909. Low frequency and high intensity ultrasound in vascular surgery: theory, instrumentation and possibilities of clinical application

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Abstract. This paper presents a brief review of applications of ultrasound in modern surgery and results of original studies of the authors in the field of application of low frequency (24-36 kHz) high-intensity (up to 20 W/cm²) ultrasonic vibrations for disruption of thrombi and calcified atherosclerotic plaques in blood vessels. Application of non-rigid wire ultrasonic waveguides with length up to 980 mm and diameter of working tip down to 0.3 mm enables minimally invasive surgical intervention, since a waveguide can be introduced along curved segments of blood vessels through a small incision situated at substantial distance from occlusion. Ultrasonic angioplasty can be successfully applied in combination with administration of thrombolytic drugs. The paper also considers physical mechanisms of thrombus disruption under influence of ultrasonic vibrations, particularly, effects of cavitation and acoustic streaming. We described design of ultrasonic waveguides for endovascular surgery and their manufacturing technology based on plasma-electrolytic etching. Application of finite element method and transfer matrix approach for design and model of wire waveguides is considered. Description of clinical system for ultrasonic angioplasty with automated resonance tuning of a waveguide is also provided. In addition, we report results of clinical application of ultrasonic angioplasty in patients with occlusion of iliofemoral segment.

Keywords: low-frequency ultrasonic vibrations, waveguides, finite element method, thrombolytic therapy.

Introduction

Ultrasound is widely used in medicine practice including functional diagnostics, therapy and surgery, due to its ability to produce targeted and controlled action on biological tissues. In surgical applications low-frequency ultrasound of high intensity (with frequency from 20 to 80 kHz) and high-frequency ultrasound of high intensity (with frequency from 0.5 to 4.0 MHz) also known as High-Intensity Focused Ultrasound (HIFU) are used. Low-frequency ultrasound is used to excite vibrations in surgical tools and reduce invasiveness of surgical procedures, it helps to increase efficiency of surgeon’s work due to the increase in cutting speed and reduction of cutting force, provides haemostatic and antiseptic effects [1-3]. Moreover, application of ultrasound enables selective dissection of tissues. High-frequency ultrasound is often used in the form of focused beam for non-invasive ablation of soft tissues, e.g. skin or brain tumors [2, 4-6]. Frequency ranges indicated above are approximate: for example, miniature surgical tools use vibrations with frequency up to 290 kHz [7]. Clinical applications of low-frequency ultrasound include cutting of soft tissues and bones, drilling of bones, fragmentation and aspiration. Ultrasonic surgical tools are widely used in minimally invasive and endoscopic operations [8]. Recently one of other actively developing directions of ultrasound application is