Ultraschall Med 2005; 26
DOI: 10.1055/s-2005-917370

ULTRASONIC DESTRUCTION OF MEDICAL MICROBUBBLES: AN OVERVIEW

M Postema[1], FJ ten Cate[2], CT Lancée[3], G Schmitz[1], N de Jong[4], A van Wamel[3]
[1] Institute for Medical Engineering, Ruhr-Universität Bochum, Bochum, Germany
[2] Department of Cardiology
[3] Department of Experimental Echocardiography, Thoraxcentre, Erasmus MC, Rotterdam
[4] Physics of Fluids, Faculty of Science and Technology, University of Twente, Enschede, Netherlands

Purpose: Ultrasound contrast agents consist of bubbles in the micrometer range encapsulated by nanoshells. These medical microbubbles oscillate linearly upon insonification at low acoustic amplitudes, but demonstrate highly nonlinear, destructive behavior at relatively high acoustic amplitudes. Therefore, medical microbubbles have been investigated for their potential applications in local drug and gene delivery. We used fast-framing photography at more than a million frames per second to investigate medical microbubbles in a diagnostic ultrasonic field. In this presentation, we give an overview of the physical mechanisms of medical microbubble destruction.

Methods and Materials: Three ultrasound contrast agents were studied with high-speed photography during insonification. The agents were inserted through a cellulose capillary with a diameter of 0.2mm. The capillary was positioned below a microscope whose optical focus coincided with the ultrasonic focus. We captured images of insonified medical bubbles at higher frame rates than the ultrasonic frequency transmitted (typically 0.5MHz). The acoustic amplitudes corresponded to mechanical indices between 0.03 and 0.8. To compare theory and experiments, we simulated insonified medical microbubble behavior, based on the behavior of large, unencapsulated bubbles in an acoustic field.

Results: At low acoustic amplitudes (mechanical index <0.1) bubbles pulsate moderately, as predicted from theory. At high amplitudes (mechanical index >0.6) their elongated expansion phase is followed by a violent collapse. Microbubbles have been observed to coalesce (merge), fragment, crack, and jet (act as a microsyringe) during one single ultrasonic cycle. From our observations of jetting through medical bubbles, we computed that the pressure at the tip of the jet is high enough to penetrate any human cell. One image sequence reveals the temporary formation of a liquid drop inside a microbubble.

Conclusions: Medical microbubble oscillation and translation can be modeled using large, unencapsulated bubble theory. The number of fragments generated by untrasound-induced microbubble break-up has been related to the energy absorbed by the microbubble. Medical bubbles might be used as vehicles that carry a drug to a region of interest, where the release can be controlled with ultrasound. Liquid jets may act as microsyringes, injecting a drug into target tissue. Microbubble phenomena also have potential applications in imaging and noninvasive pressure measurements.