Journal of Fiber Bioengineering & Informatics 5:3 (2012) 273–279
http://www.jfbi.org | doi:10.3993/jfbi09201205

Torque Transmission and Rotational Response Characteristics of Medical Guide-wire in Curved Blood Vessel Model

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Abstract

In order to provide the basic data for the development of medical guide-wire and a simulator for the PTCA (Percutaneous Transluminal Coronary Angioplasty), we have developed the blood vessel model made of PVA hydrogel and investigated the mechanical characteristics of guide-wire in the blood vessel model. In the present study, we discussed the characteristics of torque transmission and rotational response of the guide-wire in curved blood vessel model with change in the PVA concentration of the hydrogel and thickness of blood vessel model.

Keywords: Medical Guide-wire; PTCA (Percutaneous Transluminal Coronary Angioplasty); PVA Hydrogel; Blood Vessel Model

1 Introduction

Medical guide-wires used for Interventional Cardiology have a function to guide the catheter inserting to the site of coronary artery disease. In order to provide the basic data for the development of medical guide-wire and a simulator for the PTCA (percutaneous transluminal coronary angioplasty), measurements of the guide-wire's mechanical properties were conducted. Schröder measured stiffness and torsional strength of guidewires and friction of guide-wires in catheter [1, 2]. Zako et al. measured the sliding force and torque of guide-wire in guiding catheter [3]. Ceschinski et al. measured the torsional rigidity of micro guide-wires [4]. However, these measurements were only for the mechanical properties of guide-wire. The mechanical interaction between guide-wire and arteries are important. *In vivo* experiment for the measurement of mechanical interaction between guide-wire and arteries are difficult. If we conduct *in vitro* experiment for the measurement of mechanical interaction between guide-wires and isolated real arteries, there are many problems of handling real arteries, such as individual difference, few availability of artery, risk of infection disease, etc. Thus, the blood vessel models instead of real arteries are needed.

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Some of blood vessel models were used for the simulators of PTCA, but these models were simple [5]. For the *in vitro* study of atherosclerosis, we have developed the stenosis model made of PVA hydrogel closer to artery [6]. This model can be applied to the measurement of mechanical interaction between guide-wires and blood vessel model. In the present study, we have measured torque and rotational angle of the guide-wire in curved blood vessel model, and discussed the effect of the PVA concentration of the hydrogel and thickness of blood vessel model on torque transmission and rotational response of the guide-wire.

2 Methods

2.1 Blood Vessel Model

Cylinder shape of the blood vessel models were used (length: 20 mm, inner diameter d_i: 0.75 mm). To discuss the effect of the thickness of the blood vessel model, the outer diameter d_o was changed from 2.0 mm to 4.0 mm. Two types of hydrogel used for the blood vessel models (PVA-H and PVA-H (D)) were made; (1) PVA-H polyvinyl alcohol aqueous solution, (2) PVA-H (D), polyvinyl alcohol aqueous solution, a transparent hydrogel, and dimethyl sulfioxide (DMSO); all of which were used for gelation. Fig. 1 shows the device of pressurization to the blood vessel model and porcine coronary artery. Fig. 2 shows the relationships between pressure and cross sectional area of blood vessel model and porcine coronary artery. Since the mechanical properties of the blood vessel model and artery are non-linear, we used the stiffness parameter β. This parameter is adequate for arteries [7].

$$\beta = \ln(P_0/P_S)/(D_0/D_S - 1) \tag{1}$$

where P_0 is internal (luminal) diastlic pressure, P_S is internal (luminal) systolic pressure, D_0 is the outside diameter for P_0, and D_S is the outside diameter for P_S. We have changed the concentration of PVA from 10 wt% to 20 wt%. As the result of mechanical properties of the blood vessel models, stiffness parameter and Young's modulus of the PVA-H and PVA-H (D) are shown in Table 1. The stiffness parameters of the blood vessel models are closer to that of porcine coronary artery. But the stiffness parameter of human coronary artery is greater than that of porcine coronary artery.

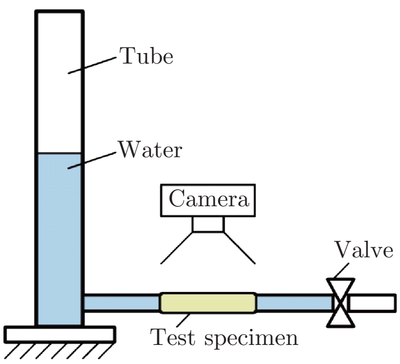

Fig. 1: Device for measurement of cross sectional area A with change in pressure P