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FINITE ELEMENT ANALYSIS OF A NEW TYPE OF POST DILATATION BALLOON CATHETER IN PCI

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SUMMARY

At present, percutaneous coronary intervention (PCI) is the most effective treatment of coronary heart disease (CHD). Unfortunately, the tip of the post-dilatation balloon catheter cannot smoothly pass through curved vessel (with a stent in it). According to a newly proposed catheter, 3D CAE models were constructed. Finite element analysis of the proposed catheter model and the traditional catheter model are implemented when they pass through curved vessel with a stent in it. The contact force and strain distribution were compared and then evaluation will be made of its clinical application.

Keywords: *finite element analysis, post dilatation, stent, catheter*

1 INTRODUCTION

In recent years, the incidence and mortality of coronary heart disease (CHD) have increased significantly. It is estimated that by 2020, the death rate of coronary heart disease will increase by 50% (approximately 25 million people per year) [1]. Percutaneous coronary intervention (PCI) has the advantages of short course of treatment, less trauma and obvious curative effect, which is the most effective treatment of CHD [2-3]. Post dilatation of balloon refers to dilating the balloon again by using a higher pressure than the implanting pressure in the stent after firstly implanting the stent to ensure the complete attachment between the stent and vascular wall, which reduces the probability of thrombosis in the stent and the rate of restenosis after operation. The tip of the post-dilatation balloon catheter in clinical is the same as predilatation catheter. It is like a cone which is conducive to the catheter passing through the narrow lesion site. But this type of catheter’s tip is always stuck in the stent because of the existence of the step-like structure (Fig. 1D). It may cause stent deformation, lead to acute myocardial infarction and even induce death of patients. A new type of balloon catheter with a spherical tip was proposed (Fig. 1C) [4]. The aim of this study is to test the performance of the new type of catheter by performing finite element analysis in Abaqus. The stent deformation and contact force between these two catheter tips and stent surface were analyzed. The performances of the new and traditional catheter are compared. In-vitro experiments will be conducted to verify the results of the simulation.

2 METHODOLOGY

The 3D CAE models of stent, catheter, guide wire and vessel are constructed and assembled. The radius of curvature of the stent and vessel is 10 *mm*. The assembled models are in Figs. 1A-B. The dimensions and structure of the two catheter tips are shown in Figs. 1C-D.

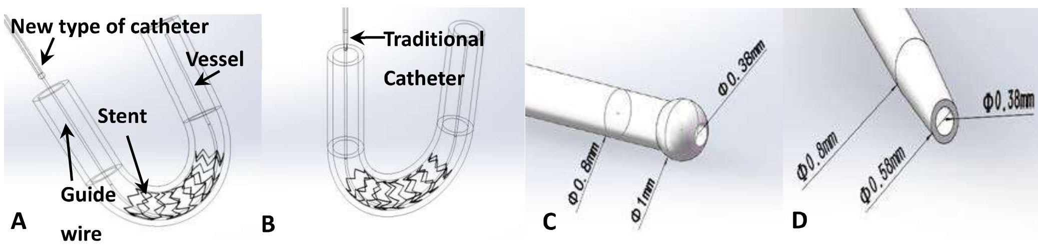

Figure 1: three-dimensional models
(A) New type of balloon catheter model; (B) traditional balloon catheter model; (C) new type of balloon catheter tip; (D) traditional balloon catheter tip.

These geometries were imported into ABAQUS v6.13 [5-6]. The mechanical properties of each component in the model were listed in Table 1. To mimic the situation in clinical application, we assumed two ends of the vessel as fixed in the computational model. The vessel and the stent are tied. Surface to surface contact was set between the outer surface of the catheter and the inner surface of the stent. The friction coefficient of this contact was considered as 0.3 according to the material properties. The other contact pairs are all general contact. The catheter moves along the guide wire and passes through curved vessel with a stent in it.

Table 1 Parameters of the materials in the proposed model [7]

	Young's modulus (MPa)	Poisson ratio	Density (g/cm^3)
Stent	24500	0.33	6.45
Catheter tip	1500	0.3	1.07
Catheter	3600	0.3	1.15
Guide wire	180000	0.3	7.8
Blood vessel	2	0.3	1

3 RESULTS AND CONCLUSIONS

Fig. 2 shows that the new type of catheter passes through stent easily (Figs. 2A-C), while the traditional catheter cannot pass it through under the same conditions (Figs. 2, D-F). The deformation of stent caused by the traditional catheter is much larger than that caused by the new type of catheter, which exactly validates the design idea. The vessels were hidden in Fig. 2 A-B, D-E in order to display the results more clearly.

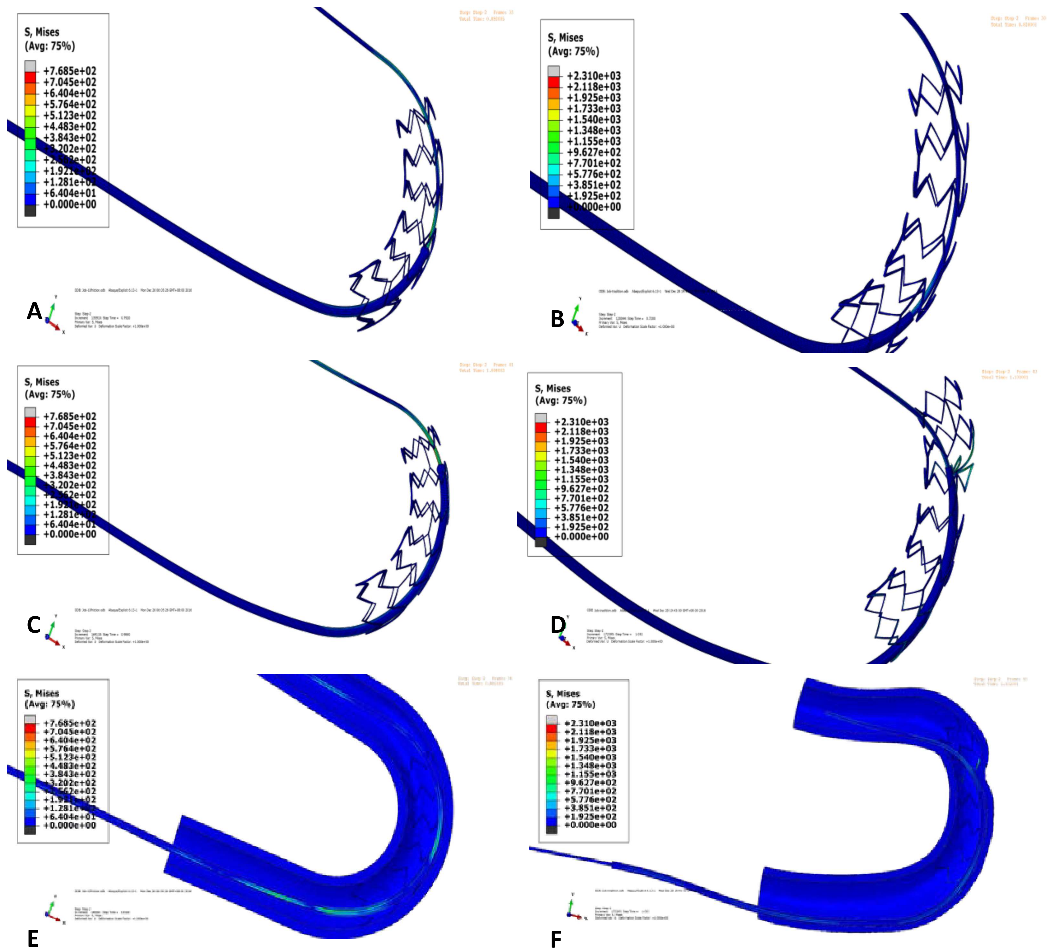

Figure 2: Visualizations of FEA for the postdilatation.

(A) The stress distribution of new catheter, T=0.8s; (B) The stress distribution of traditional catheter, T=0.8s; (C) The stress distribution of new catheter, T=1.1s; (D) The stress distribution of traditional catheter, T=1.15s; (E) The cutaway view of the new catheter model; (F) The cutaway view of the traditional catheter model.

Shown in Fig.3 is the total force between the tip and stent of the two models. The Maximum value of the force from the traditional model is 2.3N, which is much larger than 0.54N in the new catheter model. It is indicated that this new type of catheter will be easier to pass through curved vessel (with stent in it) than the traditional one. The force of the traditional catheter model decreases after reaching the highest point because the tip of the catheter passes through the stent surface after the large deformation of the stent.

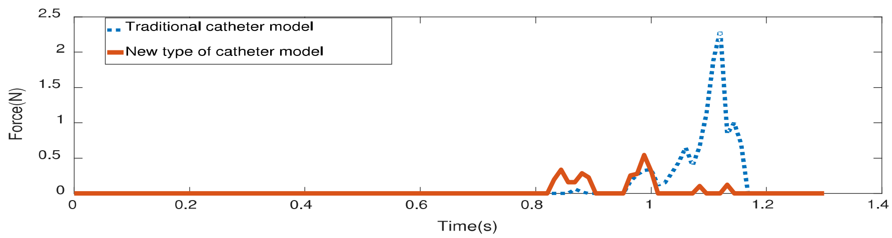

Figure 3: Total force between catheter tips and inner surface of stent

In this study, finite element analyses of a newly proposed balloon catheter model and traditional catheter model are implemented under the condition of passing through the curved vessel (with stent in it). By comparison, we can conclude that the novel catheter outperforms the traditional catheter in this process. The output from this study can provide the important implication for clinical application of the newly developed catheter. In future work, in vitro experiment will be conducted, in which the contact/frictional force will be measured using Fiber Bragg Grating (FBG) sensors to validate the computational model in this study.

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