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Underwater Shock Wave Research Applied to Therapeutic Device Developments

K. TAKAYAMA[1,c], H. YAMAMOTO[2], H. SHIMOKAWA[3],

[1]Professor Emeritus, Institute of Fluid Science, Tohoku University, Sendai Japan, 980-8577
[2]Research Associate, Tohoku University Hospital, Sendai, Japan 980-8574
[3]Professor, School of Medicine Tohoku University, Sendai, Japan 980-8574

[c]Corresponding author: Tel.: 81-22-398-5295; Email: k.takayama@mac.com

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Fluid: water; silicone oil, micro-explosion
Visualization method(s): double exposure holographic interferometry; high speed video recording
Other keywords: medical application; ESWL; soft tissue dissection; arrhythmia;

ABSTRACT: A chronological development of underwater shock wave research performed at the Shock Wave Research Center of the Institute of Fluid Science at the Tohoku University is briefly described. At the early stage of underwater shock wave research, underwater shock waves were generated in shock tubes and visualized mostly by using conventional shadowgraph. Later learning the production of lead azide pellets weighing 1mg to 100mg and their ignition by Q-switched laser irradiation in water, we visualized resulting underwater shock waves quantitatively by double exposure holographic interferometry. Soon we abandoned the use of lead azide and replaced with commercially available silver azide pellets. Figure 1 shows sequential interferograms of shock/bubble interaction visualized by double exposure holographic interferometry and their comparison with shadowgraph images. We can clearly see the reflection of expansion waves from shock impinged bubble surfaces, the process of shock wave formation induced by the bubble motion, and the simultaneous deformation of shock impinged air bubbles.

Based on fundamental the shock wave research and stimulated by medical colleagues, in 1980 we worked on focusing of underwater shock waves generated by micro-explosions and applied it to the so-called extracorporeal shock wave lithotripter (ESWL). The prototype device we developed was approved for the clinical use in 1987. Encouraged by this success, we directed our research to resolve the shock induced tissue damages. We confirmed that shock tissue damages were useful to clinically damage soft tissue in a well-controlled fashion, at first applied it to revascularization of cerebral thrombosis, and then worked on the development of a soft tissue dissection device by applying laser induced intermittent water jets. The prototype device developed on this principle is now successfully used for clinical tests. In 2004, we initiated a project in which miniature shock waves were focused onto dysfunctional nerve cells in the myocardium, which trigged arrhythmia. We inserted, through the artery into the atrium of the heart, a thin catheter on the tip of which a truncated ellipsoidal reflector was attached. Then precisely controlled miniature shock wave focusing damaged the dysfunctional nerve cells without causing serious side effects. In vivo tests, we obtained results, which would promise the completion of prototype clinical device and its clinical success.

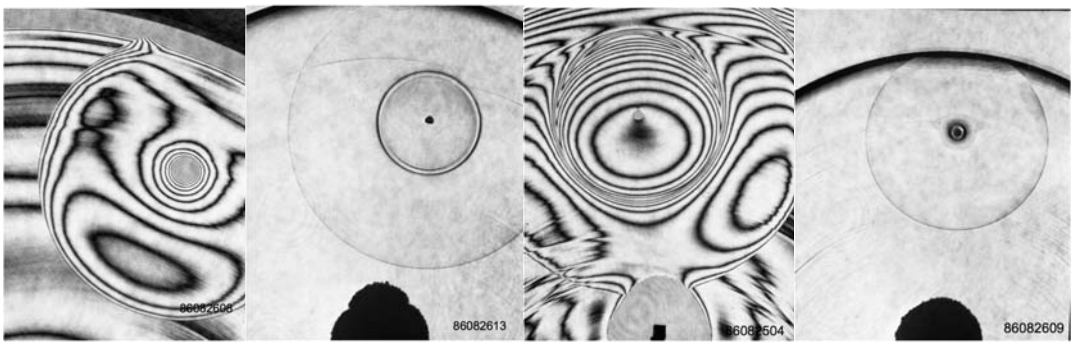

Fig. 1 Comparison of the interaction of underwater shock waves with 2mm diameter air bubbles.