Vascular Clips for the Microsurgical Treatment of Stroke

JOHN L. FOX, M.D.

SUMMARY  A synopsis of the types of vascular clips (malleable clips, screw clips, and spring clips) used by neurosurgeons during this century is presented. A review of the pertinent literature is included.

THE INCREASING IMPORTANCE of small vascular clips in the surgical treatment of stroke is apparent from the large numbers of such clips used by neurosurgeons in this century. There are more than 40 types used for vascular occlusion, obliteration of aneurysms and arteriovenous malformations, and temporary occlusion of vessels during surgery of vascular anomalies or microvascular anastomoses. More recently there has been a particular interest in types of microvascular clips which are too weak to effectively clip an aneurysm but satisfactory for nontraumatic, temporary occlusion of 1-mm vessels.

Many surgeons are wed to one or two types of clips based on personal experience. Others believe a large assortment of clips should be available so that the best clip for a given situation can be selected. The presence of a knowledgeable operating room nurse or technician familiar with the various clips and their use is important in clip selection during an operation. The following illustrations (figs. 1 through 40) and tables 1 and 2 demonstrate the type of clips available. Concerning the historical aspects as well as a description of some principles and tissue reactions the reader is referred to previous articles. See table 3 for the material component of most commercially available, permanently implantable aneurysm clips.

Malleable Clips

The first modern vascular clip was used in neurosurgery by Cushing (fig. 1) and described in 1911. McKenzie in 1927 made some modifications and that clip became more popular. He used flat instead of round wire. Most suppliers sell the individual clips although one can still purchase the roll of wire and clip-making outfit and make his own clips. Duane modified this McKenzie V-shaped clip into a U-shaped one to surround the vessel more effectively during closure of the clip which, unlike the V-shaped clip, closes first at the tips of the blades (fig. 2). Drew also used the V-shaped and U-shaped clips and developed a special clip applicator. Sugar (see table 1) used McKenzie clips that were 7-mm long. These malleable clips originally were made from silver but now some manufacturers use tantalum (see table 3). Tovi also developed a U-shaped silver clip with a special applicator (fig. 3). Samuels et al. used a modified U-shaped design (fig. 4) which, like the Tovi clip, permitted the tips of the blades of the clip to come together so as to trap the vessel during clip closure; this tantalum clip has become known as the Samuels-Weck Hemoclip® made by Edward Weck & Co., Inc. Codman and Shurtleff, Inc., altered the design (Vesclip®) in such a way that the clip stays more firmly in the clip applicer during transfer and then encircles the vessel. This tantalum clip (Ligaclip®) is sold by Ethicon, Inc. (fig. 4).

Several authors felt that tantalum was the preferable metal for malleable vascular clip construction (fig. 5) due to the tissue reaction to silver. Now as already noted, many of today's malleable clips are made from tantalum. Some surgeons have fashioned malleable clips from gold plates purchased at any dental supply house (fig. 6).

Probably the most popular malleable aneurysm clip in the 1950s and early 1960s was the Olivecrona silver clip first described by Norlén and Olivecrona in 1953. It featured winged blades (fig. 7), an innovation which allowed the surgeon to reopen the clip. Narrow and wide types, with and without wings, are available (fig. 8). More recently the Housepian clip (fig. 9) combines the U-shaped feature and the winged feature (see table 1). An innovation was the ability of its clip holder to grasp the clip more caudally thus giving the surgeon a better view of the tip of the clip and aneurysm. This clip can be angled in any direction within its special applicator and, once applied, locks in the neck of the aneurysm by first closing at the tips of its blades. The Pool-Pfeiffer clip (fig. 10) was similar to the narrow, wingless Olivecrona clip but had a unique locking mechanism as the neck of the aneurysm was encircled. This prevented arterial pulsations from opening the clip later.

Screw Clips

Unlike the malleable clips described above (figs. 1 through 10), Crutchfield developed a clip (or clamp) which screwed down to occlude a vessel or aneurysm (fig. 11). Except for the Berci-Nyhus double screw clip for use in microvascular anastomoses, screw clips have not been popular. More recently a new clip for temporary occlusion of parent vessels to an aneurysm was demonstrated. This has a long flexible cable from the aneurysm to the cranial surface and allows the surgeon to turn a screw mechanism via the cable thus closing or opening the clip.

Spring Clips

For aneurysm occlusion and for temporary vessel occlusion in microvascular surgery spring clips now are used most commonly. Schwartz in the early 1950s developed a cross-action or crossed-legged clip (fig. 12) intended to be...
TABLE 1 Intracranial Vascular Clips

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TABLE 2 Some Sources of Intracranial Vascular Clips

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TABLE 3 Material in Available Aneurysm Clips

<table>
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<th>Clip Component</th>
<th>Material</th>
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<tr>
<td>Clamp</td>
<td>17-7-PH stainless steel, Teflon adhesive</td>
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<tr>
<td>Spring clip</td>
<td>304 Stainless steel, MP-35-N (nickel, chromium, molybdenum, cobalt)</td>
</tr>
<tr>
<td>Microclip-graft</td>
<td>17-7-PH stainlees steel, Silastic adhesive</td>
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</table>

used for temporary vascular occlusion. This clip has three basic parts: a shank (which is held by the clip applier), the crossing zone of the blades, and the opposing zone of the blades. Subsequently Mayfield designed a similar clip for permanent occlusion of an aneurysm. It has the advantage of a smaller shank that can be held by a tissue forceps during transfer and application. In the 1950s and 1960s the Mayfield clip (fig. 13) made by the Kees Surgical Specialty Company seems to have been the most popular spring clip for dealing with an intracranial aneurysm or for temporary occlusion of arteries. The original version tended to have a scissoring action risking severance of the vessel (fig. 14); this was modified so that the blades do not touch along the crossing zone. Many sizes and configurations have evolved (fig. 15). For certain large aneurysms with broad necks a clip with a hole at the end of the blades was made (fig. 16); this allows the surgeon to apply during transfer and application. In the 1950s and 1960s the Mayfield clip (fig. 13) made by the Kees Surgical Specialty Company seems to have been the most popular spring clip for dealing with an intracranial aneurysm or for temporary occlusion of arteries. The original version tended to have a scissoring action risking severance of the vessel (fig. 14); this was modified so that the blades do not touch along the crossing zone. Many sizes and configurations have evolved (fig. 15). For certain large aneurysms with broad necks a clip with a hole at the end of the blades was made (fig. 16); this allows the surgeon to apply during transfer and application.
to tie the blades of the clip firmly together to prevent the clip from opening. Due to reports of spring clips slipping off the aneurysmal neck in a few instances, the Mayfield clip now also comes with corrugated inner blade surfaces, and the blades tend to be somewhat narrower (fig. 17). Chaffee modified the Mayfield clip to permit the tapering blade tips to bypass each other after application (fig. 18), thus entrapping the neck of the aneurysm.
McFadden tried to prevent tissue reaction to the clip by coating the modified Mayfield clip with silicone-rubber (fig. 19). However, this made the clip blades too slippery for practical use. The McFadden spring clip is a modification of the Mayfield cross-action clip in which the blades are narrower, thicker and stronger (fig. 20). Drake's clip is similar to the straight McFadden modification except that an opening or loop has been created between blades and the cross-action zone (fig. 21). The Drake spring clip was made by Kees one night in time for Drake to re-expose a basilar artery aneurysm the next day and successfully occlude the otherwise inoperable aneurysm while preserving the posterior cerebral artery. Subsequently this clip has allowed preservation of the following structures in the loop.
FIGURE 10. The Pool-Pfeiffer locking clip. From figure 81-C, Aneurysms and Arteriovenous Anomalies of the Brain (Harper and Row), reprinted with permission.

A. Clamp Assembly
B. Control Assembly
C. Aneurysm
D. Ant. Cerebral A
E. Ant. Communicating A

FIGURE 11. The Crutchfield screw clip. From figure 3, J Neurosurg, reprinted with permission.

FIGURE 12. The Schwartz spring clip. The opened one is held by a modified Mayfield clip holder.

FIGURE 13. Diagram of the original (A) and modified (B) Mayfield spring clip. From figure 4, J Neurosurg, reprinted with permission.

FIGURE 14. Diagram of reason for modification of the Mayfield spring clip shown in figure 13. From figure 1, J Neurosurg, reprinted with permission.
FIGURE 15. Mayfield spring clips, available in standard and miniature sizes.

FIGURE 16. Mayfield spring clip with suture hole at tip of blade; available in different lengths.

FIGURE 17. The corrugated Mayfield spring clip in various configurations.


FIGURE 20. McFadden spring clip in various configurations.
while occluding an aneurysm: posterior cerebral artery, third cranial nerve, perforators, anterior inferior cerebellar artery, posterior inferior cerebellar artery, vertebral artery, basilar artery, and blades of another clip. This loop concept, also now adapted to the Heifetz clip, is not unlike Graf's earlier idea as he evolved his original clip (fig. 22). This Graf clip (not a cross-action type) was designed in part to allow passage of a vessel in close proximity to an aneurysm. Although originally made as a temporary clip of beryllium-copper composition, it later was made from stainless steel by Hastings Laboratories and distributed as an aneurysm clip by Codman and Shurtleff, Inc.

Another cross-action clip is the Yasargil-Aesculap spring clip. It also has strong, narrow, corrugated blades but in addition has a narrow base which less easily obscures the point of interest during clipping of the aneurysm—especially when working under the microscope (figs. 23 and 24). The new McFadden-Kees spring clip (see table 1) also is a cross-action type with slight modification of the spring mechanism (fig. 25); it appears to have many of the same advantages as the Yasargil-Aesculap clip.

The Lougheed-Kerr spring clip is unique in that it gains its spring action from an attached ring (figs. 26 and 27) which can be moved to change the force of the spring. Also the clip can be swiveled in any direction in the clip holder, an advantage also found in the Scoville-Lewis, the new Sundt-Kees, and the Sparta clips (see below). The Scoville-Lewis spring clip has a coiled spring whose axis is set parallel to the line of clip action (fig. 28). This unique torsion bar mechanism also acts as a small base or shank making visualization of the site of interest easier.

In 1969 Heifetz described his spring clip which was the first to use an internal, non-fatiguing wire spring to hold the clip closed (fig. 29). This spring is inside a fairly small shank. The opposing surfaces of the Heifetz blades were slightly rounded to prevent cutting tissue and serrated to avoid slipping of the blades. The new Sundt-Kees (fig. 30) and Sparta...
(fig. 31) spring clips now have similar internal spring mechanisms (see table 1).

The next major innovation was the concept of obliterating an aneurysm on the arterial wall opposite to the surgeon by the use of a vessel-encircling clip developed by George W. Smith (fig. 32). The next logical step was the encircling clip-graft described by Sundt et al. The principle is illustrated in figure 33 and examples are shown in figure 34. Heifetz has a similar clip (fig. 29).

With the advent of microsurgical anastomoses (especially the superficial temporal artery to middle cerebral artery), less traumatic, temporary spring clips have been developed. One of the first was a modified hair clip used by Jamieson to temporarily clip the basilar artery during basilar bifurcation aneurysm surgery. Stephens did the same for microvascular anastomosis. The Jacobson clamp, Khodadad

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**Figure 25.** The new McFadden-Kees spring clip in various configurations.

**Figure 26.** Diagram of Lougheed-Kerr spring clip. From figure 2, J Neurosurg. reprinted with permission.

**Figure 27.** The Lougheed-Kerr spring clip is available in various sizes and configurations.

**Figure 28.** Scoville-Lewis spring clip; available in different sizes.
VASCULAR CLIPS/Fox

FIGURE 29. Heifetz spring clip and clip-graft in various configurations.

FIGURE 30. The new Sundt-Kees spring clip in various configurations.

FIGURE 31. Sparta spring clip; available in different sizes.

FIGURE 32. The Smith encircling spring clip is molded from polyethylene plastic.

FIGURE 33. Diagram illustrating the principle behind the use of clip-grafts. From figure 1, J Neurosurg, reprinted with permission.

FIGURE 34. The Sundt-Kees spring clip-graft is available in several lengths and diameters in both the standard series and the miniature series. On the left is the standard Mayfield clip applier. On the right is the right-angled Sundt-Kees clip applier. A new miniature series with the same type of applier used for the new Sundt-Kees spring clip (fig. 30) has been developed recently.
FIGURE 35. The original Khodadad spring clip for temporary microvascular occlusion. Note closing spring action accomplished by the silicone-rubber band. From figure 3 Neurosurg, reprinted with permission.

FIGURE 36. Modified Khodadad spring clip.

FIGURE 37. The Kapp spring clip for temporary microvascular occlusion. From figure 1, J Neurosurg, reprinted with permission.

FIGURE 38. Kleinert-Kutz spring clip for temporary microvascular occlusion; available in different sizes.

FIGURE 39. Acland spring clip for temporary microvascular occlusion; available in different sizes.

clip (figs. 35 and 36), Kapp clip (fig. 37), Kleinert-Kutz clip (fig. 38), and Acland clip (fig. 39) were subsequent developments.

Double clips to prevent excess retraction of the incised vessel during anastomosis are available (table 1) and include those reported by Jacobson, Acland, Peters and Om-maya, Henderson et al., and Berci and Nyhus. All are spring clips except the latter, which is a screw clip. Finally Malis and Decker have a unique clip that holds a hollow bypass stent inside the vessel without leakage (fig. 40).
The multitude of malleable, screw, and spring clips is apparent. Further innovations now are taking into consideration the fact that most surgery where these vascular clips are to be used will be done under the operating microscope and often through a limited cranial opening. A recent example is the bayonet-shaped clip developed by Sugita. 10, 15

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Pyramidal Tract Responses (PTR) During Hypoxia and Hypotension

ROBERT SUTTER, M.D., AND W. C. WIEDERHOLT, M.D.

SUMMARY In rats with unilateral carotid artery ligation pyramidal tract responses were studied during hypoxia and during trimethaphan-induced hypotension. Observations on EEG activity during hypoxia suggest that unilateral carotid artery ligation produces a more severe perfusion defect in lateral portions of the hemisphere. During hypoxia and during trimethaphan-induced hypotension in direct PTRs disappeared first from the hemisphere on the side of carotid artery ligation and next from the opposite hemisphere. This was followed by loss of direct PTRs in the same order. Animals could not be resuscitated once the direct PTR from the non-ligated hemisphere had disappeared. Hypotension appears to be a late contributing factor in impairing electrocerebral activity during hypoxia in this study.

Introduction

IT IS GENERALLY ACCEPTED that the human brain cannot survive anoxia for longer than approximately 5 to 10 minutes. During the last few years Hossmann and associates1-4 have demonstrated in the cat that some electrical activity of the brain returns even after one hour of anoxia. None of the cats which were made anoxic could be kept alive long enough to determine the extent of clinical recovery. Myers5 could not demonstrate residual impairment of neurological function in monkeys after circulatory arrest of less than 15 minutes. In some animals severe neurological deficits persisted for as long as 48 hours before complete recovery occurred. During hypoxia EEG activity is lost rapidly within 10 to 60 seconds.6-7 In the visual system hypoxia first produces loss of synaptic activity in the occipital cortex and only later is synaptic activity impaired in the lateral geniculate body.8 Hossmann and Sato9 have shown that pyramidal tract responses (PTRs) persist during anoxia in the absence of spontaneous EEG activity. Since the disappearance of EEG activity during hypoxia is not a reliable parameter to determine irreversible brain damage, we evaluated the disappearance of PTRs to determine if this was associated with irreparable brain damage. We chose the Levine anoxic-ischemic rat model8 because it has previously been examined pathologically,10-12 biochemically12 and electrophysiologically.7

Pyramidal tract responses consist of direct early and indirect later components.13 The early response is the result of direct stimulation of pyramidal neurons. The later responses are smaller in amplitude and are due to activation of pyramidal neurons by cortical interneurons. We were thus able to study the effect of hypoxia on direct excitability of neurons and on synaptic activity. In the Levine model the hemisphere on the side of carotid ligation is impaired in its function earlier than the opposite hemisphere. The hemisphere with the patent blood supply therefore serves as control in each animal.

In earlier studies we were not certain if death of animals during hypoxia was related primarily to cardiovascular or cerebral dysfunction. Cardiovascular function was therefore assessed by continuous monitoring of EKG and blood pressure. In order to ascertain how much hypotension contributes to cerebral dysfunction during hypoxia we studied animals which were well oxygenated but were made hypotensive by injection of trimethaphan.

Methods

Sprague-Dawley rats weighing between 250 and 400 gm were anesthetized with 15 to 30 mg of pentobarbital intraperitoneally. Following the insertion of a tracheostomy tube the carotid system was dissected free on the left side of the neck. The internal and external carotid arteries were ligated separately. A PE 60 catheter was threaded into the left common carotid artery and advanced toward the aortic arch. Blood pressure was measured by connecting this catheter to a Statham 23 transducer.

The animal was then placed in a stereotactic headholder and the skull exposed. Part of the calvarium over each frontal lobe was removed for placement of bipolar cortical stimulating electrodes. Two gold-plated screws were inserted in the bone over both parietal areas, one located medially...
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