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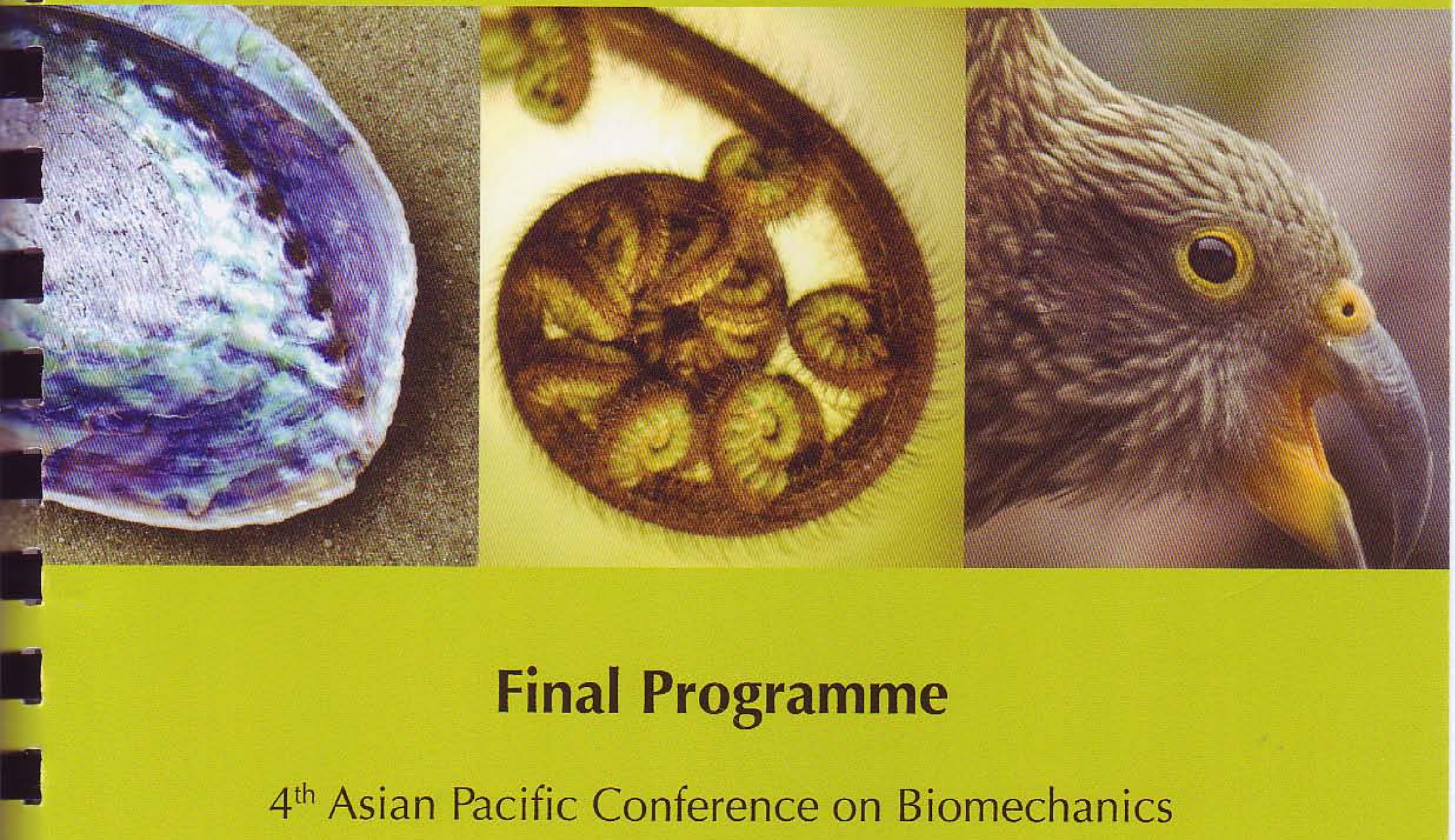

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Study on a Catheter Movement with Poly (vinyl alcohol) Hydrogel for the Development of an In-Vitro Tracking System

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Abstract : Vascular diseases, such as ischemic heart disease, infarction, aneurysms, stroke and stenosis are the leading cause of serious long-term disability and as high as a mortality rate of cancers in many countries. Recently, neurovascular intervention using catheters is the use of minimally-invasive endovascular techniques to treat vascular disease of the brain and a navigation system for catheters has been developed for surgical planning and an intra-operative assistance. Since the mechanical properties of a catheter play an important role in reaching the targeted disease, tracking of catheter movement during endovascular treatment may be useful to increase the confirmation of an operation. In this study, we developed an in-vitro tracking system for catheter motions using Poly (vinyl alcohol) hydrogel (PVA-H) to mimic an arterial wall. The models made of PVA-H is transparent and enough to observe the catheter movement on the artery. This system will contribute to validating the computer-based navigation systems for surgical assistance

Introduction

Vascular diseases, such as ischemic heart disease, infarction, aneurysms, stroke and stenosis are the leading cause of serious long-term disability and as high as a mortality rate of cancers in many countries [1]. Moreover, cerebrovascular disease ranks third in cause of death, resulting in more than 160,000 deaths in the United States annually [2]. And thus, endovascular treatments using catheters for cerebral aneurysms have been widely accepted as minimally-invasive neurovascular interventions and a catheter navigation system has been developed to support complicated treatments [3],[4].

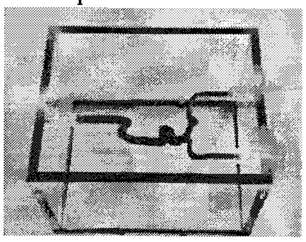
Ohta et al. proposed the development of blood vessel biomodeling made of poly (vinyl alcohol) hydrogel (PVA-H) [5]. The mechanical properties of PVA-H are controllable with various techniques. For example, Kosukegawa et al. have described the way to elucidate the mechanical properties of biomodels using various concentrations of PVA solution, degrees of polymerization, saponification values and blending techniques [6]. Mamada et al. have reported that sensory evaluation of such procedures as suturing or cutting of PVA-H yield higher scores than those of a conventional material do [7]. These results suggest the force and balance field of artery wall can be reconstructed by a PVA-H biomodel.

In this paper, we propose the development of an in vitro tracking system for catheter motion by applying a PVA-H model and evaluation of video recording of catheter motion.

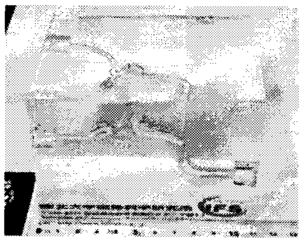
Experimental methods

Gelation of PVA and Lost wax Technique

Poly (vinyl alcohol) (PVA) (JAPAN VAM & POVAL CO., LTD., Japan) was added into a dimethyl sulfoxide (DMSO) (Toray Fine Chemicals Co., Ltd., Japan) / H_2O (80/20, w/w) [6]. After stirred for 2 hours at 100 °C, the PVA solution cast into an acrylic box with the mold to make a PVA-H box model of a realistic geometry shown as Figure 1(a), (b). This model was used for the catheter tracking. This PVA was maintained at -30 °C for 24 hours to promote PVA crystallization. After gelation, the mold material was removed using water like a lost-wax technique.



(a)



(b)

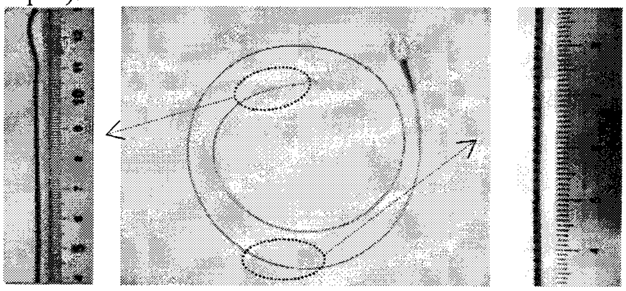
Fig.1 (a) Acrylic resin with a realistic geometry mold (b) Realistic geometry of PVA-H model

Realistic patient model for tracking System and Motion Capture System

To make a realistic model, an original geometry was acquired using a rotational angiography. A patient was set in a conventional angiography with rotational data acquisition. Three-dimensional angiography was performed on a biplane C-arc unit (BV 3000; Philips

Medical Systems, the Netherlands). The rotational run was then transferred to the angiography workstation (INTEGRIS 3D-RA, Philips Medical System) and a 3-D reconstruction was performed. The 3-D geometry was transferred to a model made of gypsum.

A zebra pattern (2 mm distance and 2 mm thickness) was painted on a catheter {2.9/2.4 Fr (0.96/0.80mm) 130cm , Cat.No.E102-130S1, Lot No.25285, GMA Co., Ltd., Japan} using an oily marker pen (MO-120-MC-BK, Zebra, Japan) shown as Figure 2 (a), (b), (c). The catheter was inserted into circulation system made of resin with a sheath and was moved by hand slowly and the motion was recorded by digital camera (Canon PowerShot G9, Japan).



(a) (b) (c)

Fig.2 (a) Soft part of catheter (b) Micro catheter made by GMA (c) Hard part of catheter

Results and Discussions

Figure 3 shows the photograph of the catheter in artery with a realistic geometry. The catheter can be inserted into the artery smoothly. PVA-H is transparent and sufficient to observe the catheter zebra patterns. The artery is soft and the catheter can be moved by force of hand.

Fig.3 The photograph of the catheter with a realistic geometry

I inserted 2 different part of catheter such as the hard and soft one into circulation system. The soft part of catheter as shown Figure 2(a) can be controlled to move at the curved line of the realistic geometry PVA-H model softly. But the other shown 2(c) is failed. It will imply that more experiments may lead development of a good catheter using the in-vitro tracking system for catheter motion.

The role of a catheter is to carry medicines and implants during operation. However, the use of a catheter requires operators to have high techniques and the medical imaging system can detect only the small markers on the catheter. For supporting the imaging, a navigator or a simulator has been developed as a computer aided surgery. However, their system only show results of force interface between operator and system.

On the other hand, Takashima et al. have developed a computer-based simulator for the catheter navigation for surgical planning based on force and balance in a catheter and a blood artery [8], [9]. This simulator would be useful for the analysis of the structure of a catheter and may help the new design of a catheter.

In this paper, we describe the development of an in-vitro tracking system for the catheter motion by applying the PVA-H model techniques and evaluated the system with observation of movies with the catheter motion.

Conclusion

An in-vitro tracking system for catheter motion by applying a PVA-H model is developed and the transparency is enough to observe a catheter through the PVA-H wall.

Acknowledgements

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