Extra-Cranial to Intra-Cranial By-Pass Anastomosis: An Initial Report on Preliminary Experience at a Low Volume Center

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Abstract

Material and Methods: 18 patients suffering either from hemodynamic ischemia or from complex aneurysms or skull base tumors were operated at Cairo university hospitals in the period between May 2009 and January 2013. All patients operated by a low flow by-pass were operated through a superficial temporal artery to middle cerebral artery anastomosis. All patients chosen for a high flow by-pass were operated using a radial artery graft interposed between the middle cerebral artery distally and the common or the external carotid artery proximally. Patency was confirmed at the end of surgery using clinical examination on table and confirmed after surgery by Trans cranial color coded duplex or C.T Angiography whenever possible. All patient data were prospectively collected and retrospectively analyzed at the end of surgery.

Results: 13 patients (72.2%) were operated upon for flow augmentation and 5 patients (27.7%) were operated upon for flow replacement. A total of 24 anastomoses were performed. All except one were patent which gives a patency rate of 95.9%. There was one death in the present series resulting from a hyper perfusion syndrome. 79.6% of patients with hemodynamic ischemia stopped having symptoms after surgery. All patients operated for hemodynamic ischemia showed a considerable cognitive improvement after surgery. None of the patients operated upon for flow replacement showed improvement of oculomotor nerve function in spite of adequate intraoperative decompression. All patients treated for flow replacement showed absence of recurrence on follow-up.

Conclusion: Our initial results for both low and high flow by-pass procedures in our low volume center indicate that such complex surgical procedures are possible with results comparable to those obtained in other larger referral centers throughout the world. This procedure not only represents a more definitive treatment when compared to other endovascular or radiation treatments but is also much less costly when compared to other treatment modalities.

Key Words: Extracranial to intracranial by-pass — Hemodynamic ischemia — Complex tumors — Vascular lesions.

Introduction and Aim of Work

EXTRACRANIAL to intracranial by-pass, either for flow augmentation or replacement, is an important tool in the armamentarium of practicing vascular and skull base surgeons [1-4]. Ever since it was introduced by Yasargil in 1967, it has become an indispensible tool for managing patients with hemodynamic ischemia, or for managing patients with complex aneurysms or skull base tumors; that are not amenable to radical resection; because of major vascular involvement [5-9]. Patients with hemodynamic ischemia have an annual stroke rate of 25% which increases by 2% every year. Such patients characteristically fail medical treatment [11. Unless some form of by-pass is performed they continue to have symptoms, and they can develop a fatal stroke. This category also includes patients with moya moya disease. On the other hand, patients with complex, giant aneurysm, have an 80% five year mortality rate. This means that they have a prognosis worse than most cancers [10-12]. Because they cannot be treated by endovascular means, surgical clipping is the only option. Clipping can usually not be performed directly because of a wide neck, a fusiform aneurysm, major parent vessels arising from the dome or the neck of the aneurysm, and because the aneurysm must be debulked under direct trapping all of which necessitate some form of by-pass. It is therefore very important that neurosurgeons managing such complex disorders would be able to perform this procedure [13,14]. We report on our initial experience with extracranial to intracranial by-pass surgery.

Material and Methods

EXTRACRANIAL to intracranial by-pass, either for flow augmentation or replacement, is an important tool in the armamentarium of practicing vascular and skull base surgeons [1-4]. Ever since it was introduced by Yasargil in 1967, it has become an indispensable tool for managing patients with hemodynamic ischemia, or for managing patients with complex aneurysms or skull base tumors; that are not amenable to radical resection; because of major vascular involvement [5-9]. Patients with hemodynamic ischemia have an annual stroke rate of 25% which increases by 2% every year. Such patients characteristically fail medical treatment [11. Unless some form of by-pass is performed they continue to have symptoms, and they can develop a fatal stroke. This category also includes patients with moya moya disease. On the other hand, patients with complex, giant aneurysm, have an 80% five year mortality rate. This means that they have a prognosis worse than most cancers [10-12]. Because they cannot be treated by endovascular means, surgical clipping is the only option. Clipping can usually not be performed directly because of a wide neck, a fusiform aneurysm, major parent vessels arising from the dome or the neck of the aneurysm, and because the aneurysm must be debulked under direct trapping all of which necessitate some form of by-pass. It is therefore very important that neurosurgeons managing such complex disorders would be able to perform this procedure [13,14]. We report on our initial experience with extracranial to intracranial by-pass surgery.

In the period between May 2009 and January 2013, 18 patients with either hemodynamic ischemia or complex aneurysms or skull base tumors were operated at Cairo university hospitals.
Preoperatively, all patients are subjected to a detailed cardiac assessment. A four vessel cerebral angiography is usually done in most patients. It is sometimes not necessary to perform a formal angiography in patients intended for flow augmentation. If preoperative trans-cranial color coded duplex shows clear evidence of hemodynamic ischemia, and provides adequate information regarding both, donor and the recipient vessels, then it is our practice not to perform a formal angiography. Cases intended for flow replacement are subjected to color coded duplex of both saphenous veins and the left radial artery. Patients are asked to discontinue antiplatelet therapy one week to ten days before surgery. The main aim of pre-operative investigations is to provide adequate information about the anatomy of both donor and recipient vessels.

After induction of general anesthesia normotension, normo-capnia and mild hypothermia are maintained throughout the surgical procedure. The procedure is started by harvesting the donor vessel in cases of flow augmentation, or the graft and preparation of the donor vessel in cases of flow replacement. This is kept in place till the time of anastomosis. (If an insufficient donor vessel is found before surgery, then an alternative option should be taken, either to choose another donor, or to augment the donor itself. For example, one of our cases had an insufficient superficial temporal artery. In this particular case we used a short saphenous vein graft to revascularize the superficial temporal artery from the transverse cervical artery and we waited for three months until flow in the artery approached the contralateral side and then we used the superficial temporal artery for bypass). Attention is then shifted to the recipient vessel. A craniotomy is done and the recipient vessel is chosen for bypass.

Once both donor and recipient vessels are ready, burst suppression is started and the patient is heparinized. Mean arterial blood pressure is elevated 20% above the baseline and the anastomosis is created using a standard technique described elsewhere ill. However, recently we started to use a standard back wall through the front wall (one way up) suture technique. We have found this technique to be faster and can be used for end to end, end to side and side to side anastomosis. After completion of the anastomosis, microvascular clamps are removed. Any bleeding from the suture line is dealt with by additional sutures when necessary. Patency is then confirmed and the wound is closed in layers making sure no compression takes place in cases of flow augmentation. In cases of flow replacement, the proximal anastomosis is then completed after tunneling the graft. For the tunneling a pediatric chest tube is used along with marking the outer layer of the graft to prevent rotation or kinking Bulldog clamps are used for cross clamping and the same process is repeated as for the distal anastomosis. In the present series, for all cases of flow replacement we have used an end to side anastomosis with the common carotid artery as the proximal anastomosis. In one case, and end-end anastomosis was used with the external carotid artery. In another case, an end-end internal carotid artery anastomosis was done.

After surgery, all cases are kept in an intensive care unit and maintained on low dose heparin along with Aspirin and Clopidogrel for the first 48 hours. After 48 hours, Heparin is stopped and patients are kept on aspirin for life. In cases of flow replacement, Aspirin is stopped 10 days before tumor surgery. In cases of aneurysms the aneurysm is dealt with in the same procedure. Blood pressure is maintained at a high normal level. In cases of flow augmentation, attention is given to prevent the development of a hyper-perfusion syndrome. This is managed by keeping the patients on selective Alfa channel blockers (Labetalol). (Figs 1-8) show a stepwise demonstration of the creation of an end to side anastomosis. (Table 1) shows details of all cases in the study.

Case presentation:

Case 1

This was a 54 year old male patient who presented with hemodynamic ischemia resulting from a right total internal carotid artery occlusion. Preoperative trans-cranial color coded duplex revealed a remarkable diminution in blood flow in the middle cerebral artery on the right side in comparison to the left side. The patient had recurrent attacks of facio-brachial monoplegia associated with amaurosis fugax in the right eye that was also associated with diminution of vision. The patient was also hypertensive and diabetic. Aggressive medical treatment including risk factor management failed to alleviate the symptoms resulting from hemodynamic ischemia. The patient was operated upon by a low flow by-pass (superficial temporal to middle cerebral artery by-pass). After surgery, the facio-brachial monoplegia disappeared and so did the amaurosis fugax. However, the diminution of vision that was present before surgery did not improve. Post-operative imaging revealed a patent graft as well as improvement of flow in the right sided middle cerebral artery in comparison to the left middle cerebral artery as compared to the preoperative status.
Table (1): Shows details of all cases in the study.

<table>
<thead>
<tr>
<th>Number</th>
<th>Age</th>
<th>Sex</th>
<th>Reason for By-pass</th>
<th>Procedure</th>
<th>Pre-operative status</th>
<th>Post-operative status</th>
<th>Anastomotic patency</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50</td>
<td>Male</td>
<td>Lt M1 and cervical ICA stenosis</td>
<td>Low flow By-pass</td>
<td>TIA,s</td>
<td>Died</td>
<td>Patent</td>
<td>Hyper perfusion syndrome</td>
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<td>Rt ICA occlusion</td>
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<td>TIA,s</td>
<td>Subsided</td>
<td>Patent</td>
<td>Non</td>
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<tr>
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<td>Lt ICA and CCA occlusion</td>
<td>Low flow By-pass after STA augmentation</td>
<td>TGA,s</td>
<td>Onset on second day after surgery and then subsided completely</td>
<td>Patent</td>
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</tr>
<tr>
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<td>51</td>
<td>Male</td>
<td>Rt ICA occlusion</td>
<td>Low flow By-pass</td>
<td>TIA,s</td>
<td>Subsided</td>
<td>Patent</td>
<td>Non</td>
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<tr>
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<td>Female</td>
<td>Rt ICA occlusion</td>
<td>Low flow By-pass</td>
<td>TIA,s</td>
<td>Ongoing symptoms</td>
<td>Occluded 2 months after surgery</td>
<td>Non</td>
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<td>15</td>
<td>Male</td>
<td>Moya-moya disease</td>
<td>Low flow By-pass+ myosinangiosis</td>
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<td>Subsided</td>
<td>Patent</td>
<td>Non</td>
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<tr>
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<td>Rt ICA occlusion</td>
<td>Low flow By-pass</td>
<td>Severe cognitive deficit</td>
<td>Remarkable cognitive improvement</td>
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</tr>
<tr>
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<td>Low flow By-pass</td>
<td>Severe cognitive deficit</td>
<td>Remarkable cognitive improvement</td>
<td>Patent</td>
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</tr>
<tr>
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<tr>
<td>10</td>
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<td>High flow By-pass</td>
<td>Rt visual loss &amp; oculomotor paralysis</td>
<td>Same</td>
<td>Patent</td>
<td>Non</td>
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<tr>
<td>11</td>
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<td>Female</td>
<td>Rt cavernous ICA giant aneurysm</td>
<td>High flow By-pass</td>
<td>TIA,s</td>
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<td>12</td>
<td>59</td>
<td>Female</td>
<td>Rt cavernous sinus meningioma</td>
<td>High flow By-pass</td>
<td>Headaches and oculomotor paralysis</td>
<td>Tumor resection</td>
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<tr>
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<td>Lt ICA occlusion</td>
<td>Low flow By-pass</td>
<td>TIA,s</td>
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<tr>
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<tr>
<td>17</td>
<td>62</td>
<td>Female</td>
<td>Lt cavernous ICA giant aneurysm</td>
<td>High flow By-pass</td>
<td>TIA,s and oculomotor deficit</td>
<td>Aneurysm exclude and decompressed</td>
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<td>Non</td>
</tr>
<tr>
<td>18</td>
<td>58</td>
<td>Female</td>
<td>Rt cavernous sinus meningioma</td>
<td>High flow By-pass</td>
<td>Headaches and oculomotor paralysis</td>
<td>Tumor resection</td>
<td>Patent</td>
<td>Non</td>
</tr>
</tbody>
</table>
Fig. (1): Shows the sequential intraoperative photographs revealing (A) Cervical carotid artery exposure, (B) Superficial temporal artery dissection, (C) Recipient vessel preparation, (D) Donor vessel or graft preparation and fish mouthing, (E) Cross clamping of the recipient vessel, (F) Creation of distal anastomosis, (G) Testing for patency, (H) Creation of proximal anastomosis after tunneling.
Case 2

This was a 58 year old female patient with a right sided cavernous sinus meningioma. The patient presented with recurrent attacks of headache associated with a complete ophthalmoplegia on the right side. The patient could not tolerate carotid occlusion on the right side as well. The patient was operated using a high flow by-pass (external carotid artery to middle cerebral artery using a radial artery graft). The internal carotid artery was then completely ligated for tumor resection. Post-operative C.T. Angiography revealed the flow on the side with the by-pass to be very good, in fact better than, the normal side because of a patent high flow by-pass graft.

![Image](A)

Fig. (2): (A) Postoperative CTA revealing a patent by-pass graft with improvement of blood flow in the MCA territory in comparison to the contralateral side, (B) Trans-cranial coloured duplex revealing the same findings with improvement of flow velocity has compared to the contralateral normal MCA.

![Image](B)

Fig. (3): Postoperative CTA revealing a patent radial artery graft with improvement in circulation in the right hemisphere as compared to the left after carotid ligation.

Results

The study included 18 patients. Patients ages ranged between 15-65 years. 11 patients (61.6%) were males and 7 (38.8%) were females. However, all patients operated upon for flow replacement were exclusively females.

Regarding surgical indications, 13 patients (72.2%) were operated upon for flow augmentation and 5 patients (27.7%) were operated upon for flow replacement. Of the 13 patients operated for flow augmentation, one patient (5.5%) had moyamoya disease, one patient (5.5%) had MCA stenosis and eleven patients (61.6%) had steno occlusive lesions of the internal carotid artery, one of whom was bilateral. Of the 5 patients operated upon for flow replacement, 2 (11.1%) had non clipping giant aneurysms of the internal carotid artery in the cavernous sinus and 3 (16.6%) had cavernous sinus meningiomas.

All patients operated for flow augmentation were operated by a standard superficial temporal artery to middle cerebral artery by-pass. One patient (5.5%) with moyamoya disease was operated in addition by mysinangiosis on one side in addition to the by-pass and by myoencephalodurosinangiosis on the other side. Another patient (5.5%) with an associated external carotid artery stenosis was operated first by and interposition short saphenous vein graft between the transverse cervical artery and the superficial temporal artery to augment flow in the superficial temporal artery 3 months before performing a superficial temporal to middle cerebral artery by-pass. 3 patients (16.6%) operated for flow replacement, were operated using an interpo-
sition radial artery graft between the common carotid artery in the neck and the middle cerebral artery. One patient (5.5%) was operated by an internal carotid to internal carotid end to end anastomosis, and one patient (3.5%) had a proximal anastomosis to the external carotid artery in the neck using end to end anastomosis with the radial artery graft.

Regarding anastomotic patency, all anastomoses were patent as confirmed by intra and postoperative testing. One anastomosis was occluded one month after surgery. This particular patient had a vasculitic disorder and initially showed a remarkable postoperative improvement. The anastomosis was initially patent. This shows finally that only one of a total of 24 anastomosis showed a delayed occlusion. The remaining 23 were all patent. This means a patency rate of 95.9%.

There was one death in the present study (5.5%). This patient died of a postoperative cerebral hyperperfusion syndrome.

Regarding surgical outcome, 10 patients (76.9%) with hemodynamic ischemia showed cessation of pre-operative TIA, 1 case of vasculitis (7.6%) started developing symptoms, severely, one month after discharge. This patient showed an occluded anastomosis. 1 patient (7.6%) developed an attack of transient global amnesia in the immediate post-operative period and then ceased to have symptoms till the time this paper was written. The same applies for the patient with moya moya disease. 11 patients (84.6%) showed a remarkable cognitive improvement after surgery. 1 patient (7.6%) was even severely confused before surgery and became cognitively normal later on. The 2 operated aneurysms (40%) were completely excluded from the circulation. None suffered any postoperative complications. However, none of them regained oculomotor nerve function after 6 months of follow-up. The 3 patients (60%) operated for cavernous sinus meningiomas were totally resected and none of them regained oculomotor nerve function as well.

**Discussion**

Ever since Alexis Carrel successfully performed vascular anastomotic procedures in 1914, the door has been opened for a new field of surgery, vascular surgery. Vascular surgery came to be an important part of every surgical discipline. Yasargil introduced superficial temporal artery to middle cerebral artery by-pass in 1967. Lougheed then performed the first high flow by-pass two years later using a great saphenous vein graft between the intrapetrous carotid artery and the supra-clinoid portion of the internal carotid artery [18-17]. However, the technical demands of the surgical procedure prevent its being widely practiced except in a few highly specialized referral centers worldwide. Very few reports have been published from low volume less equipped centers in developing countries. We report on our initial experience with by-pass surgery at a low volume and less equipped center.

Our choice of surgical procedure was a standard superficial temporal artery to middle cerebral artery by-pass. There have been a number of reports on the use of high flow by-pass grafts for flow augmentation. However, the general consensus among most by-pass authorities is to use a standard superficial temporal to middle cerebral artery by-pass. Our choice of graft was a radial artery graft in all of our cases operated for flow replacement. We did not use a great saphenous vein graft in any of our cases. The radial artery has the benefits of having a thick wall, a good size match to the M2 and providing an intermediate flow which has been proven by many authors to be ideal to the brain. The radial artery also has a proven long term patency rate that has been accepted as superior to great saphenous vein grafts. The main drawback of using the radial artery is that it can be short in patients with long necks and short arms, and the radial artery is more liable to spasm than the saphenous vein [18,19]. However, there have been many techniques described with the aim of preventing spasm. In all of our cases we have used a pressure distension technique as described by Sekhar et al. [20]. None of our cases operated for flow replacement showed post-operative spasm.

93.7% of our anastomoses were of the end to side type. 8.3% were of the end to end type. No side to side anastomoses were performed. There is also a general agreement, among by-pass surgeons, to use end to side anastomosis as the main form of anastomosis for most cases of cerebral revascularization [21-23]. All our cases were operated using a standard end to side anastomosis technique with 2 anchoring stitches at the heel and at the toe. However, only very recently, we have started to use a one way up suture technique with only one anchoring suture at the heel. The recent literature on microvascular anastomoses also shows a tendency for using an open guide technique rather than a standard technique [24]. Our initial observations show; that it saves time and is much safer; because it avoids the occurrence of a through stitch at the heel. In all our cases a slit arteriotomy was used rather than a tear drop arteriotomy. This has
been proposed by many by-pass surgeons as well [25,26,1,5].

95.9% of the anastomoses were patent at follow-up. Only 4.1% showed a delayed occlusion and this case proved to be a case of vasculitis. The reported patency rate coincides with the rate of patency described elsewhere [7,9,13].

76.9% of patients operated for hemodynamic ischemia showed a complete cessation of T.I.A, s. 7.6% continued to have symptoms due to an occluded anastomosis. 15.2% developed symptoms initially after surgery and then ceased to have symptoms during the period of follow-up. The 2 patients who developed symptoms initially were both found to have very small donor vessels at surgery. One of them was a patient with an occluded external carotid artery who had to receive a short saphenous vein graft to revascularize the superficial temporal artery from the transverse cervical artery. The second patient was the patient with moyamoya disease. Both had patent anastomoses as proven by post-operative imaging. However, this process can be explained by graft maturation. All patients treated by flow replacement were treated successfully either by complete tumor resection or by complete exclusion of the aneurysm from the circulation. None of them regained oculomotor nerve function after surgery and during follow-up. This coincides with the work of a number of authors performing by-pass for flow replacement [11,17,23].

There was one mortality in the present series. This was the first patient operated for flow augmentation. This was a 50 year old male patient who presented with hemodynamic ischemia caused by steno-occlusive disease of the left internal carotid artery and the middle cerebral artery. The patient was operated and the anastomosis was patent. 48 hours after surgery, the patient started to develop uncontrollable convulsions and severe hypertension; which were not responsive to any form of antiepileptic or antihypertensive therapy. Such symptoms characteristic for a hyper-perfusion syndrome proved to be very difficult to treat [15]. Later on the patient developed a disturbed consciousness associated with chest infection and eventually died.

Our initial results for both low and high flow by-pass procedures in our low volume center indicate that such complex surgical procedures are possible with results comparable to those obtained in other larger referral centers throughout the world. This is of particular significance because it offers hope for a group of patients with complex disorders that can be only treated by such surgical procedures. This form of treatment offers the only line of treatment for patients with hemodynamic ischemia. Patients indicated for flow replacement can usually not be treated by other means such as endovascular means or gamma knife. However, even if this is possible, in a country with limited financial resources, with a patient population mostly comprising of poor patients, this form of treatment is of a much lower cost and in most cases offers a much more definitive and radical form of treatment than otherwise endovascular means or even gamma knife.

Conclusion:

Our initial results for both low and high flow by-pass procedures in our low volume center indicate that such complex surgical procedures are possible with results comparable to those obtained in other larger referral centers throughout the world. This procedure not only represents a more definitive treatment when compared to other endovascular or radiation treatments but is also much less costly when compared to other treatment modalities.

References


