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The availability of the Pipeline Embolization Device (PED; Medtronic, Minneapolis, Minnesota) rapidly increased the number of aneurysms that were potentially treatable using endovascular therapy. The Pipeline Embolization Device for Uncoilable or Failed Aneurysms (PUFS) trial produced a superb occlusion rate (86% at 12 months) in a group of aneurysms that had previously been nearly impossible to treat with other available devices. Across time, the rate of occlusion in the PUFS trial continued to increase, reaching 95% at 5 years; there was also a low complication rate of 6%.[1] Following FDA approval in 2011, I enthusiastically began treatment of patients outside the trial. However, during the next several years, I noticed that the occlusion rates, while good, did not quite achieve the success reported in the PUFS trial. A few of these large, on-label-treated aneurysms as well as some smaller aneurysms were incompletely occluded; on follow-up DSA, some of these showed what was described by Griessenauer et al[2] as the "collar sign."

As a first step in explaining differences between the PUFS trial results and my clinical experience, I first analyzed possible changes in the treatment technique. Because of the lengths of the aneurysm necks, parent artery size, and the maximum lengths of available devices (10–20 mm), many aneurysms in the PUFS trial were treated using multiple overlapping PEDs. The aneurysms in the PUFS trial averaged 3.1 PEDs per treatment. Also, in PUFS, to achieve excellent device apposition to the vessel wall and to other PEDs, after deployment, angioplasty often was performed to optimize wall apposition. Shortly after FDA approval in 2011, device lengths up to 35 mm became available. With this experience and some pressure from hospital administrators to reduce costs, the use of multiple devices decreased and the concept of "one and done" was developed. It was, also, in this same period that the results from the Stenting and Aggressive Medical Management for the Prevention of Recurrent Stroke in Intracranial Stenosis (SAMMPRIS) trial became available. This trial demonstrated that in the treatment of an atherosclerotic stenosis, angioplasty might have more risk than the best medical treatment.[3] Because the segment of the parent artery from which an aneurysm arises often has atherosclerotic changes, many, including me, became somewhat hesitant to perform angioplasty when deploying a PED. Only if the PED failed to completely expand was angioplasty performed.

Other factors I considered related to the lower rate of complete occlusion were the amount of the vessel wall that was incorporated into the aneurysm neck, the degree of reduction of flow into an aneurysm after implantation, the apposition of the PED to the parent vessel wall, and the size of the deployed implant.[4] I began to carefully calibrate the angiographic equipment because measurement of the vessel diameter was essential in choosing the appropriate size so that apposition and pore density were optimized.[5]

At that same time, a better understanding of the importance of platelets and their modification to prevent aggregation and activation with aspirin and thienopyridines became more widely known and accepted.[6,7] The newer thienopyridines such as prasugrel and ticagrelor seem to have a much greater inhibitory effect than clopidogrel. In a review in the *American Journal of Roentgenology*, Palmaz[8] demonstrated that metallic stents implanted in vessels are rapidly coated with a combination of platelets and white and red blood cells. This deposition was shown to have a important effect on the growth and healing of the intima.

Griessenauer et al[2,9] from Beth Israel Deaconess Medical Center reported their experience with aneurysms treated with the Pipeline. Their initial report[2] included a group of patients whose aneurysms were incompletely occluded on follow-up angiograms. They observed a radiolucency parallel to the base of the nonoccluded aneurysms, which they described as the "collar sign." Their first report retrospectively analyzed 135 aneurysms and found 10 incompletely occluded aneurysms that exhibited the sign. In the current issue,[9] with an additional follow-up of 7 months, they now found 19 aneurysms exhibiting the collar sign.[2,9] The occlusion rate in their entire cohort was approximately 80%, which is similar to data provided by PUFS. This current report of their 2014–2016 experience gives some insight into both the natural history of aneurysms and the patients whose aneurysms exhibited the collar sign. They separated the nonoccluded aneurysms into 2 groups, 10 had a second PED placed; only 1 of these was occluded on subsequent follow-up. The second group, consisting of 9 aneurysms were only observed; 2 of these were occluded on subsequent follow-up.[9] Because of their busy clinical practice, these operators have overcome the learning curve associated with using the PED.[10] In their 3-year study, 285 aneurysms in 198 patients were treated. In both publications, the

authors very nicely and thoroughly discussed the healing mechanisms of vessels and aneurysms in patients treated with the PED. They have detailed the current thoughts on healing, including the slowing of flow within the aneurysm by the flow diverter, the development of thrombus and its organization, and finally, the endothelization of the PED and the restoration of the intima.[2,11,12]

Possible explanations for the collar sign may be related to technical factors. At the time of deployment, the apposition of the PED was assessed fluoroscopically and subtle areas of nonapposition might have been only detectable using DSA. Although 15 of the 19 aneurysms were smaller than 10 mm, the amount of the vessel wall that was incorporated into the aneurysm should also be considered. Calibration of the angiography equipment might also have been inaccurate, resulting in the oversizing of the PED, which affects the pore density, the degree of flow restriction, and the appropriate framework for endothelial cell support.[5,11,12]

I have observed seemingly excellent apposition of the device, but poor flow restriction within the aneurysm. Usually passing a microguidewire whose tip has been shaped in to the letter J through the device, perhaps in combination with the microcatheter and occasionally the intermediate catheter, increases flow restriction without any apparent change in the device. In the group treated with a second device, the size of that second device in comparison with the first device may also be important. There are some data that would suggest that pore density can be decreased by placing a larger device within the previous PED.

By means of optical coherence, uneven intimal growth on implanted devices has been observed.[2,13] One must question whether the etiology of this irregular intimal growth may be due to the antiplatelet agents. This irregularity of the intima, which is on a microscopic level, may prevent complete apposition of the second device placed within the first PED. This possibility suggests that the first treatment should include placement of a second device if there is concern for adequate aneurysm neck coverage and aneurysmal flow restriction.

Griessenauer and Gomz-Paz[2,9] reported that 74% of their patients with the collar sign had a branch vessel arising from the aneurysm. They discuss, at some length, the effect of the "sump" of this outflow vessel on the occlusion of the aneurysm. Complete occlusion of the aneurysm is usually the goal, but preservation of the outflow vessel may also be important.

Because only 3 of the 19 aneurysms were occluded on continued angiographic observation, the authors suggest that the low rate of further occlusion argues against additional routine follow-up angiography. Perhaps this suggestion may be judicious if one can accurately assess the aneurysm with CT or MR imaging. However, artifacts may make this difficult, especially when coils or aneurysm clips are present. If the aneurysm is small and has decreased in size with slower flow, this approach would seem to be reasonable, particularly if the aneurysm gives rise to a branch vessel. Finally, the authors report that only 1 aneurysm enlarged, 2 remained the same, and 13 of the 19 (68%) decreased in size. Most important, none of the aneurysms bled. While data suggesting a protective effect of the PED in aneurysms with the collar sign do not exist, I would suggest that with the absence of hemorrhage, stability, and improvement in 18 of 19 aneurysms, a reasonable treatment outcome has been achieved.

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