

Cavitation fields induced by shock wave propagation in polyacrylamide gel and ex-vivo porcine tissue

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Device and producing company:

OssaTron (HMT, SanuWave) D-Actor 100 (Storz Medical)

Introduction:

Extracorporeal shock wave therapy (ESWT) is the application of acoustic waves to biological tissue in the treatment of disease. These high-pressure acoustic waves deposit energy mainly at high acoustic impedance gradients through shear forces and cavitations. When this energy is released in biological tissues, the shock waves create cavitation bubbles, produce free radicals, and yield extremely high localized temperature. Cavitations are generated from the tensile portion of the shock wave (SW). It has been shown tissue cavitations can be induced by tensile pressure as low as -1 MPa. When cavitations collapse near an interface they create micro-jets pointing towards the interface and have been shown to erode kidney stones, disturb cell membrane and injure blood vessels. Therefore, roles of cavitations on a variety of SW's therapeutic efficacies as well as potential tissue injury need to be fully explored.

Methods:

Cavitation fields generated by an electrohydraulic SW device (OssaTron - HMT, SanuWave) were compared with an unfocused pressure wave device (D-Actor 100 - Storz) in polyacrylamide gel blocks, with and without an embedded marble (2cm diameter, marble-gel interface at 4.5 cm depth), and in ex-vivo porcine thighs. Cavitation fields were monitored sequentially during the application using B-mode ultrasound with MicroMaxx (Sonosite).

Results:

In polyacrylamide gel, OssaTron produced a deep (-2 cm) oval-shape cavitation field. Increases in SW energy density resulted in increases in both size and intensity of the cavitation field. Saturation of cavitation field was appreciated around 500 shocks. Increasing disruptions of the marble-gel interface from both shear stresses and cavitations were distinct with increasing number of shocks and energy density. D-Actor produced a superficial radially-diverging cavitation field, which increases in intensity with increasing number of pulses and application Pressures. Saturation of cavitation field was alan annrriated around 500 pulses. Minimal disruptions of the marble-gel interface from both shear stresses and cavitations were observed. In ex-vivo porcine thighs, using highest possible energy levels, both OssaTron and D-Actor did not produce any measurable cavitation field up to 3000 pulses cumulatively.

Discussion:

Cavitation fields with different characteristics can be generated using either a focused SW device or an unfocused pressure wave device. Presence of cavitation bubbles may greatly diffract subsequent SW propagation. Ex-vivo porcine thighs are highly resistant in producing cavitation.

Conclusion:

Both shear stresses and cavitations are important physical effects from SW application. Cavitations may induce therapeutic as well as damaging biological responses therefore need to be carefully controlled in ESWT. Characteristics of cavitation fields are tissue-, anatomy-, device-, and operation-dependent. There is obvious dynamic interaction between induced cavitations with SW applications that may greatly affect ESWT outcomes. Treatment of deep target tissue requires focused SW delivery of desired therapeutic dosages.