A Pulsating Coronary Vessel Phantom for Two- and Three-Dimensional Intravascular Ultrasound Studies

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Abstract. Intravascular ultrasound (IVUS) is an important new technique for high resolution imaging of coronary arteries. This paper describes a unique pulsating coronary vessel phantom to evaluate 2D and 3D IVUS studies. The elasticity and pulsatility of the vessel wall can be varied to mimic normal and diseased states of the human coronary artery. The phantom described is useful in evaluating image-guided interventional procedures and in testing the performance of 3D IVUS reconstruction and segmentation algorithms.

1. Introduction

IVUS has recently emerged as an important new technique for high resolution imaging of the coronaries. It provides valuable insight into the tissue characteristics of the arterial wall and plaque composition, along with high sensitivity to the detection of plaque calcification [1]. The purpose of this study was to develop an anthropomorphic pulsating coronary phantom for testing 2D and 3D IVUS techniques. This phantom is useful in evaluating the performance of image-guided interventional procedures of stent deployment, wall elasticity imaging studies, wall motion analysis, as well as 3D reconstruction and image segmentation algorithms.

2. Methods

The coronary phantom consists of an acrylic cylindrical casing with two discs attached at the ends of the casing (Fig.1a). A PVA vessel (r = 1.8mm; wall = 0.8mm) is inserted into the casing and attached to the two end discs. The acrylic casing is filled with water and sealed with a latex sheath attached over one of the end discs. The phantom is mounted on a platform in an acrylic tank filled with water (Fig.1b). The latex sheath, attached to a shaft connected to a servomotor, is stretched and relaxed causing pulsation in the PVA vessel wall. A servomotor controller is used to program motion waveforms into the servomotor, generating different vessel wall pulsation patterns. An UltraCross 3.2 IVUS catheter, driven by a motorized pull back unit at the constant speed of 1mm/s was used to image the phantom. The ClearView Ultra IVUS system was used to obtain 2D images of the phantom. Image digitization, at a frame rate of 30Hz and 3D IVUS reconstruction were controlled by a LIS L3D 3D ultrasound acquisition system (Life Imaging Systems Inc, London, Ontario).

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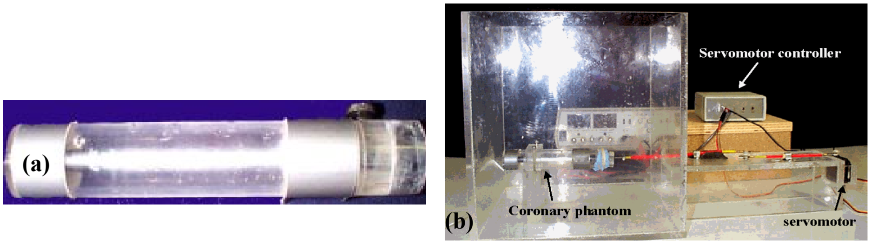

Fig 1. (a) Coronary phantom: the acrylic casing encloses the PVA vessel. (b) The coronary phantom setup: a servomotor drives the latex sheath to generate wall motion in the PVA vessel.

3. Results

Fig.2.a,b shows 3D images of the coronary vessel phantom with and without pulsation. The pulsation of the vessel wall is seen in Fig.2b. The wall pulsation was programmed using the cross-sectional area change waveform (solid line) shown in Fig.2c [2]. The resultant cross-sectional area change over one cardiac cycle, as measured from the 3D phantom image, is shown as the dotted line. The resultant phantom plot agreed with the input waveform to within 4.3%, with an r-value of 0.95.

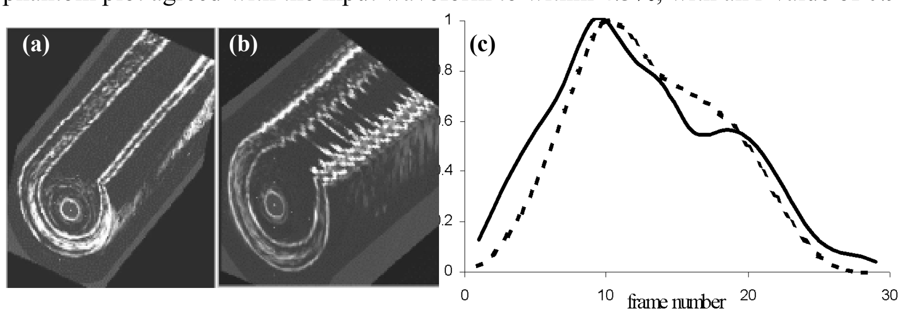

Fig.2 (a) and **(b)** 3D images of the coronary phantom: (a) no pulsation (b) with wall pulsation. **(c)** the programmed waveform (solid line) and the resultant phantom area change (dotted line) are plotted as a function of frame number. The frame interval was equal to 33ms.

4. Conclusions

We have described an *in vitro* experimental set up to test the development of new techniques in 2D and 3D IVUS imaging. The elasticity and pulsation of the phantom vessel wall can be accurately programmed to mimic normal and diseased coronaries.

References

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