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Review

Endovascular techniques for the treatment of chronic insufficiency of the lower limb's superficial venous system

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ABSTRACT

Endovenous procedures have nowadays mostly replaced classic surgery in the treatment of superficial venous insufficiency. Over the past 15 years substantial evidence has accumulated for two thermal endovenous procedures (endovenous laser ablation and radiofrequency segmental ablation) and novel methods has been developing with the aim to make the treatments even simpler, safer but equally efficacious as the well established thermal methods. Here we have reviewed principles and evidence behind all endovenous procedure with the exception of foam sclerotherapy. Covered are also other thermal interventions like steam ablation, bipolar radiofrequency and microwave ablation, and mechanochemical ablation and cyanoacrylate glue embolization.

Contents

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Introduction

Chronic venous disease ranges from asymptomatic venous valve incompetence to varicose veins, skin changes, and venous ulceration. Such changes are termed chronic venous insufficiency (CVI). CVI causes considerable morbidity and has high treatment costs. Positive family history, increasing age, pregnancy, and obesity are likely predisposing factors for the development of CVI [1,2]. According the Edinburgh vein study, visible varicose veins (C2) are a common condition affecting 18.2% (15.2–21.6%) of population (annual incidence rate of 1.4%). Incidence of CVI was similar in men and women and increased consistently with age ($P < 0.001$) [3]. There is evidence that a high proportion of patients with uncomplicated varicose veins in the CEAP Clinical Class 2 will progress to CVI, if untreated [1]. In addition, varicose veins in all clinical stages have a negative impact on quality of life [4]. Varicose veins patients with CVI (C3–C6) as well as those C2 patients with severe clinical symptoms and impaired quality of life due to CVI should be treated with ablation of the varicose veins. Recent NICE guidelines considering the varicose vein treatment recommend first endovenous thermal ablation procedures (radiofrequency and laser ablation), then foam sclerotherapy and, only if previous methods are contraindicated or unavailable, classic surgical treatment (high ligation with stripping) [5]. The minimally invasive endovenous procedures have also been considered cost-effective compared to standard surgical treatment [6]. Endovenous procedures thus became the first line treatment of CVI.

Here we present an overview of available endovenous methods for varicose veins' treatment (with the exception of sclerotherapy) both those firmly established and those that may be considered either still experimental or with insufficient data on clinical efficacy and safety to be unequivocally positioned within the armamentarium of endovenous procedures.

Endovenous thermal ablation techniques

Endovenous laser ablation

Mechanisms of action

Endovenous laser ablation (EVLA) is, with the exception of foam sclerotherapy, the most commonly performed endovascular procedure for the treatment of varicose vein disease [7]. Basically it is the targeted use of laser light to heat up the vein wall causing its damage and consequently the vein's closure and fibrosis [8]. The following wavelengths are in current use for EVLA: **810**, 940, **980**, 1064, 1319, 1320, **1470**, 1500, 1540 and 2068 nm – those printed in bold are used most commonly. What is the mechanism of heat delivery in EVLA? Recent mathematical modeling offered compelling evidence that vein wall injury is mediated primarily by the heat flow from the laser tip originating from two sources: the carbonized laser tip (reaching temperatures as high as 1200 °C) and hot blood surrounding the laser tip as a consequence of direct light absorption [9–11]. According to the model the wavelength is not crucial for the final effect as the vein wall absorption of laser light is negligible in any laser type. Carbonization of the laser tip, which occurs at about 300 °C, is noted following EVLA, and seems to occur regardless of the wavelength used [12,13]. Carbonization of the fiber tip creates a point heat source and reduces light penetration into blood by 30–70% [13]. These findings sound plausible inasmuch as there have not been studies showing significant differences in clinical efficacy of lasers of various wavelengths. Obviously it is imperative to thermally damage the vein wall adequately in order to obtain effective ablation [8]. Histological changes in the veins treated by EVLA confirms immediate loss of intima, whereas at 1 month vein wall thickening, intraluminal heat-generated thrombus and inflammatory changes with many fibroblasts and inflammatory cells. At 4 months, collagen was the predominant histologic finding [14]. How much the heat generated within the vein dissipates into the surrounding tissue potentially causing collateral damage? A study measured peak temperature at the outer vein wall during EVLA in a live pig ear vein and in exposed hind limb veins [15]. Results demonstrated that peak temperatures ranged from 34.6 °C to 49.1 °C as a function of joules delivered, with lower peak temperatures obtained when tumescent fluid was present. In a human study during EVLA (12 patients, 810 nm, 12 W, 1 s pulses, 1 s intervals, tumescent technique), peak temperatures were 43.3 °C, 42.0 °C, and 36.0 °C measured at 3 mm, 5 mm, and 10 mm from the GSV, respectively [16].

Although it is widely accepted that tumescent solution is very important for efficacy and safety of EVLA, a study showed that, if performed under general sedation and external cooling with ultrasound probe pressure, treatment with 980-nm laser is as safe and effective as when the procedure is performed with the tumescence [17]. Moreover our group has shown, in more than 600 treated saphenous veins, that when EVLA is performed under general or regional anesthesia with 810-nm laser without any tumescence, cooling or external pressure, it is not only equally effective as the same procedure with tumescent solution but actually with less side effects like ecchimoses and postoperative pain (Schuller-Petrović et al., *manuscript in preparation*). Thus, at least for bare fiber lasers, it may be that intraluminal blood enables adequate heat diffusion and reduces direct fiber contact with the vein wall (the principal cause of perforation). Continuous laser light delivery is better that the intermittent [13]. Many authors have shown that a threshold of delivered laser energy is required for long-term closure: energy density (J/cm of vein's length) of at