Laser Angioplasty
Now and in the Future

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H.L. Mencken, one of this century's foremost skeptics, was fond of saying that civilizations advance not in proportion to their willingness to believe but in proportion to their willingness to doubt. Mencken's wisdom applies equally to science and medicine, and in this spirit, I will discuss an alternative view to that presented by Dr. T.A. Sanborn in his editorial in this issue. I stake no claim to being correct, only different, because our different views derive not from facts but from uncertainties. I see two crucial uncertainties in laser angioplasty: which of the new interventional systems will be most effective, and will answers derived from peripheral vascular interventions apply to coronary arteries?

Effectiveness of New Devices in Peripheral Circulation

As Dr. Sanborn points out, there is already considerable experience and reasonable success with heated metal caps in treating both stenotic and obstructive vascular disease in the iliofemoral artery system of humans. The success in recanalizing femoral arteries, however, is no way confined to this particular technology. In addition to the techniques he mentions, there are many others. Nordstrom et al have used an argon laser catheter fitted with an angioplasty balloon to achieve similar results in 34 patients. Geschwind has used a spectroscopically guided argon laser catheter to recanalize the femoral artery in a smaller group of patients. Using an excimer laser catheter, we have had an 86% success rate in femoral arteries of 19 patients. Simpson et al have reported 93% success rate in removal of atheromatous tissue with a rotating blade in a tubular housing; in fact, if one were to restrict analyses to discrete stenoses and exclude concomitant balloon angioplasty, this device probably produces the most impressive short-term angioplasty results. Still others, including Kensey et al and Ritchie et al, have used intravascular drills. It is difficult to identify any superior technology among these approaches based solely on clinical efficacy: in my view, the most reasonable statement about "what we have learned" is that the femoral artery system, large in diameter and straight in its course, is very forgiving—all these devices work reasonably well.

There are, however, most instructive advantages and disadvantages that become apparent when one uses these devices to treat femoral atherosclerosis in humans. The "hot tip" system, for instance, has one immediately obvious advantage over other systems: it works very quickly. In our first case, for instance, we recanalized a 10-cm complete femoral artery occlusion by one pass in less than a minute. An additional advantage is that the size of the new vascular orifice created by the 2–2.5-mm tip is large in comparison to other techniques. Finally, clinical experience has shown that the bullet-shaped tip tends to follow the course of the vessel, even when it is totally occluded so that, although perforation occurs, it is uncommon. On the other hand, a serious limitation of the hot tip becomes quite apparent when one attempts to treat smaller-diameter vessels. The hot tip is hard to use effectively below the knee, where diameter of the blood vessels of the extremity approximate that of the coronary arteries, because the heated cap induces vascular spasm and, in some cases, thrombosis.

For treating smaller peripheral vessels, it is possible that the pulsed excimer laser represents a viable alternative therapy. In our experience treating femoral arteries, excimer laser energy cuts through obstructions more slowly than does the hot tip (a 10-cm obstruction takes about 2 minutes of operating time), and the orifice it creates is smaller. On the other hand, Isner, Grundfest et al, and others have shown that excimer laser energy is capable of cutting through tissue without creating thermal injury. This characteristic is a potential major advantage. We have used the excimer laser below the knee in humans to open obstructed vessels both with and without follow-up balloon angioplasty.

Given the efficacy of so many devices in the peripheral vascular system, I do not believe that we can yet say which is likely to predominate. One possibility is that given equal efficacy, many angiologists will choose their device based more on mundane considerations such as cost and ease of use. If this is the case, a hot tip with a nonlaser power
source would be an appealing approach. Lu et al.\textsuperscript{11,12} have described both electrical and catalytic thermal tip catheters. Litvack et al.\textsuperscript{7} has described a radiofrequency power source that is capable of heating the metal cap to temperatures identical to those achieved with the argon laser power source; the device has been used successfully in humans. The advantages of these systems are that they are hand portable, require no special maintenance, and can be produced at a fraction of the cost of the laser. It seems likely, therefore, that if hot tip technology emerges as a preferred approach to peripheral vascular disease, laser energy will be replaced by a more practical power source. Alternatively, it is quite possible, even likely, that more than one device will find a place in intravascular therapy: one reasonable scenario is that the atherectomy catheter will be used for localized stenosis in straight vessels, the hot tip for long segment occlusions in large arteries, and the excimer laser for smaller vessels.

Extrapolating From Peripheral Vessels to Coronary System

For laser angioplasty, the coronary circulation differs from the peripheral circulation in two critical ways; one is readily apparent, the other is far less obvious. The evident difference is anatomic: the coronary artery is smaller in diameter, thin walled, and tortuous. This difference may have great significance in the choice of devices that are applicable to coronary arteries. Just as in the smaller arteries below the knee, heated metal caps frequently induce spasm in coronary arteries,\textsuperscript{13} and thrombus formation is also more frequent.\textsuperscript{14} Based on the first 14 human coronary cases thus far reported in letters to the editor and addenda to manuscripts, the rate of important complications such as perforation, thrombosis, and myocardial infarction appears to be quite high.\textsuperscript{15-17} Thus, the hot tip system, which seems to have much promise for larger peripheral vessels, cannot yet be recommended for use in the coronary arteries. It remains uncertain whether downsizing the tip or other design changes can resolve the spasm-thrombus problem. One can speculate that a similar problem will occur with the class of lasers that vaporize atheroma by heat.

The pulsed excimer laser, which can cut without producing histologic evidence of thermal injury, probably circumvents this particular problem. In the only coronary artery data yet available, Mohr et al.\textsuperscript{13} reported one incident of nitroglycerine-reversible coronary spasm with the excimer laser in the coronary arteries of 12 pigs. However, even if the excimer laser proves to be less prone to induce vasospasm, there are other problems that require resolution: the fiberoptic must be sufficiently flexible to traverse the tortuous coronary arteries and the diameter of recanalization, currently 0.5–1 mm, may need to be increased. Further, there is the possibility that nonthermal laser endothelial injury will also induce thrombosis when the depth of vascular penetration is sufficiently deep into the media. Nevertheless, given the level of our current knowledge and these important uncertainties, a reasonable case could be made that this technology currently holds the most promise for human coronary application.

There is a second less obvious difference between peripheral vascular and coronary arteries that has become apparent through clinical experience. Ileofemoral atherosclerotic disease is frequently characterized by 5–30-cm long segment occlusions. These obstructions are believed to be the result of an endothelial ulceration with retrograde propagation of thrombus. The vascular occlusion encountered by the angioplasty catheter, therefore, is a long length of organized thrombus. During angioplasty, one has the impression that the advancement of the angioplasty catheter is in part the result of mechanical force applied by the operator. We have very little insight into the capabilities of any system, hot tip or laser, to penetrate the more discrete fibrous and calcified lesions of human coronary arteries. I do not believe that success in peripheral vessels necessarily implies that similar effectiveness will be found for ablating atheromatous obstructions in coronary arteries.

In several important ways, therefore, I find that my view of the status laser angioplasty differs from that of my colleague. While I believe the hot tip can have an important role in peripheral angioplasty, I think it is unlikely that the energy source will be a laser. I also suspect that introduction of heat into smaller vessels will frequently cause spasm and that this will be an important limiting factor in coronary application. Even if thermal injury can be eliminated, however, I am not convinced that ablation of atheroma can be accomplished without thrombosis. Finally, while I do not share my esteemed colleague’s conviction that “we are definitely entering a new era of intervention techniques,” I do share his enthusiasm for the field of laser angioplasty to which he has made important contributions. As I imagine Mencken would have said, skepticism about today’s beliefs can pave the way for tomorrow’s knowledge.

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