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CLINICAL INVESTIGATIONS

The qualitative effects of laser irradiation on human arteriosclerotic disease

To determine the effects of laser irradiation upon human coronary atherosclerotic disease, coronary plaques were extracted from fresh human cadaver hearts. Seventy-four diseased artery samples were sectioned either transversely or longitudinally and subjected to laser treatment from argon-ion and carbon dioxide sources. The laser beam affected vaporization and patency in fibrous, lipoid, and calcified plaques as observed histologically. Calcified blockage showed greater extent of charred remnants following controlled thermal injury than did fibrous or lipoid obstructions. The area and depth of penetration varied directly with intensity and duration of photoirradiation and inversely with the density of the atherosclerotic tissue. This study supports further research work on the use of lasers to effect relief of atherosclerotic obstructions. (Am Heart J 105:885, 1983.)

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During the past decade, the use of lasers has gained widespread applications in the fields of opthalmology,[1] otorhinolaryngology,[2] gastroenterology,[3] gynecology,[4] and dermatology.[5] However, its potential use in diseases of the heart and blood vessels, the foremost cause of death in the United States, is virtually unexplored. To determine the role of laser irradiation on atherosclerotic obstructions, we studied the effects of several laser sources, including argon-ion and carbon dioxide, upon human cadaver coronary arteriosclerotic occlusions.

METHODS

Material. Intact coronary arteries with arteriosclerotic plaques were extracted from patients who died from complication of coronary heart disease. The 74 samples utilized were fresh, generally not more than 3 to 4 days old. The diseased artery was either sectioned transversely or cut longitudinally exposing the entire inner luminal surface.

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Laser irradiation. The interaction of visible to midinfra-red wavelength laser radiation on coronary plaques was conducted by means of a Spectra Physics Model 170 argon-ion (4880-5145 A) and a laboratory-constructed carbon dioxide (10.6 μm) laser. The laser beam was focused by simple lens onto the transversely cut or longitudinally exposed arteriosclerotic artery which was mounted in ambient air at room temperature within 1 mm of the focus. The laser power intensity and exposure time upon coronary plaque samples were recorded. Typical focal lens and maximum laser powers were 13 W in the lowest-order transverse mode (TEMoo) and 10 to 60 cm focal lengths for the multiline argon-ion laser, and 5 W (TEMoo) and 40 cm focal length (barium fluoride) lens for the carbon dioxide laser. The estimated maximum intensity at each specimen was approximately 10^6 W/cm^2 at 4880-5145 A and 500 W/cm^2 at 10.6μ. The exposure times were varied from 1/50 to 25 seconds. A camera shutter was used for time exposures of less than 3 seconds; the laser was timed and controlled for longer exposures.

Histologic study. Following laser irradiation, the coronary artery samples were placed and fixed in formalin and later sectioned for staining with hematoxylin and eosin for histologic examination.

RESULTS

Area and depth of penetration by laser beam. The beam provided by an argon-ion laser or a carbon

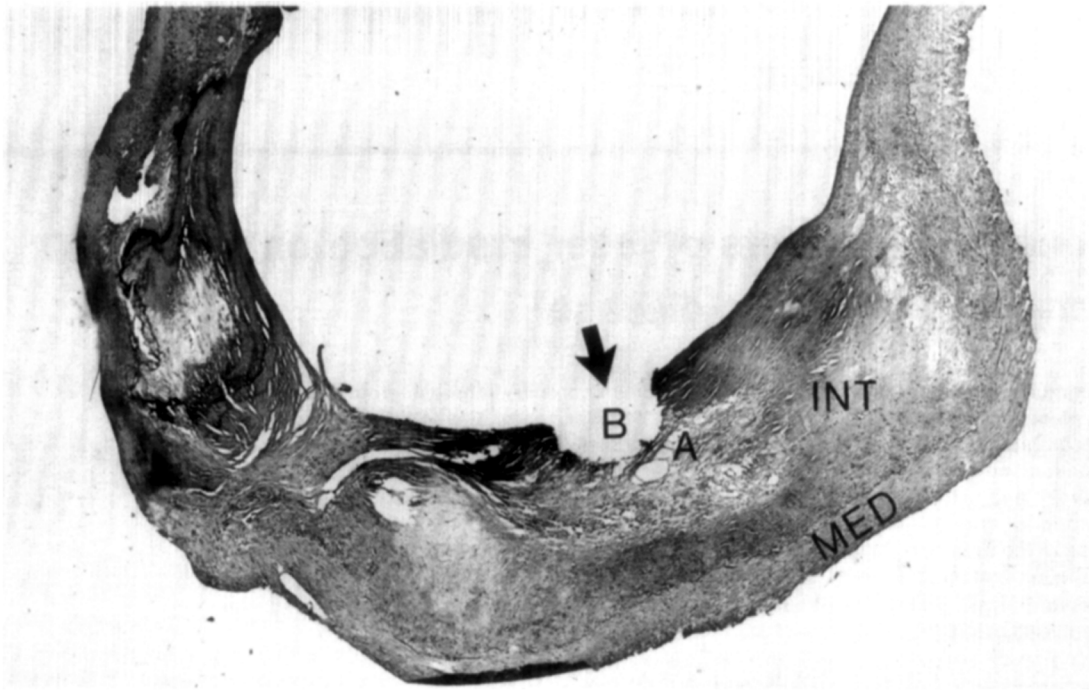

Fig. 1. Longitudinal section of human epicardial coronary artery exposing the inner luminal lining of the atherosclerotic plaque. An argon-ion laser beam (7 W, 0.4 second) directed perpendicular *(arrow)* to the hyalinized fibrous and lipid intimal area *(A)* of the plaque created a punched-out crater *(B)*. *INT* = intima; *MED* = media. (Original magnification ×26.)

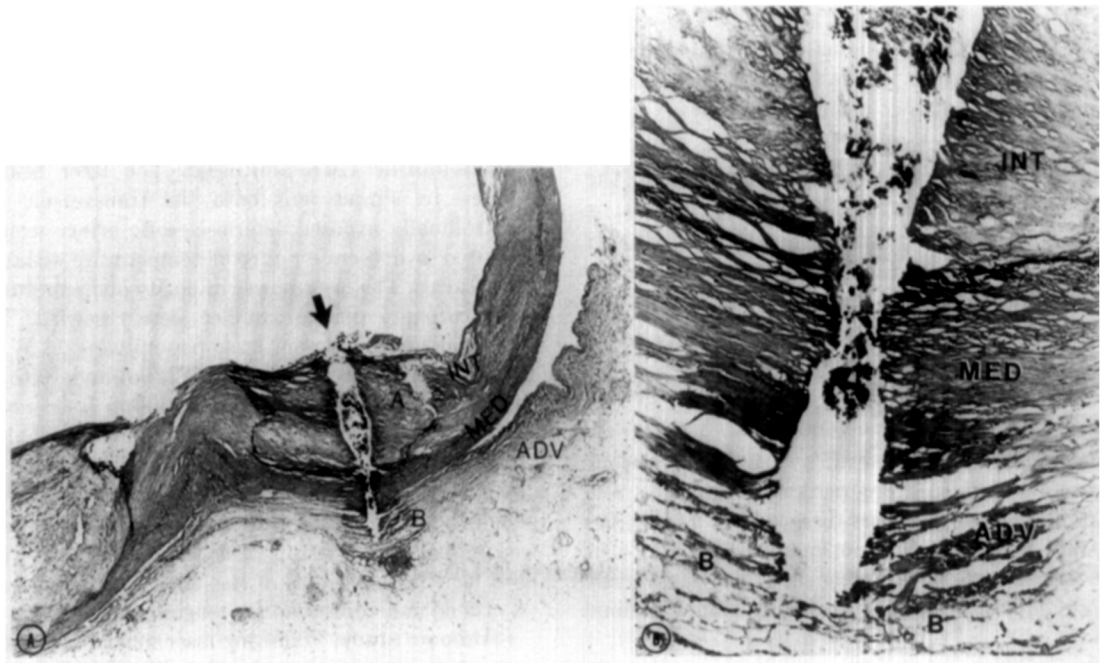

Fig. 2. A, Longitudinal section of another human atherosclerotic cornary artery. A higher intensity laser beam (10 W) *(arrow)* exposed for a longer duration (1.0 second) from an argon-ion laser source created a channel through a calcified atherosclerotic plaque *(A)* with extension through the entire vascular wall from the intima *(INT)* to the adventitial layer *(ADV)* and surrounding fat *(B)*. *MED* = media of coronary artery. (Original magnification ×26.) **B,** Higher power view (×130) of Fig. 2, *A*, demonstrating the channel created by the argon-ion laser beam. Note the dark rim produced by the laser path, the charred remnants within the channel adjacent to calcified and hyalinized areas in the intima *(INT)* and media *(MED)*, but no fragments adjacent to the lipid areas *(B)* of the adventitia *(ADV)*.

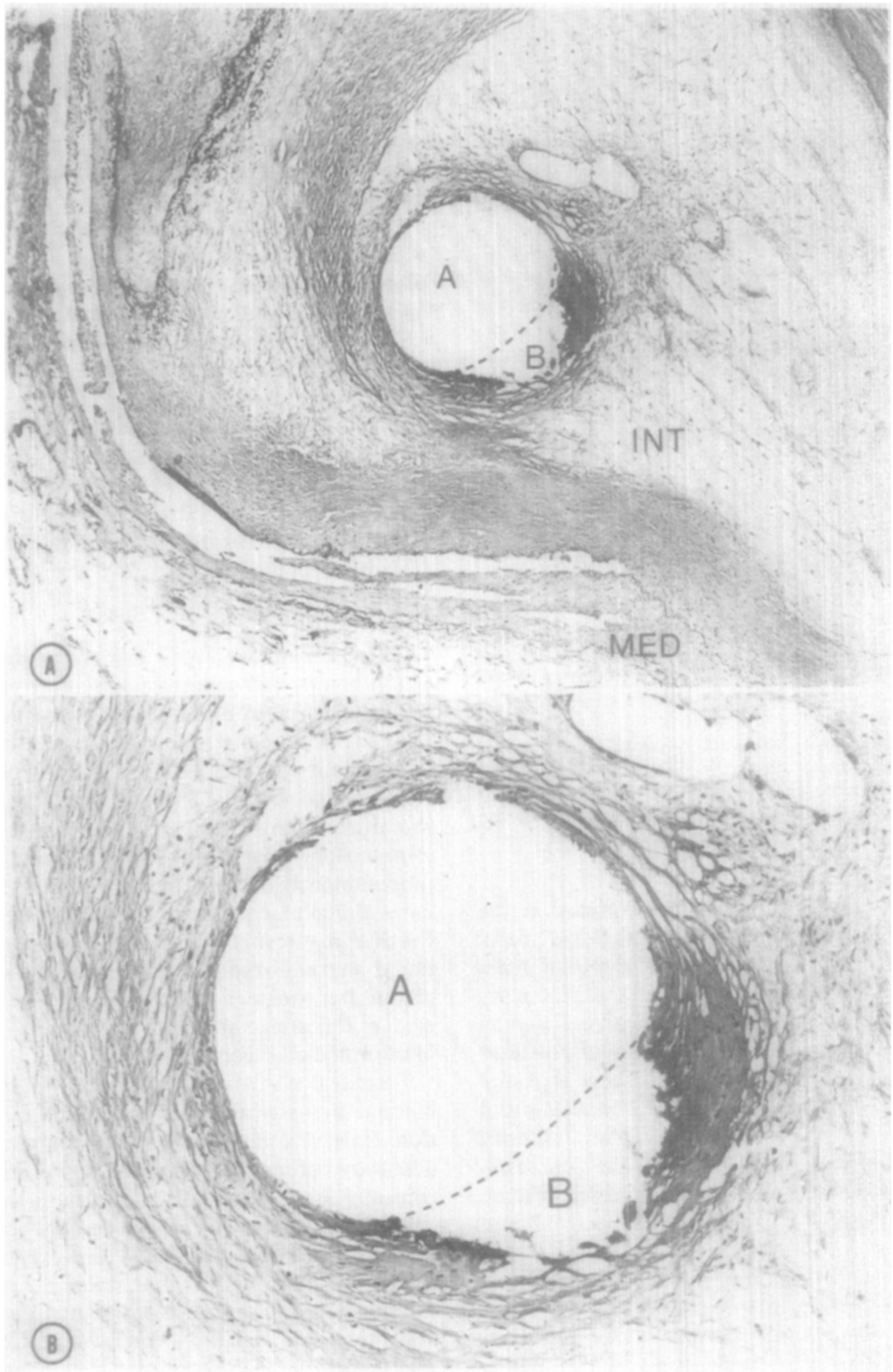

Fig. 3. A, Cross section of human atherosclerotic epicardial coronary artery showing the original lumen *(A)* and expansion of the luminal area *(B)* of approximately 25% by phototherapy from a carbon dioxide laser (40 W, 0.4 second). (Original magnification ×52.) **B,** Higher power view (×325) of Fig. 3, *A*. Note again the dark rim produced by laser irradiation on this fibrous fatty atherosclerotic plaque.

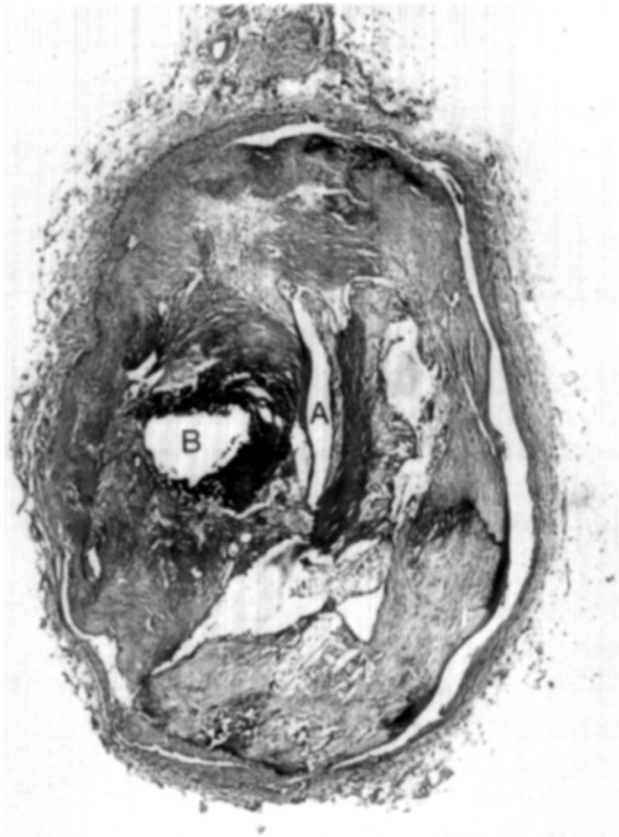

Fig. 4. Cross section of a severely obstructed human atherosclerotic coronary artery with its slitlike lumen *(A)*. Irradiation from a carbon dioxide laser (40 W, 0.4 second) vaporized a hyalinized fibrous area creating a channel *(B)* adjacent to the original lumen *(A)*. There is now a twofold widening of vessel patency with the newly created channel. Note the dark rim and the tiny fragments in the channel. (Original magnification ×26.)

dioxide laser produced a vaporized crater in the human coronary atheromatous plaques (Figs. 1 to 4). Generally, the punched-out area and depth of penetration varied directly with the laser power intensity and the duration of radiation exposure. As observed in the histologic sections in Fig. 1, an argon-ion laser of lower power intensity (7 W) and short exposure time (0.4 second) produced a crater 0.3 mm deep and 0.5 mm in diameter. In Fig. 2, a higher intensity argon-ion laser beam (10 W) with longer time exposure (1 second) focused onto a calcified plaque produced a channel 1.1 mm in depth and 0.2 mm diameter.

The area and penetrating capacity were not only dependent on power intensity and time exposure but also on the density of the tissue that was irradiated. Highly lipid-laden areas in the plaque were easily traversed and vaporized by the laser beam. Hyalinized or fibrous regions of the plaque and particularly calcified areas were more difficult to penetrate.

Expansion of the stenotic luminal area. The ability of laser irradiation to expand the narrowed lumen of atherosclerotic obstruction is demonstrated in the cross sections of human coronary arteries of Figs. 3 and 4. In Fig. 3, the stenotic luminal area was increased approximately 25% by phototherapy from a carbon dioxide laser source. In Fig. 4, the laser exposure to an area adjacent to the narrowed slit lumen more than doubled the original luminal area.

Effects of laser irradiation. During laser irradiation of an atherosclerotic plaque, gas was emitted as tissue vaporization occurred. The laser beam left a dark rim of irradiated tissue along its beam path (Figs. 1 to 4). Depending on the type of tissue which had undergone thermal injury, remnants of charred material may be left in the irradiated pathway or channel. Phototherapy of chiefly lipid-laden plaque material produced vaporization but no charred debris in its beam path (Figs. 1 and 3). Hyalinzed fibrous (Fig. 4) and particularly calcified plaques yielded greater amounts of residual fragments in their beam paths (Fig. 2).

DISCUSSION

This preliminary study demonstrates that laser phototherapy can penetrate and affect vaporization of human coronary atherosclerotic plaques. The area and depth of penetration vary directly with the laser's ability to focus its beam, power intensity, and time of exposure, and inversely with the density of the atherosclerotic tissue the laser beam traverses. Penetration is easier with plaque being comprised predominantly of lipid deposit, whereas it becomes more difficult to penetrate the harder calcified area. Further, as previously reported, no fragments were found in the irradiated pathway of chiefly lipid plaque but greater extent of charred material was evident following vaporization of fibrous and particularly calcified obstructions.[6]

The ideal result is the expansion of the stenotic luminal diameter and the relief of vascular obstruction. However, more basic experimental research is necessary before laser phototherapy can be applied clinically for the dissolution of atherosclerotic vascular obstructions. The heat-generated power intensity and time exposure of the laser beam must be accurately controlled so that thermal injury is not extended beyond the vascular obstruction. The thermal interaction with red blood cells must be studied. The density of the atherosclerotic plaque composition must be reasonably estimated. The effects and outcome of the gas emitted by the vaporization process and of the charred remnants remaining in the irradiated pathway also must be known.

A laser catheter prototype (Trimedyne, Inc., Arlington Heights, IL) equipped with a laser fiber, and illumination and viewing, fiber bundles, and distal suction and flushing capabilities has been devised. More recently, we have demonstrated the practicality of observing and conducting laser energy into living blood vessels.[7] Further investigations are currently in progress to determine the applicability of this new therapeutic modality in the clinical relief of atherosclerotic obstructions in the coronary and other vascular beds.

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Exercise training improves lipoprotein lipid profiles in patients with coronary artery disease

The effects of endurance exercise training on plasma lipoprotein lipids were determined in 10 men, ages 46 to 62 years, with coronary artery disease (CAD). Patients maintained body weight, health-related behaviors, and stable diets throughout the program. Training was at 50% to 85% of maximal oxygen consumption ($\dot{V}O_2$ max) for 40 to 60 minutes, 3 to 5 days/week for 29 ± 7 weeks. Training increased $\dot{V}O_2$ max (31 ± 19%, $p < 0.001$), reduced plasma cholesterol (C) (−8 ± 4%, $p < 0.01$), low-density lipoprotein-C (LDL-C) (−9 ± 9%, $p < 0.01$), and triglyceride (TG) (−13 ± 32%, $p < 0.05$) concentrations, and increased high-density lipoprotein-C (HDL-C) levels (11 ± 13%, $p < 0.05$) and HDL-C/LDL-C ratios (25 ± 20%, $p < 0.01$). Changes in LDL-C and $\dot{V}O_2$ max were correlated ($r = -0.73$, $p \pm 0.01$), while the changes in LDL-C and HDL-C each correlated inversely with pretraining lipoprotein levels (rLDL-C = −0.77, $p < 0.01$; rHDL-C = −0.68, $p < 0.05$). Thus potentially "antiatherogenic" benefits of exercise seem to be due to a training effect, since they correlate best with changes in $\dot{V}O_2$ max and are maximal in patients with initially low $\dot{V}O_2$ max, high LDL-C, and low HDL-C levels. (AM HEART J 105:889, 1983.)

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Epidemiologic studies report a direct relationship between plasma low-density lipoprotein cholesterol (LDL-C) levels and the prevalence of coronary heart disease.[1,2] The relationship for high-density lipoprotein cholesterol (HDL-C) is an inverse one, indicating that high levels of HDL-C are protective against coronary heart disease.[3,4]

Cross-sectional studies show that individuals who engage in endurance exercise training on a regular basis have lower plasma levels of LDL-C,[5,7] total