Original Article

Efficacy and outcomes of perioperative anesthetic management of extracranial to intracranial bypass for complex intracranial aneurysm in the absence of advanced neurological monitoring

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Abstract

Background and Aims: Anesthetic management of extracranial to intracranial (EC-IC) bypass for complex intracranial aneurysms is challenging as the goals involve balancing the cerebral perfusion during parent artery clamping and avoiding factors that predispose to rupture of the unsecured aneurysm. There is very sparse literature available on anesthetic management for this procedure.
Materials and Methods: A retrospective review of the records of 20 patients undergoing EC-IC bypass was performed with an objective of assessing the efficacy and outcomes of anesthetic management in the absence of advanced neurological monitoring.
Results: A total of 20 patients underwent EC-IC bypass as an adjunct cerebral revascularization in the management of complex intracranial aneurysms. Intraoperatively normotension and normocarbia were maintained. During the EC-IC bypass, when the temporary clamp was applied, mild hypertension (increase from baseline by 20%) and hypervolemia (central venous pressure increased to 12 mmHg) were maintained. Cerebral protection during temporary clipping of intracranial vessel was provided using moderate hypothermia to 34°C and intravenous thiopentone. Temporary clip time ranged from 15 min to 54 min (mean-25 min). All patients except one were extubated post-operatively (19/20 = 95%). None of the patients had rupture of aneurysm in the peri-operative period. Three patients developed neurologic events (3/20 = 15%). One patient had cerebral vasospasm and two patients developed cerebral infarction. Two patient subsequently improved and one succumbed to the neurological deterioration (mortality 1/20 = 5%).
Conclusion: Adherence to the principal goals for the procedure, avoidance of hemodynamic fluctuations such as hypotension and hypertension, maintenance of normocarbia, and cerebral protection, result in favorable neurological outcome even in the absence of advanced neuromonitoring.

Key words: Anaesthesia, cerebral protection, complex, extracranial to intracranial bypass, goals, intracranial aneurysm, neuromonitoring, outcome, peri-operative, rupture

Introduction

Despite new endovascular techniques and technological advances in microsurgery, the treatment of giant intracranial aneurysms is still a daunting neurosurgical task. Many of these aneurysms have a large, calcified neck, directly involve parent and collateral branches and are partly thrombosed. Surgery for complex brain aneurysms is evolving rapidly.[1] The role of extra- intracranial (EC-IC) bypass in the management of complex intracranial aneurysm is being increasingly accepted as it avoids the complications of prolonged temporary clipping, cardiopulmonary bypass and deep hypothermic arrest. Anesthetic management of EC-IC bypass for complex intracranial aneurysms is challenging as the goals involve balancing the cerebral perfusion during parent artery clamping and avoiding factors that predispose to rupture of the unsecured aneurysm. Electroencephalography, somatosensory evoked potential monitoring, microvascular doppler ultrasonography[2] and indocyanine green (ICG) videoangiography are frequently used intraoperatively in advanced neurosurgical centers to assess both the brain physiology and vascular anatomy. In institutions where advanced monitoring is unavailable the

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anesthesiologist plays an important role in the management of hemodynamics to attain the goals. There are several reports in the surgical literature regarding EC-IC bypass for complex aneurysms.[3-5] There is very sparse literature available on anesthetic management for this procedure. Considering the early part of the learning curve, limited volume of cases performed and constraints of limited neurological monitoring in the author's institute, the anesthetic management strategies were developed. A retrospective review of the records of patients undergoing EC-IC bypass was performed with an objective of assessing the efficacy and outcomes of anesthetic management in the absence of advanced neurological monitoring. We present a case series of 20 cases of EC-IC bypass performed at our institute for aneurysms deemed not amenable to placement of a clip on the neck of the aneurysm or endovascular coiling.

Materials and Methods

The cases were retrieved from the computerized database after obtaining the approval of the Institutional Ethics Committee using key words EC-IC bypass. The EC-IC bypass performed by the neurosurgeons for ruptured or un-ruptured intracranial aneurysms at our institute between 2005 and 2009 were included in the study. The procedure performed for other conditions were excluded. Retrospective data of these patients was collected by manual search of the following hospital records-case sheets obtained from the medical record department, anesthesia register, neurosurgical register and nursing register. The following data was collected-age, gender, state of the aneurysm - ruptured or unruptured at presentation, preoperative neurological status, location of aneurysm, size of aneurysm, collateral flow on angiogram, assessment of autoregulatory reserve by acetazolamide single photon emission computed tomography (SPECT), co-existing medical disorders with potential to interfere with anesthetic management were noted.

All potential patients underwent cerebral angiogram with cross compression studies and SPECT with acetazolamide challenge. EC-IC bypass was performed for patients who demonstrated poor collateral perfusion on cross compression angiographic studies and poor circulatory reserve on SPECT with acetazolamide challenge. The procedure was performed in two stages, Stage I - an EC-IC bypass was performed. Stage II-aneurysm clipping, trap ligation or Hunterian occlusion strategy (carotid ligation) was performed either in the same sitting or separate sitting.

The anesthetic protocol for EC-IC bypass was as follows — all patients received premedication with intravenous (I.V) glycopyrrolate 0.1 mg and I.V fentanyl-2 μg/kg. Induction of anesthesia done with thiopental sodium (titrated), I.V vecuronium 0.1 mg/kg used to facilitate muscle relaxation for intubation. Anesthesia was maintained on continuous infusion of propofol, fentanyl and atracurium, O_2, N_2O, isoflurane. Intraoperative monitoring included electrocardiogram, SpO_2, $ETCO_2$, blood gas analysis, blood glucose, invasive artery blood pressure, central venous pressure (CVP), urine output, nasopharyngeal temperature, neuromuscular junction monitoring and bispectral index (BIS) (using occipital electrodes). Normocarbia was maintained. Intraoperatively normotension was maintained. Any hypotension was initially treated using bolus of fluid. If the CVP was more than 12 mmHg or if there was no response to fluid therapy dopamine or noradrenaline infusion was initiated. Hypertension was treated by deepening of anesthesia with propofol, or use of labetalol or nitroglycerin infusion. Intraoperative blood sugar was targeted to values between 120 and 150 mg%. Insulin therapy was initiated when blood sugar was >150 mg%.

During the EC-IC bypass, when the temporary clamp was applied, mild hypertension (increase from baseline by 20%) and hypervolemia (CVP increased to 12 mmHg) were maintained. Rate of ventilation increased and tidal volume was reduced to reduce excursions on the surface of brain during anastomosis. Heparin 1 mg/kg was administered intravenously before the application of clamp on the artery. Cerebral protection during temporary clipping of intracranial vessel was provided using moderate hypothermia by allowing the temperature to drift under anesthesia without active cooling or warming. Pharmacological cerebral protection was provided with thiopental. Burst suppression was titrated and monitored using the electroencephalogram on the BIS monitor or a bolus of 5 mg/kg with an infusion of 2 mg/kg/h was administered in the absence of BIS monitoring, microvascular anastomosis was performed. Patients were warmed using forced air warmers after the anastomosis concluded. Neurological assessment was performed at the conclusion of the procedure and extubation in the operating room (OR) was planned for those patients without neurological deterioration. Patients intraoperative evidence of cerebral edema, bleeding or post-operative neurological deterioration underwent post-operative mechanical ventilation.

Post-operatively monitoring was continued. Normotension and normovolemia were maintained. Low molecular weight dextrans were administered postoperatively for 3 days. A postoperative digital subtraction angiography or computed tomography angiography was performed in all patients to verify the efficacy of treatment.

Surgical procedure performed (type of bypass performed), intraoperative hemodynamic fluctuations, duration of temporary clip, cerebral protection during temporary clip, post-operative recovery, neurological deficit on recovery, intraoperative and postoperative complications and their management, post-operative recovery and outcome were noted. Patient outcome was noted as the extended Glasgow Outcome Scale (GOS-E) at discharge. The data was analyzed to assess specific anesthesia related complications and also to assess whether the anesthetic management confirms to the goals of the procedure.

Results

We performed a retrospective record review of the 20 cases of difficult (giant) aneurysm who underwent EC-IC arterial bypass. Complete records were available for all patients. Six aneurysms required bypass because of large size and the remaining due to inaccessible location. The demographic details and indication for bypass and procedures performed are listed in Table 1.

No deviations from the basic anesthetic management protocol were necessary in any of the patients. The co-morbid conditions are shown in Table 2. There were no significant hemodynamic changes at induction. There were 13 episodes of significant intraoperative hemodynamic fluctuations requiring intervention in nine patients [Table 2]. The incidence of hemodynamic fluctuations was higher in patients with ruptured aneurysm and subarachnoid hemorrhage (SAH). (5/6 [83%] vs. 4/14 [28.5%] in unruptured aneurysms) BIS (occipital electrodes) was usable in seven cases only. Burst suppression with thiopentone was titrated using BIS in these patients. The remaining patients were administered thiopentone as described in the protocol. All patients had nasopharyngeal temperatures ranging from 32.5 to 34 at the time temporary arterial occlusion. Interventions were required to raise systolic blood pressure to 20% baseline or to 160 mmHg in all the patients [Table 2]. Temporary clip time ranged from 15 min to 54 min (mean-25 min). Intraoperative blood glucose was maintained between 120 and 150 mg/dl without intervention in 11 patients. Nine patients required insulin for glycemic control. None of the patients required blood transfusion. All patients except one were extubated postoperatively (19/20 = 95%). 17 patients (85%) were extubated in the OR. Two patients extubated on the 1st post-operative day (POD). The first patient with a temporary clip time of 54 min did not regain consciousness and was ventilated for 3 days. None of the patients had rupture of aneurysm in the peri-operative period. Three patients developed neurologic events (3/20 = 15%). Two patients developed cerebral infarction, one patient subsequently improved and one succumbed to the neurological deterioration (mortality 1/20 = 5%). One patient developed post-operative hemiparesis due to vasospasm on 3rd POD and recovered subsequently with supportive therapy. There was no neurological deterioration in the other patients (17/20 = 85%). There were no

Table 1: Demographic and clinical characteristics of patients who underwent EC-IC bypass

Age/sex	Location	Size (cm)	Presentation	WFNS	Stage I	Stage II
50/male	Sc ICA	1.2	SAH	3	ST-MCA	ICA ligation
52/female	Ca ICA	2.4	Mass effect	0	CCA-MCA SVG	ICA ligation
48/female	Sc ICA	2.5	SAH	3	ECA-MCA SVG	Clipping
45/female	Ca ICA	2.3	Headache	0	ST-MCA	ICA ligation
55/female	Sc ICA	3.0	Seizures	0	ECA-MCA SVG	Trapping
70/male	Ca ICA	3.2	Mass effect	0	ST-MCA	ICA ligation
56/female	Ca ICA	3.1	Mass effect	0	ST-MCA	ICA ligation
50/female	Ca ICA	3.2	Mass effect	0	ST-MCA	ICA ligation
66/male	Sc ICA	1.6	Mass effect	0	ECA-MCA SVG	None
44/female	Ca ICA	3.9	Mass effect	0	ST-MCA	ICA ligation
40/female	Ca ICA	1.3	Mass effect	0	ST-MCA	ICA ligation
34/female	Sc ICA	2.6	SAH	2	ST-MCA	ICA ligation
50/female	Sc ICA	2.8	SAH	2	ECA-MCA SVG	Trapping
35/female	MCA	2.8	Seizures	0	ST-MCA	ICA ligation
45/male	Ca ICA	2.4	Mass effect	0	ST-MCA	Trapping
38/male	Ca ICA	3.1	Mass effect	0	ST-MCA	ICA ligation
52/female	Ca ICA	3.2	Mass effect	0	ST-MCA	ICA ligation
54/female	Sc ICA	1.6	SAH	2	ECA-MCA SVG	Ligation#
44/female	Ca ICA	3.9	SAH	1	ST-MCA	Trapping
40/female	Ca ICA	3.3	Mass effect	0	ST-MCA	None

#Ligation abandoned due to cerebral edema and difficult surgical access, Mass effect is with cranial nerve palsy, CCA = Common carotid artery, ICA = Internal carotd artery, Ca ICA = Cavernous internal carotd artery, Sc ICA = Supraclinoid internal carotd artery, ST = Superficial temporal, MCA = Middle cerebral artery, ECA = External carotid artery, SVG = Sephanous vein graft, EC-IC = Extracranial to intracranial, WFNS = World Federation of Neurosurgical Societies, SAH = Subarachnoid haemorrhage

Table 2: Peri-operative management of EC-IC bypass

Parameter	*N* (%)
Co-morbidity	
HTN	7 (35)
DM	4 (20)
Respiratory disease	None
Renal disease	None
Intraoperative haemodynamic changes	
None	11 (55)
Hypertension	9 (45)
Hypotension	4 (20)
Interventions required to achieve haemodynamic goals	
None	11 (55)
Fluid bolus	2 (10)
Propofol	9 (45)
Labetalol	4 (20)
Dopamine	1 (5)
Norepinephrine	1 (5)
Interventions during temporary clipping	
Intravenous fluid	5 (25)
Dopamine	8 (40)
Norepinephrine	7 (35)
Postoperative outcome	
Extubated in OR	17 (90)
Extubated after post-operative ventilation	2 (10)
Mortality on ventilator	1 (5)
GOS-E at discharge	
1	1 (5)
5	1 (5)
7	1 (5)
8	17 (85)

EC-IC = Extracranial to intracranial, HTN = Hypertension, DM = Diabetes mellitus, GOS-E = Extended Glasgow Outcome Scale, OR = Operating room

patients with intra cerebral bleed, wound infection, scalp necrosis. There were no cardiac complications or other systemic complications in any of the cases. On angiography, all bypasses were patent. The GOS-E at discharge is shown in Table 2.

Stage II procedures: The Stage II procedures were performed in seventeen patients. The first patient had internal carotid artery ligation in the same setting but developed cerebral infarction. Clipping of the aneurysm was successfully performed in the same setting in one patient. A planned Stage II procedure of parent artery ligation in the same setting was abandoned in one patient due to cerebral edema and difficult surgical access. One patient had spontaneous obliteration of the aneurysm and did not require a Stage II procedure. The delayed Stage II procedures were performed following verification of patency of the bypass after 1 week to 10 days. With an exception of one patient, all the Stage II procedures performed were uneventful and patients had an uneventful recovery.

Discussion

The results of this retrospective analysis of outcomes of 20 cases of EC-IC bypass for complex intracranial aneurysms show that adherence to hemodynamic goals and cerebral protection can ensue in good neurological outcomes.

Anesthesia for cerebrovascular surgery is a challenging facet of neuroanesthesia. Cerebral ischemia is one of the most dreaded complications of neurovascular procedures. Cerebral revascularization to augment blood flow distally is used as an adjunctive measure in the treatment of complex (giant) aneurysms. It is considered in patients in whom the collateral circulation is marginal and in whom lesions are treated either using a proximal occlusion or trapping of parent artery,[6] Hunterian-based strategy[7,8] or clip-assisted reconstruction requiring a prolonged period of temporary occlusion. The EC-IC bypass is a technique that allows the blood supply from the extracranial carotid circulation to be routed to the distal middle cerebral artery (MCA) branches. The procedure allows blood flow to bypass proximal lesions of the intracranial vasculature and supplements the cerebra perfusion when carotid is occluded by the above procedures. The superficial temporal artery or a saphenous venous conduit from the external carotid artery are grafted to the MCA.

There are several surgical reports of bypass procedures for complex intracranial aneurysms.[3,9-11] Though the basic principles of anesthetic management for this procedure are widely described, the anesthetic experience is underreported. This report comes from a tertiary referral center in India with meager availability of neuromonitoring that are used in advanced neurocenters. This may be the prevailing monitoring situation in several developing countries and smaller centers. We report good neurological outcome with physiological and hemodynamic monitoring alone and strict adherence to the goals of management for the complex procedure. Hence, it was considered important to report our experience with EC-IC bypass.

The anesthetic requirements for this procedure to maintain the cerebral perfusion, cerebral protection during temporary clipping of the cerebral vessels, maintenance of graft/bypass patency contradict with those of avoidance of rupture of an aneurysm. The intraoperative goals include avoidance of hemodynamic fluctuations such as hypotension and hypertension, maintain normocarbia, cerebral protection and early awakening to facilitate neurological assessment. The anesthetic regimen that was adopted by the institute conformed to the requirements of the procedure. In addition, use of propofol for maintenance enabled titrating blood pressure to the desired level and early awakening. Regardless of the drug regimen chosen, meticulous attention to the goals of management are important. There are several reports of rupture of aneurysms during intraoperative manipulation.[12-14] There was no incidence of intracerebral bleeding in our series.

Intraoperatively, along with standard monitoring, usage of neuromonitoring would help in guiding anesthetic and neurosurgical management. Monitoring technologies, including electroencephalography, somatosensory evoked potential monitoring, microvascular Doppler ultrasonography,[15] and/or ICG videoangiography[16] are frequently used in advanced neurosurgical centers intraoperatively to assess both brain physiology and vascular anatomy. In institutions where such monitoring is unavailable, the anesthesiologist relies entirely on the management of hemodynamics to maintain cerebral oxygenation. The hemodynamic fluctuations were frequent in patients with ruptured aneurysms and SAH. However, these were promptly managed by titration of the propofol infusion rates and use of vasoactive drugs when necessary and the gross outcomes suggest that there was no evidence of cerebral infarction in 90% of the procedures.

We have used burst suppression with thiopental sodium to provide burst suppression and cerebral protection. It has been shown that cerebral arterial occlusion of 10-14 min is well tolerated.[17,18] However, longer duration of temporary clipping has a potential to cause permanent neurologic injury. The evidence from the IHAST study that there is no benefit to pharmacologic neuroprotection or hypothermia relates to patients having temporary clipping of short duration (<10 min).[19] Studies have shown that for surgical complex aneurysms pharmacological protection with thiopental improves the ability to tolerate ischemia when the clip time is longer than 10 min.[17,20] It is practically difficult to predict the duration of temporary clipping especially during the early part of the learning curve of the surgeons. Therefore, we preferred to use neuroprotection with thiopental burst suppression and hypothermia prior to temporary clipping. All the surgeries involved continuous application of temporary clip on the MCA for more than 14 min. The mean temporary occlusion time was 25 min which exceeded the safe upper limit for developing cerebral ischemia. Except the first patient where the temporary vessel occlusion exceeded 50 min none of the patients developed cerebral infarction attributable to temporary clipping. The major concern during burst suppression was hypotension. It has been noted that if preoperative ventricular function is good, thiopental loading to electroencephalographic burst-suppression causes negligible cardiac impairment. And does not impede separation from cardiopulmonary bypass.[21] All patients required intervention during administration of thiopental for cerebral protection in the form of fluid boluses or infusion of dopamine or noradrenaline.

Anesthetic management was be titrated to allow rapid recovery to facilitate neurological assessment. 85% of the patients could be extubated in the OR. It has been noted that in addition to excellence in surgical technique for EC-IC bypass surgery judicious post-operative combination of anticoagulation, fluid and pressure management may help enhance clinical outcome.[8] Post-operative management is mainly dictated by the need for maintenance of perfusing pressure through the bypass graft. This should be balanced against the risk of rupture of an aneurysm.[22] Continuation of invasive monitoring and the anesthetic principles in the post-operative period was effective in achieving this goal. The post procedural neurological complications occurred in two patients who presented with aneurysmal rupture and SAH. The other postoperative complications such as infraction, intracranial hemorrhage, seizures, (thrombo/atherosclerotic) embolism, graft occlusion, scalp necrosis, subgaleal hematoma did not occur in this series. GOS-E at discharge was good in all survivors. The mortality and morbidity in this series were comparable to those from other advanced centers.[4,5,23]

The major limitation of this report is the retrospective nature of study and manual method of data collection. The possibility of bias of data entry and collection cannot be eliminated.

Conclusions

Anesthetic management of EC-IC bypass for giant intracranial aneurysms is challenging as the goals involve balancing the cerebral perfusion during parent vessel clamping and avoiding factors that predispose to rupture of the unsecured aneurysm, both of which contradict each other. Adherence to the principal goals for the procedure results in favorable neurological outcome even in the absence of advanced neuromonitoring.

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