15. LASER ANGIOPLASTY WITH OPTICALLY MODIFIED FIBER TIPS

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From the short UV to the far infrared wavelengths, lasers are capable of evaporating tissue, such as atheromatous plaque [1, 2]. Percutaneous laser angioplasty, however, requires the intra-arterial delivery of the laser beam by a thin, flexible fiber (Figure 15-1). Suitable fibers are commercially available only in the range of about 200- to 2200-nm wavelengths. Outside this range, attenuation of fiber transmission is prohibitive [3]. As a result, percutaneous laser angioplasty with a CO₂ laser is still experimental.

Initial attempts at percutaneous laser angioplasty were accomplished with fibers 300-600 μm in diameter, coupled to an argon or a CW Nd:YAG laser. The distal end of the fiber tip was bare, i.e., the support was removed at the end for a few millimeters, and core plus cladding protruded from the guiding catheter (Figure 15-2).

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IV. LASER DELIVERY SYSTEMS

LASER ANGIOPLASTY

FIBER CATHETER

BARE FIBER TIP

FIGURE 15-1. Diagram of percutaneous laser angioplasty. Used with permission from Borst [16].

Bare Fiber Lasing

The rationale for modifying the fiber tip was based on a number of serious problems encountered in the early experimental [4–7] and clinical studies [8–10] using a bare fiber. First, the thin, bare, fiber tip is exceedingly sharp and easily perforates the artery wall mechanically (Figure 15-2). Second, the fiber tip is invisible under fluoroscopy, and, third, it provides no tactile feedback at all during catheterization. Fourth, it is difficult to direct the laser beam axially in a tortuous artery. Thus, as a result, a beam from a CW Nd:YAG laser may easily cause thermal perforation of a coronary artery. Both mechanical and thermal perforation are, to a large extent, due to the incapacity to identify the axis of the obstructed segment and to aim properly. To date, target identification and aiming problems still are the major obstacles to the clinical application of laser angioplasty in the coronary arteries. Fifth, the presence of blood between the fiber tip and target tissue modifies energy delivery to the target tissue because the Nd:YAG (1064 nm) and, especially, the argon wavelengths (488 and 514 nm) [11–13] are strongly absorbed by blood. A sixth problem encountered in the early studies using CW lasers is backburning of the silica fiber, usually due to the presence of blood, which causes excessive absorption and heat generation at the tip. To obtain a proper output beam profile, the fiber core must have a perfectly polished end. As a result of backburning, the spatial distribution of the output beam becomes unpredictable and the distal end of the guiding catheter melts. The seventh problem is the inadequate lumen size of the channel, which is created by a laser beam from a 600-μm fiber. As a result, in the femoropopliteal artery, the laser channel has to be enlarged by balloon dilatation or by some other method. It is to be expected that, similarly, coronary recanalization with flexible fibers with 100- to 250-μm core diameters results in channels that are also too narrow [14–16].

Modifications of the Fiber Tip

For different reasons, various modifications of the fiber tip were proposed shortly after the start of laser angioplasty in 1980. Common to this particular strategy to reduce the risk of vessel-wall perforation were the need for visualization of the fiber end,atraumatic tissue contact, and tactile feedback, displacement of blood from between the fiber end and the target, and a larger channel.

Abela and coworkers [17] originally added a radiopaque,atraumatic metal ring to the fiber end to visualize the tip. The metal ring later expanded into the 2-mm diameter “hybrid” metal laser probe described by Abela in Chapter 16.