Cranioplasty and Duraplasty with Transcranial Color-Coded Duplex Sonography after Aneurysmal Subarachnoid Hemorrhage

Hirokazu Sadahiro, MD, Akinori Inamura, MD, Kazutaka Sugimoto, MD, Akiko Yamane, MD, Hideyuki Ishihara, MD, Satoshi Shirao, MD, Hiroshi Yoneda, MD, and Michiyasu Suzuki, MD

Background: Transcranial color-coded duplex sonography (TCCS) is a noninvasive technique for monitoring of cerebral vasospasm after neurosurgery for aneurismal subarachnoid hemorrhage. In this surgery, surgical materials are used. The goal of the study was to identify materials that can be used with ultrasound and to propose methods for cranioplasty and duraplasty using materials that permit TCCS. *Methods:* The chosen neurosurgical materials were titanium mesh plate (TMP), Gore-tex, SEAMDURA, gelatinous sponge, and oxidized cellulose. B-mode imaging was recorded with the materials placed between urethane resin 10 mm in diameter and the urethane phantom model. TCCS was performed to detect middle cerebral artery flow through TMP and Gore-tex. *Results:* TMP and SEAMDURA permitted penetration of ultrasound in B-mode and Doppler imaging, but the other materials did not do so. *Conclusions:* A postcraniotomy window (PCW) on a line extending from the horizontal portion of M1 using only TMP permitted flow imaging with TCCS. In external decompression, TCCS was effective only without use of Gore-tex around the postcraniotomy window. This method allows the middle cerebral artery flow to be detected easily. **Key Words:** TCCS—vasospasm—SAH—titanium mesh plate—Huygens principle—acoustic impedance.

Introduction

Cerebral vasospasm is a major cause of morbidity and mortality after aneurysmal subarachnoid hemorrhage (SAH). Transcranial Doppler (TCD) and transcranial color-coded duplex sonography (TCCS) are noninvasive methods for real-time monitoring of blood flow and detection of cerebral vasospasm.[1-5] In the 2012 American Stroke Association/American Heart Association guidelines, TCD is newly recommended for monitoring the development of vasospasm.[6]

Ruptured aneurysms in the anterior circulation are often clipped with frontotemporal osteoplastic craniotomy. It may be difficult to use TCD with a temporal bone window in elderly patients[7,8] and craniotomy is performed to permit use of TCD. A titanium plate or titanium mesh plate (TMP) and an artificial dura mater are used in cranioplasty and duraplasty, respectively, and oxidized cellulose and a gelatinous sponge are used for hemostasis. However, to our knowledge, it is unclear if ultrasound can penetrate these neurosurgical materials for detection of cerebral blood flow with TCD and TCCS. In the present study, we investigated the effects of these materials on ultrasound and

From the Department of Neurosurgery and Clinical Neuroscience, Yamaguchi University School of Medicine, Yamaguchi, Japan.
Received April 23, 2015; revision received June 30, 2015; accepted July 20, 2015.
Address correspondence to Hirokazu Sadahiro, Department of Neurosurgery and Clinical Neuroscience, Yamaguchi University School of Medicine, 1-1-1 Minami-Kogushi, Ube, Yamaguchi, Japan. E-mail: sadahiro@kenwakai.gr.jp.
1052-3057/$ - see front matter

http://dx.doi.org/10.1016/j.jstrokecerebrovasdis.2015.07.023

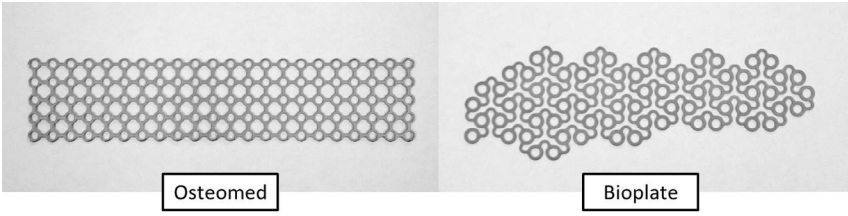

Figure 1. *Titanium mesh plates from OsteoMed (left) and Bioplate (right).*

we propose an operative method for cranioplasty that permits use of TCCS after cranioplasty.

Materials and Methods

Neurosurgical Materials

Two types of TMP (Bioplate Inc., Los Angeles, CA; and OsteoMed, Addison, TX) (Fig 1), two types of artificial dura mater (Gore-tex, W.L. Gore & Associates, Flagstaff, AZ; and SEAMDURA, Gunze, Ayabe, Kyoto, Japan), gelatinous sponge (Spongel; Astellas Pharm, Chuo-ku, Tokyo, Japan), and oxidized cellulose (SURGICEL; Ethicon, Inc., Somerville, NJ) were tested. The TMPs in Bioplate and OsteoMed had thicknesses of .3 and .4 mm, respectively.

TCCS

TCCS was performed using Prosound α-7 (Hitachi-Aloka Medical, Mitaka, Tokyo, Japan) with a 1- to 5-MHz 90° phased-array probe for B-mode imaging and color Doppler imaging. Middle cerebral artery (MCA) flow signals were recorded at the depth (45-60 mm) showing the highest Doppler velocity, with a 4-mm-wide sample volume placed on the MCA. Penetration of the neurosurgical materials by ultrasound in TCCS was investigated using 3 methods, as described below. All study protocols followed the principles outlined in the Declaration of Helsinki. The present study was approved by the Ethics Committee of Yamaguchi University.

B-Mode Imaging with Material Placed between Urethane Resin and a Urethane Phantom Model

B-mode imaging was performed with urethane resin and a urethane phantom model (sound velocity 1434 m/second, attenuation ratio .57 db/cmMHz, acoustic impedance 1.37 rayl, density .956) (Kyoto Kagaku, Kyoto, Japan). B-mode imaging was recorded with artificial dura mater (Gore-tex and SEAMDURA), TMP, gelatinous sponge, or oxidized cellulose placed between urethane resin 10 mm in diameter and the urethane phantom model (Fig 2). Each material was soaked with echo jelly, and the gelatinous sponge and oxidized cellulose were dampened well. The gelatinous sponge had a thickness of 10 mm in dry condition and was sufficiently dampened and deaerated. Four layers of oxidized cellulose were used.

TCCS after Cranioplasty with TMP

Consecutive patients who underwent osteoplastic craniotomy for SAH caused by rupture of an anterior circulation aneurysm were enrolled from January 2011 to January 2012. In all cases, the sphenoidal ridge was eliminated; duraplasty was performed with autologous dura mater; and cranioplasty was performed with autologous bone, TMP, and a titanium plate. TMP was laid as covering from the keyhole to the shaved sphenoidal ridge. There was no hemostatic material around the TMP. After surgery, TCCS was performed to detect bilateral MCA flow. The probe was fixed in a line extending from the horizontal portion of the MCA (M1) to show ipsilateral M1 flow without angle compensation. This probe position, which is referred to as the postcraniotomy window (PCW), was approximately 2 cm above and 1 cm forward from the midpoint of the zygoma (Fig 3).

TCCS after External Decompression and Duraplasty with Gore-tex

Consecutive patients who underwent external decompression for SAH caused by rupture of an anterior circulation aneurysm were enrolled from January 2011 to January 2012. In all cases, loose duraplasty was performed with Gore-tex, including underlay of Gore-tex from

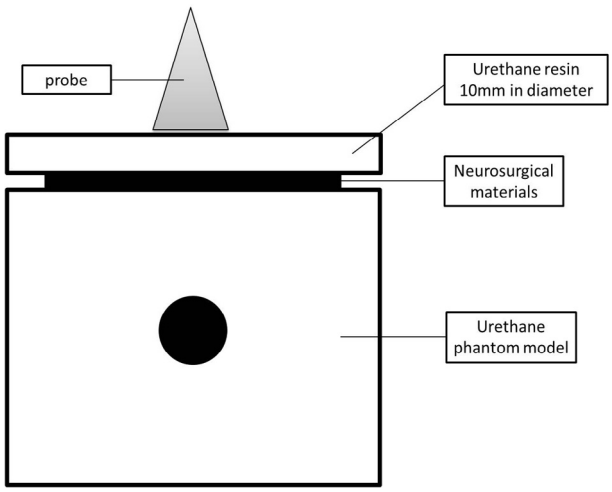

Figure 2. *Model system to evaluate penetration of neurosurgical material by ultrasound. B-mode imaging was recorded with neurosurgical materials placed between urethane resin 10 mm in diameter and a urethane phantom model. Neurosurgical materials were filled with echo jelly without air.*