Ultrasound transducers for endoscopic dual thermal therapy of deep-lying tissue

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Background, Motivation and Objective

Photothermal therapy (PTT) has the advantage of selective treatment, but it has a disadvantage that the treatment depth is limited due to light scattering in tissue. To overcome this limitation, dual thermal therapy (DTT) was previously proposed, in which both ultrasound and light are simultaneously transmitted into a treatment region; the ultrasound energy only raises the temperature up to 40°C to avoid normal tissue damage, and the light energy eventually increase the temperature of the target chromophores to above 60°C, thus increasing the treatment depth of PTT. Endoscopic PTT has been used for treating colon, esophagus, and stomach cancers, but it has the same problem of limited treatment depth. Although DTT is able to solve the problem, it is challenging to develop a DTT probe accommodated in a commercial endoscopic probe of which size is up to 14 mm in diameter.

Statement of Contribution/Methods

The endoscopic DTT probe consists of two ultrasound transducers with a diameter of 8 mm, an optical fiber, and an optical lens (see Fig. 1(a)). The transducers were designed to have a center frequency of 3 MHz and a focal length of 10.8 mm. The two transducers were tilted 25 degrees from the lateral axis to achieve maximum ultrasound energy at treatment depths ranging from 10.8 mm to 16.5 mm by overlapping the focal areas of each ultrasound transducer. The two transducers were 6 mm apart, and a 2 mm hole was created between the two transducers. A 45-degree rod lens with a diameter of 2 mm was used to transmit light through the hole.

Results/Discussion

The beam field measured using a hydrophone showed that the two beams generated by the two transducers were properly overlapped; the overlap was about 3.8 mm in the axial direction and 1.8 mm in the lateral direction (see Fig. 1(b)). When only the laser with a fluence of 10 mJ/cm^2 was irradiated into the tissue-mimicking phantom, coagulation did not occur in the phantom (see Fig. 1(c)). When only ultrasound with an I_{SPTP} of 171 W/cm^2 was transmitted, coagulation was not observed in the phantom (see Fig. 1(d)). However, when both laser and ultrasound were simultaneously delivered, coagulation occurred with a length of 3.44 mm that was similar to the beam overlap region in the axial direction. The experimental results demonstrated that the developed endoscopic DTT probe is able to solve the limited treatment depth problem of endoscopic PTT.