Automated, compliant, high-flow common carotid to middle cerebral artery bypass

Technical note

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The authors describe the use of the Cardica C-Port xA Distal Anastomosis System to perform an automated, high-flow extracranial–intracranial bypass. The C-Port system has been developed and tested in coronary artery bypass surgery for rapid distal coronary artery anastomoses. Air-powered, it performs an automated end-to-side anastomosis within seconds by nearly simultaneously making an arteriotomy and inserting 13 microclips into the graft and recipient vessel. Intracranial use of the device was first simulated in a cadaver prepared for microsurgical anastomical dissection.

The authors used this system in a 43-year-old man who sustained a subarachnoid hemorrhage after being assaulted and was found to have a traumatic pseudoaneurysm of the proximal intracranial internal carotid artery. The aneurysm appeared to be enlarging on serial imaging studies and it was anticipated that a bypass would probably be needed to treat the lesion. An end-to-side bypass was performed with the C-Port system using a saphenous vein conduit extending from the common carotid artery to the middle cerebral artery. The bypass was demonstrated to be patent on intraoperative and postoperative arteriography. The patient had a temporary hyperperfusion syndrome and subsequently made a good neurological recovery.

The C-Port system facilitates the performance of a high-flow extracranial–intracranial bypass with short periods of temporary arterial occlusion. Because of the size and configuration of the device, its use is not feasible in all anatomical situations that require a high-flow bypass; however it is a useful addition to the armamentarium of the neurovascular surgeon. (DOI: 10.3171/JNS/2008/109/9/0559)

**Key Words** • extracranial–intracranial arterial bypass • intracranial aneurysm • vessel anastomosis

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**Abbreviations used in this paper:**
CCA = common carotid artery; EC–IC = extracranial–intracranial; ICA = internal carotid artery; MCA = middle cerebral artery; SAH = subarachnoid hemorrhage; C-Port xA Distal Anastomosis System (Cardica, Inc.); SAH = subarachnoid hemorrhage.
circumferentially into the graft and recipient vessel. The device creates a compliant (nonrunning suture) anastomosis and provides a systems-based approach to the problem of technically inconsistent anastomoses.

We report here the first description of the use of this device for creation of a high-flow EC–IC arterial bypass in a patient with a traumatic pseudoaneurysm of the proximal intracranial ICA.

Illustrative Case

History and Examination. This 43-year-old right-handed man was assaulted, struck in the occipital region, and then lost consciousness. His condition was initially evaluated at an outside hospital, where he complained of a severe headache; results of a neurological examination were normal. A CT scan demonstrated an SAH in the basilar cisterns and the early onset of hydrocephalus (Fig. 1A). Computed tomography angiography was performed and no aneurysm was found (Fig. 1B). The patient presented again 3 weeks later to the same outside hospital with headaches, and a CT scan of his head revealed a new focal SAH in the region of the left ICA (Fig. 1C). The patient was transferred to our hospital (Barnes-Jewish Hospital in St. Louis, Missouri) and a catheter cerebral angiogram was obtained, revealing a 3 × 4-mm aneurysm involving the left distal ICA (Fig. 2).

Operation. This aneurysm was deemed to be a fusiform traumatic aneurysm, probably requiring trapping and EC–IC bypass. In preparation for anticipated aneurysm trapping, an EC–IC artery bypass was constructed as follows: 1) a left frontotemporal craniotomy and wide opening of the Sylvian fissure was performed; 2) a long segment of the saphenous vein was harvested and prepared in the standard fashion and was mounted in the cartridge. After preparation of the recipient vessel and application of temporary clips, a 1-mm incision is made in the recipient vessel with a No. 11 blade just distal to the anastomosis site and the anvil is inserted into the recipient vessel (Fig. 6 left). The anastomosis is created by depressing the trigger on the handle of the device, which makes the arteriotomy and deploys the cartridge assembly, inserting the microclips through the adventitia of the vein graft and into the artery. After the anvil is...

Methods

Cardica C-Port xA Distal Anastomosis System

The C-Port system we used is composed of 2 components: the anvil that contains a microknife for the arteriotomy, and the cartridge containing 13 microclips for the automated anastomosis (Fig. 5). The device is powered by a CO₂ cartridge in the handle. The vein graft is prepared in the standard fashion with the spatulated end mounted in the cartridge. After preparation of the recipient vessel and application of temporary clips, a 1-mm incision is made in the recipient vessel with a No. 11 blade just distal to the anastomosis site and the anvil is inserted into the recipient vessel (Fig. 6 left). The anastomosis is created by depressing the trigger on the handle of the device, which makes the arteriotomy and deploys the cartridge assembly, inserting the microclips through the adventitia of the vein graft and into the artery. After the anvil is...
removed, the procedure is completed by placing a single 10-0 nylon suture in the anvil insertion site (Fig. 6 right).

**Cadaveric Simulation**

Prior to its application in our patient, the use of the device in an EC–IC bypass was simulated using a polytetrafluoroethylene conduit in a cadaver prepared for microdissection. The M2 branches of the MCA were chosen as the recipient vessels. Anatomically successful anastomoses were created in vessels with diameters of 1.75–2.5 mm (Fig. 7). The cartridge extended 3.0-mm beyond the tip of the anvil during deployment. For this reason, we found that a more extensive dissection of the Sylvian fissure must be performed so that the cartridge would not collide with the dura mater over the sphenoid ridge or the inferior frontal or superior temporal gyrus. The segment of the M2 divisions of the MCA within 10 cm of the bifurcation appeared to be the optimal recipient zone for the distal automated anastomosis given the anatomy of the vessels, the Sylvian cistern, and the configuration of the device.

**Operative Procedure**

Following a standard frontotemporal craniotomy and harvest of the saphenous vein graft in our patient, the Sylvian fissure was opened widely. Based on our experience in the cadaver, a more extensive Sylvian fissure dissection was performed to allow adequate working space for the C-Port system. The anterior M2 branch of the MCA was chosen as a recipient vessel. After barbiturate-induced electroencephalogram-burst suppression was achieved for neuroprotection, temporary clips were placed across the recipient...
M₂ vessel. A 1-mm incision distal to the anastomosis was fashioned, the anvil inserted, and the device deployed. The device was removed, and the distal incision closed with a single 10-0 nylon suture. No significant bleeding was noted between the microclips, no supplemental sutures were required, and excellent backflow through the vein graft was demonstrated. The C-Port system was similarly utilized for performance of the proximal anastomosis at the CCA. The total temporary clipping times for each anastomosis were 3 and 2 minutes, respectively.

**Discussion**

This is the first report of the use of the C-Port system for EC–IC bypass. We found the device relatively straightforward to use, and we noted that temporary clipping times were significantly shorter than that ordinarily achieved with traditional hand-sewn techniques. We observed that the end-to-side anastomoses yielded excellent short-term flow and patency. Although a postoperative complication occurred—a hyperperfusion syndrome from which the patient recovered well—this was unrelated to use of the C-Port system. Our experience suggests that this system is well-suited to the performance of a CCA to M₂ MCA division bypass using the saphenous vein as a conduit.

Bregy and colleagues have simulated the use of the C-Port system for cerebral bypass procedures in human cadavers and rabbits. They demonstrated that use of the C-Port system was suitable for high-flow EC–IC bypass to the MCA. They found that the length of the M₂ division to which the automated anastomoses were performed was 13.1 ± 5.1 mm. Similar dimensions were found in the cadaver simulations we performed (Fig. 7). The C-Port anvil is 10-mm long. Given that temporary clips were applied during our initial experience with the device and that a small arteriotomy is necessary for insertion of the anvil, a recipient vessel length of ~12–13 mm is required for use of the device. It is not necessary for this length to be completely branch-free, but smaller branches of the recipient vessel adjacent to the anastomosis might be subject to occlusion when the device is deployed.

The cartridge head of the C-Port system extends...
about 3 mm beyond the anvil tip when it is deployed. Although this additional length is not required in the recipient vessel, it is necessary that the dissection of the Sylvian fissure be more extensive than usual for an anterior circulation aneurysm exposure. We found that care in vessel selection and microdissection must be exercised to avoid collision of the descending cartridge head with the pial surfaces of the superior temporal or inferior frontal gyri or with the sphenoid wing. This need for substantial anatomic space for safe and effective C-Port deployment not only impacts the exposure needed for M\(_2\) division anastomoses, but also limits the potential application of this device to other recipient vessels such as the internal carotid or posterior cerebral arteries. Appropriately sized M\(_4\) branches of the MCA with a minimum 1.3-mm internal diameter and a wall thickness of 0.75 mm, however, may be acceptable, either in the context of an interposition graft or potentially a superficial temporal artery bypass.

Matschke and colleagues\(^6\) reviewed the results of a multicenter prospective clinical trial examining utility of the C-Port system in coronary artery bypass grafting surgery. Rates of success in constructing the bypass were good, and long-term graft patency rates were excellent. Of 130 patients intended to undergo coronary artery bypass grafting, 116 had successful C-Port bypass procedures. Of the 14 unsuccessful anastomoses, 11 were due to ineffective initial C-Port deployment (primarily due to inadequate clearing of connective tissue resulting in obstructed approximation of anvil to cartridge) and 3 were due to inadequate blood flow after C-Port anastomosis. When failure occurred, grafts were removed from the recipient vessels by “unzipping” the anastomosis from the toe end of the graft and then proceeding with conventional hand-sewn anastomosis. This bail-out procedure was successful in all 14 cases. Overall graft patency for the C-Port procedure was 99% at discharge and 96% at...
the 6-month follow-up examination. The average target vessel diameter was 1.6 ± 0.4 mm.

Over the past few years, several new automated devices have become available and have been relatively well-examined in the setting of cardiac bypass procedures. It is attractive to consider whether the use of such devices designed to produce more uniform anastomoses in a shorter period of time might ultimately reduce ischemic complications and improve the long-term patency rates of traditional EC–IC bypass procedures. Newell et al. described the use of a novel microanastomotic device for end-to-end anastomosis in patients with MCA aneurysms. Tulleken and colleagues have developed an ingenious system for excimer laser-assisted EC–IC anastomosis. This system has the advantage in that occlusion of the recipient and donor arteries is not necessary. Short-term and intermediate patency has been good in a series of patients with complex aneurysms. This system represents a very important addition to the neurovascular armamentarium and highlights the potential advantages of automated approaches to the performance of microsurgical procedures.

The Cardica device can potentially be modified to further enhance its ability to facilitate EC–IC bypass. Currently Cardica, Inc. anticipates that the length of the anvil can be reduced by 50% and the width of the cartridge by 75%. These modifications of the device would increase its ease of use for saphenous vein or radial artery bypass in the Sylvian fissure by reducing the potential for collision of the cartridge with the crowns of surrounding gyri. A smaller device would also significantly facilitate superficial temporal artery bypass to angular opercular branches of the MCA given the somewhat shorter lengths of the superficial temporal artery pedicle.

Automated bypass appears to offer a significant advantage over traditional hand-sewn anastomosis by reducing temporary occlusion time. Occlusion times of 20–45 minutes are reported for conventional hand-sewn anastomosis. It is conceivable that with more experience, the Cardica C-port device could be used to fashion a bypass with minimal occlusion times (less than the 5 minutes reported in the present study) to place the single stitch for the anvil hole closure.

Conclusions

The use of the Cardica C-Port xA Distal Anastomosis System in the treatment of a patient who required a high flow EC–IC bypass for an intracranial aneurysm was associated with short temporary arterial occlusion times. Our positive initial experience with this system suggests that these devices may have a role in cerebral revascularization in the future. Clearly, additional experience and studies will be needed before conclusions can be drawn regarding the benefits of these devices compared with those of traditional hand-sewn anastomoses.

Disclaimer

The authors do not report any conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

References


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