Evolution of the crossed-action intracranial aneurysm clip

Technical note

JOSEPH T. McFADDEN, M.D.
Department of Neurosurgery, Eastern Virginia Medical School, Norfolk, Virginia

The hazards of using a malleable clip or a suture for ligation of an intracranial aneurysm led to the development of self-closing coiled-spring crossed-action clips, designed to give the neurosurgeon greater dominion over particular anatomical problems. Surgical control depends on two clip characteristics which evolved over the past four decades: 1) reach that goes beyond or encompasses the structural limits of a particular aneurysm base; and 2) grasp sufficient to sustain occlusion without creating future problems. Both characteristics rely upon clip design but the second primarily depends on materials science, specifically metallurgy.

Structural Developments

Black and German and then Schwartz introduced a small bulldog clamp (based on the crossed-action principle introduced by Charrière in 1840) to neurosurgery for temporary clipping of blood vessels. Refinement of this instrument for permanent implantation by Mayfield and Kees vastly improved ligation (Fig. 1); however, two potentially detrimental features, the thin metal and the large spring, soon stimulated further modifications. The thin legs (0.012 in., the same as a razor blade), in the presence of weak bulging vascular walls, posed a distinct hazard at clipping. In 1963, I modified the clip legs to imitate both the structure and function of a blunt nerve hook which had proved to be a safe instrument for initial freeing of aneurysmal anatomical interclusions (Fig. 2). The first instrument maker involved in these changes fastened split wire (as requested) to the existing Mayfield clip legs, but he used silver solder. We disagreed on these metallurgical principles, but we did agree on testing; the clips rusted overnight in normal saline. The second manufacturer, George Kees, used spot welds and heat treatment to produce a tissue-compatible clip. In addition to modifying the existing straight-clip model, we introduced at that time two new configurations, the curved and the right-angled clips, all with legs that open almost parallel and tips that toe-in to deter slippage. These three represent the basic patterns from which all future variations
developed (Fig. 3). Axiomatically, not only do these clip legs enter the opened aneurysmal arterial interclu-
sions with the same relative safety inherent in the blunt nerve hook, but they also serve to complete the dissec-
tion of these pathways immediately prior to clip closure. This final maneuver, which creates space for adjusting the clip legs on the aneurysm base, became feasible from the standpoint of safety only when these modifi-
cations were made (Fig. 4).

The second problem, the large spring loop, occupied too much space in any surgical field and also probably contributed to certain postoperative ischemic problems — the brain moving against the loop could torque the clip, thus compromising the lumen of the parent artery. Scoville’s "... in an effort to do away with this bulk ..." devised the miniature torsion-bar aneurysm clip (Fig. 5). Certainly, this solved the problem of size, but the uncrossed and V-shaped leg action severely limited control over numerous aneurysms. Obviously, the need existed for combining the better features of the Mayfield and the Scoville concepts: a tiny powerful spring and crossed-action legs designed to provide greater reach and grasp. Kees took the idea and worked with suggestions made to him for reversing the spring action of the Scoville model and for crossed legs in the McFadden-Mayfield patterns.

Kees demonstrated the new clip (Fig. 6) at national meetings beginning in 1970, at the annual Microsurgical Symposium in Cincinnati, Ohio, for several years beginning in 1971, and at the World Congress of Neurosurgery in Tokyo, Japan, in October, 1973. After initial clinical use, three modifications rapidly ensued: 1) a limb was added to prevent scissoring; 2) a stop was provided to prevent excessive opening (which would ruin the spring by surpassing its elastic limit); and 3) holes were placed in the sides of a widened spring loop to accommodate a special applier designed for multi-
gle clip rotation (Fig. 7). In keeping with efforts to produce a clip with maximum tissue compatibility and strength, the stop and the anti-scissoring mechanism were designed as limbs bent from one piece of metal comprising the entire clip; thus, there were no welds or appurtenances, both of which change the electrochem-
ical activity and the strength of a metallic implant. A Swiss group developed a clip similar to the initial pro-
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FIG. 6. Photograph of the original prototype of the helical coiled-spring aneurysm clip with crossed legs, first exhibited by Kees in 1970.

Prototype, adding a welded-on anti-scissoring mechanism; Yaşargil, *et al.*, acknowledged the priorities. Subsequently, others made similar clips with minor modifications. Drake and Peerless (personal communication, 1986) suggested the majority of the numerous clip leg patterns (all being variations of the three basic types) which were developed by several different manufacturers for use on aneurysms presenting special access problems; many of these evolved from the fenestrated clip which Drake initially conceived as a modification of the McFadden-Mayfield clip.

Materials and Methods

The metallurgical misadventure with the first clip modification (due to use of silver solder) led to a number of developments. A search of existing neurosurgical writings revealed a paucity of information in general and nothing in the *Journal of Neurosurgery* regarding the basic principles of metallurgy or the metals in use for permanent implantation. The publication on this subject in 1969 stimulated the neurosurgical community to join the efforts of other surgical specialties in following orthopedics and dentistry which, goaded by recognizable clinical syndromes of implant reaction, had already established scientific guidelines. Neurosurgical patients are, however, unlikely to present symptoms characteristic of implant failure.) This initial representation of the Harvey Cushing Society at the American Society for Testing and Materials eventually evolved into the Joint Committee on Devices and Drugs of the American Association of Neurological Surgeons and Congress of Neurological Surgeons, now representing American neurosurgery nationally and internationally. Neurosurgery has received much valuable guidance from the metallurgists, engineers, physicists, and others who attend these meetings for scientific interest only.

At that time all intracranial spring clips were made of stainless steel. None of these steels, however, belong to the categories considered by other surgical specialties acceptable for implantation. Those approved for orthopedic use possess relatively poor spring properties and therefore are inappropriate for the manufacture of clips with reliable strength. Following a discussion of this impasse by the original neurosurgical committee, a metallurgist in attendance suggested MP35N as an ideal clip material. This ultra high-strength alloy, developed by E. I. duPont de Nemours and Co. for acid vats and consisting of cobalt 35%, nickel 35%, molybdenum 10%, and chromium 20%, had been found to be highly resistant to corrosion in the severest environments. Kees accepted the suggestion and made the new clip of MP35N.

The problem of ferromagnetic behavior of neurological implants predated magnetic resonance (MR) imaging. Those steels considered acceptable for implant use are nonferromagnetic and belong to the group (austenitic) having the highest tissue compatibility; therefore, any metal attracted to a magnet possesses inferior or unacceptable corrosion resistance in body tissues. The Schwartz clip is martensitic and strongly ferromagnetic but was not designed for implantation. The Mayfield clips and all modifications are made of an austenite (301) bordering on the martensitic group, and display capricious, weak, and unpredictable ferro-
magnetic activity usually due to changes in the crystal structure of iron caused by manufacturing procedures.

Clips made of the nonferromagnetic alloy MP35N have greater strength and compatibility1 and fortuitously cause no MR imaging difficulties9 (AL Benabid and C Ochiai, unpublished data). While this material contains two ferromagnetic elements, cobalt and nickel (but no iron), the alloying process with the other elements lowers the Curie point (the temperature at which a ferromagnetic material becomes nonferromagnetic) to below room temperature and creates an entropic state that dissipates any effective ferromagnetic propensities of the metal in the magnetic fields of MR imaging devices. Unpublished studies by Benabid and Ochiai have shown that the clips made from this metal not only remain motionless in the magnetic fields of current MR imagers, but are also the only ones that do not distort images. (The Yaşargil clip, initially made of stainless steel, is now made of a metal similar or identical to MP35N, according to the standards written by the neurosurgical committee.) The studies by Benabid and Ochiai also revealed that clips made of Elgiloy (the Japanese version of the McFadden-Kees clip5,13) cause some image distortion. Elgiloy, a nickel cobalt alloy developed by the Elgin watch company for watch springs, contains 17% iron.

In summary, in the late 1960's, Kees took a basic idea for combining the Mayfield and Scoville concepts and produced a clip so superior that it quickly became the dominant prototype used and imitated worldwide. Various neurosurgeons, metallurgists, and others made suggestions that contributed to its evolution.

References


Manuscript received March 29, 1988.
Accepted in final form December 19, 1988.
Address reprint requests to: Joseph T. McFadden, M.D., 513 Mowbray Arch, Norfolk, Virginia 23507.