Rapid M1 Hemoclips Arteriotomy Repair After Emergency Coil Embolectomy

BACKGROUND: The vascular closure staple clips have been studied in animal models and shown to have comparable results with sutured repair when it comes to the healing process, degree of vessel narrowing, and risk of thrombosis. However, they are clearly superior when the speed of application is taken into account, and they were clinically used in many vascular repair processes. Nevertheless, their usefulness in intracranial vascular surgery has not been described.

OBJECTIVE: To describe the usefulness of hemoclips in fast and efficient repair of medium-sized and large intracranial vessels.

METHODS: Two female patients diagnosed with giant symptomatic cavernous sinus aneurysms were undergoing elective endovascular procedures that were complicated by the dislodgement of coils into the M1 segment of the middle cerebral artery. Both patients were treated performing M1 arteriotomies and coil embolectomy. To avoid prolonged temporary occlusion in the M1 perforator’s territory, the arteriotomies were repaired using microhemoclips in less than 10 min with re-establishment of flow.

RESULTS: In both patients, flow was re-established in the M1 segments. In 1 patient, the coils extended to the temporal M2 causing intimal injury and leading to diminished flow. M1 segments in both patients were patent on later angiographic studies.

CONCLUSION: We describe the advantage of emergent cerebrovascular arteriotomy and embolectomy in a rapid repair process that helped avoid massive ischemic injury. We believe this technique should be added to the armamentarium of neurosurgical cerebrovascular options.

KEY WORDS: Primary vessel repair, Arteriotomy closure, Coil dislodgment, Microvascular anastomosis

Cerebral vessel closure using suture material has been widely accepted as the conventional method of primary vessel repair amongst many neurosurgeons. While the aforementioned method is a reliable method of repair demonstrating formidable results of well-preserved vessel patency, integrity, histology, and physiologic function, it is not necessarily the best method of repair, and may not be the most suitable technique for intracranial vessel repair in instances where quick closure with short procedural and clamp times are of the essence to help mitigate the risk of cerebral ischemia. The application of vascular closure staple (VCS) clips made of titanium, originally developed for microvascular anastomoses, is a great alternative method for primary vessel repair offering faster arteriotomy closure and reduced vessel clamp time while arguably maintaining superior histological and flow qualities compared to suture closure.1-10 Also, closure, with VCS titanium clips is a relatively simple technique with a shallow learning curve that is quick and easy to implement in emergent situations.11 Herein, we describe the use of this simple technique in 2 cases requiring primary middle cerebral artery (MCA) vessel closures following emergent arteriotomy for retrieval of dislodged endovascular coil material.

ABBRVIATIONS: CTA, computerized tomographic angiography; FDA, Food and Drug Administration; ICA, internal carotid artery; ICG, indocyanine green; MCA, middle cerebral artery; VCS, vascular closure staple

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METHODS

Case 1

A 75-yr-old female presented with the chief complaint of headaches and dizziness. Her neurological exam was consistent with a third nerve palsy and ophthalmoplegia. Computerized tomographic angiography (CTA; Figure 1A) and magnetic resonance imaging studies demonstrated a partially thrombosed left cavernous internal carotid artery (ICA) aneurysm.

After informed consent, she underwent endovascular treatment for coil embolization of her cavernous ICA aneurysm. The procedure was complicated by coil dislodgement into the parent vessel with extension into the M1 segment of the MCA resulting in acute proximal MCA trunk occlusion (Figure 1B). After multiple failed attempts at endovascular coil retrieval using the snare technique, she underwent emergent pterional craniotomy for proximal MCA arteriotomy for open coil retrieval. After retrieving the coils and noting brisk blood flow through the arteriotomy site, 2 temporary aneurysm clips were applied, 1 along the M1 segment proximal to our arteriotomy site and another clip along the superior branch of the M2 segment (Video, Supplemental Digital Content 1). An intraluminal thrombus involving the inferior temporal MCA branch was encountered and carefully removed with controlled suction.

To help minimize our total ischemic time, our arteriotomy was reconstructed using small VCS titanium clips (span of arcuate legs 0.9 mm; US Surgical Corp, Norwalk, Connecticut). Total clamp time was approximately 3 min and 2 s. Anterograde blood flow was confirmed with both intraoperative finger microdoppler and indocyanine green (ICG). Intraoperative angiogram was not attempted in this case, as we did not see any added benefit over the ICG angiography. The M1 and superior trunk of the MCA filled well but with decreased flow through the inferior trunk (Figure 1C). Postoperatively, the patient suffered an ischemic stroke secondary to an MCA distal inferior trunk reocclusion. On the day of discharge, she had receptive aphasia and right-sided limb hemiplegia. On her 2-mo follow-up, she was alert and able to partially communicate. However, she had a right-sided dense hemiparesis with some movement in her right lower extremity and no significant movement in her right upper extremity. She was lost to follow-up at our clinic; nevertheless, she was admitted to another hospital 18 mo later and was diagnosed with pneumonia.
Case 2

A 54-yr-old female presented with acute onset of headache. A computerized tomography scan and 4-vessel angiography (Figure 2A) demonstrated a giant right intracavernous ICA aneurysm. Owing to failure of balloon test occlusion, she underwent successful superficial temporal artery-MCA bypass surgery followed by endovascular ICA coil occlusion. During the procedure, the right ICA was successfully occluded; however, part of the distal coil became dislodged into the right M1 segment resulting in acute obstruction (Figure 2B). After failed retrieval through the snare technique, she underwent emergent pterional craniotomy for M1 arteriotomy. The dislodged coil and clot were removed through the arteriotomy site and immediately followed by brisk blood flow. The M1 segment was then trapped across the arteriotomy site using temporary aneurysm clips and the arteriotomy was repaired with small VCS titanium clips (span of arcuate legs 0.9 mm; US Surgical Corp; Video, Supplemental Digital Content 2). Total clamp time was under 3 min. A postoperative angiogram confirmed good cross filling from the left ICA and the right posterior circulation (Figures 2C and 2D) and a postsurgical 3-dimensional reconstructed CTA scan showed a patent M1 segment (Figure 3). The patient developed transient left limb hemiparesis with full recovery to baseline prior to her discharge home. On her 6-mo follow-up, the patient was neurologically intact and doing well. One year after that, the patient started having transient ischemic attacks and was started on medical therapy. Further follow-up revealed occlusion of her previous bypass. Despite maximal medical therapy, the transient ischemic attacks persisted and she underwent another superficial temporal artery-MCA bypass on the right side. The patient fully recovered with no additional neurological symptoms reported.

All patient information used in this study is based on completely anonymous and retrospective data, so ethics committee approval was not needed.

DISCUSSION

Krisch et al were the first to develop a nonpenetrating method for microvascular anastomosis. This consisted of the application of arcuate-legged clips to everted vessel edges in an intermittent manner. Final approval for its use in vessel anastomosis and repair was granted by the Food and Drug Administration (FDA) in 1993 and was referred to as the VCS (vessel closure system). Numerous animal and clinical studies in addition to prospective randomized controlled trials were undertaken leading up the FDA approval of the device and its subsequent marketing and
distribution. Many of the studies preceding and following the release of VCS were comparison studies comparing VCS to the conventional suturing method of vessel anastomosis and repair. Several parameters were closely evaluated such as vessel patency, pattern of healing of the anastomosis, time to perform the procedure, vessel compliance, burst strength, intimal hyperplasia, and endothelial function.\(^1,3,7,15-18\)

A large number of reports have demonstrated equal to superior healing with clips compared to sutures. Inflammatory cells and platelet aggregation along with fibrin deposition were much less pronounced with clips when compared to suture.\(^2,4-6, 8,9,15,19-23\) This may very likely be attributable to the nonpenetrating design of the clips that translates into less intimal injury compared to sutured vessels. With vessel suturing there is penetration and exposure of the subendothelial matrix to the blood stream resulting in inflammatory changes and intimal hyperplasia.\(^10,12\) In addition, in vitro studies have demonstrated superior tensile strengths with clipped anastomoses vs sutured, and improved para-anastomotic compliance.\(^7,15,18,24\) Interestingly, compared with traditional suturing techniques, the risk of anastomotic failure using the VCS titanium clip technique may be lower, or at least similar according to animal and human cadaveric studies.\(^18,25,26\) The reasons for potentially lower risk of anastomotic failure may be related to fewer endothelial disruptions, less reaction to foreign bodies, and reduced intimal hyperplasia.\(^1,8,9\)

The titanium clips are applied using an applier known as VCS (Tyco Healthcare–United States Surgical, Norwalk, Connecticut). Each applier holds a cartridge with a number of titanium clips, which are delivered in a single-step fashion. The end of the applier may be adjusted as necessary for preferred clip positioning. There are several staple sizes available and are selected based on the vessel diameter needing repair. In the cases described above, “small” size staples with span of arcuate legs of 0.9 mm were used. Additional instruments that may be used to help allow good vessel wall apposition and facilitate proper clip application are approximating microjeweler forcesps and forceps to aid in removing misplaced clips. Once the temporary clips are applied, both proximal and distal to the arteriotomy site, it is best and most convenient to apply the staples from proximal to distal or anterior to posterior (Figure 4). In our case, suction was used in the nondominant hand to allow for traction and vessel wall apposition. This is especially useful in instances where, despite proximal control, there remains some backflow of blood obscuring the field of view. Alternatively, if there is a clean field with good visualization of the vessel walls, a jeweler microforceps may be used in the non-dominant hand to help bring the walls together before applying each staple.

In our 2 cases, the follow-up angiography did not show any restenosis involving the reconstruction site. While there are mixed study results related to vessel patency favoring 1 method over the other, the general consensus echoes similar vessel patency rates for both VCS and suture repair. For the majority of the studies, patency rates varied from 93% to 100%.\(^12\)

Despite the many advantages of VCS titanium clips, their main benefit is in their time-saving effect in vascular closure.\(^2,10,11,16-18,22,24,27-30\) In a study by Cope et al,\(^29\) the time it took for vascular anastomosis using VCS titanium clips was less than 5 min. Pikoulis et al,\(^31\) also reported a series of arteriotomy cases that were closed using the VCS titanium clip technique resulting in significant reduction in closure time compared to conventional suturing. This is especially helpful in cases that require multiple vessel repairs, in transplant cases where warm ischemia time needs to be kept at an absolute minimum, and in cerebrovascular cases where the risk of brain tissue ischemia can result in devastating consequences. In the latter scenario, time saved repairing a vessel or performing a vessel bypass also helps to reduce the risk of perforator ischemia. That was the case in both patients we treated, as the occlusion was at the level of the M1 segment. Trapping this segment for a long time can cause perforator ischemia because of the lack of collaterals at this level. Shortening occlusion time allowed us to avoid perforator ischemia, which is more debilitating and disabling than ischemia in the distal MCA distribution. Yanagisawa et al\(^32\) first described the use of VCS clips to directly repair a tear in the dorsal ICA wall from a blister-type aneurysm with great success. They commented on the time-saving value of the technique and the ease with which the clips could be applied resulting in very subtle vessel wall manipulation and injury especially in light of the friable nature of the ICA vessel wall when dealing with dorsal variant aneurysms. Since time is of the essence when confronted with ischemia, it is important to consider repair options such as the one described by Yanagisawa et al\(^32\) to help save the maximum amount of time saved.
while minimizing the amount of manipulation directly performed to the vessel wall. Our 2 cases are the first-reported cases of the use of VCS clips to repair deliberate arteriotomies performed to retrieve dislodged endovascular coils. This method of closure allows for quick vessel repair while maintaining vessel patency and good distal flow as measured by our intraoperative microdoppler and ICG. One patient had a good functional outcome with distal vessel patency as demonstrated by our postoperative angiography, while the other one had an acceptable outcome taking in consideration that the surgery was done as a life-saving measure.

When compared to microsurgical suturing techniques, the learning curve for titanium VCS clip application is relatively swift. With the VCS method, the surgeon only needs simple steady hand movements to complete the arteriotomy closure. This is helpful especially in the limited or deep surgical field. The latter was exemplified in both of our cases, where the arteriotomy sites involved the M1 segment of the MCA vessel, which were quite deep within the Sylvian fissure, making the closures technically demanding. We also believe that the VCS method should not be limited to arteriotomy site repairs and can be extended to other demanding vascular procedures like bypass. Despite our lack of experience in utilizing the VCS clips in such procedures, we suggest that more studies should be done to expand on the applications of hemoclips and elucidate their benefits compared to regular repair suturing techniques. This is especially advantageous when longer temporary occlusion time could be of high risk.

**Limitations**

While this is a very practical and time-saving arterial closure technique especially in emergent cases where rapid closure is crucial, it is not without its disadvantages. A common oversight is the seemingly simple application of the clips. Despite the simplicity of the method, many authors advocate laboratory training to help decrease the rate of dehiscence. Training is required to ensure that the surgeon becomes adept at proper vessel wall eversion and approximation and the proper use and handling of forceps to evert vessel wall before clip application. With proper training and education, the disinclination to use clips on the part of the surgeons will subside as they become more comfortable and begin to appreciate its benefits. Another seemingly disadvantageous feature of VCS clips is their greater cost. While the upfront cost is greater than using conventional suture, if we consider the reduction in reoperation rates from complications of advanced ischemia, it may very well prove to be more cost effective in the long run. This is well demonstrated in the literature by articles that have reported on the potential cost savings of titanium clip in vessel anastomosis and repair. Further long-term studies, however, are needed to better elucidate this likely advantage. Also, during vessel anastomosis, there are instances where a surgeon may encounter vascular size mismatch. In such a situation, interrupted sutures to adjust the diameter at both ends are necessary prior to applying the clips. An additional drawback of VCS clips is the limited reporting on their application in vessels of growing organisms and inadequate experience of their use in calcified and atherosclerotic vascular walls. Lastly, titanium clips are not always available in every hospital.

**CONCLUSION**

To our knowledge, this is the first reported use of VCS titanium clips for the primary repair of a planned arteriotomy for treating...

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establish the overall efficacy and applicability of the VCS titanium clip technique in intracranial surgery.

Disclosure

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

REFERENCES


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The authors would like to thank Nathan Moore, BA, for editing the videos and the figures.

COMMENTS

The main interest of the paper is that it describes and depicts a technique that has had little prior reporting in the literature. And although I hope I never ever have to use it and I suspect with endovascular growth it will be extremely rarely used, it does represent something that cerebrovascular surgeons might benefit from being aware of. I would recommend watching these informative videos as well. Personally, I would think that both indocyanine green videoangiography and intraoperative catheter-based angiography would both be very useful in such cases. Lastly, I wonder about the application for bypass.

Jonathan Lazarus Brisman
Lake Success, New York

In this paper, the authors describe the use of vascular closure staple (VCS) clips for the rapid closure of microvascular arteriotomy sites in order to minimize total ischemic time. These clips are obviously not part of the typical armamentarium of the cerebrovascular neurosurgeon but, given the short clamp times in each of the two patients presented, the authors make a good case for them to be used routinely for procedures such as this. In these supplemental videos, it certainly seems as though application of these clips is technically easier that traditional suturing. On the other hand, I am relatively confident that some of the best microvascular surgeons using traditional suturing methods could rival the clamp times obtained in this paper. Perhaps the utility of VCS clips, therefore, could be for surgeons who do not employ microvascular suturing techniques often enough. Whichever method one chooses for arteriotomy closure, however, regular practice and a comprehensive knowledge of the tools involved, including their potential pitfalls, are crucial elements for success.

Alim P. Mitha
Calgary, Canada

The authors illustrate 2 interesting cases were non-penetrating vascular closure staple (VCS) titanium clips were successfully used in 2 embolectomy cases for dislodged aneurysm coils. The significance of the report lays in the fact that there are other potentially reliable alternatives for the microsurgical repair of small vessel arteriotomies and simple anastomoses. The availability of other techniques cannot replace the need for learning and training in the basic and advanced principles of suturing and micro-anastomosis techniques—proven reliable and more versatile. Nevertheless, this denotes the importance of new technology and devices—closure clips, synthetic grafts and experimental vessel adapters, laser-assisted procedures—that may improve outcomes in patients requiring vascular reconstructive procedures, especially in cases where short clamping times are of the essence, difficult and/or deep anatomy, infratable tissues not amenable for suturing.1–4

Caleb E. Feliciano
San Juan, Puerto Rico


In this article and accompanying video, the authors describe the use of vascular microclips to repair M1 segment arteriotomies performed to extract migrated coils. The video in particular is most impressive as it shows the ease of application of the microclips and most surprisingly no leak from the repair after the proximal temporary clip is removed. The authors review the research literature on these microclips, with excellent reported patencies. The microclips are commercially available as vascular closure staple (VCS) titanium clips manufactured by Tyco Healthcare-United States Surgical, which is based in Norwalk, Connecticut. Four microclip sizes are available, but the size used in these 2 cases had a span of arcuate legs of 0.9 mm. The authors recommend applying the microclips from proximal to distal or anterior to posterior. The authors also recommend, if possible, approximating the arteriotomy edges using jeweler forceps. The ICG and angiography images in their 2 cases showed excellent patency. Obviously, the advantage of these microclips is the ease of application, which minimizes temporary occlusion time. I plan to obtain these microclips and test them in the rabbit carotid artery, which has a diameter of 2 mm (the human M1 segment has an average diameter of 3 mm) to become comfortable with their application, and then have them available in the operating room for emergencies.

Rafael J. Tamargo
Baltimore, Maryland