Fundamental Research on Catheter Inserting Monitoring with the FBG Sensor

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Abstract: During catheterization, the doctor manipulates the catheter based on a slight tactile sensation and the photograph with the x-rays. Therefore, the some problems occur during treatment such as long surgery time, insertion into wrong blood vessel, on the penetration of the vessel wall by adding an excessive force. The monitoring of the catheter inserting process with the FBG sensor was carried out to prevent these problems. FBG sensor is the thing which the plurality of slits is created in the optical fiber. Only light of a specific wavelength is reflected when incident light to the FBG. It is proportional to the distance between the slits. The distance between the slits varies depending on the strain. Therefore, FBG sensors can measure the strain by a change in the reflection wavelength. Through the insertion experiment by using the silicon blood vessel model, it was found that change in reflection wavelength showed states of the catheter contact to the vessel wall, to the entrance of the carotid artery.

***Key-Words**: FBG, Catheter, Strain, Reflection Wavelength, Catheter Inserting Monitoring*

1. Introduction

Minimally invasive treatment to reduce the cut of a patient in the operation is watched in recent medical. Its representative is a catheterization.

The doctors insert a catheter in a blood vessel of patients based on a slight tactile sensation and the photograph with the x-rays. The tactile sensation is difficult to be transmitted to the doctor and the photograph is difficult to see in monochrome. Therefore, the some problems occur during treatment such as long surgery time, insertion into wrong blood vessel, on the penetration of the vessel wall by adding an excessive force. Monitoring the state of the catheter during operations is considered to be a significant support to the operator.

There is the magnetic sensor system for detecting position and orientation of a catheter tip as prior research [1]. But the magnetic sensor is not suitable for catheter. Because the magnetic sensor may affect other medical equipment and have plurality of leads. FBG is optical fiber sensor solve these problems. Catheter FBG is attached can be measured the bend at the time of catheter insertion.

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2. Method

2.1 FBG sensor

FBG is the optical fiber sensor having diffraction gratings whose refractive index changes periodically in the fiber [2]. It reflects only light of a specific wavelength by the spacing of the grating. The specific wavelength is called the Bragg wavelength. When the distortion has occurred in FBG, Bragg wavelength is changed by a change in the spacing of the grating. The strain of the optical fiber can be measured by this change in the Bragg wavelength.

FBG is different from the strain gauge and the magnetic sensor are another strain measurement sensors. FBG has features such as not necessary leads and a thin as a single hair, safe to the human body to use the light, possible multipoint measurement to use only a single optical fiber [2]. These features enable to make compact instrument. Sensors which can multipoint measurement has multiple FBG in a single fiber. Each FBG reflects different wavelengths. Therefore, It can distinguish the sensor strain occurs by changes in each of the Bragg wavelength.

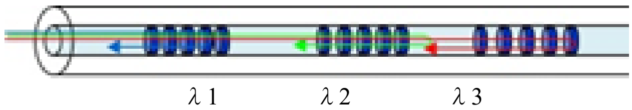


Figure 1 Multipoint measuring sensor

2.2 experimental device

Catheter to be used this research is Judkins type (JR). JR catheter is bent 50 ° from 10mm of the tip. It is measured by attaching a FBG in this catheter. FBG is attached to 30mm from the catheter tip. Measurement equipment are the optical spectrum analyzer (sm130) and the dedicated software. These devices can observe changes of the Bragg wavelength in real time.

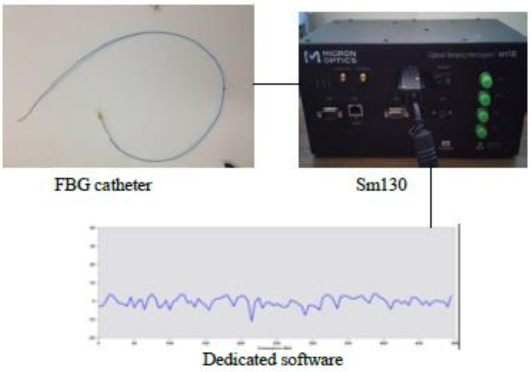


Figure 2 experimental device

3. Result

Vascular model (Altamira) used in the experiment is one that is used in practicing catheterization. This is reproduced sense of insertion of the actual blood vessels. It shows the blood vessel model in Figure 3.

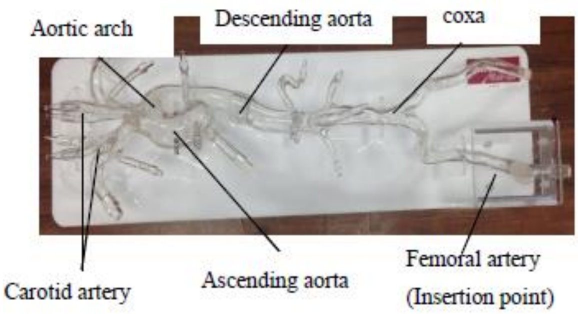


Figure 3 Altamira

The catheter is inserted from the insertion portion of the right femoral artery to the ascending aorta (See Figure 3). Direction of the catheter tip is divided into back direction and abdomen direction. Figure 4-a is back direction. Figure 4-b is abdomen direction.

Bragg wavelength shows the same reaction until the descending aorta after catheter insertion. It is rapidly decreased in the coxa (Figure 5-a, 5-b). Because, Catheter tip is compressed by the blood vessels of the coxa are meandering and thin. Change of the Bragg wavelength is stabilized in the descending aorta for the descending aorta is a linear.

Bragg wavelength of the two patterns are different by the contact with the wall of the aorta. (Figure 4-a, 4-b)

The catheter tip is large warp, whole is contacted with the aortic arch in back direction. Therefore, FBG is lengthened and the Bragg wavelength is increased. (Figure 5-a)

The catheter tip is pressed against the aortic arch, whole is not contacted in abdominal direction. Therefore, FBG is compressed, the Bragg wavelength is reduced. (Figure 5-b)

When the tip is the back direction, the catheter is inserted into the carotid artery. At this time, Bragg wavelength is decrease by contact with the carotid artery wall when further inserted the catheter. (Figure 5-a)

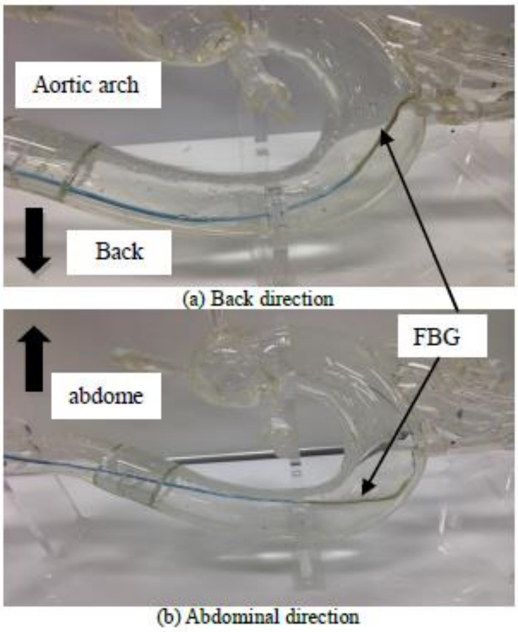
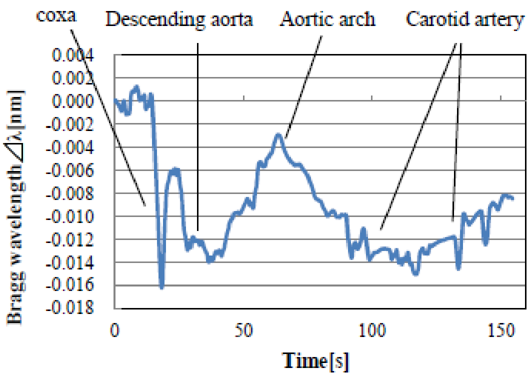
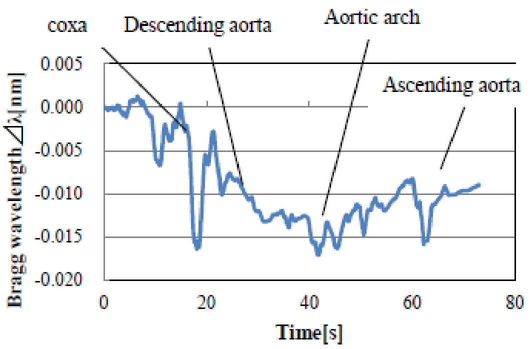


Figure 4 State during insertion



(a) Back direction



(b) Abdominal direction

Figure 5 Experimental result

4. Conclusion

When the experiments were performed using the Altamira, the characteristic waveforms were observed at each vessel. Rough position of the catheter was able to estimate by the waveform. When the tip is pressed against the vessel wall, it was estimated that to put pressure on blood vessels by reduction of the waveform. Therefore, the catheter was measured to be inserted into the carotid artery by reduction of waveform. Because catheter hit the wall when exit from the carotid artery. But the distinction between the left and right carotid artery is impossible. This problem would be able to distinguish by increasing another FBG.

The target of future research is such as creating a more good accuracy sensor and particular better position of sensor, experiment with different conditions.

References:

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