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Development of a Vascular Endoscopic System for Observing Inner Wall of Large Arteries for the Use of Endovascular Intervention

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***Abstract*— We have been developing an endoscopic system for observing inner wall of large arteries. The purpose of this system is to visualize the inner wall of large arteries, *e.g.*, an aorta, without blocking off the blood stream for the use of an assistive technique for endovascular interventions such as stent-graft placement for aortic aneurysm. The technique newly introduced for this purpose was the use of intermittent high-pressure saline jet synchronized to heart beat (diastolic phase). In the previous paper [1], we reported performance of a prototype system using a commercially available bronchoscope having an outer diameter of 5mm with a biopsy channel. A discharging system for intermittent high-pressure saline jet was also constructed using a high-speed solenoid valve and a pressurizing tank. In this study, we tried to introduce a special hood (we call "Hemo-visor") on the tip of the endoscope in order to more clearly observe the target (inner wall of artery). From *in vitro* tests using a mock circulation system, it was confirmed that the Hemo-visor was highly effective for keeping saline solution around the endoscope tip against the blood stream, and for improving the quality of the picture obtained.**

I. Introduction

FOR minimally invasive endovascular therapy, vascular endoscopes with balloon have been commercially available [2] and widely used for visually inspecting inner wall of blood vessels. However, application of this method is limited to only small arteries because it requires blockage of blood flow by the balloon [3, 4]. On the other hand, there have been strong requirement for visually inspecting inner wall of large arteries such as aorta in case of stent-graft treatments for aortic aneurysms and so on [5]. Based on this requirement, we have been developing a prototype endoscopic system applicable for large arteries without blocking off the blood flow, and preliminary results of in vitro and in vivo tests using swine were reported [1]. In this study, an attempt was made to improve the quality of the picture obtained by the system. An outline of the idea and some results obtained by *in vitro* tests using a mock circulation system are described.

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II. System description

Fig. 1 shows a basic concept for visualizing inner wall of large arteries without stopping blood flow. Intermittent saline jet is discharged from the tip of an endoscope. Timing of the jet discharge is synchronized to diastolic phase (minimal blood flow phase) so as to obtain more clear view of the wall. Synchronized to discharge, endoscopic view (movie) is captured and displayed on a monitor. During the other phase (systolic phase without saline jet flow), the latest picture of the captured view (still picture) is displayed so as to obtain "pseudo-movie" of the wall during whole cardiac beat.

In Fig. 2, outline of the endoscope used in this study is shown. It is a commercially available bronchoscope with a channel for forceps. We used this channel (inner diameter: 2.2 mm) for saline jet discharge. Fig. 3 shows an outline of the saline-jet discharge control system. A saline tank (capacity: 5 litters, max. pressure: 0.6 MPa) was pressurized by a conventional air cylinder. At the outlet port of the tank, a high-speed solenoid valve (A2013, Precision Dynamics Co. Ltd.) was connected to control timing and amount of the jet

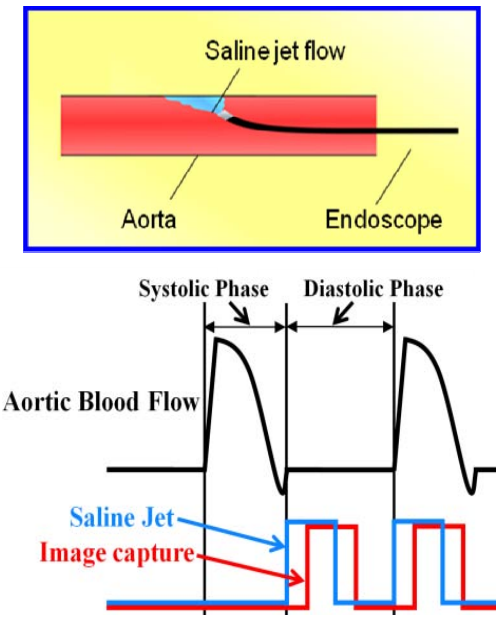

Fig. 1 Basic concept for observing inner wall of large arteries using intermittent saline jet flow

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stream. For *in vitro* tests, the valve was operated by pulse signal (duration: ΔT [ms], frequency: f [Hz]) generated by a function generator *via* a solid state relay. For *in vivo* tests, on the other hand, the pulse signal will be triggered by ECG R-wave.

III. MATERIALS AND METHODS

Fig. 4 shows an experimental set up of *in vitro* test for evaluating visualization performance of the prototype system. A part surrounded by a red square shows a mock circulation system which composed of (i) a compressed air driven pulsatile pump, (ii) an air chamber mimicking aortic compliance, (iii) a valve mimicking total peripheral resistance, (iv) a reservoir mimicking atrium, and (v) an acrylic tube for the endoscope insertion on the inner surface of which an observation target is installed (see the right upper part of Fig. 4). The fluid used was bath salts solution (10g/l; mainly sodium bicarbonate) color of which was milky white (impossible to observe the target through this solution). The driving condition of the pulsatile pump and circulation parameters were adjusted as follows considering the physiological values of male adults at rest;

- ✓ pumping rate : 60 bpm
- ✓ duty ratio: 30%
- ✓ mean pump flow: 6 l/min
- ✓ mean pressure: 100 mmHg
- ✓ pulse pressure: 50 mmHg

(systolic: 130 mmHg, diastolic: 80 mmHg)

The tip of the endoscope was inserted retrogradely into the tube (see the right lower part of Fig. 4) and fixed using a specially made lantern-shaped stent. The intermittent saline jet flow made by the injection system was discharged from

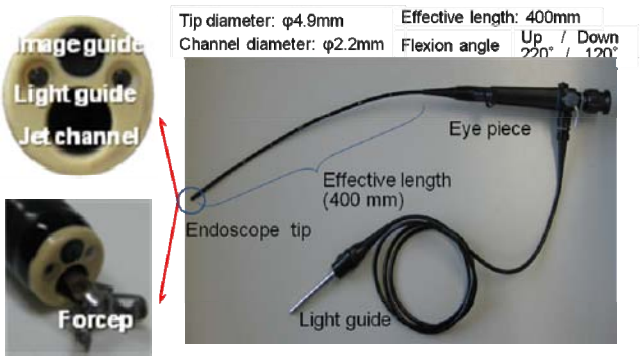

Fig. 2 Photographs of the endoscope

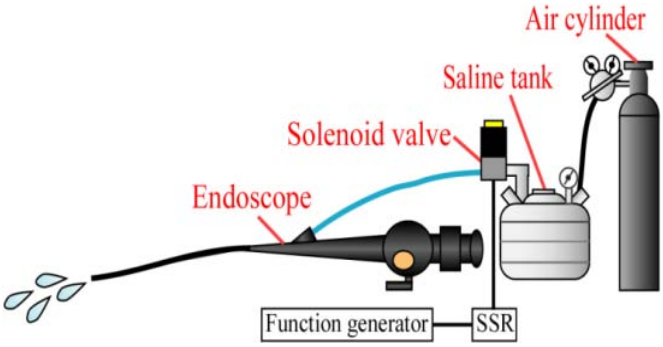

Fig. 3 Outline of the saline discharge system

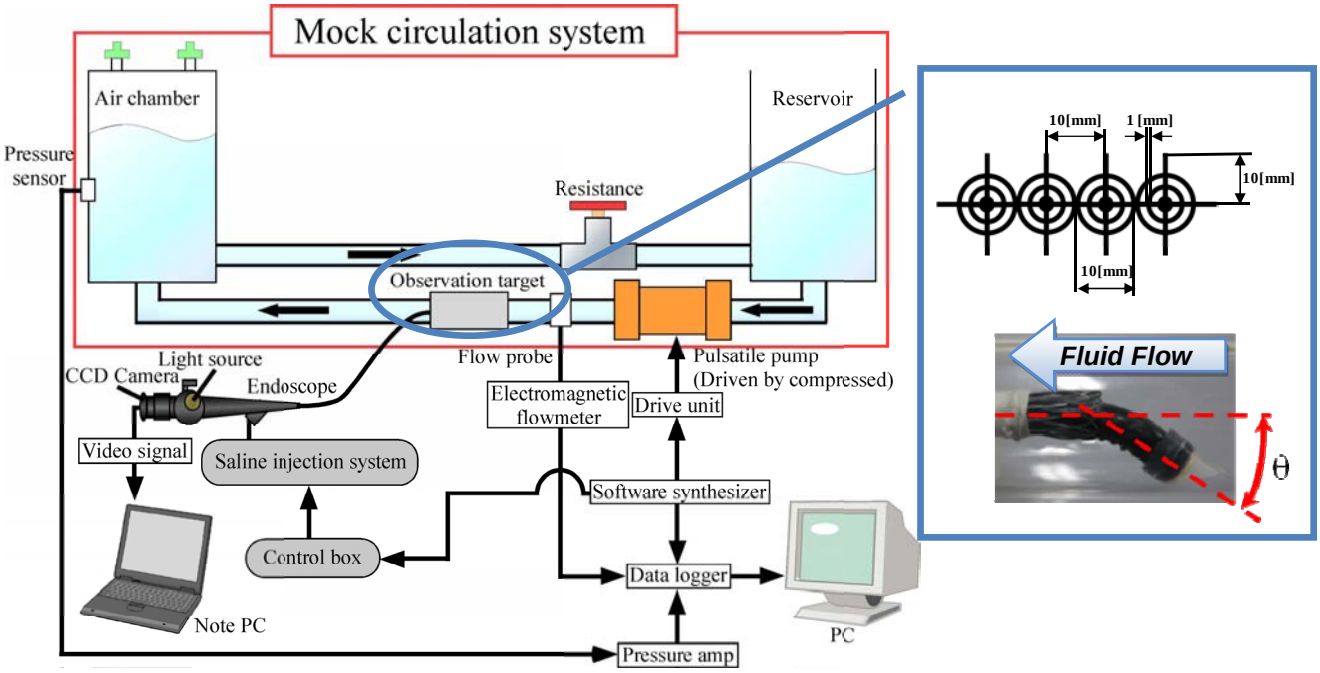

Fig. 4 Outline of the experimental set up for *in vitro* test

the jet channel during the diastolic phase of the pulsatile pump. For synchronization, the driving signal of the pump was used.

For quantitative evaluation of the "clearness" of the obtained picture (movie) of the target, we introduced an index of "visualization scale" which was a difference of the value of brightness between the black line and the white part of the target. Before the experiments, the mock system was once filled with water and the picture of the target obtained by the endoscope was recorded and the value of brightness of the each two part were calibrated to "0" for the black line and "255" for the white part, respectively. And thus, the value of the visualization scale of the most "clear" picture will be "255", and the worst will be "0", which means "all white".

During the experiments, flexion angle of the tip: θ was changed from 30 to 90 degrees and the quality of the picture was quantitatively assessed by the scale. Also changed was the tip configuration, *i.e.*, with or without "Hemo-visor". The "Hemo-visor" is our original naming of a small hood attached on the top of the endoscope tip (see Fig. 5) expecting an effective role in keeping the saline solution between the endoscope tip and the target against the fluid (blood) stream to more clearly obtain the picture.

IV. Results and Discussion

Fig.6 is the results of *in vitro* tests showing the values of visualization scale (vertical axis) in each flexion angle (horizontal axis) with and without Hemo-visor (H-V). Regarding the results of "without H-V", high values (>150) of the scale were obtained only at the high flexion angle (80 – 90 deg), and at the angle of 50 deg, the scale value decreased to about 80 and the black lines of the target were scarcely observed (photograph "A" of Fig. 6). On the other hand, in the results of "with H-V", even at the flexion angle of 50 deg, quite high value of the scale (200) could be attained and the black lines of the target were clearly observed as shown in the photograph "B" of Fig. 6.

The reason for the considerable decrease in the scale value of "without H-V" with the flexion angle change would be explained as follow; At the high flexion angle, the surface of the tip was very closed to the wall (target), and therefore, the discharged saline solution could be staying in the space between the tip and the target, and thus, the clear picture could be obtained. On the other hand, at the lower flexion angle, the space would increase and the saline solution was easily removed by the fluid stream.

.By attaching the Hemo-visor on the top of the tip, the discharged saline could be staying in the space much longer period of time even at the low flexion angle, and thus, the clear picture could be obtained

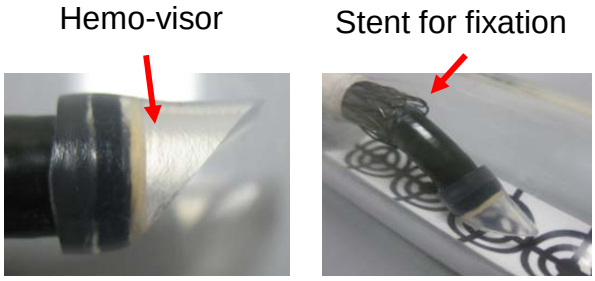

Fig. 5 Photographs of the tip with Hemo-visor

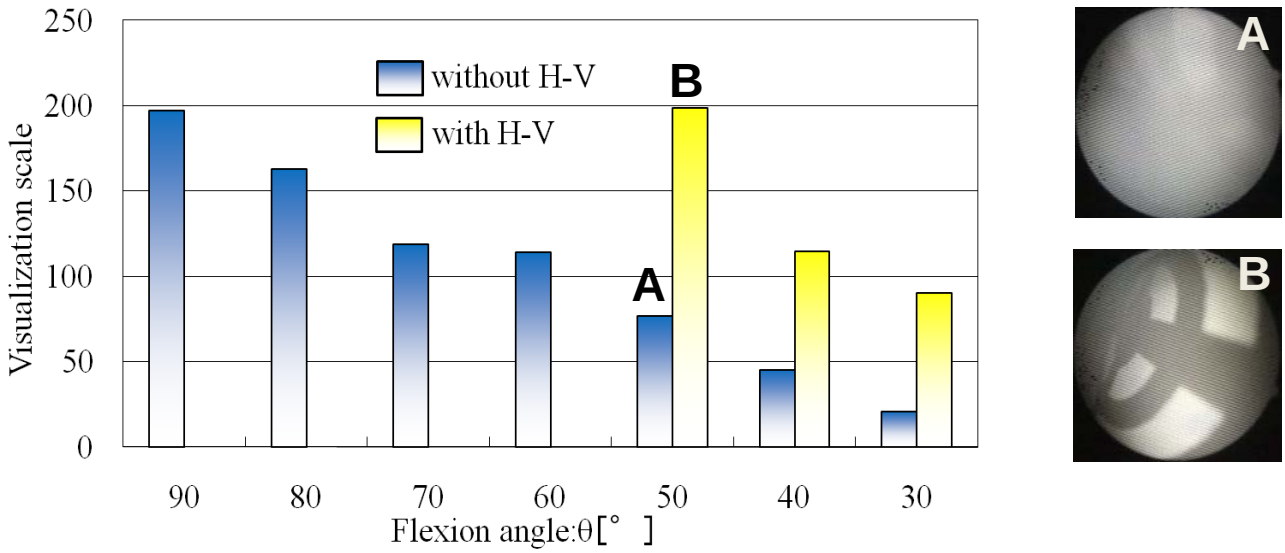

Fig. 6 Results of *in vitro* visualization test (left) and examples of the pictures obtained by the system

V. Conclusion

A prototype endoscopic system for observing inner wall of aorta using intermittent saline jet was devised and evaluated by *in vitro* tests. From the results obtained, it was confirmed that using this system the target attached on the inner surface of the tube of the mock circulatory system could be observed without blocking off the fluid stream, and the Hemo-visor was highly effective in improving the quality of picture presumably due to high ability in keeping the saline solution between the tip and the target. From these results, it is suggested that the present method could be a useful assistive technology for the endovascular interventions in aorta. This method is highly invasive and has some difficulties for practical use, although, it requires no large, bulky and extremely expensive instrument as an angiography and has no risk for the exposure to radiation. These two points are quite big practical advantages of our method.

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