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EDITORS:
WILLIAM C. STWALLEY
UNIVERSITY OF IOWA

MARSHALL LAPP
SANDIA NATIONAL LABORATORIES

TISSUE MORPHOLOGIC ANALYSIS AND ABLATION RATES IN THE UV AND VISIBLE FOR LASER ANGIOPLASTY

M. Sartori, P.D. Henry, and R. Roberts
Section of Cardiology, Baylor College of Medicine, Houston, TX 77030

R. Sauerbrey and F.K. Tittel
Department of Electrical and Computer Engineering, Rice University
Houston, TX 77251-1892

ABSTRACT

Ablation rates were determined in human and canine aortas subjected to excimer and visible laser radiation. For UV and pulsed frequency doubled Nd:YAG lasers ablation rates were constant and depended linearly on average laser power, while for cw argon lasers ablation rates depended nonlinearly on laser power.

DISCUSSION

A major difficulty in applying lasers to cardiovascular therapy is arterial perforation. Therefore, it is important to assess in quantitative terms how changes in laser parameters influence the extent of laser induced injury. In this study, ablation rates for different lasers are experimentally determined.

The lasers used in this study were an excimer, argon ion, and a pulsed frequency doubled Nd:YAG laser. The excimer laser was operated at 193, 248, and 351 nm. The argon laser radiation used was continuous wave (cw) and chopped (duration 50 msec). The pulsed frequency doubled Nd:YAG laser was chosen because it generates a wavelength (532 nm) that is similar to the wavelength of the argon laser and pulse width (7 ns) close to the pulse duration of the excimer laser (12-20 ns). Segments of dog and human aortas were mounted perpendicular to the path of the laser beam at the focal point of a CaF_2 lens ($f \cong 50$ cm). Perforation of the sample was detected by placing an energy meter behind the sample.

The relationship between power and tissue penetration of the cw argon laser in the dog aorta is illustrated in Fig. 1. For power densities up to 12 W/mm^2, no ablation occurred in a time period of 60 seconds. However, with only a minor increase in power density to 14 W/mm^2, there was a dramatic increase in crater depth accompanied by wall perforation. A similar phenomenon was observed for argon laser radiation in the chopped mode. Thus, in these experiments the ablation rate has a strongly nonlinear dependence on the laser power density with cw and chopped argon laser radiation.

Effects of UV pulsed lasers on dog aorta are shown in Fig. 2. The crater depth produced by the lasers at a constant power density and repetition rate is plotted as a function of the irradiation time. In contrast to the argon laser, the crater depth (d) was proportional to the duration of exposure to irradiation (t). Thus, the slopes of the straight lines representing the ablation rates ($R = d/t$) were independent of d and t. Similarly, with pulsed Nd:YAG irradiation the crater depth increased linearly with time for constant power density and repetition rate. By varying power density and/or repetition rate of the pulsed UV and Nd:YAG lasers, it was demonstrated that R was a linear function of the product of power density and repetition rate only.

Comparing ablation rates at the same average power density of 1 W/mm^2, the R values for KrF, Nd:YAG, ArF, and XeF were 120, 75, 15, and 12 μm/s. No power density threshold was observed for ArF and KrF within the investigated parameter range.

This study shows the advantage of pulsed lasers as compared to cw laser irradiation for the effective control of tissue ablation. The linear relationships between ablation rate and laser power density for pulsed lasers make the ablation predictable. In the case of cw lasers, ablation rates increased nonlinearly with increasing power, making the selection of appropriate irradiation parameters difficult. The lack of control with cw lasers may explain the high incidence of perforation reported with the use of such lasers [1,2].

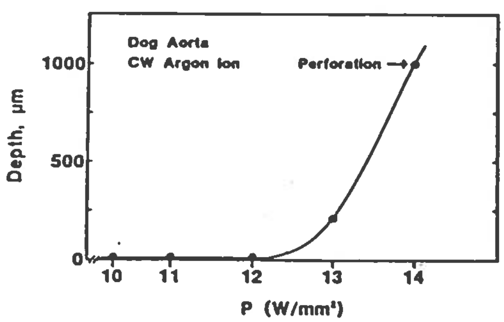

Fig. 1: Ar ion laser penetration depth as a function of power density for dog aorta.

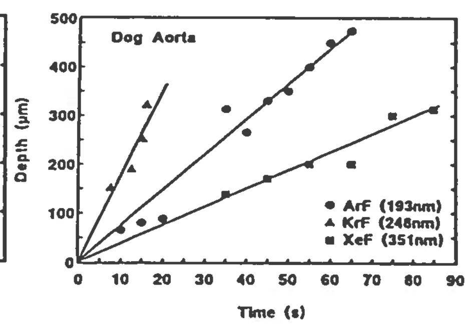

Fig. 2: Excimer laser penetration depth as function of irradiation time for a constant power density of .375 W mm^{-2}.

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