35th Annual International Conference of the IEEE EMBS
Osaka, Japan, 3 - 7 July, 2013

A Novel Method for Monitoring Urinary Bladder Internal Pressure : Feasibility Test

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Abstract— **The study presents a new approach for measuring non-invasively urinary bladder internal pressure which can resolve all the shortcomings of existing methods. The novel method makes use of acoustic cavitation. The theoretical foundation for the proposed technique was presented, together with the preliminary experimental validation. The study claims that the proposed novel non-invasive ultrasonic urinary bladder internal pressure monitoring is feasible and can be used any time regardless of gender, so that it will be of a great benefit to the diagnosis and therapy of urination related diseases.**

I. Introduction

Method with a transurethral catheter offers the most accurate measurement for urinary bladder internal pressure[2]. However it is invasive and uncomfortable and may cause complication[3][4]. There are noninvasive methods reported but they have serious shortcomings and therefore are not clinically accepted. The present study proposes a new noninvasive method which resolves all the existing problems in monitoring urinary bladder internal pressure. The proposed method makes use of acoustic cavitation. The present study presents the theoretical foundation and the preliminary experimental verification for the feasibility test.

II. Materials and Methods

The theory underlying the bubble generation by ultrasound and the dissolution process is complex. It needs to consider an ultrasonic field, the bubble motion equations, the rectified gas diffusion, and so on. Once bubbles are generated by ultrasound, they dissolve with time. A simplified expression for the process may be given by Leighton [1].

$$\frac{dR_o}{dt} = \frac{C_o D}{\rho_g}\left(\frac{C_\infty}{C_o} - 1 - \frac{2\sigma}{P_o R_o}\right)\left(\frac{1}{R_o} + \frac{1}{\sqrt{\pi D t}}\right) \qquad (1)$$

Where R_0 is the equilibrium radius of a spherical bubble, t is the time, C_0 is the saturation concentration of gas dissolved within liquid, D is the diffusion coefficient for dissolved gas within liquid, ρ_g is the density of gas inside the bubble, C_∞ is the concentration of gas dissolved liquid far from the bubble,

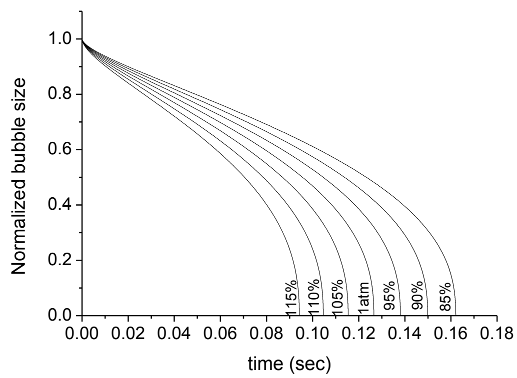

Figure 1. Dissolution curve of an air bubble (R_0 = 12 μm) in water under the static pressures (P_0) varying from 85% to 110% of the atmospheric pressure ($C\infty/C_0$=0.9)

σ is the surface tension of liquid and P_0 is the static pressure of liquid. The ρ_g should be modified as it varies with the volume of bubble. Note that the liquid is regarded as urine and P_0 as the urinary bladder internal pressure. The numerical solution of Equation (1) for $R_0(t)$ at various P_0 illustrates that, as seen in Fig 1, the bubbles in urine dissolve more quickly at higher values in the urinary bladder internal pressure.

For experimental verification, the bubbles were generated in the urine of an experimental urinary pressure chamber by an extracorporeal high amplitude focused ultrasonic pulse which is clinically used for extracorporeal shock wave treatment (ESWT). The dynamic behavior of the bubbles which is expected to be related to the static pressure of the surrounding fluid was monitored via the strength of the ultrasonic signal echoed back from the bubble could. The bubble behavior is closely related to echogenicity in B-mode images. In the present study, the strength of the ultrasonic backscattering from the bubbles was estimated with the gray scale magnitude of the echogenic region of interest in the B-mode image. Note that the time resolution of the ultrasonic backscatter strength was 1/30 seconds because the frame rate of the B-mode video images was 30 Hz.

III. Results & Discussion

Fig 2 shows the time history of the strength of the ultrasonic signals backscattered from the bubble cloud in the urine of the experimental urinary pressure chamber produced by a short high amplitude ultrasonic pulse used in ESWT. The urinary bladder internal pressure was set to 0mmHg, 30mmHg, and 60mmHg (dot: data, line: mean for the 10 repeating measurements). As predicted in Fig 1, the ultrasonic backscattering from bubbles decreased more quickly for the

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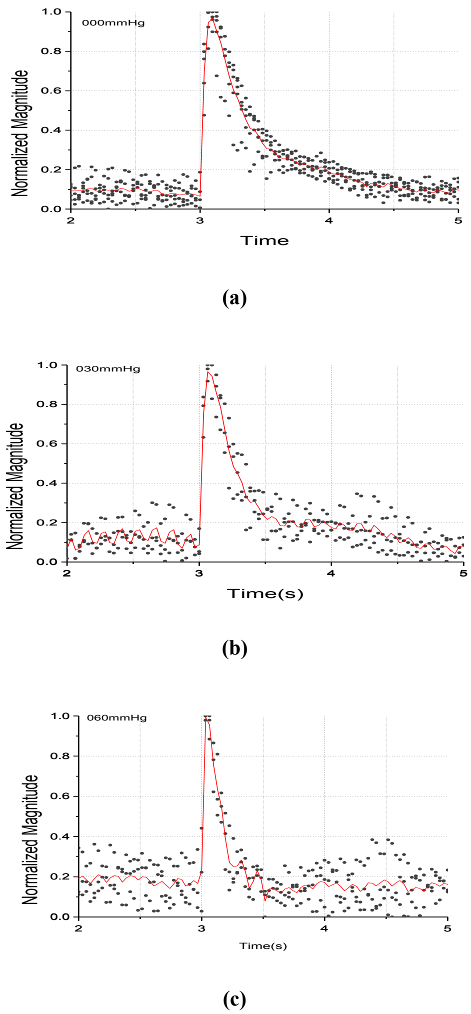

Figure 2. Time history of the strength of the ultrasonic signals backscattered from the bubble cloud in the urine of an experimental urinary pressure chamber produced by a short high amplitude ultrasonic pulse at the urinary bladder internal pressure of (a) 0mmHg, (b) 30mmHg, and (3) 60mmHg (dot: data, line: mean for the 10 repeating measurements).

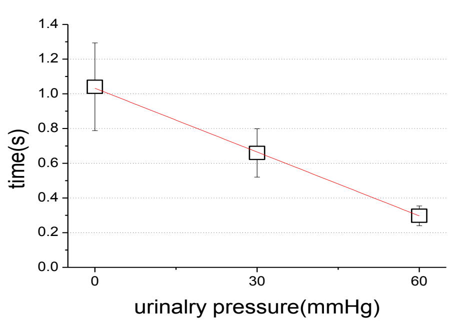

Figure 3. The bubble disappearance time versus the urinary bladder internal pressure.

urinary bladder internal pressure. The time at which the magnitude was reduced to the 80% of the peak, regarded as the time for bubbles in urine to disappear, linearly decreased as the urinary bladder chamber pressure rose, as shown in Fig 3. This proves that the ultrasonic measurement on the bubble dissolution allows us to estimate the urinary bladder internal pressure. A modification of the experimental system is required for clinical tests which are underway. Table 1 summaries the key features of the proposed method in contrast to existing clinical techniques for monitoring the urinary bladder internal pressure.

TABLE I. COMPARISON BETWEEN EXISTING CLINICAL METHODS AND THE PROPOSED ULTRASONIC METHOD FOR MONITORING THE URINARY BLADDER INTERNAL PRESSURE.

Methods	Type	Sex	Measurements	References
external condom catheter	noninvasive	male	isovolumetric detrusor pressure when voiding	Blake & Abrams (2004)
inflatable penile cuff	noninvasive	male	isovolumetric detrusor pressure when voiding	Griffiths et al (2006)
ultrasonic method (proposed)	noninvasive	any	internal urinary bladder pressure any time	Choi et al (2012)
trans-urethral catheter	invasive	any	internal urinary bladder pressure any time	Yol et al (1998)

IV. CONCLUSIONS

The study claims that the proposed novel noninvasive ultrasonic urinary bladder internal pressure monitoring is feasible and can be used at any time regardless of gender, so that it will be of a great benefit to the diagnosis and therapy of urination related diseases.

ACKNOWLEDGMENT

This work was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology(2009-0076846) and by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MEST) (No. 2012R1A2A2A03044996).

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