Echocardiography-guided aortic cannulation by the Seldinger technique for type A dissection with cerebral malperfusion

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ABSTRACT

Objective: The purpose of this study was to assess the efficacy of echocardiography-guided ascending aortic central cannulation using the Seldinger technique during surgery for type A acute aortic dissection complicated by stroke due to cerebral malperfusion.

Methods: Between April 2007 and December 2017, 208 patients with type A acute aortic dissection underwent echocardiography-guided ascending aortic central cannulation using the Seldinger technique. We analyzed 16 of these patients (7.7%; median age, 63 years; 8 men) with stroke due to cerebral malperfusion, including 10 in a comatose state (Glasgow Coma Scale ≤ 8) and 6 with hemiplegia (manual muscle test ≤ 1) on hospital arrival. The Modified Rankin Scale was used to evaluate activities of daily living.

Results: The median time from onset of symptoms to establishment of cardiopulmonary bypass was 327 (176-561) minutes. The median time from the start of surgery to establishment of cardiopulmonary bypass was 34 (30-44) minutes. The mortality rate was 6.3% (1/16). In patients with preoperative coma, the Glasgow Coma Scale improved significantly after surgery from 4.5 to 15 at 30 days ($P < .001$). In patients with preoperative hemiplegia, 4 showed improved motor function on the manual muscle test score at 90 days. In all patients, Modified Rankin Scale scores improved significantly from 5.0 preoperatively to 1.0 after follow-up ($P < .001$).

Conclusions: Echocardiography-guided ascending aortic central cannulation using the Seldinger technique has potential as a rapid and reliable perfusion route during surgery for type A acute aortic dissection complicated by stroke due to cerebral malperfusion. (J Thorac Cardiovasc Surg 2020;159:784-93)

Doppler echocardiography of the BCA (A) before and (B) after EGACS.

Central Message

EGACS provides rapid antegrade perfusion that has the potential to facilitate immediate central aortic repair for TAAAD complicated by CM.

Perspective

In this study, we used EGACS as a supportive technique during surgery for TAAAD complicated by CM. To our knowledge, this is the first study to evaluate the efficacy of this perfusion strategy in relieving CM associated with dynamic obstruction in TAAAD.

See Commentaries on pages 794 and 796.

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According to the International Registry of Acute Aortic Dissection study,¹ type A acute aortic dissection (TAAAD) with cerebral malperfusion (CM) has poor outcomes, and 6% of TAAAD cases are complicated by stroke, resulting in higher in-hospital mortality or a longer stay. On the

Scanning this QR code will take you to the article title page to access supplementary information.

Abbreviations and Acronyms

AXA	= axillary artery
BCA	= brachiocephalic artery
CCA	= common carotid artery
CM	= cerebral malperfusion
CPB	= cardiopulmonary bypass
CT	= computed tomography
EGACS	= echocardiography-guided ascending aortic central cannulation using the Seldinger technique
FA	= femoral artery
GCS	= Glasgow Coma Scale
IQR	= interquartile range
MMT	= manual muscle test
mRS	= Modified Rankin Scale
POD	= postoperative day
rSO ₂	= regional oxygen saturation
TAAAD	= type A acute aortic dissection
TAR	= total arch replacement

other hand, several studies²⁻⁵ have confirmed the efficacy of early surgery for TAAAD complicated by CM. We use echocardiography-guided ascending aortic central cannulation using the Seldinger technique (EGACS) as a supportive technique during surgery for TAAAD. The EGACS technique is simple, and central cannulation can be achieved using the Seldinger technique⁶ because it promptly provides antegrade blood flow in the true lumen coupled with core cooling.⁷ This mechanism might be effective for correction of CM, especially in cases associated with dynamic obstruction; however, there is no evidence of this. This study aimed to evaluate the outcomes of EGACS for TAAAD complicated by stroke due to CM.

MATERIALS AND METHODS

Patients

From April 2007 to December 2017, 229 consecutive patients with TAAAD underwent graft replacement and 208 patients were treated with EGACS. The remaining 21 patients with ascending aortic rupture or a false lumen with thrombosis encircling the ascending aorta who were treated with single cannulation from the femoral artery (FA) were excluded from this study. To exclude coma caused by shock and circulatory failure, patients in a coma but without dissection in branches of the aortic arch were excluded from this study. During the same period, 5 patients who were not able to undergo surgery because of deep coma with brain death (1 patient), coma with cardiopulmonary arrest after arrival at the hospital (2 patients), and rejection of surgery for being bedridden or for religious reasons (2 patients) were excluded from this study.

The study participants consisted of 16 (7.7%) of the 208 patients treated for TAAAD complicated by stroke due to CM using EGACS (Video 1) on arrival at the hospital. Median patient age was 63 years (range, 32-83), and 8 were male. The patients' backgrounds are summarized in Table 1. Our hospital is a core hospital in the western district of Kanagawa Prefecture, Japan, and initial clinical diagnosis was performed in the advanced emergency center of our hospital. This single-center retrospective study was

Insertion of venous drainage

VIDEO 1. A general method of EGACS and a representative case of a 68-year-old patient with left hemiplegia and in a comatose state (GCS 7) on hospital arrival who underwent EGACS. EGACS, Echocardiography-guided ascending aortic central cannulation using the Seldinger technique; GCS, Glasgow Coma Scale. Video available at: [https://www.jtcvs.org/article/S0022-5223\(19\)30565-3/fulltext](https://www.jtcvs.org/article/S0022-5223(19)30565-3/fulltext).

performed using data obtained from medical records. All patients or relatives gave informed consent. The study was approved by the institution's ethics committee.

Neurologic Evaluation

Neurologic evaluation on arrival at the hospital was performed by an emergency physician or neurologist. Coma and hemiplegia were defined as neurologic deficits. The level of impaired consciousness was assessed using the Glasgow Coma Scale (GCS),⁸ and GCS 8 or less on arrival was defined as preoperative coma. Hemiplegia was assessed using the manual muscle test (MMT),⁹ and MMT 1 or less was defined as hemiplegia on arrival. To exclude the uncertainty in false-positive neurologic findings, GCS 8 or less and MMT 1 or less were defined as neurologic deficits. Transient impaired consciousness was excluded. Although all patients in this study underwent preoperative head computed tomography (CT) due to the existence of prehospital neurologic impairment, imaging of the brain, such as CT or magnetic resonance imaging, was not routinely conducted to allow performance of surgery as promptly as possible. Ten patients presented in a comatose state, and 6 patients presented with hemiplegia in a semicomatose state or not. Patients with transient consciousness disturbance were not included in this study. Before and after surgery and during follow-up, the level of consciousness of patients with preoperative coma was assessed using the GCS, and the motor function of the paralytic side was evaluated using MMT in patients with preoperative hemiplegia, performed strictly according to the common manual of GCS and MMT. The Modified Rankin Scale (mRS) was used to evaluate the degree of independence in activities of daily living during follow-up.

Surgical Procedure

Patients were placed in the standard supine position. Cerebral blood flow was monitored by echoencephalography to confirm blood flow in the true lumen in a branch of the aortic arch ($n = 16$). Near-infrared spectroscopy was used to measure regional oxygen saturation (rSO₂) in the bilateral frontal regions using a noninvasive monitoring system (INVOS 5100C, Medtronic, Boulder, Colo) ($n = 9$). Transesophageal echocardiography was used to visualize the extent of aortic dissection during the procedure. Surgery was performed via a median sternotomy. Extracorporeal circulation was achieved by venous drainage from the superior and inferior vena cava, with both FA cannulation and EGACS in 2 patients, and EGACS alone in all other patients.

The systolic arterial pressure was controlled to less than 80 mm Hg before EGACS. Mattress sutures were placed between the ascending aorta and pulmonary trunk using a 4-0 monofilament pledget-supported surgical

TABLE 1. Characteristics of patients treated with ascending aortic cannulation

Characteristics	No.
No. of patients	16
Age	63 y (range, 32-83)
Male/female	8/8
Neurologic deficits	
Coma: GCS ≤ 8 (with hemiparesis)	10 (3)
Hemiplegia: MMT ≤ 1 (with semi-coma)	6 (2)
Conjugate deviation of the eyes	8
Cardiac tamponade	5
Successful cardiopulmonary resuscitation	3
History of brain attack	1
Concomitant organ malperfusion	
Heart (defibrillated ventricular tachycardia)	1
Spine (paraplegia)	1
Leg ischemia	1
Dissection of arch vessels	
BCA	16
Right CCA (with occlusion)	12 (7)
Left CCA	7
Left subclavian artery	8
Thrombosed false lumen	3

GCS, Glasgow Coma Scale; MMT, manual muscle test; BCA, brachiocephalic artery; CCA, common carotid artery.

suture and needle. A 20F flexible spindle-shaped cannula (DLP Arterial Cannula: Medtronic Inc, Minneapolis, Minn) was inserted into the ascending aorta using the Seldinger wire technique. To install a cannula at the exact point of the true lumen, true and false channels were detected using epiaortic and transesophageal echocardiography (Vivid i Ultrasound System and i12L-RS Transducer: GE Medical Systems, Haifa, Israel; or Vivid E9 Ultrasound System and i1L-D Transducer: E Vingmed Ultrasound, Horten, Norway) to confirm the presence of the wire in the true lumen in both the ascending and descending aortas, in combination with anatomic information from preoperative CT scans.

Antegrade perfusion was started, and core cooling began at a flow rate of 2.4 L/min/m². The left ventricle was vented through the right superior pulmonary vein. Carbon dioxide was continuously infused into the surgical field at a flow rate of 2 L/min. A centrifugal pump (CAPIOXR Disposable Centrifugal Pump, CX*SP45: Terumo Corp, Tokyo, Japan) was used for extracorporeal circulation. At the start of extracorporeal circulation and

when a steady flow from the centrifugal pump was reached by cooling, epiaortic echocardiography was performed to confirm that the true lumen in the ascending aorta and a branch of the aortic arch was enlarged after EGACS (Figure 1). Thiopental sodium (30 mg/kg) was injected into the cardiopulmonary bypass (CPB) circuit just before circulatory arrest. The patients were placed in the Trendelenburg position, and circulatory arrest was established at 17.5°C as drained blood temperature. An arterial cannula was removed after incising the ascending aorta and confirming that the tip of the cannula was placed in the true lumen. Ascending aortic replacement was performed when an intimal tear was found in the ascending aorta or total arch replacement (TAR) was performed when it was found in the aortic arch.

After closing the false lumen with stump formation using a continuous horizontal mattress suture buttressed with Teflon felt strips through an open distal procedure, ascending aortic replacement was performed with a Dacron 1-branched graft (J Graft Shield Neo, Japan Lifeline Co, Tokyo, Japan), followed by distal anastomosis. TAR was performed with a Dacron 4-branched graft (Hemashield Platinum Plus Woven Double Velour, 4 branch, Intervascular SAS, LaCiotat, France) for branch revascularization of the aortic arch, with arch branches reconstructed first to minimize the period of circulatory arrest. We used retrograde cerebral perfusion for all patients who underwent surgery for TAAAD to flush out air and atheromatous debris and for auxiliary neuroprotection. On completion of distal repair or anastomosis of all branches of the aortic arch, retrograde cerebral perfusion was performed to flush out air and atheromatous debris within the arch vessels. It was also performed to provide cerebroprotection for 30 minutes or more after arresting the cerebral circulation. In ascending aortic replacement, after the completion of distal anastomosis, extracorporeal circulation and rewarming resumed from the branch graft at a flow rate of 2.4 L/min/m². In TAR, after branch revascularization in the aortic arch, cerebral perfusion resumed from the branch graft at a perfusion volume of 10 mL/kg/min. At the start of perfusion from branch grafts, 30 mg of edaravone,¹⁰ which was approved in Japan in 2001 as a drug targeting peroxyl radicals to treat acute phase cerebral infarction, was injected via a CPB device for cerebroprotection. Before and after circulatory arrest, D-mannitol (35-45 g) was injected via the CPB device. In TAR, distal anastomosis was performed by open distal anastomosis with the elephant trunk technique while lower body circulation was arrested. Subsequently, graft-graft anastomosis was performed. During both ascending aortic graft replacement and TAR, cardioplegia was intermittently performed using antegrade selective coronary reperfusion every 30 minutes. The aortic valve was resuspended, and the proximal aortic stump was repaired as follows. Reinforcement of the dissected aortic wall using band-like felt in a false lumen with gelatin-resorcin-formalin biological glue (Caridal SA, Saint-Etienne, France) was used in the first 8 patients. In subsequent patients, base formation was performed using a double felt strip due to discontinuation of the glue. No patient simultaneously underwent coronary artery bypass graft surgery.

FIGURE 1. Epiaortic Doppler echocardiography shows a compressed true lumen of the BCA (A) before EGACS and enlargement of the true lumen of the BCA (B) after EGACS. EGACS, Echocardiography-guided ascending aortic central cannulation using the Seldinger technique.

TABLE 2. Surgical variables in performance of ascending aortic cannulation

Variables	Time (min)
Onset to establishment of CPB	327 (176-561)
Start of operation to establishment of CPB	34 (30-44)
Establishment of CPB to cardiac arrest (cooling time)	30 (21-45)
CPB time	203 (128-304)
Surgery time	378 (231-917)
Brain circulatory arrest time	33 (25-45)

CPB, Cardiopulmonary bypass.

Postoperative Neurologic Care

All patients were examined by a neurologist. Glycerol (200 mL, twice/day) and edaravone (30 mg/day) were routinely administered up to 14 days based on the regulations for use, until the patient was completely awake and could comply with instructions as a result of improvement of neurologic function. Rehabilitation started earlier at the bedside and mobility training started after weaning from a mechanical ventilator. Except for those with postoperative prolonged coma, patients who did not require surgical care were discharged and transferred to a rehabilitation hospital as soon as possible.

Statistical Analysis

The rSO_2 in the bilateral frontal regions before and after the start of CPB with EGACS was evaluated by the Wilcoxon-signed rank test. Evaluations using GCS in the coma group, MMT in the hemiplegia group, and mRS in all patients were performed before and after surgery at different time points using the Friedman's test. The cumulative survival was estimated by the Kaplan-Meier method. All analyses were performed using SPSS v.23.0 (IBM Corp, Armonk, NY).

RESULTS

Operative Findings

Surgical data are shown in Table 2. The median time from onset to establishment of CPB was 327 (176-561) minutes. The median time from the start of surgery to establishment of CPB was 34 (30-44) minutes. The median time to cardiac arrest from establishment of CPB (cooling time) was 30 (21-45) minutes. Antegrade blood flow was obtained without breakdown of the cannulation site or cannulation to the false lumen in all patients. The median rSO_2 level in the bilateral frontal regions, which was observed using

near-infrared spectroscopy, improved significantly after EGACS from 55.0% (interquartile range [IQR], 47.5%-65.0%) to 74.0% (IQR, 66.5%-80.5%) ($P = .015$) on the right, and from 66.0% (IQR, 52.0%-72.0%) to 79.0% (IQR, 70.0%-84.5%) ($P = .008$) on the left (Figure 2). All patients underwent emergency surgery, and near-infrared spectroscopy was not performed in some cases because of limitations of staff and facilities. After incising the ascending aorta, the tip of the cannula was confirmed to be placed in the true lumen. Intimal tear was found in the ascending aorta and aortic arch in 9 and 6 patients, respectively, and was not detected in 1 patient. Ascending aortic graft replacement was performed in 10 patients and TAR in 6 patients. The time of circulatory arrest in the brain was 33 (25-45) minutes, the CPB time was 203 (128-304) minutes, and the surgery time was 378 (231-917) minutes.

Early Outcomes

One patient (6.3%) died in the hospital. This patient had preoperative left hemiplegia associated with mildly impaired consciousness and died of severe cerebral edema on postoperative day (POD) 18. In patients in a preoperative comatose state, median postoperative GCS scores significantly improved from 4.5 (IQR, 3.8-7.3) at arrival to 11.5 (IQR, 8.8-15.0) at 7 days, 15.0 (IQR, 14.0-15.0) at 30 days, and 15.0 (IQR, 15.0-15.0) at 90 days ($P < .001$), showing improved consciousness (Figure 3). Fourteen patients (87.5%), including 10 with preoperative coma, had a GCS score of 15 and full recovery of consciousness at 90 days. Of the 6 patients with preoperative hemiplegia, 4 showed improved motor function on the MMT of 4 or greater at 90 days (preoperative median 0.5, IQR, 0-1.0, 30-day median 4.0, IQR, 0-4.5, and 90-day median 5.0, IQR, 2.0-5.0; $P = .057$), and of the remaining 2 patients, 1 was in a postoperative coma and 1 died (Figure 4). A male patient aged 36 years with preoperative hemiplegia who underwent ascending aortic graft replacement developed severe cerebral coma on POD 2 and was treated with decompressive craniectomy by neurosurgeons. Three

FIGURE 2. The median rSO_2 levels in the bilateral frontal regions observed using near-infrared spectroscopy. Median rSO_2 levels improved significantly after EGACS from 55.0% (IQR, 47.5%-65.0%) to 74.0% (IQR, 66.5%-80.5%) ($P = .015$) (right) and from 66.0% (IQR, 52.0%-72.0%) to 79.0% (IQR, 70.0%-84.5%) ($P = .008$) (left). rSO_2 , Regional oxygen saturation.

FIGURE 3. GCS scores of patients with preoperative coma. In these patients, median GCS scores improved significantly after surgery from 4.5 to 15 at 30 days, and full recovery of consciousness at 90 days was achieved. GCS, Glasgow Coma Scale; POD, postoperative day; IQR, interquartile range. This figure was made on the basis of the design of a similar figure by Tsukube and colleagues.³

patients were discharged to home, 12 patients were transferred to rehabilitation hospitals, and 1 patient was transferred to a healthcare hospital. A CT scan of a representative case with coma is shown in Figure 5.

Late Outcomes

During the final follow-up at the end of April 2018, all patients, except for 1 who died in the hospital, were alive, and 14 patients (87%) lived at home. The mean follow-up period was 101 ± 7 months, and the cumulative 5-year survival was 93.8%. The median mRS significantly improved over time; median mRS was 5.0 (IQR, 5.0–5.0) preoperatively, 4.0 (IQR, 3.0–4.8) at discharge, 2.0 (IQR, 0–4.8) at 90 days, and 1.0 (IQR, 0–4.8) at final follow-up ($P < .001$). Independence in activities of daily living ($mRS \leq 2$) was achieved in 12 patients (75%) during follow-up. Physical impediments remained in 3 patients, 1 with preoperative coma and paraplegia (GCS 15, mRS 5), 1 with preoperative coma and hemiplegia (GCS 15, mRS 5), and 1 with preoperative hemiplegia and postoperative new coma with anamnesis of decompressive craniectomy due to severe cerebral edema (GCS 5, mRS 5).

DISCUSSION

From the data in the Japan Cardiovascular Surgery Database, in 2014, the 30-day and in-hospital mortality rates after surgery for TAAAD were 8.8% and 10.6%, respectively.¹¹ Aortic branch vessel occlusion makes mortality higher in surgery for TAAAD.² In particular, CM in TAAAD worsens a patient's prognosis and postoperative quality of life.^{12,13} Urgent surgical repair is required for TAAAD because conservative management is associated with a high incidence of early mortality.^{14,15} Some studies have suggested that urgent surgical repair in the presence of stroke has a risk of hemorrhagic worsening of ischemic infarction after reperfusion and before CPB and full anticoagulation.^{16,17} Others have suggested that delaying aortic repair until the cerebral injury stabilizes may minimize brain dysfunction, even though this exposes patients to a risk of death due to rupture.¹⁸ On the other hand, several studies^{2–5} have confirmed the efficacy of early surgery for TAAAD complicated by stroke. In patients with TAAAD complicated by coma who underwent emergency surgery within 5 hours after onset, Tsukube and colleagues³

FIGURE 4. MMT scores of patients with preoperative hemiplegia. Of the 6 patients with preoperative hemiplegia, 4 showed a tendency toward improved motor function of MMT 4 or greater at 90 days. *MMT*, Manual muscle test; *POD*, postoperative day; *IQR*, interquartile range.

reported an in-hospital mortality rate of 14% and a rate of recovery of consciousness of 86%. Estrera and colleagues⁴ reported the operative results of 16 patients with TAAAD complicated by preoperative stroke. The median time from onset of stroke to surgery was 9 hours, and 80% of patients who underwent surgical repair within 10 hours had improvement in neurologic status, whereas no patient who was operated on beyond 10 hours showed improvement. Furthermore, both the early- and long-term outcomes after immediate aortic repair for TAAAD complicated by CM are reported to be satisfactory.¹⁹

Ischemic penumbra is the term used to define ischemic but still viable cerebral tissue. It was classically defined as the hypoperfused tissue surrounding the ischemic core in which blood flow is too low to maintain electric activity, but sufficient to preserve ion channels.²⁰ The 2015 guidelines of the Healthcare Professionals from the American Heart Association/American Stroke Association reported the efficacy of endovascular treatment within 8 hours of symptom onset for patients with acute ischemic stroke.²¹ The reduction of the time from onset to blood

reperfusion to the brain is the most important parameter in surgery for TAAAD complicated by CM. In this study, all patients underwent immediate emergency surgery, with a median time from onset to establishment of CPB of 331 minutes (5 hours, 31 minutes), and the median time from the start of surgery to establishment of CPB of 34 minutes. There is a possibility that EGACS contributes to immediate blood supply within the ischemic penumbra in patients with TAAAD complicated by CM.

Although opinions on the optimal cannulation strategy for TAAAD surgery vary,^{12,22–25} cannulations of the FA, axillary artery (AXA), and central aorta are the major strategies for TAAAD surgery, and Abe and Usui²² indicated that each procedure has advantages and disadvantages. Orihashi¹² showed that FA perfusion started promptly and was effective in patients with shock, but had a higher incidence of false lumen perfusion (4/44 cases, 9.1%) compared with AXA perfusion, including 3 patients who developed CM. We now use EGACS only, except for patients with mesenteric malperfusion or lower-body ischemia. In cases with combined FA perfusion, we control

FIGURE 5. Preoperative enhanced CT scan of the thorax (A-C) and postoperative CT scan with 3-dimensional reconstruction (D) in a representative case of a 68-year-old patient with coma (GCS 7) and left hemiplegia on arrival. Total arch graft replacement was performed 3 hours after onset. The patient recovered with full consciousness and hemiplegia improved postoperatively. A, Occluded right CCA (arrow). B, Intimal tear in the aortic arch (arrow). C, Compressed true lumen of the ascending aorta (arrow). D, Postoperative CT scan with 3-dimensional reconstruction shows enlargement of true lumens of branches of the aortic arch.

the perfusion of ascending aortic flow to FA flow at a ratio of 2:1 using an infrared flow meter. In EGACS, the cannula is placed in the true lumen of the ascending aorta using the Seldinger wire technique under epiaortic echocardiography with confirmation of the supply site using preoperative CT.^{6,7,26} This procedure has good outcomes, because it takes less time to establish CPB, antegrade blood flow in the true lumen is obtained, and any new CM induced by CPB might be prevented.^{6,7,27} Cannulation breakdown and a risk of blood supply to the false lumen are concerns.^{28,29} We observed 3 (1.4%; 3/208) cases of false lumen cannulation in early patients, 1 for each of the 3 operating surgeons. However, these cases could have been avoided with strict observance of the process described in the “Materials and Methods” section. Therefore, this has not occurred after April 2013.

The strategy of perfusion for TAAAD surgery complicated by CM has not been established.^{12,23}

Although AXA perfusion is generally considered a standard cannulation method for TAAAD, Orihashi and colleagues³⁰ reported that if dissection extends to the innominate artery and stenosis in the true lumen is complicated, the certainty of AXA perfusion is reduced. One case report showed that the thrombus in the false lumen of the right common carotid artery (CCA) was scattered to the true lumen in a patient with right CCA occlusion due to dissection.³¹ Therefore, AXA perfusion for TAAAD complicated by CM is not completely safe. However, some studies have shown that direct cannulation of the right CCA and brachiocephalic artery (BCA) is effective.^{32,33} Okita and colleagues³⁴ performed reperfusion of the right CCA before CPB in patients with TAAAD complicated by CM, with good outcomes. This is a definite method for reperfusion on the distal side of an occluded CCA. However, to make an exact diagnosis of static or dynamic obstruction, even in patients with shock, is difficult.

FIGURE 6. Postoperative plain CT scan of the head (A, C) and postoperative magnetic resonance imaging (B) and CT scan (D) of intracranial and cervical arteries with 3-dimensional reconstruction in patients who underwent ascending aortic graft replacement with preoperative hemiplegia without coma; 1 patient developed severe cerebral edema within 3 days of surgery and died in hospital (A, B), and 1 patient underwent decompressive craniectomy (C, D). Although the postoperative CT scans show severe cerebral edema, postoperative magnetic resonance imaging and CT scan with 3-dimensional reconstruction show patent intracranial and cervical arteries.

Therefore, it is preferable to promptly perform EGACS for true lumen perfusion and cooling in patients with stenosis in the true lumen due to dynamic obstruction, and add direct cannulation of the CCA and BCA if required.

The intraoperative cerebroprotection used in this study was deep hypothermic circulatory arrest. We consider that cannulation of dissected branches of the aortic arch carries a risk of development of new intimal tears in the aortic arch. Cerebroprotection is the highest priority for critical patients with TAAAD with CM; therefore, we consider that a

combination of quick and simple EGACS and deep hypothermic circulatory arrest is appropriate.

Intimal tear in the distal site of the aortic arch, distant from the cannulation site, was found in 7 patients in this study. However, no new malperfusion on the distal side of the cannulated site was found in any of the 16 patients. Heart beats decreased as central cooling time increased, and an enlarged true lumen of BCA was seen on intraoperative echocardiography, as shown in [Figure 1](#). Inoue and colleagues⁷ showed that ascending aortic

perfusion improved dynamic obstruction in the true lumen caused by increased pressure in the false lumen, along with prompt core cooling by antegrade blood flow in the true lumen. In addition, a centrifugal pump is always used for CPB in our hospital; therefore, new malperfusion was unlikely because the above mechanism was likely controlled by the pump-assisted, nonpulsating steady flow. The result that the median rSO_2 level in the bilateral frontal regions improved significantly after EGACS supports the facts mentioned.

Two patients who underwent ascending aortic graft replacement with preoperative hemiplegia without coma developed severe cerebral edema within 3 days of surgery. One died on POD 18; the other patient underwent decompressive craniectomy, resulting in coma. The times from onset of symptoms to establishment of CPB were 192 minutes and 416 minutes, and times to circulatory arrest in the brain were 28 minutes and 36 minutes, respectively. The rSO_2 in near-infrared spectroscopy increased after starting CPB in these patients, and increased blood flow in the true lumen of the BCA was identified on intraoperative echocardiography. Although the postoperative CT scans showed severe cerebral edema, postoperative magnetic resonance imaging and CT scan with 3-dimensional reconstruction showed patent intracranial and cervical arteries (Figure 6). Furthermore, the first patient required a large volume of perioperative infusion for shock, and the second patient underwent a prolonged time before restoration of cerebral perfusion. These results suggest the possibility that cerebral edema may have developed as the result of cerebral reperfusion injury in these patients. Because postoperative cerebral edema was not found in other patients, this condition was identified as a poor prognostic factor.

Study Limitations

This study has several limitations. First, the sample size was small. Second, a comparative study using other blood supply procedures was not performed. Third, all patients underwent emergency surgery, and near-infrared spectroscopy was not performed in some cases because of limitations of staff and facilities.

CONCLUSIONS

EGACS has potential as a rapid and reliable route of antegrade central systemic perfusion during surgery for TAAAD complicated by stroke due to CM. However, further quantitative analysis of the blood flow in the dissected aorta is warranted for this method.

Conflict of Interest Statement

Authors have nothing to disclose with regard to commercial support.

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