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Technique Articles

Bifurcated Arterial Circulation for Hybrid Aortic Reconstruction: A Novel Technique

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Abstract: Hybrid aortic procedures present many new challenges to the management of cardiopulmonary bypass (CPB). Reoperation or previous thoracic endovascular aortic repair (TEVAR) can further complicate these procedures, increasing the need for flexibility within the CPB system to execute multiple perfusion strategies as cases dictate. This technique describes the use of a bifurcated arterial circulation to provide both cerebral and lower body perfusion during a redo hybrid aortic arch reconstruction. The arterial line was divided into upper and lower body limbs, and connected to an 8-mm Dacron graft to the axillary artery, as well as a percutaneous 16-Fr. OptiSite femoral arterial cannula respectively. A 25-Fr. multi-stage femoral venous cannula was placed percutaneously as well. CPB was initiated utilizing both arterial cannulas with near-infrared spectroscopy and electroencephalogram to monitor the adequacy of cerebral perfusion. Moderate hypothermia of 26°C was induced and a CODA balloon (Cook Medical, Bloomington, IN) was deployed to occlude the proximal limb of a thoracic endovascular repair (TEVAR) graft; the common trunk of the debranched arch vessels was clamped proximally, allowing for simultaneous upper and lower body perfusion. Upon completion of the distal arch, the CODA balloon was removed and total body perfusion was reinitiated via central cannulation utilizing a sidearm on the arch graft. **Keywords:** hybrid aortic arch, TEVAR, axillary and femoral arterial cannulation, moderate hypothermic circulatory arrest, NIRS, EEG. *J Extra Corpor Technol. 2021;53:302–5*

Thoracic endovascular aortic repair (TEVAR) has revolutionized aortic surgery by creating a safe and comparable alternative to open aortic aneurysm repair (1). However, as with any intravascular procedure, TEVAR is not free from risk and the need for secondary reoperation is relatively common (1). In addition, unrepaired sections of the aorta may progressively dilate, resulting in the need for further repair and creative techniques to solve a unique set of challenges after TEVAR (1). Implementation of hybrid aortic arch repair surgical techniques can combine traditional and endovascular techniques to solve these challenges, while minimizing the morbidity risks of each technique respectively (2).

Complex aortic surgery often utilizes a myriad of cardiopulmonary bypass (CPB) techniques including deep or moderate hypothermic circulatory arrest (DHCA/MHCA), antegrade cerebral perfusion (ACP), retrograde cerebral perfusion and multisite arterial perfusion strategies (2–6). Flexibility to use multiple perfusion techniques within the same procedure can be critical to the success of complex aortic surgery. Machin et al. presented a technique for divided cerebral and lower body perfusion utilizing Dacron grafts in traditional repairs of the descending aorta (7). Hybrid aortic procedures, however, present new challenges to this technique, as the TEVAR grafts are wire reinforced and cannot be clamped with traditional aortic cross-clamps. This article describes a technique for bifurcated arterial circulation to accommodate simultaneous antegrade cerebral and lower body perfusion during hybrid aortic aneurysm repair; utilizing a CODA balloon catheter (Cook Medical, Bloomington, IN) as an Endoclamp within a TEVAR graft.

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DESCRIPTION

The patient was a 75-year-old male status post-high-grade aortic arch three-vessel debranching, with a zone 0

TEVAR and a reverse saphenous vein to the left anterior descending coronary artery bypass grafting. He presented for a chronic retrograde aortic root/ascending dissection with asymptomatic severe aortic valve regurgitation. Additionally, he had a history of stage 2 chronic kidney disease and 3–4-mm intracranial aneurysm.

EXTRACORPOREAL CIRCUIT

Our standard Terumo tubing pack (Terumo Medical, Somerset, NJ) with a 3/8”×1/2”-arterial-venous loop was used along with an FX25W40 Oxygenator and hard-shell venous reservoir combination (Terumo Medical). The LivaNova CSC14 (LivaNova, Houston, TX) cardioplegia set was incorporated into the circuit, which was built on a LivaNova S5 (LivaNova) roller pump. A CardioQuip MCH-1000(i) (CardioQuip, College Station, TX) heater/cooler was used to provide systemic heating and cooling to the patient.

A 3/8-inch Y connector was cut into the arterial line distal to the bubble detector and arterial flow probe. A 3/8-inch PVC line, for the right axillary arterial cannulation site, was handed back from the sterile field and connected to the Y connector. An additional ultrasonic arterial flow probe, using the LivaNova SCP console (LivaNova) was attached to this upper body limb for monitoring flows during standard bypass and ACP (Figure 1). Lower body flows were calculated by subtracting the upper limb flow from arterial flow on the main arterial line. The bypass circuit was primed with 1,565 mL PlasmaLyte, 10,000 IU of porcine heparin solution, and 25-mEq sodium bicarbonate.

Procedure

The right axillary artery was cannulated using an 8-mm Gelsoft graft (Terumo Medical) while the right femoral

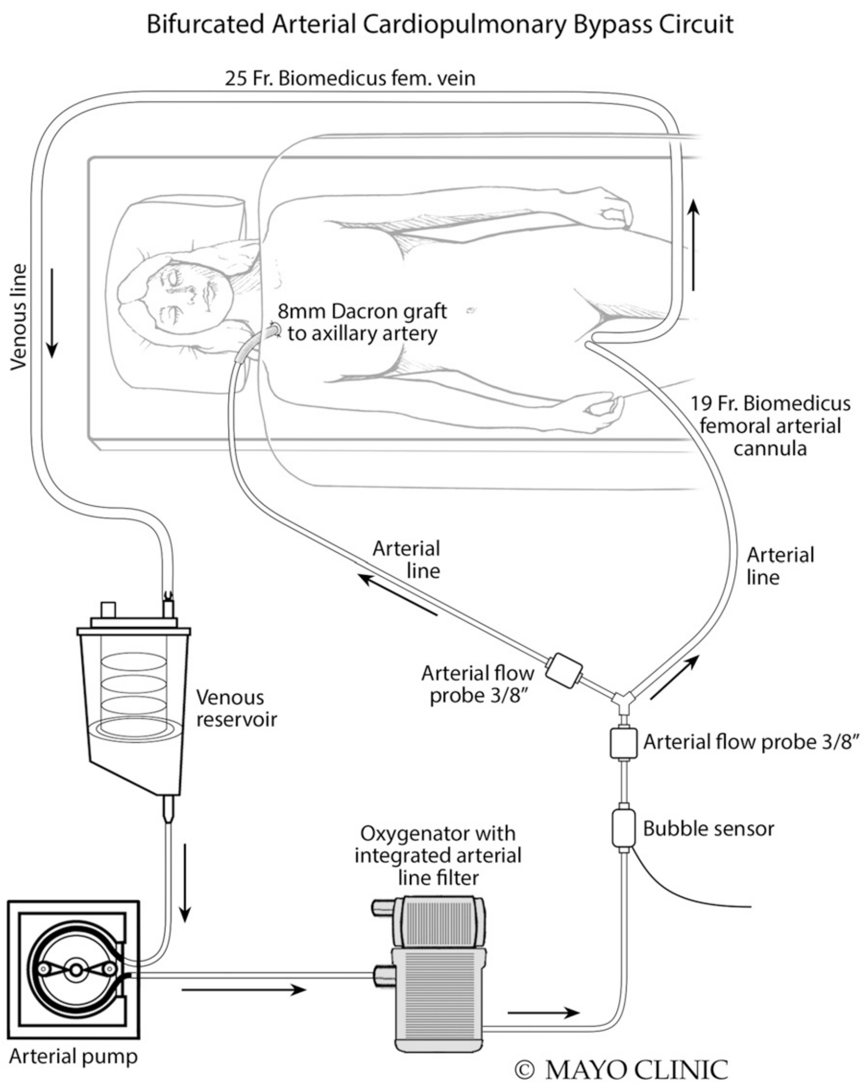

Figure 1. Cardiopulmonary bypass circuit design and cannulation configuration.

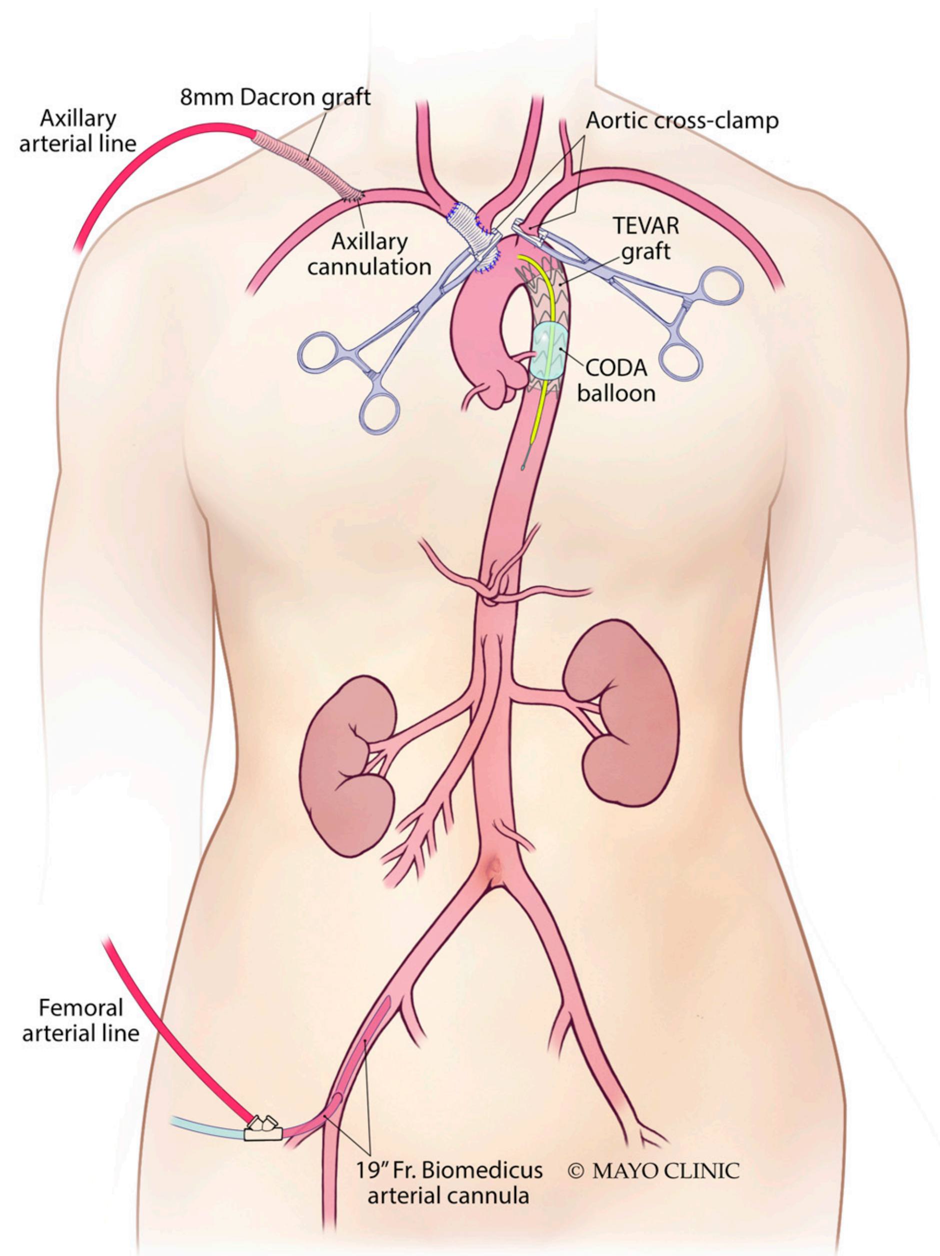

Figure 2. Cannulation, clamp and CODA balloon configuration for split arterial circulation during hybrid aortic procedure.

artery was cannulated with a 16-Fr. OptiSite cannula (Edwards Lifesciences, Irvine, CA). Venous cannulation was achieved in the right femoral vein with a 25-Fr. Multi-Stage Biomedicus venous cannula (Medtronic, Minneapolis, MN). Transesophageal echocardiogram guided cannula placement was used. CPB was established through both arterial bypass lines, utilizing left and right radial pressures as well as a left femoral pressure line. The patient's mean arterial blood pressure was kept above 70 mm Hg (left radial and left femoral) during the cooling and rewarming phases of the operation. Aortic root vent and left ventricular vent, via the right superior pulmonary vein, were placed for cardiac decompression. A retrograde cardioplegia cannula was also placed. The aortic cross-clamp was applied and del Nido cardioplegia was administered, initially retrograde, followed by direct ostial cannulation. Subsequent doses of cardioplegia were administered every 40–60 minutes. The patient was cooled to 26°C to prepare for MHCA. Near-infrared spectroscopy (NIRS) (Nonin, Plymouth, MN) and electroencephalogram (EEG) monitoring were used throughout the procedure to ensure adequate cerebral perfusion (4,6). Upon reaching the target temperature, CPB was ceased and the common trunk of the debranched arch vessels was clamped (Figure 2). ACP was initiated via the right axillary arterial graft at 10 mL/kg and a right radial pressure of 60 mm Hg was maintained for 15 minutes; during this time the aortic arch was removed and the TEVAR graft was resected. A CODA® balloon was advanced to the mid-descending aorta within the TEVAR graft. The balloon was inflated, and lower body perfusion was reinitiated via the femoral cannula to maintain a femoral arterial pressure of 50 mm Hg (Figure 2). The distal arch vessels were attached to a collared multibranch Siena graft (Terumo Medical). After completion of the distal arch anastomosis to the proximal endograft suture line, central cannulation was achieved via an 8-mm sidearm branch of the Siena graft. The femoral arterial cannula was clamped and left in place, while the line was detached and connected to the central arterial line site of the arch graft. CPB was reinitiated and the axillary graft was clamped, thereby diverting all flow to the central cannulation site. All three arterial pressure lines were correlating, and rewarming was commenced while the Bentall portion of the procedure was completed. Bypass was weaned and the patient was placed on extracorporeal membrane oxygenation (ECMO) for acute right heart failure secondary to coagulopathy. ECMO was successfully weaned after 48 hours, and the patient was discharged home on post-op day 18.

DISCUSSION

It was important to develop a cannulation strategy that can be achieved through minor modifications to a standard tubing pack, while providing ACP and lower body perfusion simultaneously. The goals of this strategy were to simultaneously reduce the end-organ ischemic time and provide adequate delivery of blood flow to the brain. This cerebral perfusion strategy supports the trend toward MHCA for complex aortic surgery that is used to reduce postoperative coagulopathy associated with DHCA (3,5).

Safety and monitoring of the brain during ACP are critical to the success of this procedure. EEG and NIRS are both proven, noninvasive tools for monitoring brain function and appropriate oxygenation, respectively, and are integral to the safe conduct of ACP particularly in the setting of MHCA (4,6). These tools are highly recommended for the implementation of this technique to allow for rapid troubleshooting during the procedure, allowing the team to pivot to another strategy, if necessary. The use of multiple arterial pressure monitoring sites can help guide flow requirements during the bifurcated arterial circulation period. A partial clamp can be applied to the appropriate limb of the CPB arterial line to divert more flow to the upper or lower circulation as needed. Additionally, NIRS monitoring of the flank to assess adequacy of perfusion to the lower body may be used.

The CODA balloon was chosen as the endoclamp due to its ready availability and common use in antegrade TEVAR deployment. Proper sizing and inflation of the CODA balloon is important to prevent migration or leak during the lower body perfusion period. Failure to create a tight seal can result in loss of blood to the surgical field, or an inability to generate an adequate femoral arterial pressure, thereby reducing end organ perfusion.

While this patient provided a unique set of challenges during this procedure, the authors believe this technique can be safely and effectively be applied to standard hybrid aortic procedures with antegrade TEVAR graft deployment or redo procedures with previously deployed, well-adhered TEVAR grafts.

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