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Visualization of the cavitation bubble cloud produced in a clinical shock wave field using micro-pulse LED light.

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1. Introduction

Shock wave-induced cavitation plays an important role to pulverize kidney stones (Extracorporeal Shock Wave Lithotripsy) and treat chronic tendonitis (Extracorporeal Shock Wave Therapy)[1,2]. Shock wave generates cavitation cloud which results in mechanical effects toward clinical target objects. The activity of the cavitation bubbles has been found to be associated with the therapeutic effects[3]. Despite the cavitation has been drawn attention to understand its role in the therapeutic effects, it is not clearly characterized yet because the chaotic nature of cavitation makes it difficult to measure[4].

The present study has demonstrated the optical visualization of cavitation distribution using micro length pulse LED light system.

2. Materials and methods

An experimental setup used in this study is shown in Fig 1. A clinical electromagnetic ESWT system(ShineWave-sonic, HnT Medical System, Korea) was employed as a shock wave generator. The main part of the generator is a capacitor (0.15uF) and in the present experiment it was electrically charged to 19.75kV to produce shock pulses. CCD camera(EOS 5D Mark III, Canon Inc., Japan) and macro lens(EF 100mm F2.8L Macro IS USM, Canon Inc., Japan) were used to focus and observe cavitation cloud. The instantaneous images of bubbles were taken in the dark room under the micro pulse LED light with an illumination time

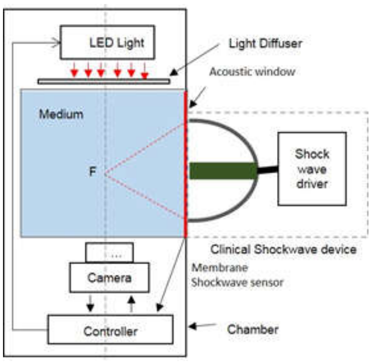

Fig 1. A schematic block diagram of the experimental setup.

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(T_{ex}) of 100 μs produced by micro pulsed LED light (MPLL, KIS tech, Korea). The shutter and iris of the camera remained open to acquire the optical image of bubbles during hundred micro second light exposure. A trigger pulse from the function generator (33250A, Agilent Tech., USA, function generator is not displayed in Fig 1) was used to operate the shock wave generator and the MPLL controller (MPLL, KIS tech, Korea). The MPLL controller trigger to LED after a preset time. Repeated acquisitions were carried out for 20 times. Numerical simulation was performed in time domain using PZFlex(ver 2014, Weidlinger Associates Inc., USA) to estimate the acoustic profile produced by shockwave device. 2D cross-section geometry was provided by manufacturer. In the simulation, rectangle shape in the middle on right side represents shock wave converter which is surrounded by parabolic structured reflector. The propagation direction is from right to left and water is selected as medium.

3. Results and Discussion

Simulation results displayed in Fig 2 present the acoustic distribution of (a) peak positive and (b) peak negative pressure respectively. Shock wave generated up and downward from shockwave converter in the model and then focused by reflector. Black dot line indicates the geometric focal point. The acoustic pressure at the focal point is extremely higher than other regions. Focal region of peak positive field is narrow and localized then negative

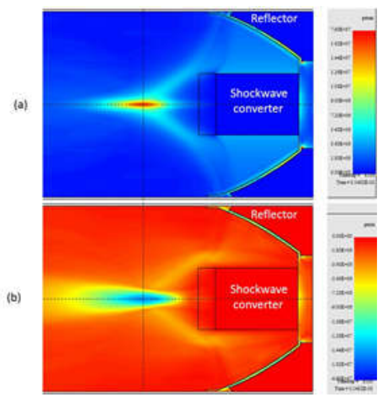

Fig 2. Cross sectional 2-D geometry of the shock wave device and the simulation results of shock wave field. (a) Peak positive pressure, (b) Peak negative pressure.

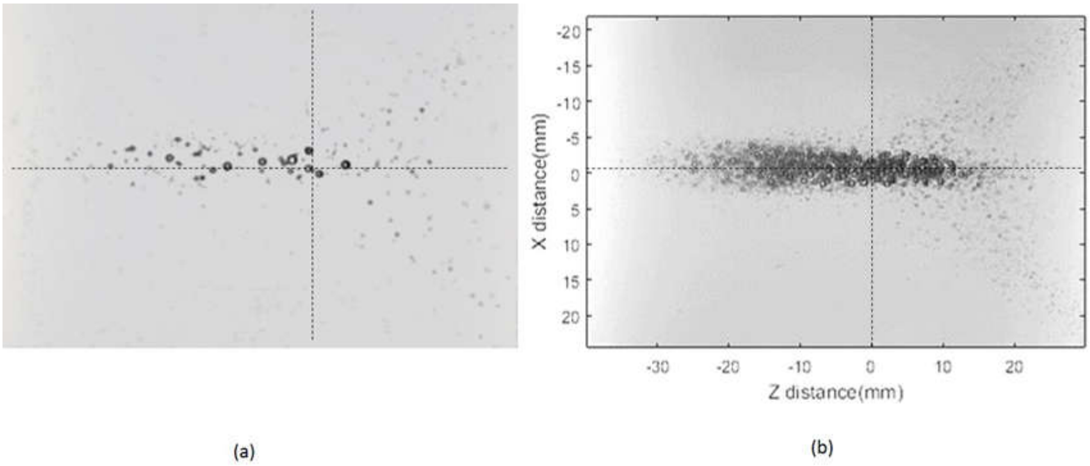

Fig 3. Snapshot image of cavitation cloud produced by shock wave device. (a) Instantaneous image, (b) merged image(N=20).

field.

Fig 3(a) depicts the snapshot image of cavitation bubble cloud taken at a time delay of from 50 μs to 150 μs after the shock wave generator was triggered so that the behavior of cavitation bubble could be overlapped on a single image. Cavitation bubbles sparsely occurred in the focal region where is the center of the image. Small bubbles were observed in the pre-focal region(right side of the image). Note that the shock pulse propagates from right to left on the image. When 20 instantaneous images were merged into one image, the rim of cavitation cloud was obviously appeared in the focal zone forming a rocket-like structure(Fig 3(b)). Comparing Figs. 2(b) and 3(b), it could be found that the region of cavitation cloud represents the focal zone of the peak negative pressure field rather than peak positive pressure field. This result could possibly be explained by the role of negative pressure to generate cavitation bubble.

4. Summary

The visualization of cavitation bubble cloud using micro length pulse light has been demonstrated experimentally. The region and structure of cavitation cloud in merged image represented well the peak negative pressure field of the shock wave. It will be useful to characterize acoustic field produced by shock wave device and may provide clues in understanding the behaviors of cavitation cloud.

Acknowledgment

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