学 位 論 文 の 要 旨

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学 位 論 文 名　A Doppler Flow Analysis of the Neovascular Flow in Carotid Plaque Using Ultrasound Micro-flow Imaging

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論 文 内 容 の 要 旨

INTRODUCTION

Internal carotid artery stenosis accounts for approximately 20% of all cases of cerebral infarction; the major cause of stenosis is atheromatous plaque. The current treatments for carotid artery stenosis include medical treatment and surgical treatment. If carotid artery stenosis is severe or symptomatic, carotid artery stenting (CAS) or carotid endarterectomy (CEA) is recommended as an evidence-based treatment for carotid stenosis.

One problem associated with CAS is cerebral infarction due to embolic events. Vulnerable plaque with bleeding and neovascularization is a risk factor for such events. Bleeding in plaque has been evaluated by ultrasonography and MRI. However, detection of neovascularization in plaque has not been established. Contrast-enhanced ultrasound (CEUS) has been used to examine neovascularization, but it is not common due to problems such as possible side effects associated with the use of contrast agents. On the other hand, superb micro-vascular imaging (SMI), a recent ultrasound technology, is capable of displaying images equivalent to CEUS.

We are investigating the possibility of assessing and quantifying plaque vulnerability, which is a risk factor for CAS, by capturing the micro blood flow of neovascularization around the plaque and measuring Doppler signaling by carotid ultrasonography without contrast

medium.

MATERIALS AND METHODS

The subjects included 6 consecutive patients who underwent CAS for internal carotid artery stenosis at Shimane University from January 2018 to April 2018. Patients who could not undergo carotid ultrasound, CAS, or filter protection were excluded.

The ultrasound was performed as a preparative test for CAS. The following parameters were measured: peak systolic velocity (PSV), end diastolic velocity (EDV), mean diastolic flow velocity (MFV), inner diameter of blood vessel, and maximum intima-media thickness (maxIMT) of the internal carotid artery. The stenosis rate was calculated using the ECST method and the area method. In addition to these measured values, We measured the intraplaque microcirculatory blood flow with SMI. We compared the SMI signal and the embolic events following CAS.

In addition, as a preoperative evaluation, ulcer formation was evaluated by measuring the diameter, length, and shape of the stenosis on 3D-CT angiography (CTA). Vulnerability was evaluated based on the presence or absence of intra-plaque bleeding by MR carotid plaque imaging and time-of-flight (TOF)-MR angiography.

The study protocol was approved by the Research Ethics Committee of Shimane University.

RESULTS AND DISCUSSION

In the target blood vessels, the average flow velocity was 223.8 cm/s (42.3-337.3 cm/s) for PSV, 76.6 cm/s (19.0-165.6 cm/s) for EDV, and 86.9 cm/s (27.5-125.5 cm/s) for MFV. The average stenosis rate was 72.2% (65-82%) in ECST and 87.75% (79-97%) in area. The average plaque thickness was 4.4 mm (3.1-5.5 mm) at max IMT. A positive of the high echo signal of SMI in the plaque was detected in all 5 cases. A clear Doppler signal at the SMI-positive site could not be detected in the plaque, with the exception of Case 3.

The preoperative examination of the target vessels revealed ulceration by CTA in 3 of 5 cases, and MR plaque imaging suggested bleeding in 2 of 5 cases.

Intraoperative plaque protrusion was only seen in 1 (Case 3) of 5 cases. Case 3, postoperative MRI revealed high intensity spots on DWI. On the other hand, preoperative CTA was revealed no ulceration, and MR plaque imaging showed some high signals in the plaque.

In addition to the superiority in the evaluation of the plaque morphology, SMI has been attracting attention as a test that can visualize low-flow blood flow without using contrast medium. Zhang et al. and Mahtab et al. noted, "A significant proportion of ischemic strokes are

caused by emboli from unstable carotid artery plaques with intra-plaque neovascularization as a key feature of plaque instability. When intra-plaque neovascularization was evaluated using SMI and CEUS and compared with pathological findings, there was a correlation between the density of intra-plaque neovascularization and the findings of SMI and CEUS". Intra-plaque neovascularization was reported to be associated with the promotion of the inflammatory reaction, increased permeability of the fibrous cap, increase of the atheroma core, and intra-plaque hemorrhage. These findings of neovascularization are suggested to be possible causes of plaque vulnerability.

In this study, routine imaging modalities such as CTA, MR plaque imaging and carotid ultrasonography did not reveal any specific results in any of the 5 cases. Thus, we did not think that all patients had a high risk of CAS before surgery. However, in Case 3, plaque protrusion occurred at the time of stent procedure, and asymptomatic embolic lesions were seen by DWI postoperatively. In this protrusion case, the preoperative findings included high echo plaque on carotid ultrasound, no ulceration on CTA, ISO intensity on MR-TOF, ISO to high intensity on T1WI of MR plaque imaging, and high echo signal on SMI. These findings were also observed in the other 4 cases. The present case differed from the other cases in the positive Doppler signal at the site of the plaque that showed a high echo signal on SMI.

CONCLUSION

We are investigating the possibility of assessing and quantifying plaque vulnerability, which is a risk factor for CAS, by capturing the micro blood flow of neovascularization around the plaque and measuring Doppler signaling by SMI. In this study, Doppler flow detected by SMI was found to be related to neovascularity of plaque. This finding might indicate the plaque vulnerability.