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Percutaneous Laser Catheter Recanalization of Carotid Arteries in Seven Cadavers and One Patient

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Reports have been published describing successful in vivo recanalization of atherosclerotic plaque-occluded peripheral and coronary arteries using energy from argon and carbon dioxide laser sources [1–3]. In the case of the argon laser, optical fibers acting as waveguides incorporated in catheters were used. In the case of the carbon dioxide laser, direct line-of-sight application through a needle into a straightened artery was employed. These initial laser applications in the treatment of occlusive vascular disease in patients were based on extensive in vitro and animal data accumulated by numerous groups over the past five years [4–13]. Our group extended the range of these studies to carotid stenosis using a percutaneous approach. Seven cadavers and one patient were studied. The sole objective of the study was to determine the feasibility of percutaneous laser recanalization of partially and totally obstructed carotid arteries under fluoroscopic guidance.

Materials and Methods

The common, internal, and external carotid arteries were surgically exposed in seven cadavers. These consisted of three right and two left common carotid arteries and three right and two left internal carotid arteries, for a total of 10 arterial segments. Artificial thrombi were created in six of the arterial segments according to a method previously described [7]. Four of the segments contained native atherosclerotic plaque.

A 4-mm (ID) plastic tube was inserted into the external carotid for effluent studies. With clamp occlusion of the distal internal carotid artery during the lasing/flushing process, it was felt that cannulation of the external carotid artery alone would be sufficient to collect all the effluent. A steerable catheter with tip orientation controllable with four wires (Meditech, 9 French) was inserted via the Seldinger technique into the right femoral artery and guided fluoroscopically to the carotid lesion. A pre-laser angiogram was performed. The laser catheter, consisting of a dual channel 4-French cardiac catheter with a 100 μm core silica fiber in one channel, was calibrated with a power meter to register tip output and then inserted through the guiding catheter and advanced until the tip barely protruded beyond the guiding catheter. Saline flush was introduced at 50 ml/min through the empty channel. When the laser catheter tip was judged to be 1 to 2 mm from the lesion by fluoroscopy, the laser (Cooper Lasersonics Model 770, Argon) was turned on intermittently at 2 sec exposures (range: 6–9.5 watts; 22–88 sec) until the artery was patent.

Progress of thrombus/plaque ablation was monitored by sequential angiography. Patency was ascertained both by angiography and by visual monitoring. The totally obstructed artery is dark beyond the lesion; when patency is achieved, the distal arterial segment is brilliantly transilluminated. In arteries partially obstructed by plaque, the plaque-involved arterial wall transmits less light than the normal wall, and thus appears darker. When the plaque is ablated, transmission of laser light approaches that of the normal wall. Patency was determined angiographically by radiocontrast material flowing freely distal to the site of obstruction. The effluent from the external carotid artery was studied for particle size by millipore filtration and microscopic analysis.

Results

Perforation occurred in one of the four plaque-involved segments, and since the procedure was terminated at that point, two plaque segments could not be recanalized. Partial recanalization was achieved in one of the thrombosed arteries. Two other plaque-stenotic and five thrombosed arterial segments were completely recanalized (Figs. 1 and 2). Thus, of 10 arterial segments, recanalization was 0% in one, 25% in one, and 100% in seven; one was perforated. A partial laser recanalization of an internal carotid artery was performed in one patient without complications. Filtration and microscopic analysis of effluent revealed a paucity of debris, with no particle larger than 7 μm in diameter.

Discussion

Ablation of a thrombotic plaque by argon laser results from direct transfer of photon energy to the target tissue leading to a vibrational mode that generates intense heat. Each material has its own latent heat of vaporization. When this is supplied to a limited volume of tissue, vaporization results.

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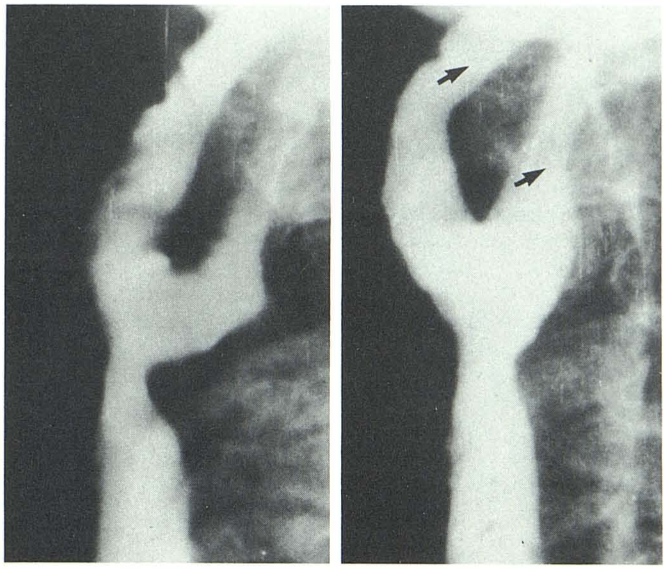
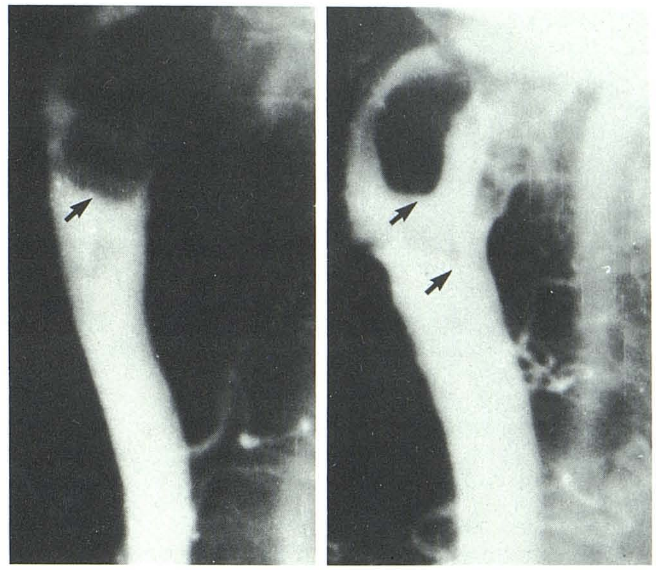


A B

Fig. 1.—**A**, Common, internal, and external carotid arteries with atherosclerotic changes in walls. **B**, Relatively smooth walls of same arteries after laser recanalization. Laser catheter was advanced as far as *arrows*.



A B

Fig. 2.—**A**, Thrombus occlusion (95%) of common carotid artery. Note meniscus sign (*arrow*). **B**, Angiographic appearance after laser recanalization. The zone of laser recanalization was between *arrows*. There is moderate run-off to internal carotid artery and good run-off to external carotid artery.

Local conduction of heat causes thermal damage to a narrow contiguous zone. Our use of a clear saline flush provides a "heat sink" to limit local thermal damage as well as a clear optical zone for the argon laser beam. Even very dilute blood absorbs the argon laser [14], reducing the power density (watts/cm^2) to an ineffective level.

The laser catheter tip is positioned 1 to 2 mm from the target tissue because the power density of the laser beam falls exponentially with increasing distance from the fiber tip [15]. This is due to a 14-degree divergence of the beam. Thus, if the laser catheter tip is greater than 2 mm from the target tissue, the power density is insufficient to produce ablation of the tissue.

Balloon angioplasty of extracranial cerebral arteries has been limited because of fear of potential distal cerebral embolization. In our current study, no particle larger than 7 μm was found in the effluent. Previous studies using two marker systems [15, 16] demonstrated absence of significant particulate matter generated by laser ablation of thrombi and plaque. However, there is a possibility that a fragment of ulcerated plaque can be dislodged by direct mechanical trauma from a catheter tip, and this must be addressed. Perhaps laser recanalization can be accompanied by external compression of the distal carotid artery or by an occlusive balloon placed distally, followed by active suction through the catheter at the end of the procedure. The use of the Meditech guiding catheter enabled us to steer the laser catheter with a high degree of confidence, and in no instance was there direct mechanical contact of the tip with the lesion. In future trials we plan to perform laser recanalization in patients under fluoroscopic guidance alone.

The laser catheter, introduced percutaneously, could conceivably reduce both morbidity, by decreasing the degree of invasiveness, and duration of hospitalization, by transferring the endarterectomy procedure from the operating room to the interventional radiologic suite. Further, there is a saving in time, since the laser recanalization can be accomplished concurrently with the initial angiogram. Whether the incidence of perioperative stroke, cerebral hemorrhage, and postoperative restenosis can match that of surgical endarterectomy can only become apparent in time.

We believe these first studies have demonstrated the feasibility of recanalizing stenotic carotid arteries with a laser catheter introduced at a remote site under fluoroscopic guidance. The relative safety of the procedure remains to be determined.

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