Incidence of Ischemic Lesions by Diffusion-Weighted Imaging After Carotid Endarterectomy With Routine Shunt Usage

Tomohiro INOUE, Kazuo TSUTSUMI, Keiitirou MAEDA*, Shinobu ADACHI, Shota TANAKA, Kyoko YAKO, Kuniaki SAITO, and Naoto KUNII

Department of Neurosurgery, Showa General Hospital, Kodaira, Tokyo; *Department of Neurosurgery, Aizu Chuou Hospital, Aizu, Fukushima

Abstract
Temporary intraluminal shunt was used during 72 consecutive carotid endarterectomies (CEAs) in 61 patients (bilateral CEA in 11 patients) during October 2001 and September 2005. The medical records of these patients were retrospectively reviewed. All procedures were performed with routine shunt insertion without monitoring such as electroencephalography. Pre- and postoperative diffusion-weighted magnetic resonance (MR) imaging was used to detect ischemic complications. Postoperative angiography was performed in 70 cases to detect abnormalities such as major stenosis or dissection of the distal end. Symptomatic ischemic complication occurred in one patient at 1 month. Postoperative diffusion-weighted MR imaging detected new hyperintense lesions in three patients including the symptomatic patient. Postoperative angiography confirmed that the distal end was satisfactory in all cases. The incidence of ischemic lesions of embolic origin after CEA with routine shunt usage is acceptably low if the procedure of shunt device insertion and removal is meticulously conducted.

Key words: carotid endarterectomy, shunt, diffusion-weighted magnetic resonance imaging

Introduction
Carotid endarterectomy (CEA) is considered to be the most effective treatment for stroke prevention in patients with high grade carotid stenosis, and is associated with low incidences of perioperative neurological complications and death.4,9,13 Most perioperative neurological complications are ischemic complications caused by hemodynamic hypoperfusion, which is considered to be relatively rare, and emboli released from the fragile plaque during arterial dissection or cross-clamping.3,10,12 Therefore, the most common strategy to prevent ischemia during CEA is selective shunt usage based on the findings of electroencephalography (EEG), stump pressure, or transcranial Doppler sonography, to reduce the risk of embolic complication resulting from shunt device insertion or removal.2,11,16 As shunting carries the risk of embolus release,9,12,17 However, the intraoperative decision-making for selective shunt usage following monitoring changes during cross-clamping requires vast experience. In fact, most CEA series with good results performed with EEG monitoring and selective shunting occurred at large centers.10 In addition, none of the hemodynamic criteria are absolutely reliable for predicting the need for shunting since both false negatives and positives are observed.2

Our center has a medium case load in a medium size hospital, so we considered that routine shunt use would be safer, as long as precautions were taken to prevent the generation of emboli during shunt device manipulation. We did not use any monitoring method such as EEG, because the only responses to detection of ischemic change are shunt insertion and blood pressure elevation, which were both performed routinely.

Here we retrospectively analyze our series of 72 cases of CEA, performed with careful and meticulous routine shunt insertion without monitoring, and evaluated by preoperative and postoperative diffusion-weighted magnetic resonance (MR) imaging for the occurrence of emboli during CEA, including neurologically silent emboli.

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Methods

I. Patient population

This series consisted of 76 consecutive CEAs performed in 64 patients with high grade carotid artery stenosis between October 2001 and September 2005 in Aizu Chouo Hospital (October 2001–March 2002) and Showa General Hospital (April 2002–September 2005) under the supervision of the senior author (K.T.). Preoperative and postoperative diffusion-weighted MR imaging was obtained within the 5 days before and again within the 5 days after surgery in 72 of 76 CEAs. Three patients (bilateral CEA in 1 patient) had contraindications such as pacemaker insertion (2 CEAs) and coronary stent (2 CEAs). Three other CEAs were emergent procedures performed for acute internal carotid artery (ICA) occlusion caused by rupture of atheromatous plaque, so were not included in this study since it was difficult to evaluate whether the ischemic event happened preoperatively or during the procedure. Therefore, we retrospectively analyzed the medical records of 72 CEAs performed in 61 patients (bilateral CEAs in 11 patients).

The 61 patients, 15 women and 46 men, were aged 51 to 81 years (mean 70.1 ± 7 years). Arterial hypertension (80%) was the most frequent risk factor followed by history of coronary artery disease (39%), cigarette smoking (39%), diabetes mellitus (38%), and hyperlipidemia (30%). The carotid artery stenosis was symptomatic in 32 of 72 cases, and asymptomatic in 40 cases. Severe stenosis (>90%) was observed in 26 cases. The contralateral ICA was occluded in nine cases, with six CEAs preceded by contralateral superficial temporal arterial-middle cerebral artery anastomosis after confirming the compromised vascular reserve of contralateral side with single photon emission computed tomography.

The preoperative diagnosis of high grade carotid artery stenosis was confirmed with angiography in all cases. The degree of stenosis was determined with the North American Symptomatic Carotid Endarterectomy Trial criteria. All patients underwent coronary evaluation before surgery and some patients needed percutaneous transluminal coronary angioplasty to reduce the risk of cardiac events in the perioperative period. All patients were screened for diabetes mellitus by measuring the hemoglobin A1c level, and appropriate control of the blood sugar level was achieved before surgery. Medication of antiplatelet drugs was continued throughout the course of treatment including the day of surgery and postoperative day 1.

II. CEA procedure

The systolic blood pressure was maintained at the preoperative level to avoid hypoperfusion. Nasal intubation was performed and the patient’s neck was extended to expose the high cervical level. The ICA was exposed adequately above the upper extent of the stenosis. Intravenous heparin (5000 U) was administered, then cross clamping was performed in the order of the superior thyroid artery, external carotid artery (ECA), ICA, and common carotid artery (CCA). Arteriotomy was then performed, and the lumen was rinsed with heparinized saline to remove debris.

Shunting was performed with a commercially available tri-lumen flexible “Furui Shunt” (Inter Medical Co., Ltd., Nagoya, Aichi). The proximal tube was clamped, then the distal shunt tube was inserted carefully into the ICA, taking care not to push in debris, then the balloon of the distal tube was inflated with 0.2–0.3 ml of saline with great care taken not to damage the intima of the ICA by overinflation. The balloon was held in place from the outside of the ICA with a small encircling clip, far enough distal to the upper extent of arteriotomy to not hinder the manipulation of the distal plaque end (Fig. 1). Back flow was drawn from the third tube of the shunt to extract any small debris in the distal ICA followed by flushing with heparinized saline. Similarly, the proximal tube was placed into the CCA and the balloon was inflated with 0.7–0.8 ml of saline and held in place with vessel tape and tourniquet. Again, extraction of back flow as well as flushing with heparinized saline were carefully performed to remove debris. The blood flow was then restored through the shunt.

The 22 cm long flexible shunt could be mobilized and did not hinder plaque dissection (Fig. 1) or distal end manipulation (Fig. 2). In fact, insertion of the tacking suture in the distal end to prevent subintimal dissection was facilitated as the shunt held the lumen of the ICA open so the needle was easier to pass from inside to out. The arteriotomy was then closed from each end toward the center, primarily with a running 6-0 prolene suture. With a few stitches before completion, the shunt device was removed. Before tying the prolene suture at the center, the lumen was inflated with heparinized saline. After tying, the ICA was declamped for a few seconds, then clamped again to wash out possible distal debris by back flow, then the ECA and CCA were declamped to wash out possible debris into the ECA. After a short time, the ICA was finally declamped and the flow was restored. Systemic heparinization was then reversed with protamine.
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III. Neuroimaging evaluation

MR imaging used a Eclipse 1.5T system (Marconi medical systems, London, U.K.) with B factor 1000, repetition time (TR)/echo time (TE)/excitations 6265 msec/103 msec/1, section thickness 6 mm, matrix 100 × 100, and field of view 22 × 22 in Aizu Chuo Hospital, and a Signa Lx 1.5T system (General Electric Company, Fairfield, Conn., U.S.A.) with B factor 1000, TR/TE/excitations 9999 msec/130 msec/1, section thickness 5 mm, matrix 256 × 128, and field of view 32 × 32 in Showa General Hospital.

Diffusion-weighted MR images of the whole brain were evaluated to detect the occurrence of emboli, even neurologically silent emboli, during surgery. Any new hyperintense area on the surgical side was interpreted as a sign of new embolic lesions after CEA. Postoperative computed tomography (CT) was performed several times to exclude ischemic lesions in addition to neurological evaluations in all patients. Angiography was performed at around postoperative day 7 in 70 cases. MR angiography was substituted for postoperative angiography in two cases because of suboptimal renal function in the patients.

Results

Only one case (Fig. 3) of the 72 CEAs resulted in ischemic morbidity at 1 month postoperatively. Postoperative diffusion-weighted MR imaging showed new embolic lesions in three cases (Figs. 3–5) including this case.

The patient with ischemic morbidity was a 73-year-old man who was treated for symptomatic high
grade stenosis of the left ICA (Fig. 3A). The plaque was very extensive and fragile. Shunt manipulation was conducted as usual and the distal plaque was removed meticulously, but we were obliged to leave some proximal plaque which apparently continued far distal toward the aorta. He awoke with right hemiparesis, especially in the upper extremity. Postoperative diffusion-weighted MR imaging showed several new high intensity spots around the centrales semiovale (Fig. 3C, D). Postoperative angiography showed that the ICA was patent but the ECA was occluded (Fig. 3B). Fortunately, his neurological status continued to improve, although he had slight clumsiness of the right hand even at follow up at 6 months postoperatively.

The other two patients (Figs. 4 and 5) remained neurologically silent. Postoperative angiography or MR angiography was performed in 70 cases of CEA, and detected no major stenosis or dissection at the distal end of ICA.

Discussion

Our strategy of routine shunt insertion without monitoring during CEA resulted in only one ischemic complication in 72 consecutive cases (1.4%). Postoperative diffusion-weighted MR imaging showed ischemic lesions in three cases of 72 CEAs (4.2%). Despite the small sample size, this result is acceptable compared with previous reports evaluating postoperative ischemic lesion with diffusion-weighted MR imaging. We assumed that these ischemic lesions were emboli since the total times for shunt insertion and plaque removal were not longer compared to other cases in this series without lesions, although we could not investigate the definite mean time of shunt manipulation because of the retrospective nature of this study.

Two of the three cases with ischemic lesions were associated with atheromatous plaque extending even into the ECA, so that the ECA was occluded by postoperative angiography (Figs. 3 and 5). We hypothesize that some debris was passed toward the ICA during the declamping procedure. Transcranial Doppler sonography has shown that the highest number of microembolic signals is detected during the declamping period. We consider that shunting itself does not increase the risk of ischemic lesion, even clinically silent lesions detected only by diffusion-weighted MR imaging, if the shunt device is carefully used with meticulous preparation before insertion, and careful rinsing with heparinized saline through the third lumen as detailed in our endarterectomy method.
Another problem with shunt usage is the possible interference with the removal of the distal extension of the plaque.14) However, in our experience, the long flexible internal shunt does not kink easily, and is slightly smaller in diameter than the ICA, so did not interrupt plaque dissection but rather held open the distal end of the arteriotomy and helped to visualize the distal plaque as well as the tacking suture from inside the lumen.

Postoperative angiography showed a slight notch in the ICA in two of the three cases with ischemic lesions, possibly indicating insufficient distal plaque removal (Figs. 3 and 5). However, we completely removed the distal plaque in the case with symptomatic ischemic complication (Fig. 3), suggesting that the distal ICA became focally stenotic because we took a slightly larger bite than usual during primary closure due to the fragile arteriotomy line after removal of extensive and invasive plaque. In contrast, we did not consider the notch was due to residual plaque or inappropriate suturing in the case with neurologically silent lesion (Fig. 5). In our experience, in which almost all CEAs are followed by postoperative conventional angiography, this type of slight notch sometimes occurs regardless of the method of distal plaque manipulation, for example, appearing if the distal plaque was completely removed but not if the distal end was secured with several tacking sutures. Comparison of the slight notch in postoperative conventional angiography with MR angiography or three-dimensional CT angiography might reveal the meaning of this finding.

References

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Address reprint requests to: K. Tsutsumi, M.D., Department of Neurosurgery, Showa General Hospital, 2–450 Tenjin–cho, Kodaira, Tokyo 187-8510, Japan. e-mail: k.tsutsumi-md@nifty.com

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Commentary

The authors have described a consecutive series of 72 carotid endarterectomies performed in 61 patients over a four year period utilizing a strategy of routine shunting without any intraoperative monitoring. To evaluate for ischemic lesions, the patients underwent both preoperative and postoperative diffusion-weighted MRI. Postoperative angiography was performed in 70 of the 72 cases to determine the technical result of the endarterectomy. Although three of the 72 endarterectomies resulted in an ischemic injury on postoperative diffusion-weighted MRI (4%), only one patient (1.3%) was symptomatic from the ischemic lesion.

The primary importance of this article is to illustrate that excellent results can be obtained with carotid endarterectomy utilizing a variety of surgical strategies, as long as meticulous attention is employed in performing the surgical procedure. It is perhaps more important for the surgeon to be comfortable with his or her own technique than to adhere to a specific strategy that may include local or general anesthesia, routine or selective shunting or utilizing various types of intraoperative monitoring.

In my own practice, I routinely use EEG monitoring and selectively shunt patients based upon demonstration of hemodynamic insufficiency. This results in a very small minority of patients requiring shunts and, in my hands, allows for a more meticulous endarterectomy, particularly at the crucial distal internal carotid artery. Working around an indwelling shunt can be cumbersome and obtrusive, but the present study certainly indicates that excellent results can be achieved with routine shunting.

I would note that the specific findings on postoperative angiography were not reported in any detail in this series. In both of the illustrative cases, however, the external carotid artery was occluded on the postoperative angiogram. Furthermore, both postoperative angiograms demonstrated noticeable constriction at the distal aspect of the endarterectomy. Whether these technical issues were affected by the presence of an indwelling shunt is unclear.

Daniel L. Barrow, M.D.
Department of Neurosurgery
Emory University
Atlanta, Georgia, U.S.A.

Inoue and colleagues reviewed 72 consecutive carotid endarterectomies (CEAs) with routine intraluminal shunting and analyzed the postoperative clinical course and changes on diffusion-weighted magnetic resonance imaging (DWI). Postoperative DWI detected new hyperintense lesions in three patients including one symptomatic patient, and these changes were considered to be embolic complication. In this series, no complication due to hemodynamic hypoperfusion was experienced, and symptomatic embolic complication was also rare (1 case, 1.4%). They concluded that the incidence of ischemic lesions of embolic origin after CEA with routine shunt usage is acceptably low if the procedures of shunt device and removal are meticulously conducted.

Shunt usage has an advantage for prevention of hypoperfusion, but also disadvantages for embolus formation and disturbance of operative field. In this study, the authors suggested that the risk of embolism will be minimum in CEA with routine shunt. This may not be new information, but such actual data has not been presented previously. I would like to pay my respects to the clinical policy and effort of the authors. On the other hand, this result does not prove that shunt usage is the best method of CEA. The important subject is meticulous and careful procedure, and perioperative management depends on the patient's condition, and is not "shunt use or not."

Shunro Endo, M.D.
Department of Neurosurgery
Faculty of Medicine
University of Toyama
Toyama, Japan

The use of a shunt device in carotid endarterectomy (CEA) to prevent cerebral hypoperfusion during the cession of internal carotid flow after cross-clamping has been adopted by many surgeons. However, shunt insertion may also increase the possibility of dislodging clots or debris from atheromatous plaque to cause distal embolism during the surgery. Thus, instead of routine use of the shunt, most surgeons only select patients with poor collateral as candidates for shunt usage in CEA.

In this article, to verify that intraluminal insertion of shunt during CEA would not increase the chance of intracranial embolism, the authors retrospectively analyzed their 72 consecutive CEAs on 61 patients with high-grade carotid stenosis. Shunt was routinely used in all patients. Their results showed that the postoperative diffusion-weighted MR imaging study demonstrated newly developed embolic events in 3 patients. However, the embolic events in 2 of these 3 patients were clinically silent. Thus, the ischemic morbidity after these 72 CEAs was 1.4%. There was no control group in the present study.

In our own practice, we very rarely use the shunt during CEA. We try to minimize the ischemic time by a circumferential dissection of the plaque without opening the lumen of the artery. Cross-clamping of the internal carotid artery is not applied until this dissection reaches both ends of the plaque to open the arterial lumen. The ischemic time can be reduced to 15 min on average. With continuous monitoring of computed electroencephalography and oxygen saturation by infrared oximeter, we do not find any necessity for using the shunt device in CEA. There were 2 perioperative ischemic complications among our 298 CEAs (0.7%).

Yong-Kwang Tu, M.D.
Department of Neurosurgery
College of Medicine and Hospital
National Taiwan University
Taipei, Taiwan, R.O.C.

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