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*Case Series*

# Cannula Placement for Cerebral Protection Without Circulatory Arrest in Patients Undergoing Hemiarch Aortic Aneurysm Repair

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**Keywords:** Cardiopulmonary bypass; circulatory arrest, deep hypothermia induced; hemiarch; aortic aneurysm, thoracoabdominal; cerebral protection

## Abstract

**Background:** Aortic aneurysms involving the proximal aortic arch, which require hemiarch-type repair, typically require circulatory arrest with antegrade cerebral perfusion. Left carotid antegrade cerebral perfusion (LCP) via distal arch cannulation without circulatory arrest was used in this study's patient population. The goal was to assess the operative efficiency and clinical outcomes of using a distal arch cannulation technique that would not require any hypothermic circulatory arrest (HCA) time compared with more traditional brachiocephalic artery cannulation with right-sided unilateral antegrade cerebral perfusion (RCP) and HCA.

**Methods:** A single-center retrospective review of patients with replacement of the distal ascending aorta involving the proximal arch was performed. Patients with an intramural hematoma or dissection were excluded. Between January 2015 and December 2019, 68 adult patients had undergone a hemiarch repair because of aneurysmal disease. Analysis of baseline demographics, operative data, and clinical outcomes was performed.

**Results:** Comparing the 68 patients: 21 patients were treated with RCP (via brachiocephalic artery graft with HCA), and 47 patients were treated with LCP (via distal aortic arch cannulation with cross-clamp between the brachiocephalic and left common carotid arteries without HCA). Baseline characteristics and outcomes were evaluated for both groups. The LCP group was younger (LCP median [IQR] age, 60 [53-65] years vs RCP median [IQR] age, 67 [59-71] years]. Sex, race, body mass index, comorbidities, and ejection fraction were similar between the groups. Cardiopulmonary bypass time (LCP, 123 minutes vs RCP, 149 minutes) and unilateral cerebral perfusion time (LCP, 17 minutes vs RCP, 22 minutes) were longer in the RCP group. Bleeding, prolonged ventilatory support, kidney failure, and length of stay were similar. In-hospital mortality was 2% in the LCP group vs 0% in the RCP group. Stroke occurred in 2 patients (4.2%) in the LCP group and in 0% of the RCP group. Mortality at 6 months in the LCP and RCP groups was 3% and 10%, respectively.

**Conclusion:** Distal arch cannulation with LCP without HCA is a reasonable and safe alternative strategy for patients requiring hemiarch replacement for aneurysmal disease. This technique may provide additional benefits by avoiding circulatory arrest in these complex cases.

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## Introduction

Thoracic aortic aneurysm is an often subtle disease process that presents as an urgent or emergent problem. In the United States, it is the 18th leading cause of death in individuals aged 55 years and older, resulting in 10,037 deaths.[1] Surgery is typically recommended for symptomatic thoracic aortic aneurysms (including rupture, dissection, and pain). Repair of asymptomatic thoracic aortic aneurysms is recommended when the ascending aorta is greater than 5.5 cm in diameter or the descending aorta is greater than 6.5 cm in diameter, with adjustments for earlier intervention according to patient height, family history of dissection, rapid growth of aneurysm (>5 mm per year), comorbidities, and genetic conditions.[2] Surgical intervention involves cardiopulmonary bypass (CPB) and replacing the diseased aorta with a prosthetic graft. If the aortic arch is involved, a hemiarch or total-arch repair is performed, often requiring hypothermic circulatory arrest (HCA) and possibly cerebral perfusion.

The optimal method for attaining cerebral protection during such procedures is widely discussed but not currently standardized. A review of the Society of Thoracic Surgeons Adult Cardiac Surgery Database suggests that patients undergoing more than 30 minutes of circulatory arrest benefit from either deep hypothermia with antegrade or retrograde cerebral perfusion or from moderate hypothermia with antegrade cerebral perfusion (ACP).[3] Retrograde cerebral perfusion is performed via the superior vena cava to perfuse the cerebral venous system with cooled perfusate for cerebral hypothermia. Antegrade cerebral perfusion traditionally is performed via cannulation of the axillary or brachiocephalic artery, perfusing the brain unilaterally or bilaterally.[4] The literature to date suggests noninferiority of ACP compared with retrograde cerebral perfusion, deferring to patient specifics and surgeon preference, with an international trend in preference for ACP.[5,6] There is an appeal to performing this operation without targeted hypothermia because of the concern for hypothermia-induced coagulopathy, cerebral microvasculature dysfunction, hypothermic neuronal injury, and systemic inflammatory response.[7] Cannulating the axillary or brachiocephalic artery for ACP is both time-consuming and not without risk of embolism, which can be a deterrent to this technique. This technique also requires circulatory arrest using a clamp across the more proximal brachiocephalic artery, often with an additional clamp across the left common carotid artery, to prevent retrograde bleeding into the field through the circle of Willis. This study used left-sided unilateral antegrade cerebral perfusion (LCP) via distal aortic arch cannulation for cerebral protection without circulatory arrest to allow for a simpler cannulation technique in hemiarch replacements. This study explores outcomes using LCP with aortic arch cannulation for normothermic CPB. The outcomes of ACP using right-sided unilateral antegrade cerebral perfusion (RCP) during HCA with brachiocephalic artery cannulation are also reported.

### Key Points

- Reducing circulatory arrest time should improve overall neurologic outcomes in patients requiring replacement of the ascending aorta and hemiarch.
- It is possible to provide adequate cerebral protection by maintaining antegrade flow through the left carotid artery.
- Distal aortic arch cannulation with the cross-clamp placed between the brachiocephalic artery and the left carotid artery avoids the need for HCA and is a safe alternative technique.

### Abbreviations and Acronyms

| | |
|---|---|
| ACP | antegrade cerebral perfusion |
| CPB | cardiopulmonary bypass |
| HCA | hypothermic circulatory arrest |
| LCP | left-sided unilateral antegrade cerebral perfusion |
| RCP | right-sided unilateral antegrade cerebral perfusion |

## Patients and Methods

This study was reviewed by the institutional review board and obtained an exempt status, given its retrospective nature. Informed consent was waived for this study. Clinical trial registration was not applicable for this study. No identifying information or individual data were used in this manuscript.

### Study Participants and Characteristics

A retrospective review of patients who underwent aortic surgery by a single surgeon at a center between January 2015 and December 2019 was performed, identifying 195 patients who were at least 18 years old. Patients who had undergone surgery for aortic dissection (21 [10.8%]) or for endocarditis (8 [4.1%]) and patients who did not require cerebral protection (98 [50.3%]) were excluded. Patients requiring total arch replacement were also excluded because this procedure would preclude the use of this technique. After excluding these patients, 68 patients remained who had undergone aortic repair primarily for aneurysmal disease involving part of the arch. These 68 patients made up the study cohort. Baseline comorbidities, surgical details, and operative outcomes were collected from variables provided by the Society of Thoracic Surgeons Adult Cardiac Surgery Database (version 2.81). Additional information about patient outcomes and operative information was obtained by standard chart review.

## Operative Technique

A consistent surgical approach was used regardless of the cerebral protection technique used. Neuromonitoring was performed by a dedicated neuromonitoring colleague in every case, which included continuous quantitative electroencephalography monitoring of cerebral oxygen saturation and middle cerebral artery Doppler flows. Median sternotomy was performed, and dissection was carried out in normal fashion. The decision to use RCP vs LCP was made based on surgeon preference and mainly related to the feasibility of placing the aortic clamp between the origins of the brachiocephalic and left common carotid arteries. For patients receiving RCP, an 8-mm graft was anastomosed in an end-to-side fashion to the brachiocephalic artery using a 5-0 polypropylene suture (Prolene; Ethicon Inc) and connected to the CPB circuit. For patients receiving LCP, an aortotomy was made distal to the origin of the left common carotid artery, and the arterial bypass cannula was inserted and secured with purse-string sutures, then was connected to the CPB circuit. In both techniques, a venous cannula was inserted into the right atrium through the right atrial appendage, and a left ventricular vent was placed via the right superior pulmonary vein and connected to the venous circuit. With the help of perfusion colleagues, CPB was initiated; antegrade cold cardioplegia was delivered initially, and then intermittently into the coronary ostia throughout the case by hand, with retrograde cardioplegia delivered via coronary sinus. An aortic cross-clamp was placed, and the proximal aorta was transected at the proximal level of the aneurysm. If the aortic valve or root required replacement, this was performed at this time by valve replacement, resuspension, or Bentall procedure in normal fashion. For the RCP group, adequate deep hypothermia (approximately 22 °C) was deemed achieved once cerebral oxygen saturations reached a plateau and electroencephalogram silence was achieved. If a plateau was achieved but with mild, persistent electroencephalographic activity, propofol was used for neuroplegia. Circulatory arrest was achieved by placing vascular clamps on the brachiocephalic and left common carotid arteries, allowing RCP via the brachiocephalic artery. Cerebral flow was managed by neuromonitoring and perfusion colleagues for unilateral cerebral perfusion. Neuromonitoring consisted of cerebral oximetry with middle cerebral artery flow monitoring. Cerebral flow was initiated at 5 to 10 mL/kg/min and increased to a goal of 15 mL/kg/min, with the possibility of further increase if inadequate cerebral perfusion was noted by the neuromonitoring colleague. In the LCP group, the same neuromonitoring was performed, but no hypothermia was used. Vascular clamps were placed on the brachiocephalic artery and on the aortic arch between the origins of the brachiocephalic artery and left common carotid artery while CPB was continued through the aortic arch cannula (Fig. 1), allowing for continued systemic perfusion. Flows were adjusted in response to arterial carbon dioxide levels and mean arterial pressure monitoring. The original aortic cross-clamp was removed, and the aorta was resected and replaced with a prosthetic tube graft. The great vessels and arch were de-aired, and an aortic cross-clamp was placed on the aortic graft. The vascular clamps were then removed, restoring normal bilateral cerebral perfusion, and the proximal anastomosis was completed.

## Outcomes Assessed

The outcomes assessed were in-hospital mortality, permanent stroke, mortality at 6 months postoperatively, postoperative bleeding events, prolonged ventilatory support, kidney failure requiring hemodialysis, length of stay, CPB time, and circulatory arrest or unilateral cerebral perfusion time. *Permanent stroke* was defined as any neurologic deficit with acute onset confirmed by computed tomography or magnetic resonance imaging caused by inadequate blood supply to the brain that did not resolve within 24 hours. These patients were all evaluated by neurology colleagues. Transient ischemic attacks were not included in primary outcomes. Prolonged ventilatory support was defined as more than 24 hours before postoperative extubation.

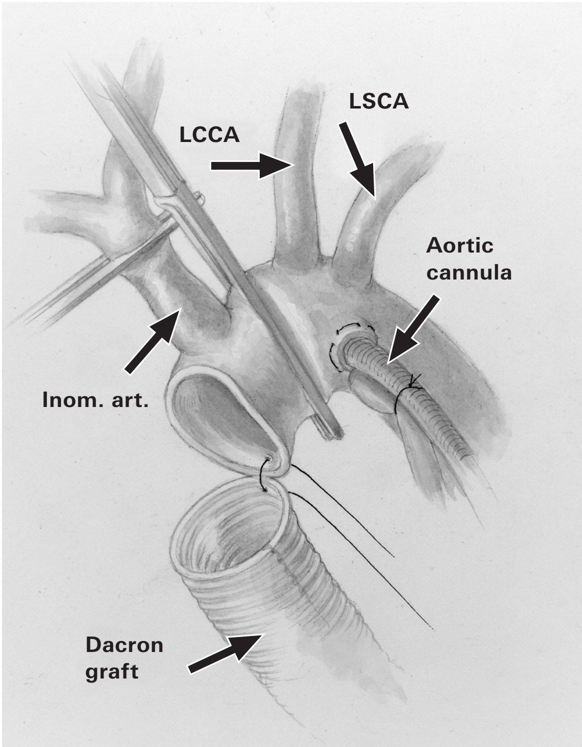


**Fig. 1** Illustration of the surgical technique for left-sided unilateral antegrade cerebral perfusion. A vascular clamp is seen on the brachiocephalic artery, and there is a vascular clamp on the aorta between the brachiocephalic artery and the LCCA. The cardiopulmonary bypass cannula enters the aortic arch distal to the takeoff of the LCCA near the LSCA.

Inom. art., innominate artery; LCCA, left common carotid artery; LSCA, left subclavian artery.

# Results

## Study Population

A total of 68 patients underwent ascending aorta hemiarch replacement between January 2015 and December 2019. Fifty-three of these patients also underwent aortic root replacement at the time of surgery. The LCP group had 47 patients (69%), and the RCP group had 21 patients (31%). The LCP group was 60% male (n = 28) and 91% White (n = 43), with a median age of 67 years. The RCP group was 57% male (n = 12) and 90% White (n = 19), with a mean age of 67 years. Baseline patient characteristics are summarized in Table I.

## Operative Technique

Patients in the RCP group were maintained in deep HCA during circulatory arrest. Patients in the LCP group were not actively warmed during the procedure; however, deep HCA was not performed, given that patients maintained systemic perfusion and unilateral cerebral perfusion. Upon observation, patients in the LCP and RCP groups had similar aortic cross-clamp times. The median unilateral cerebral perfusion time was 123 minutes and for the RCP group was 149 minutes. The mean unilateral cerebral perfusion time was 17 minutes for the LCP group and 22 minutes for the RCP group (Table I).

## Outcomes

The LCP and RCP groups' rates of postoperative bleeding events requiring reoperation (2 [4%] in the LCP group vs 1 [5%] in the RCP group), prolonged ventilatory support (9 [19%] in the LCP group vs 4 [19%] in the RCP group), kidney failure requiring hemodialysis (2 [4%] in the LCP group vs 1 [5%] in the RCP group), and length of stay (6 days in the LCP group vs 6 days in the RCP group) are reported in Table II. Rates of in-hospital mortality (1 [2%] in the LCP group vs 0 [0%] in the RCP group), permanent stroke (2 [4%] in the LCP group vs 0 [0%] in the RCP group), and 6-month mortality (1 [3%] in the LCP group vs 2 [11%] in the RCP group) are also reported in Table II. The rates of follow-up at 6 months were 72% (n = 34) for the LCP group and 90% (n = 19) for the RCP group.

# Discussion

Left-sided unilateral antegrade cerebral perfusion using distal aortic arch cannulation for CPB access and an aortic clamp between the origins of the brachiocephalic and left common carotid arteries permitted a hemiarch repair without circulatory arrest or hypothermia. Observed outcomes in both groups are similar to previous studies looking at brain protection for aortic arch aneurysm.[3,5,6,8] This finding would suggest that aortic arch cannulation, when possible in the context of disease and patient anatomy, is feasible and may serve as an alternative to standard brachiocephalic artery cannulation for CPB and unilateral cerebral perfusion in an appropriately selected patient. Though the risk of aortic rupture is often a concern when directly cannulating a dissected aorta, this was not evident in the review of these patients without aortic dissection.

This approach may be easier and faster overall than the standard brachiocephalic artery cannulation that can be used in hemiarch aortic repair. Of the 47 patients assigned to the LCP group, 2% (n = 1) were reported

**TABLE I. Baseline Demographics and Operative Data**

| Characteristics | LCP without HCA (n = 47) | RCP with HCA (n = 21) |
|---|---|---|
| Age, median (IQR), y | 60 (53-65) | 67 (59-71) |
| Male sex, No. (%) | 28 (60) | 12 (57) |
| White, No. (%) | 43 (91) | 19 (90) |
| Body mass index, median (IQR) | 27 (25-32) | 27 (24-33) |
| Creatinine, median (IQR), mg/dL[a] | 0.9 (0.8-1.0) | 1.0 (0.8-1.1) |
| Chronic lung disease, moderate to severe, No. (%) | 2 (4) | 1 (5) |
| Hypertension, No. (%) | 33 (70) | 17 (81) |
| Diabetes, No. (%) | 3 (6) | 0 (0) |
| Ejection fraction, median (IQR), % | 60 (55-63) | 60 (55-63) |
| Elective surgery, No. (%) | 44 (94) | 20 (95) |
| Redo operation, No. (%) | 2 (4) | 3 (14) |
| CPB time, median (IQR), min | 123 (107-139) | 149 (128-161) |
| Cross-clamp time, median (IQR), min | 105 (86-115) | 107 (76-124) |
| Circulatory arrest time, median (IQR), min | N/A | 22 (20-24) |
| Unilateral cerebral perfusion time, median (IQR), min | 17 (15-19) | 22 (20-24) |

CPB, cardiopulmonary bypass; HCA, hypothermic circulatory arrest; LCP, left-sided unilateral antegrade cerebral perfusion; N/A, not applicable; RCP, right-sided unilateral antegrade cerebral perfusion.
[a] SI conversion factor: To convert mg/dL to μmol/L, multiply by 88.4.

**TABLE II. Outcomes Data**

| Outcomes | LCP without HCA (n = 47) | RCP with HCA (n = 21) |
|---|---|---|
| In-hospital deaths, No. (%) | 1 (2) | 0 (0) |
| Stroke, No. (%) | 2 (4) | 0 (0) |
| Bleeding requiring reoperation, No. (%) | 2 (4) | 1 (5) |
| Prolonged ventilation (>24 h), No. (%) | 9 (19) | 4 (19) |
| Kidney failure requiring dialysis, No. (%) | 2 (4) | 1 (5) |
| Length of stay, median (IQR), d | 6 (5-8) | 6 (4-8) |
| Follow-up at 6 mo, No. (%) | 34 (72) | 19 (90) |
| Mortality, n/N (%) | 1/34 (3) | 2/19 (11) |

HCA, hypothermic circulatory arrest; LCP, left-sided unilateral antegrade cerebral perfusion; RCP, right-sided unilateral antegrade cerebral perfusion.

for in-hospital mortality and 4% (n = 2) for permanent stroke. No statistical significance can be assumed for the different observed outcomes reported between the LCP and the RCP groups. Left-sided unilateral antegrade cerebral perfusion via the distal arch may decrease overall procedure time by eliminating the need to sew a graft onto the brachiocephalic artery; however, it is unclear why this also decreased CPB and unilateral cerebral perfusion times. It also avoids the need for hypothermia, which could reduce the risk of hypothermia-associated coagulopathy, cerebral microvasculature dysfunction, hypothermic neuronal injury, and systemic inflammatory response. Avoiding circulatory arrest also avoids the risks associated with abdominal and spinal malperfusion, which tend to be lessened by hypothermia.[9] Deep HCA has furthermore been shown to have developmental and neurological sequelae in children.[10] Avoiding this altogether may have implications on the longevity of cognition, behavior, and memory that has not been a target of evaluation thus far. Further studies may be able to elucidate the ideal setting in which to use LCP and whether hypothermia has any added benefit in this modality of unilateral cerebral perfusion.

Though this technique was effective in this carefully selected population of patients with aneurysmal disease of the aorta, aortic dissection represents a more complicated problem for which this technique is less likely an option. Patient disease may also preclude the use of this technique if the distal aorta is heavily calcified or atheromatous, precluding adequate cross-clamping between the brachiocephalic artery and left common carotid artery or if the anatomy of the aneurysm requires a more oblique transection of the aorta, which would not allow for a vascular clamp to be placed between the brachiocephalic and left common carotid arteries. Disease involving only the aortic root and ascending aorta will often not require circulatory arrest, making this technique irrelevant to those cases. Disease involving the distal arch and great vessels would also not be amenable to this technique because of the requirement to operate directly on this area. Deep HCA continues to have its place in cerebral protection and circulatory arrest; however, the techniques explored in this study could potentially avoid the associated risks of hypothermia and circulatory arrest and decrease operative time in an appropriately selected patient population.


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### Study Limitations

This study reports experiences and outcomes associated with LCP. The inherent nature of retrospective review may have contributed to the observed outcomes. There was no defined method for choosing between LCP or RCP as this was decided intraoperatively by the experienced surgeon on a case-by-case basis. The determination came from the intraoperative findings of the extent of aneurysmal dilatation, favorable anatomy, and the ability to place the aortic clamp between the brachiocephalic and left common carotid artery. Though patients were not specifically chosen for aortic cross-clamping based on aortic pathology, atheromatous disease may preclude aortic cross-clamping. The stroke rate reported from this study's outcome may have been related to diseased aortas that were not evident intraoperatively and were not reported in the study's chart review. The reported outcomes furthermore cannot be compared with the standard RCP method given the lack of power to perform statistical analysis. From this limited cohort size, and with the outcomes observed, this study provides one experience of using LCP in hemiarch repair of the aorta. The data show, however, that further research needs to be conducted in order to properly determine the technique's overall benefit. Future studies should focus on increasing the sample size in this retrospective chart review or in a prospective study that may provide further insight into how LCP can be incorporated into the repair of aortic aneurysms.

## Conclusion

A single center used a unilateral LCP with aortic arch clamp between the brachiocephalic and left common carotid arteries while continuing CPB without circulatory arrest or hypothermia in a retrospective chart review. Though this technique is not appropriate for all cases or patients, it could reduce unilateral cerebral perfusion and CPB times; avoid the risk of hypothermia and circulatory arrest; and decrease the risk of further long-term, neurologic complications. Larger studies will be needed to further evaluate the utility of this technique in treating patients with aortic aneurysm who need a hemiarch repair.

## Article Information

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