Triple-Balloon Shunt Placement for Carotid Endarterectomy: A Novel Intraluminal Shunt Designed to Preserve the Internal and External Carotid Blood Flow

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Key words
- Carotid endarterectomy
- Cerebral blood flow
- Intraluminal shunt
- Triple-balloon shunt

Abbreviations and Acronyms
ACA: Anterior cerebral artery
CEA: Carotid endarterectomy
ECA: External carotid artery
ICA: Internal carotid artery
MCA: Middle cerebral artery
STA: Superficial temporal artery

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■ OBJECTIVE: **To report a newly developed intraluminal triple-balloon shunt designed to preserve the blood flow of both the internal carotid artery (ICA) and the external carotid artery (ECA) during carotid endarterectomy in patients with a previous ipsilateral extracranial-intracranial bypass, in whom hemodynamic cerebral ischemia might be caused by cross-clamping at the ICA as well as the ECA.**

■ METHODS: **The novel device consists of 3 silicone tubes equipped with balloons at each end. The design facilitates insertion proximally to the common carotid artery and distally to both the ICA and the ECA.**

■ RESULTS: **The new shunt tube was used in 3 patients, each of whom had previously undergone ipsilateral superficial temporal artery−middle cerebral artery bypass for proximal middle cerebral artery occlusion. The blood flow of the middle cerebral artery and anterior cerebral artery was supplied independently from the ECA via the bypass and from the ICA, respectively. There were no shunt-related complications.**

■ CONCLUSIONS: **This novel shunt device can be used safely and effectively in cases requiring preservation of the blood supply to both the ICA and the ECA during carotid endarterectomy.**

INTRODUCTION

We recently developed an intraluminal triple-balloon shunt derived from a modification of the conventional double-balloon shunt, Furui's shunt (Inter Medical Co., Ltd., Nagoya, Japan), with an additional third silicone tube. This novel shunt can be placed in the external carotid artery (ECA) and the internal carotid artery (ICA) and may preserve the blood flow of both arteries during carotid endarterectomy (CEA). We report use of this shunt in CEA performed in 3 patients who had previously undergone ipsilateral superficial temporal artery−middle cerebral artery (STA-MCA) bypass for symptomatic proximal MCA occlusion.

METHODS

Description of the Triple-Balloon Shunt

The triple-balloon shunt consists of 3 flexible silicone tubes equipped with a silicone rubber balloon at each end that can be inflated through a small lumen in the wall of the tube to be held in place without blood leakage. This novel shunt device was created by modifying Furui's double-balloon shunt, a widely used shunt that we have employed for many years. The original shunt, which we modified to devise the new shunt, measures 3.0 mm or 3.5 mm in outer diameter and 30 cm in length with the side arm at the middle portion, forming a T-shaped device (Figure 1A) (4). The novel triple-balloon shunt has another balloon-equipped silicone tube that measures 12 cm in length attached to the original tube at a site 3 cm from the middle portion at a 25-degree angle (Figure 1B). This design enables insertion into both the ICA and the ECA in patients requiring preservation of flow of both the ICA and the ECA during cross-clamping for CEA. Similar to the original shunt, this device is designed to overcome shunt-related problems, such as the risk of intimal damage, distal embolism, and blood leakage. In addition, the flexible silicone tube has sufficient pliability and length to form a "U" shape outside of the vessel lumen, which prevents it from interfering with the operating field (Figure 1C). The side arm of the shunt tube can be used to assess the shunt patency, remove air bubbles, and monitor the stump pressure.

Indications

In our practice, we have a policy for performing routine shunt placement during CEA. Among 193 consecutive patients who underwent CEA with shunt placement at our stroke center between January 2006 and December 2012, 3 patients had previously undergone ipsilateral STA-MCA bypass for symptomatic proximal MCA occlusion. Each of these patients presented with mild stenosis in the ICA at the time of the bypass surgery; however, the degree of stenosis progressively increased during the follow-up period. Angiograms of all 3 patients demonstrated that the collateral blood supply from the

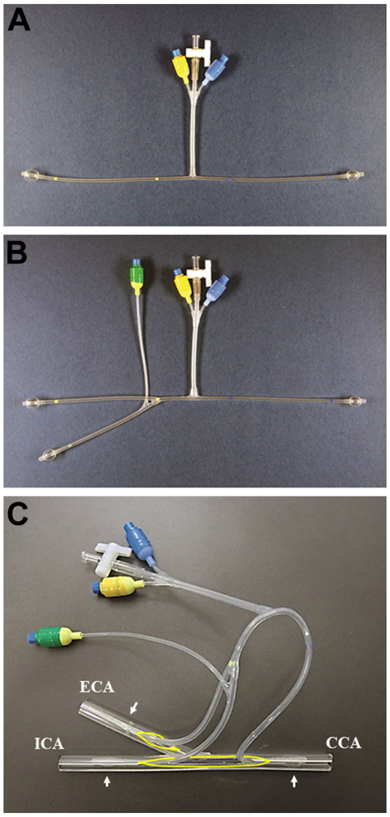

Figure 1. Furui's double-balloon shunt (**A**) and novel triple-balloon shunt derived from a modification of the original device with the addition of a third balloon-equipped shunt tube (**B**). This design enables the insertion of the device into the internal carotid artery and the external carotid artery to preserve the carotid flow of both vessels during carotid endarterectomy. The flexible silicone tube has sufficient pliability and length to allow it to be formed into a "U" shape outside of the vessel lumen, which prevents it from interfering with plaque visualization (**C**). A short arteriotomy created at the proximal site of the external carotid artery, in addition to and discontinuous with the longitudinal incision over the carotid bifurcation through the common carotid artery to the internal carotid artery, helps to prevent the limitation of plaque exposure. The arteriotomy sites are highlighted by yellow lines, and the sites where balloons sit are indicated by *arrows*. ICA, internal carotid artery; ECA, external carotid artery; CCA, common carotid artery.

contralateral carotid artery through the anterior communicating artery or proximal anterior cerebral artery (ACA) and from the ipsilateral posterior cerebral artery through the posterior communicating artery was insufficient. The blood flow of the MCA and ACA was thought to be independently supplied; the MCA flow was from the ECA via the STA-MCA bypass, and the ACA flow was from the ICA. These patients were considered to have indications for triple-balloon shunt placement during CEA.

Surgical Technique

Placement of the triple-balloon shunt can be performed easily in the usual manner during CEA. A short arteriotomy should be made at the proximal site of the ECA that is in addition to and discontinuous with the longitudinal incision made over the carotid bifurcation through the common carotid artery to the ICA (Figure 1C). This additional ECA incision helps to prevent the limitation of plaque exposure and permits complete resection of the plaque at the proximal ECA if a lesion exists. To make the ischemic time during the arterial closure after shunt removal as short as possible, the arteriotomy should be closed from each end to the middle portion to facilitate shunt tube removal.

RESULTS

Clinical Results

The clinical data of the 3 patients who underwent CEA using the triple-balloon shunt are summarized in Table 1. The shunt system was used safely in all cases. Each patient underwent CEA because of an increased degree of carotid stenosis 20–34 months after ipsilateral STA-MCA bypass. The collateral blood supply from the contralateral or posterior cerebral circulation through the anterior communicating artery or posterior communicating artery was insufficient in these cases. To keep the ischemic time for carotid cross-clamping short, the shunt needed to be placed in <7 minutes, and the arteriotomy needed to be closed after shunt removal in <15 minutes. There were no abnormal changes on intraoperative electroencephalography or somatosensory evoked potential monitoring, new ischemic brain lesions on diffusion-weighted imaging performed 1 day after CEA, or perioperative strokes or deaths.

Illustrative Case Presentation

A 69-year-old man who had previously undergone right STA-MCA bypass for symptomatic proximal MCA (M1) occlusion presented with progressively worsening carotid stenosis requiring CEA 34 months after the bypass surgery (Figure 2A–C). Digital subtraction angiography demonstrated that the blood flow of the MCA and ACA was supplied independently from the ECA via the STA-MCA bypass and from the ICA, respectively (Figure 2D). There was no visualization of the ACA on a left carotid angiogram, indicating poor collateralization (Figure 2E). CEA was performed using the triple-balloon shunt to preserve the blood flow of both the MCA and the ACA territories during carotid cross-clamping (Figure 3). There were no intraoperative electroencephalography or somatosensory evoked potential changes consistent with cerebral ischemia. No new ischemic brain lesions were detected on diffusion-weighted imaging 1 day after the surgery. The carotid stenosis was repaired with no perioperative adverse events (Figure 2F). Postoperative ultrasound examinations performed every 3 months after CEA demonstrated no abnormal changes in the ICA or ECA. No cerebrovascular events occurred during a 3-year follow-up period.

DISCUSSION

The role of shunt placement during CEA has been widely debated (2, 3, 6, 7, 11, 13). Several large series have documented that the use of routine shunt placement and selective shunt placement is associated with a low rate of stroke. Both methods are considered to be acceptable, and the individual surgeon can select the method with which he or she is more comfortable (1). However, the surgeon's familiarity and comfort with shunt placement during CEA can influence the incidence of perioperative stroke or death in the setting of contralateral carotid occlusion; patients treated by surgeons who place shunts routinely have a lower risk of stroke and death than patients treated by surgeons who place shunts selectively (5). In our facility, we have a policy for performing routine shunt placement, which simplifies intraoperative decision making regarding shunt use. This policy is based on the results of several trials in which the indications for shunt placement were not standardized. We routinely use shunt devices during CEA procedures, and no shunt-related complications were observed in 193 consecutive patients who underwent CEA with shunt placement at our stroke center between January 2006 and December 2012.