Method to Quantify Flow Reduction in Aneurysmal Cavities of Lateral Wall Aneurysms Produced by Stent Implants Used for Flow Diversion

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Summary

Stent implants placed across the neck of cerebral aneurysms are capable of reducing aneurysmal flow when coils are not used for filling the aneurysms. It is important to evaluate the effects of flow reduction caused by stent implants used for the treatment of cerebral aneurysms. Subtracted vortex centers path line method (SVC method) is one of the image post processing methods employed for quantitative flow measurement. We developed a modified SVC method by employing Cinematic Angiography (25 frames/s) and digital video recording (30 frames/s) with a commercial digital camera. We successfully compared the flow effectiveness using a tubular silicon model with a sidewall aneurysm.

The result suggests that our modified SVC method is useful for a comparative examination of the effect of aneurysmal flow reduction caused by stent implants.

Introduction

The subtracted vortex centers path line method (SVC method) developed by Baráth et Al.¹ is one of the methods for measuring the flow speed in an aneurysmal cavity. We developed a modified SVC method for the measurement of flow speed by employing high-speed digital angiography termed Cinematic Angiography and

a slipstream injection method² that uses a commercial digital camera. The modified method was verified using an aneurysmal model.

Material and Methods

The investigations were conducted using a simple transparent lateral wall silicon aneurysmal model (ESASTRAT Sarl., Switzerland) with a diameter of 5 mm for the neck, 10 mm for the dome, and 3.5 mm for the parent artery. The model was integrated into a tubular circulation system with a pulsatile flow of one pulse per second. Water was used as the fluid. The pressure and pulsatile curves were monitored using a pressure transducer (figure 2). The flow rate was 200 ml/min at the injection point in the system. Cinematic Angiography (INTERGRIS 3D-RA release 2.2, BV 3000, Philips Medical Systems, The Netherlands) was performed at a rate of 25 frames per second (60 kV, 300 mA). Subsequently, the slipstream injection method was recorded using a digital camera (T-1, Sony Corporation, Japan) at a rate of 30 frames per second. Contrast material (Iopamiron 300, Schering, Germany) containing a red dye (chlorhexidine with azorubine E122 alcohol) was injected using a 5F catheter that was placed upstream of the aneurysm, and sequential images were obtained for 4~8 s after the placement of the stents. We compared the

Figure 1 Lateral view of the transparent silicon tubular model with a sidewall aneurysm. Arrows indicate different diameters of the aneurysm.

effects of five different stents including Neuroform (Target/BSC/Smart Therapeutics, CA), Leo (Balt, France), INX (Medtronic Inc., MN), Driver (Medtronic Inc., MN), and Lekton Motion (Biotronik GmbH & Co., Germany). For varying the flow in the aneurysm, the flow speeds before and after the placement of stents were measured by both Cinematic Angiography and the slipstream injection method (2 Imbesi, Karber 1999). The 2-cycle sequential images obtained from Cinematic Angiography and digital video recording were analyzed by the SVC method for subtraction. Microsoft Photo Editor 3.0.1 (Microsoft Corporation) was used for enhancing the images, and subtraction was carried out using Jasc Paint Shop

Pro 6.00 (Jasc Software). The subtracted vortex center positions were traced using NIH images (Scion Corporation). The resolution used in this study was 0.36 mm/pixel.

Results

Figure 3 shows successive sequential images of slipstream injection and the enhanced images of the aneurysm. The flow pattern in the aneurysm was composed of an inflow zone at the distal neck and an outflow zone at the proximal neck. A rotating vortex was formed at the distal neck. It circulated along the aneurysmal wall, rotating by itself, requiring 0.26 seconds per cycle. After two cycles, it diffused and disappeared. The SVC method, which employed both digital video recording and Cinematic Angiography, accurately described the flow reduction caused by the stent implants in the aneurysmal cavity. For example, the traveling time was 1.65 times the control time after the placement of Leo stent. Figure 4 shows the pixel-time linear relationships for all the results of slipstream injection obtained with and without the five types of stents (commercial names are not shown). A low inclination of mean velocity is advantageous to flow speed reduction. These results suggest that the extent of flow reduction varied depending on the type of stent. As shown in the graph, stent N3 appears to be the best stent for aneurysmal flow reduction. The flow pattern and speed were similar in both Cinematic Angiography and slipstream injection (not shown).

Discussion

Stent implantation may potentially lead to embolization of cerebral aneurysms by decreasing the inflow into the aneurysms^{3,4}. We had previously reported that stent design plays an important role in changing or diverting the flow^{5,4}. It is important to measure the flow speed in cerebral aneurysms and quantify the flow effects produced by stent implantation. As mentioned earlier, the SVC method developed by Baráth et Al.¹ is one of the methods for measuring the flow speed in the aneurysmal cavity. This method essentially involves the illumination of particles using a laser sheet integrated into an in vitro aneurysm model. It also performs the post processing of successive images for tracing a vortex in an aneurysm and for estimating the

Figure 2 A display showing the arterial pressure curve, which is almost similar to that of humans (the photo shows a pressure of 145/71 mmHg).

Figure 3 Sequential images of slipstream injection with a Leo stent (A) and without a stent (B) and images subtracted from raw images (C).

Figure 4 A graph of the pixel-time linear relationship curve obtained by the SVC method without stents (control) and with stents (N1-3 and C1,2). The line inclinations represent the flow velocities in the aneurysmal cavity; thus, a low inclination indicates good flow speed reduction.

speed of the vortex center. We applied the SVC method to digital angiography and digital video recording. These facilities are readily available in all clinical institutes. Cinematic Angiography involves high-speed imaging with and without subtraction, which is achieved using a clinical angiography software. This technique may be used for in vivo flow analysis of aneurysms in the near future. We could compare the effects of different stent implants by employing the modified SVC method. However, in case the aneurysmal cavity is filled with an object (e.g., platinum coil), it might be difficult to evaluate the flow because contrast or dye in the cavity cannot be visualized.

Conclusions

The modified SVC method employing Cinematic Angiography and digital video recording successfully quantified the flow reduction caused by stent implants in aneurysmal cavities.

This method is useful and convenient for evaluating the impact of stents on flow reduction inside a cerebral aneurysm.

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