Commentary

Coil Embolization of Aneurysms: Angiographic and Histologic Changes

John Pile-Spellman, *Associate Professor of Radiology and Neurosurgery, Columbia-Presbyterian Medical Center, New York, NY,* and Julian Wu, *Associate Professor of Neurosurgery, Tufts University School of Medicine, Boston, Mass*

Coil embolization for aneurysms has been shown to be highly effective treatment to prevent acute recurrent hemorrhages (F. Viñuela, "Summary of the Multicentric Study Results of the Treatment of Cerebral Aneurysms using the GDC System," presented at the 33rd Annual Meeting of the American Society of Neuroradiology, Chicago, Ill, April 1995). The long-term durability is increasingly important as more and more people benefit from this treatment. J. V. Byrne's (1) and J. Reul's (2) teams are to be commended for their contribution to our knowledge of the biological effects of Guglielmi detachable coils (GDCs) and mechanically detachable coils (MDCs) in animal aneurysm models in this issue of *AJNR*. Byrne et al, in their prospective, randomized, blinded, controlled study of acute surgically prepared lateral wall venous-pouch aneurysms in swine, show that all aneurysms (including controls) thrombosed and clotted over the 7-week longitudinal study. The healing in the GDC- or MDC-treated aneurysms was characterized by increased cellularity. Reul et al, in their prospective, nonblinded, controlled, nonrandomized, surgically prepared rabbit bifurcation aneurysm model, show in their 6-month longitudinal study: (*a*) that angiographic appearance underestimated histologic occlusion, (*b*) a tendency of the aneurysm to grow over time, (*c*) a tendency for treatment to be more effective in the smaller aneurysms, and (*d*) that the confluent scarring, endothelialization, and healing was very incomplete in the great majority of aneurysms.

Virchow's triad of (*a*) blood flow, (*b*) blood, and (*c*) blood vessel is extremely complex even without the addition of an artificial device (3, 4). The flow of blood, as Virchow knew, is an important determinant of clotting and healing. The blood elements move by convection and diffusion with both macroscopic and microscopic rheologic considerations. The major factor of each is the shear rate of the flow. In short, high flow rates with shear stresses lead to activation of platelets and a "white clot." Low flow rates lead to a predominately red blood cell fibrin or "red clot" (5). Even different sides of the same clot can have different composition; with the "windward" side of the clot being white and the "leeward" side being red. The tightness of the coil packing would be expected to affect blood flow and therefore the nature of the clot.

In addition, the presence of an artificial surface in the blood stream may lead to several different consequences, including: (*a*) thrombosis, (*b*) embolization, (*c*) consumption, (*d*) systemic effects, and (*e*) altered coagulation (6). The device's surface physical properties that initiate and support these reactions include: (*a*) "wetability" (related to surface tension and surface free energy), (*b*) surface shape, (*c*) crystallinity (orderliness of the surface), (*d*) surface topography (roughness), and (*e*) microbubbles. The molecular surface is critical and unless it is fully characterized by techniques such as x-ray photon-electron spectroscopy, one cannot be certain of the surface composition. A device slightly soiled by waxes, polishes, detergents, glove talc, plastic sleeve liners, and so forth, may have a molecular surface different from its natural surface as well as the device's core (7).

Different animals respond differently (8). The swine and canine lateral wall aneurysm models almost always clot spontaneously. The rabbit bifurcation aneurysm model has been studied extensively and more clearly mimics human blood vessels in their response. The rabbit model is probably the more appropriate for the

Address reprint requests to John Pile-Spellman, MD, 177 Ft Washington Ave, MHB 8, South Knuckle, New York, NY 10032.

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study of aneurysms. However, its limitations will have to be further delineated.

The significance of the increased cellularity in the thrombus in the swine aneurysms treated with the GDC or MDC in Byrne et al's work is unclear, because all of the aneurysms in this model thrombose, indicating that a vigorous cellular response is not necessary for pigs to thrombose and heal their aneurysms. What cellular response allows swine always to heal aneurysms spontaneously could prove to be a fruitful area of study. The fibrosis, endothelialization, and healing seen around implantable devices is often histologically incomplete (9). Reul et al have suggested that in the rabbit model with GDC and MDC, this is also the case.

It is still very early in our clinical experience with endovascular treatment of cerebral aneurysm. The durability of aneurysm healing with coils can probably not be inferred directly from these animal studies, given these complex phenomena. However, the incomplete healing determination in the paper does give one pause. Animal work such as these authors' is essential to help us understand the scope and range of changes we may see in clinical practice, and suggests avenues to enhance aneurysm healing with coils (Y. Murayama, F. Viñuela, Y. Suzuki, et al, "Ion Implantation: A New Surface Modification Technique for GDC Coils," presented at the 34th Annual Meeting of the American Society of Neuroradiology, Seattle, Wash, June 1996).

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