vessels cannot be occluded. The hemostasis of these feeders, especially in the deep white matter is the most difficult part of this surgery.

Spetzler described the placement of Sundt microclips, specifically designed for this purpose, in order to control the bleedings of these fine vessels.[2]

Sometimes when the hemostasis is difficult, because of the small vessels' high pressure, finding their parent arteries and applying temporary clips, reduces the flow and helps hemostasis.[3]

A new useful prospective: the use of Laser

The described technique is based on blunt dissection of the vessel, temporarily stopping the flow inside it using jewelers' forceps, and cauterizing it by laser. These small vessels can be coagulated effectively, not having to follow them in the white matter, saving surgical time, and reducing damage of the surrounding parenchyma.

The use of laser in AVMs surgery has been reported since the 1908s.[5] It ensures reduced bleeding and easier microsurgical dissection.[6-8] In our institution, we adopted the thulium laser.

Advantages of the thulium laser over the diode and CO2 laser:

- due to a wavelength of 2 µm, it has a quick superficial increase of temperature (2) with minimal penetration within cerebral parenchyma;
- it works in wet ambient allowing, in addiction, the dispersion of the heat preventing tissue damage;
- it uses a thin and reusable optic fibers, with a limited cost (less than 100 $ is the cost

difference per case).

Diode Laser has a 0.805 µm wavelength, thus it is not absorbed by water but highly absorbed by pigments such as hemoglobin and melanin. Depending on the local concentration of hemoglobin it can penetrate deeply in poorly pigmented tissues being potentially dangerous in a neurosurgical field.[5]

CO2 laser requires a very expensive single use dedicated fiber. It has a high absorption in water and therefore is not effective in most of the neurosurgical wet fields.

Indications

The main indication for the use of laser in brain AVMs surgery is concerned with the bleeding control of small deep white matter vessels during and after the removal of the nidus. Temporary interruption of the blood flow with tweezers allows a more effective and time saving coagulation using thulium laser. Once the AVM has been resected, the thulium laser can be also used to obtain a diffuse coagulation, to control small oozing, on the surface of the dissected field.

A secondary application of the laser is the shrinkage of large venous vessels for a better mobilization of the nidus after maximal deafferentation, which consequently become smaller, more compact, and easy to manipulate. Also, this maneuver allows the visualization of eventual hidden proximal large feeders.

Limitations

The effectiveness of this technique in our experience is limited to small vessels (1-2 mm in diameter), but most of the deep, and difficult to deal with, feeders vessels are of this size.

The coagulation of the thulium laser gets to the surface of the white matter; therefore, a more extensive bleeding cannot be controlled just by its use.

Conclusion

Small deep feeder in the white matter have a disproportion between the diameter of the vessel and the thickness of the wall. The coagulation of the proteins of the wall are therefore often not sufficient to occlude the vessel. For this reason, the Hernesniemi's "dirty coagulation" that also takes the white matter proteins is more effective.

We propose the here described technique, based on a temporarily interruption of the blood flow using tweezers, and coagulation with thulium laser. We found this technique to be a more effective, less costing, and time saving method to control the bleeding of the small deep white matter vessels feeders of AVMs. Our results encourage a more diffuse use of this technique, in adjunction to the already consolidated ones.

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Figures and Video

Figure 1.

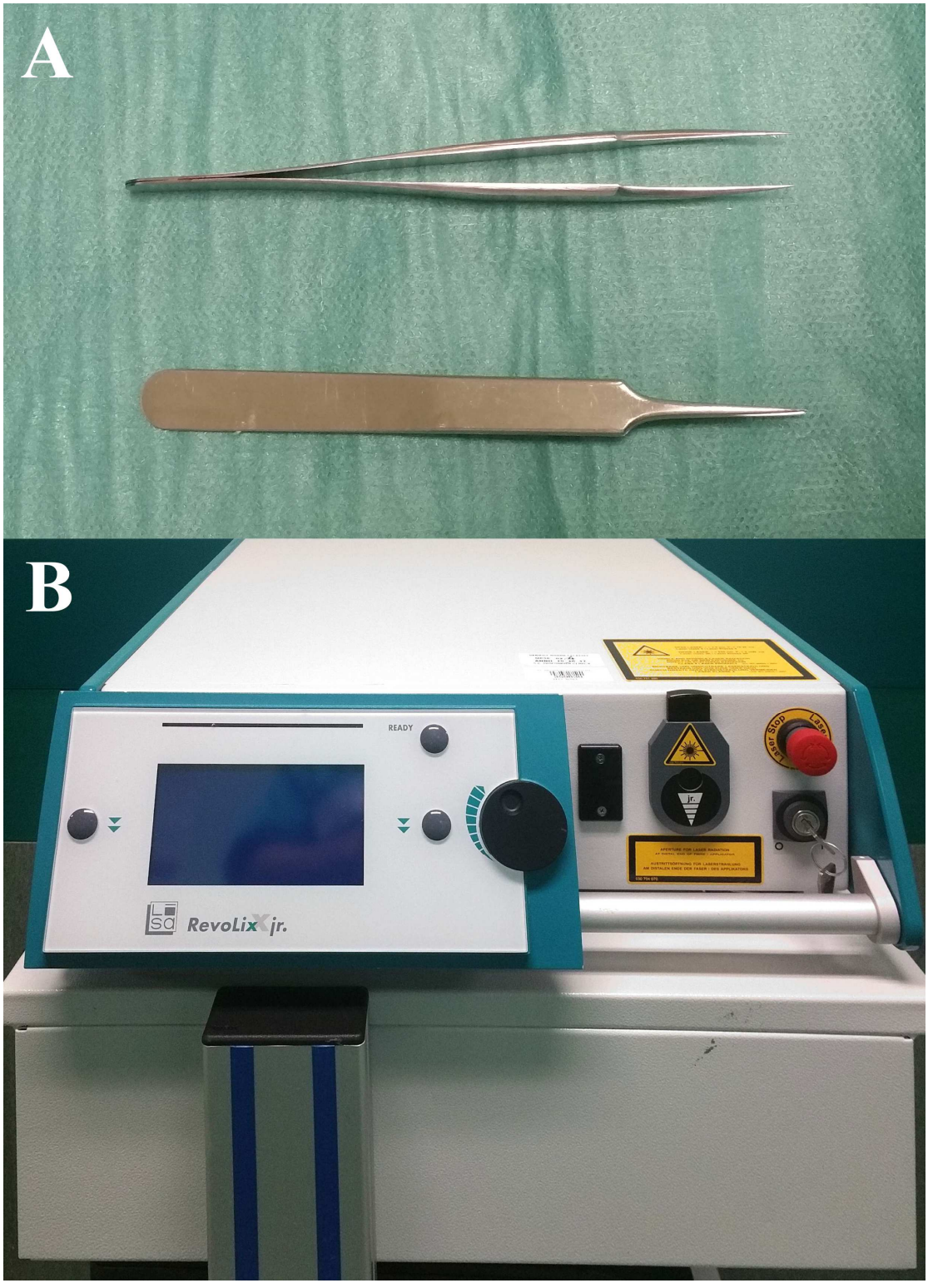
A. Jewelers' tweezers. Under microscope, they are used to dissect the arachnoid into the sulci, to isolate the vessels of the AVM, and to keep the small white matter vessels closed in order to stop the flow and coagulate them.

B. Thullium Laser. In order to obtain coagulation of the small and deep white matter vessels the fiber with frontal laser emission is used. It has 2-micron wavelength and continuous emission. It doesn't penetrate deep tissue and it works in wet field with high absorption.

Figure 2. Sequence of the exposition of a small deep feeder in the white matter (1-2), interruption of the blood flow with tweezers (3), subsequent coagulation with Laser (4-8) and cutting of the vessel (9).

Video 1: Sequence of the exposition of a small deep feeder in the white matter, interruption of the blood flow with tweezers, and subsequent coagulation with laser as shown in Figure 2.

Video 2: Shrinkage of the malformation, once the major arterial feeders have been isolated and coagulated, keeping the laser tip distant from the wall.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Highlights

- AVM surgery is particularly demanding as for the bleeding control of small deep white matter vessels during and after the removal of the nidus
- The finer and deeper feeders were frequently more difficult to coagulate with bipolar because of their fragile walls and high blood flow
- Temporary occlusion of the vessel using tweezers followed by its coagulation with thulium laser is an effective method
- Thulium laser is also useful to achieve a shrinkage of the malformation, once the major arterial feeders have been isolated and coagulated.
- Thulium laser is a safe, effective, and time saving procedure to be considered in AVM surgery

Abbreviations:

AVMs: Arteriovenous Malformations

AGF: Angiography