Pulsed Doppler 초음파속도측정의 정확도 판정: 유동 phantom 연구

o 김 영호, 민 병구
서울대학교 의과대학 의공학연구소

Accuracy of Pulsed Doppler Ultrasound Velocity Measurements: In Vitro Flow Phantom Study

o Youngho Kim and Byunggoo Min
Institute of Biomedical Engineering, College of Medicine, Seoul National University

ABSTRACT

An in vitro steady flow experiment was performed in order to test the accuracy of velocity measurement obtained through a pulsed Doppler echocardiography. A flow phantom was designed for the use in a wide velocity range at a given flow rate. The results showed that the pulsed Doppler velocity measurement obtained in this flow phantom is accurate at low flow rates. However, ultrasound velocity measurement should be performed under a careful considerations of PRF and Doppler gain settings, especially at higher flow rates.

Key Words: pulsed Doppler echocardiography, flow phantom, PRF, Doppler gain

INTRODUCTION

Echocardiography is used extensively in patient examinations. Other than the 2-D image, velocity obtained from the pulsed Doppler echocardiography is more important to diagnose the patient. Examples of this include imaging the coronary arteries and the heart where the flow patterns of the blood are important indicators of pathology and disease severity [1-4]. Clinical Doppler use has shown that the appearance of the color Doppler flow map can be changed if the machine parameters are adjusted [5-7]. The problem of aliasing is important in Doppler flow imaging because the maximum velocities attainable before aliasing can be significantly below those found in the body. Medison (Medison Co. Inc., Korea) developed ultrasound echocardiography few years ago and color Doppler ultrasound machine is under development. However, the evaluation of the Doppler velocity measurement has not done yet. The accuracy of the ultrasound velocity measurement is extremely important and needs to be checked under an in vitro flow phantom which provides known velocity fields. Therefore, the aims of the study is to design a flow phantom to evaluate the accuracy of Doppler velocities using a pulsed Doppler ultrasound machine.

METHODS

In order to obtain a known velocity field, a flow phantom was designed. A water/corn starch (2%) solution was pumped at steady flow rates from 4 to 20 liter/min through a linearly convergent plexiglass flow tube. The flow tube had an internal diameter of 29 mm at the inlet, 12 mm at the outlet and the length of 100 mm. The outlet of the flow tube was connected to a narrow plexiglass box. An ultrasound transducer was placed against this box and the flow along the center line of the flow tube was imaged. The orientation of the imaging plane was checked from the B-mode image before the Doppler mode was installed. A rotameter, situated downstream of the plexiglass box, measured the flow rate. The inlet length of the flow tube was short enough to maintain a blunt velocity profile. The convergence of the flow tube and the subsequent decrease in cross sectional area, created an increase in the fluid velocity along the length of the flow tube as illustrated by the three velocity profiles shown in Figure 1.

A Medison Sonoace-4800HD (Medison Co., Korea) echocardiography [8] with 2.52 MHz probe was used for recording the velocity fields. Effects of PRF settings and the Doppler gain on the velocity measurement were investigated at various steady flow rates.

RESULTS AND DISCUSSION

The flow phantom which was designed for the present study sucessfully describes several true velocity distributions along the center line at a fixed flow rate. It can be very useful for evaluating the accuracy of velocity measurements through color Doppler echocardiography. Figure 2 shows the typical B/D mode with a depth of 48 mm from the transducer, in which decribes the velocity in the converging flow tube at steady flow rate of 5 liter/min. its instrument setting was as follows: PRF 3.0 KHz, Doppler power Med, Reject 36 dB, Doppler gain 50%, and Filter 100Hz. Figure 3 shows the velocity distributions along the center line of the flow tube at steady flow rates of 4, 8 and 20 liter/min. The experimental results showed an excellent agreement with the true velocities at relatively low flow rates.

Effect of PRF settings

PRF (pulse repetition frequency) controls the range of the velocity in the Doppler mode. When the flow velocity is high, the pulse frequency can be increased so that the range of measurable velocity can be wider. However, the increase in PRF also restricts the depth of the measurement. Therefore, the aliasing takes place in different velocities with the different PRF settings. With 2.52 MHz probe, PRF 6.0 KHz provides an aliasing problem at multiple number of 0.92 m/s On the other hand, PRF 8.4 KHz produces them at multiple number of 1.29 m/s. Therefore, the multiple measurements with different PRF settings or by different observers may be required to accurately measure the velocities near the Nyquist limit .

Effect of Doppler gain

As Doppler gain is increased, the noise also increases and thus the standard deviation of Doppler signal increases. Velocities outside the aliasing range was noisier with high (100%) Doppler gain than with low (10%) gain. The variation due to the noise makes the average velocity off the true value. Therefore, Doppler gain should be selected as low as possible in order to eliminate the error in velocity measurements.

CONCLUSIONS

The present in vitro ultrasound velocity measurement showed an excellent agreement with the true velocities. However, the aliasing problem involved with an inherent Nyquist velocity limit may create a significantly large error in measuring velocities by ultrasound machine. Therefore, an ultrasound velocity measurement should be performed under a careful considerations of PRF and Doppler gain settings, especially at higher flow rates.

Acknowledgements

The present study was supported by the Medison Co.

REFERENCES

1. Miyatake K, Okamoto M, Kinoshita N, et al.: Clinical applications of a new type of real-time two-dimensional Doppler flow imaging system. AM J Cardiol 54:857-868, 1984.

2. Omoto R, Yokote Y, Takamoto S, et al: The development of real-time two-dimensional Doppler echocardiography and its clinical significance in acquired valvular disease: With

specific reference to the evaluation of valvular regurgitation. Jpn Heart J 25:325-340, 1984.

3. Miyatake K, Izumi S, Okamoto M, et al: Semiquantitative grading of severity of mitral regurgitation by real-time two-dimensional Doppler flow imaging technique. J Am Coll Cardiol 7:82-88, 1986.

4. NC Nanda. Textbook of color Doppler echocardiography, Lea & Febiger Co., 1989.

5. Utsunomiya T, Ogawa T, King W, et al: Pitfalls in the display of color Doppler jet area: Combined variability due to Doppler angle, frame rate and scan direction. Echocardiography 7:739-745, 1990.

6. Rao SR, Richardson SG, Simonetti J, et al: Problems and pitfalls in the performance and interpretation of color Doppler flow imaging: Observation based on the influence of technical and physiological factors on the color Doppler examination on mitral regurgitation. Echocardiography 7:747-762, 1990.

7. Stewart WJ, Cohen GI, Salcedo EE: Doppler color flow image size: Dependence on instrument settings. Echocardiography 8:319-327, 1991.

8. Medison Sonoace 4800HD manual

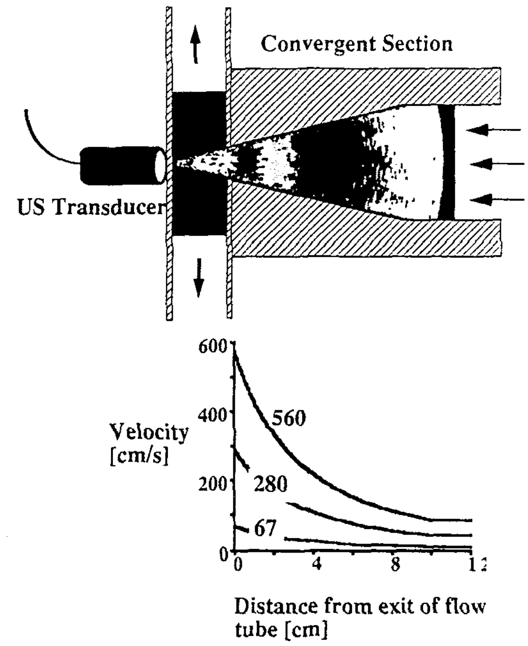

Figure 1. Schematic of the flow phantom and true velocities at various flow rates.

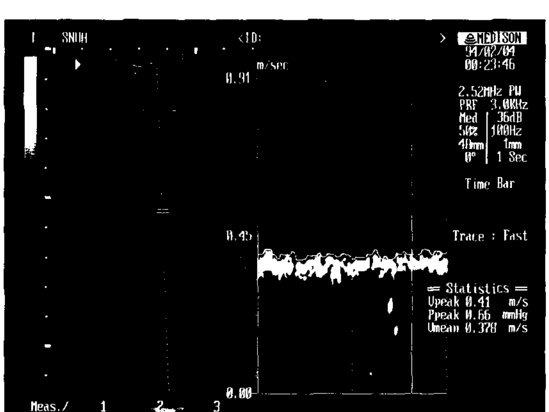

Figure 2. A typical B/D mode with a depth of 48 mm at 5 liter/min.

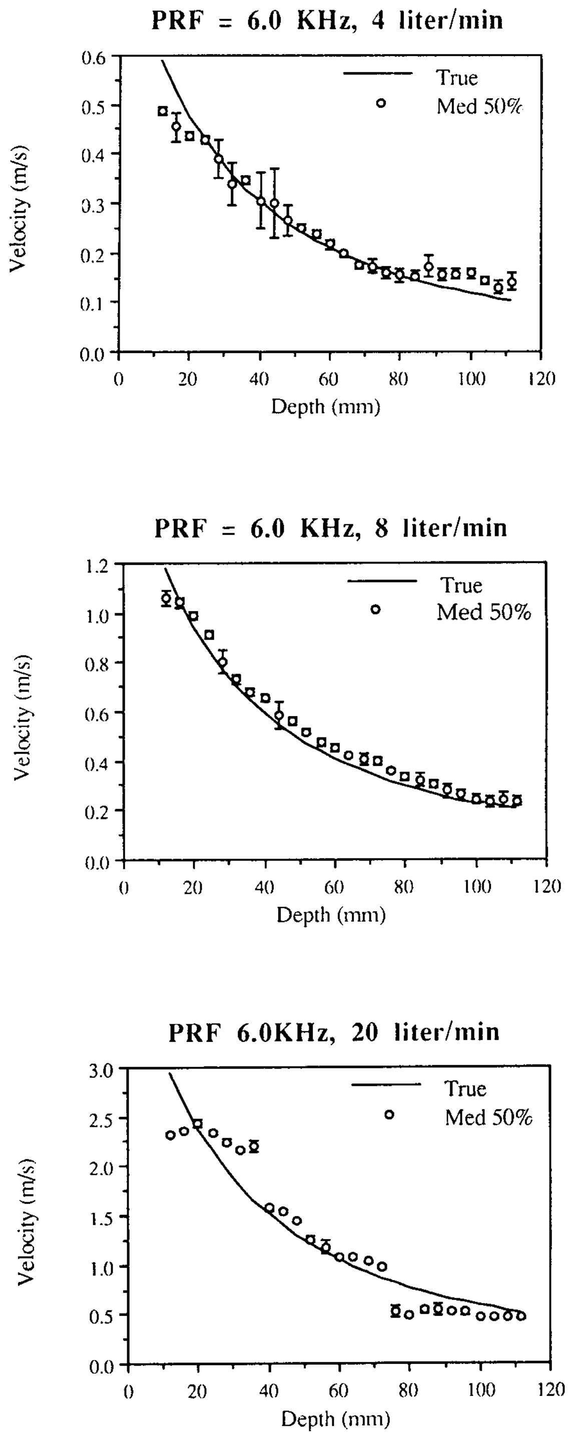

Figure 3. Velocity distributions along the center line of the flow tube at various steady flow rates of 4, 8 and 20 liter/min