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Reduced Debris Size and Improved Efficiency in Acoustic Vortex-assisted Sonothrombolysis

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Background, Motivation and Objective

The potential of HIFU to induce thrombolysis has been demonstrated previously. However, clinical concerns still remain related to the size of clot debris produced via fragmentation of the original clot potentially being too large and hence occluding downstream vessels, causing hazardous emboli[1]. Though standing waves formed via HIFU have been demonstrated to generate smaller debris than travelling waves[2], their maneuverability was limited *in vivo*. In this work, we introduce acoustic vortex into sonothrombolysis in an attempt to reduce the clot debris size and improve the sonothrombolysis efficiency.

Statement of Contribution/Methods

A focused acoustic vortex (PNP: 500 KPa) was generated by a 16-element spherical transducer (center frequency: 645 KHz), and its focus was overlapped by that of a HIFU field (PNP: 4.49 MPa) generated by a 1.6 MHz concave transducer. Another 5 MHz focused transducer was used to monitor the cavitation activity. Clots (approximately 5 mm in diameter and 20 mm in height) were placed in a transparent tissue-mimicking phantom with a wall-less vessel of 6 mm diameter. The size distribution of the resulting debris was measured by a Coulter Counter particle sizing system after each treatment. A microscope was used for real-time observation of the thrombolytic process (cf. Fig. 1).

Results/Discussion

The measurement of the clot debris indicated that the volume percentage of the large particles (above 10 µm) was significantly reduced when introducing vortex (cf. Fig. 2), especially at high duty cycle, as well as the average diameter of the debris calculated by volume percentage. Thrombolysis efficiency increased with co-occurrence of vortex, and it increased with the increasing duty cycle (cf. Fig. 3). Stable cavitation dose (SCD) and inertial cavitation dose (ICD) showed opposite trends with the increasing duty cycle, but both were smaller in vortex-assisted thrombolysis (cf. Fig. 4). The latter indicated that a reduction of the clot debris size with vortex may be attributed to the particle trapping of the acoustic potential well (cf. Fig. 5) which contributed to particle fragmentation.

Ref.

[1] A.D. Maxwell, et al., Ultrasound Med. Biol. 35: 1982–1994 (2009).
[2] S. Guo, et al., Appl. Phys. Lett. 111, 123701 (2017).

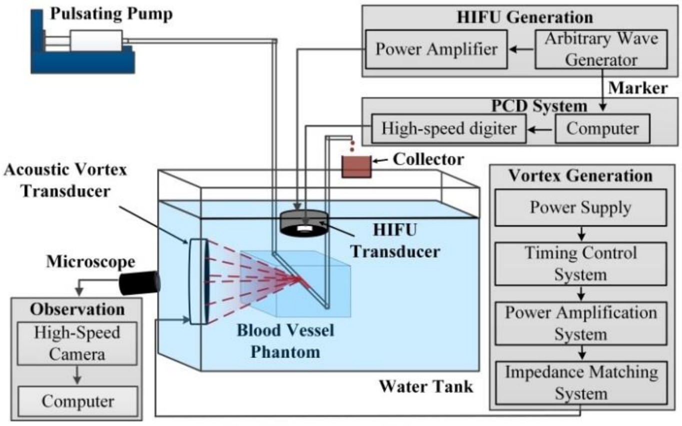
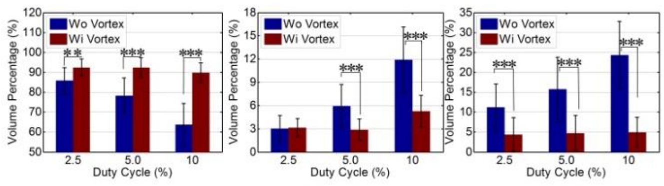
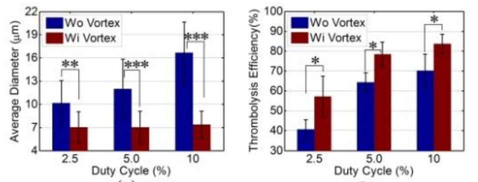


Fig. 1 Experimental Setup.



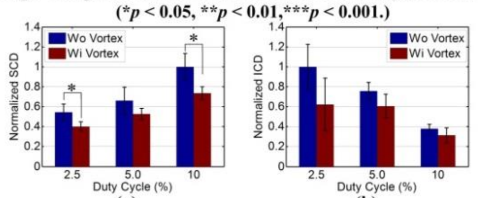
(a)2-10 µm (b)10-30 µm (c)30-60 µm

Fig. 2 Volume distribution of the debris in thrombolysis with and without vortex. (*$p < 0.05$, **$p < 0.01$,***$p < 0.001$.)



(a) (b)

Fig.3 Comparision of the debris size and thrombolysis efficiency. (*$p < 0.05$, **$p < 0.01$,***$p < 0.001$.)



(a) (b)

Fig. 4 Comparision of the cavitation activity in sonothrombolysis. (*$p < 0.05$, **$p < 0.01$,***$p < 0.001$.)

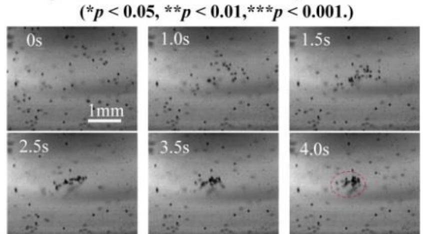


Fig.5 Aggregation process of disperse polystyrene microspheres.