Zone 2 arch repair for acute type A dissection: Evolution from arch-first to proximal-first repair

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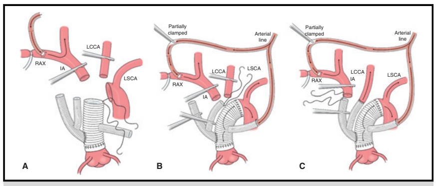
ABSTRACT

Objective: With growing experience of acute type A aortic dissection repair, Zone 2 arch repair has been advocated. The aim of this study is to compare the outcome between "proximal-first" and "arch-first" Zone 2 repair.

Methods: From January 2015 to March 2023, 45 patients underwent Zone 2 arch repair out of 208 acute type A aortic dissection repairs: arch-first, N = 19, and proximal-first technique, N = 26, since January 2021. Indications were aortic arch or descending tear, complex dissection in neck vessels, cerebral malperfusion, or aneurysm of the aortic arch.

Results: The lowest bladder temperature was higher in the proximal-first technique (24.9 °C vs 19.7 °C, $P < .001$). Cardiopulmonary bypass (230 vs 177.5 minutes, $P < .001$), myocardial ischemic (124 vs 91 minutes, $P < .001$), and lower-body circulatory arrest (87 vs 28 minutes, $P < .001$) times were shorter in the proximal-first technique. The arch-first group required more packed red blood cells (arch-first, 2 units vs proximal-first, 0 units, $P = .048$), platelets (arch-first, 4 units vs proximal-first, 2 units, $P = .003$), and cryoprecipitates (arch-first, 2 units vs proximal-first, 1 unit, $P = .024$). Operative mortality and major morbidities were higher in the arch-first group (57.9% vs 11.5%, $P = .001$). One-year survival was comparable (arch-first, 89.5% ± 7.0% vs proximal-first, 92.0% ± 5.5%, $P = .739$). Distal intervention was successfully performed in 5 patients (endovascular, N = 3, and open repair, N = 2).

Conclusions: Zone 2 arch repair using the proximal-first technique for acute type A aortic dissection repair yields shorter lower-body ischemic time with a warmer core temperature, resulting in shorter cardiopulmonary bypass time, less blood product use, and fewer morbidities when compared with the arch-first technique. (JTCVS Techniques 2023;21:7-17)



Proximal-first Zone 2 arch repair in ATAD.

CENTRAL MESSAGE

Zone 2 arch repair using the proximal-first technique in acute dissection yields shorter cardiopulmonary bypass and lower-body ischemic times, resulting in better outcomes compared with the arch-first technique.

PERSPECTIVE

Zone 2 arch repair using the proximal-first technique for ATAD repair is reproducible, which is associated with lower operative mortality and morbidity, and less blood product use when compared with the arch-first technique. Both proximal and distal intervention including endovascular repair can be safely performed after Zone 2 arch repair, if necessary.

With growing experience of acute type A aortic dissection (ATAD) repair and the evolution of endovascular technique, extended arch repair has been proposed to resect or cover the primary entry and allow more options for distal intervention, if necessary.[1-7] Although total arch repair is the most extensive procedure to address problems in the aortic arch and proximal descending aorta, this procedure may add significant lower-body circulatory arrest time because of the need to address the left subclavian artery (SCA) and deep surgical field in this acute setting. All of these may result in higher mortality and morbidity outcomes.[2,4,8,9] For improved safety and efficacy, the concept of Zone 2 arch repair has been advocated.[1-12] This procedure provides more endovascular options for the downstream aorta, including thoracic endovascular aortic repair (TEVAR) with a left common carotid artery (CCA) to left SCA bypass or TEVAR using a 1-branched graft. To date, favorable remodeling of the distal aorta after TEVAR or frozen elephant trunk (ET) technique has been reported, although further evidence is necessary in terms of the safety of these approaches.[2,4,6,7]

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Abbreviations and Acronyms

ACP	= antegrade cerebral perfusion
ATAD	= acute type A aortic dissection
CCA	= common carotid artery
CT	= computed tomography
ET	= elephant trunk
IA	= innominate artery
RAX	= right axillary artery
SCA	= subclavian artery
TEVAR	= thoracic endovascular aortic repair

The arch-first technique is another approach used to treat arch pathology.[13-15] We previously reported on the safety and efficacy of the arch-first technique in complex cases such as the redo total arch repair.[14,15] Arch-first repair often is used with deep hypothermia; however, in the setting of ATAD repair, there is a longer cardiopulmonary bypass time and lower-body ischemic time, which may be associated with coagulopathy, respiratory failure, and renal failure, among others.

On the basis of this background, we recently introduced the unique technique of proximal-first Zone 2 arch repair, which yields shorter lower-body and myocardial ischemic times similar to hemiarch repair, facilitates subsequent TEVAR, and enables a concomitant Bentall procedure by using a single piece of ascending graft, if necessary.[11] There is a paucity of data comparing different types of Zone 2 arch repair in the setting of ATAD. We hypothesized that our new technique of Zone 2 arch repair with a warmer core temperature theoretically shortens lower-body ischemic and cardiopulmonary bypass time, which could improve the outcome. The aim of this study is to compare the characteristics and outcome between "proximal-first" Zone 2 arch repair and "arch-first" Zone 2 repair as a historical control.

PATIENTS AND METHODS

From January 2015 to March 2023, 45 patients (21.6%) out of 208 ATAD repairs underwent Zone 2 arch repair at our center (Figure E1). Indications for Zone 2 arch repair were aortic arch or descending tear, complex dissection in neck vessels, cerebral malperfusion, or aneurysm of the aortic arch. After January 2021, we started the proximal-first technique for Zone 2 arch repair. This retrospective study was approved by the Institutional Review Board, with a waiver of informed consent (#14209, approval date 5/2/2020).

The details of each technique and ATAD repair at our institute have been described by others.[11,15,16] The summary is shown in Figure 1. The right axillary artery (RAX) was used for arterial return.[16] Cerebral oximetry monitoring was routinely used.

Proximal-First Technique

After aortic crossclamping, proximal repair was performed by using a 1-branched Dacron graft.[11] Core cooling was initiated, aiming for a bladder temperature of 25 °C to 26 °C. A 12 × 8 × 8-mm trifurcated graft (MAQUET) was trimmed to a bifurcated graft that is anastomosed to a proximal, right greater curvature of the ascending graft. Alternatively, a 4-branched graft (Hemashield Platinum Woven Aortic Branch, MAQUET) could be used. Unilateral antegrade cerebral perfusion (ACP) was then initiated by reducing pump flow from the RAX (6-10 mL/kg/min) followed by clamping the innominate artery (IA) and left CCA (Figure 2, *A*). Distal aortic anastomosis was then performed under hypothermic circulatory arrest of the lower body. After completion of the distal aortic anastomosis, total cardiopulmonary bypass flow resumed by perfusing both the RAX and the side branch of an ascending graft, and rewarming then ensued, thus ending cardiac ischemia and lower-body ischemia (Figure 2, *B*). The left CCA was reconstructed, followed by the IA anastomosis (Figure 2, *C*). At the time of completion of IA anastomosis, rewarming was usually completed.

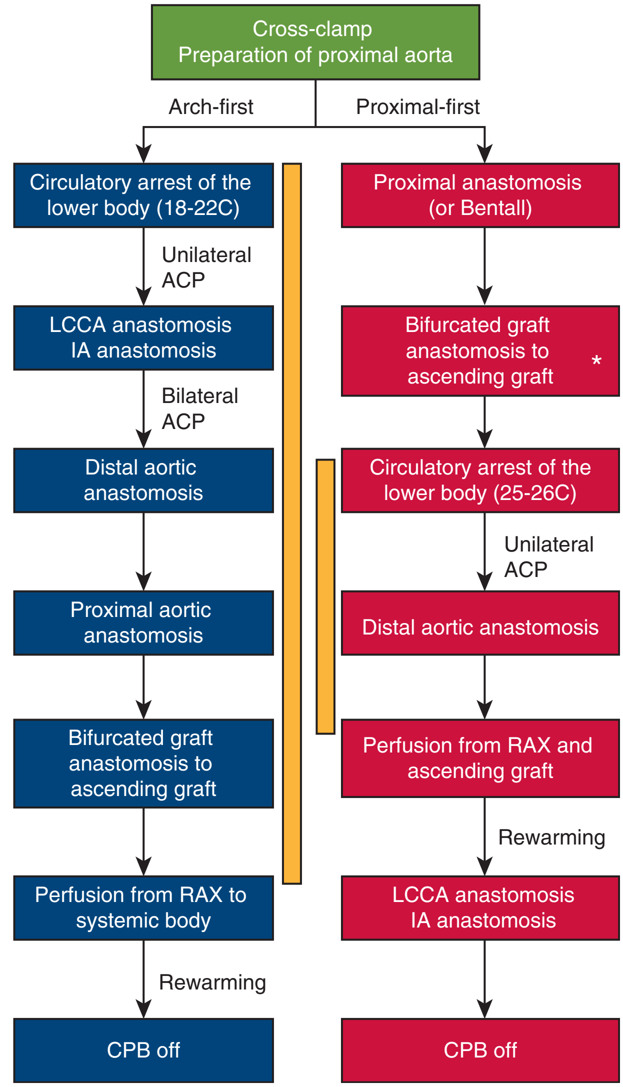

FIGURE 1. Surgical steps of arch-first and proximal-first Zone 2 arch repair. Yellow bars show the duration of circulatory arrest time of the lower body for each technique. *This step can be skipped when sawing a bifurcated graft before crossclamp or using a 4-branched graft. *ACP*, Antegrade cerebral perfusion; *LCCA*, left common carotid artery; *IA*, innominate artery; *RAX*, right axillary artery; *CPB*, cardiopulmonary bypass.

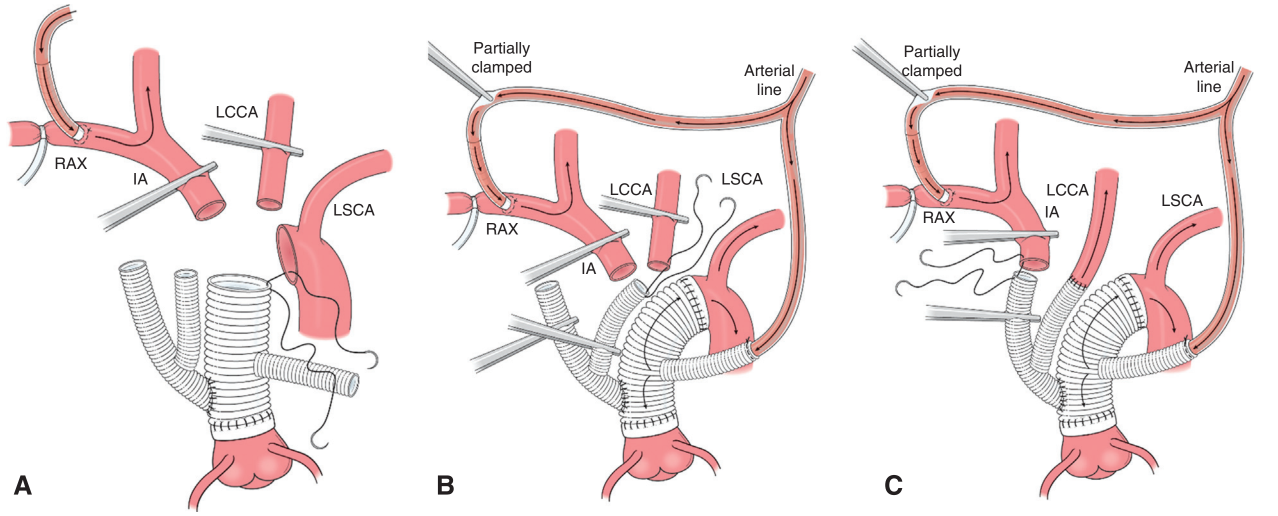

FIGURE 2. Proximal-first technique. A, After proximal anastomosis, distal anastomosis is performed with moderate hypothermic circulatory arrest. The brain is perfused by unilateral ACP from the RAX. B, After completion of distal anastomosis, systemic perfusion is resumed including the lower body and left SCA. Rewarming is initiated during left CCA anastomosis. C, The IA is anastomosed and the end of selective ACP. *LCCA*, Left common carotid artery; *RAX*, right axillary artery; *IA*, innominate artery; *SCA*, subclavian artery.

Arch-First Technique

The ascending aorta was crossclamped, and the proximal aorta was dissected out. Core cooling was initiated aiming for a bladder temperature of 18 °C to 22 °C.[15] After reaching the target temperature, unilateral ACP via the RAX was initiated. A 12 × 8 × 8-mm trifurcated graft was fashioned to a bifurcated graft that was anastomosed to the left CCA followed by IA anastomosis (Figure 3, *A*). Next, distal aortic anastomosis with a conventional ET technique under bilateral ACP was performed (Figure 3, *B*). This was followed by proximal aortic anastomosis using the same ET graft (Figure 3, *C*). Finally, the proximal portion of bifurcated graft was performed (Figure 3, *D*), and the systemic circulation and rewarming process resumed. For patients who underwent aortic root replacement or ascending repair using a separate graft, an ascending/aortic root graft to ET graft anastomosis was required.

End Points and Definitions

The primary outcomes were operative mortality and major morbidity (reoperations for any cardiac reason, renal failure, deep sternal wound infection, prolonged ventilation/intubation, and cerebrovascular accident/permanent stroke) defined in the Society of Thoracic Surgeons database. Secondary outcomes were blood product use and intraoperative measures (cardiopulmonary bypass time, myocardial ischemic time, lower-body circulatory arrest time, and lowest bladder temperature).[4,12] The end of selective ACP time was defined when both systemic and brain perfusion were restored through a single arterial inflow; this corresponded to completion of the IA anastomosis in the proximal-first group and completion of proximal anastomosis of the bifurcated graft in the arch-first technique. A follow-up was performed at the aortic clinic every 1 to 2 years after surgery; the follow-up included an office visit and computed tomography (CT). Two patients were lost to follow-up within 1 year after ATAD repair.

Statistical Analysis

Continuous variables were presented as the median (first; third quartile) and compared using the Mann–Whitney *U* test. Categorical variables were expressed in percentages and compared using the chi-square or Fisher exact test (N < 5). The survival curve was analyzed by the Kaplan–Meier method with the log-rank test. Statistical analyses were performed using SPSS 24.0 (IBM Corp).

RESULTS

The median age of patients was 64 years (Table 1). Forty-four patients (97.8%) had DeBakey type I dissection. Forty-three patients (95.6%) had a primary tear in the ascending aorta or aortic arch. Baseline characteristics were comparable except that arch tear or ascending + arch tear was more predominant in the arch-first group ($P = .022$). Any organ malperfusion preoperatively was observed in 42.2% (N = 19) of cases, and cerebral malperfusion rate was 26.7% (N = 12). Dissection of neck vessels was common: innominate artery, 61.4% (N = 27), right CCA, 34.1% (N = 15), left CCA, 46.5% (N = 20), and left SCA 39.5% (N = 17).

Operative Outcomes

The median lowest bladder temperature was higher in the proximal-first technique (24.9 °C) compared with the arch-first technique (19.7 °C) ($P < .001$) (Table 2). Cardiopulmonary bypass time (230 vs 177.5 minutes, $P < .001$), myocardial ischemic time (124 vs 91 minutes, $P < .001$), and lower-body circulatory arrest time (87 vs 27.5 minutes, $P < .001$) were significantly shorter in the proximal-first technique. The arch-first group required more packed red blood cells (arch-first, 2 units vs proximal-first, 0 units, $P = .048$), platelets (arch-first, 4 units vs proximal-first, 2 units, $P = .003$), and cryoprecipitates (arch-first, 2 units vs proximal-first, 1 unit, $P = .024$).

Although mortality was comparable between groups, the composite outcome of operative mortality and major morbidities was higher in the arch-first group (57.9% vs 11.5%, $P = .001$) (Table 3), which was likely driven by a

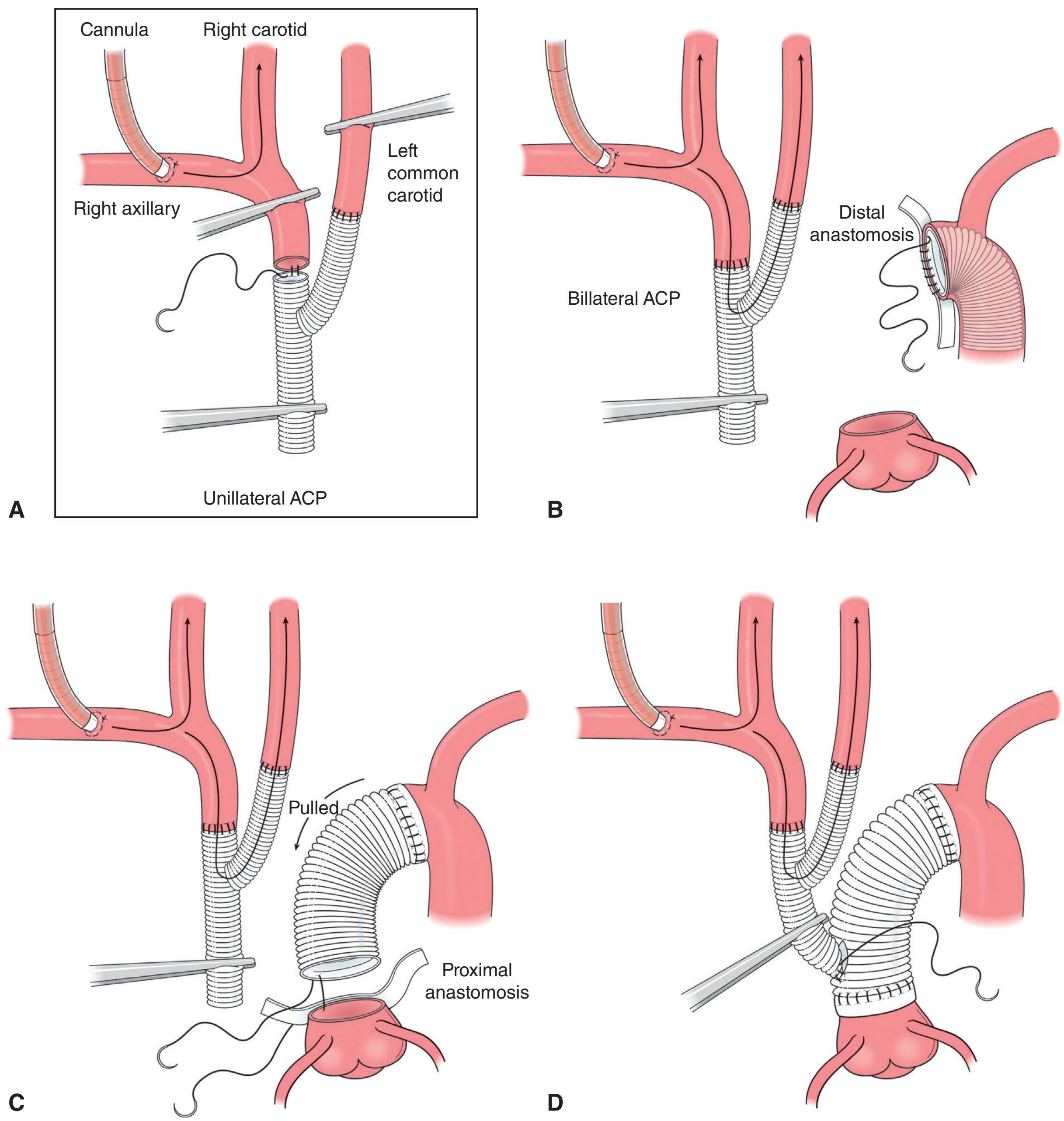

FIGURE 3. Arch-first technique. A, After circulatory arrest of the lower body, the bifurcated graft is anastomosed to the left CCA followed by IA anastomosis. B, Bilateral ACP is established and distal anastomosis is performed with an inverted graft into the distal aorta. C, Ascending graft is pulled out and anastomosed above the sinotubular junction. D, Proximal part of a bifurcated graft is anastomosed to the ascending graft. Systemic perfusion is resumed and rewarming is initiated. *ACP*, Antegrade cerebral perfusion.

combination of the following complications: reoperation for bleeding (arch-first, 15.8% vs proximal-first, 0%, $P = .136$), respiratory failure including tracheostomy (arch-first, 36.8% vs proximal-first, 7.7%, $P = .042$), stroke (arch-first, 26.3% vs proximal-first, 7.7%, $P = .198$), and kidney failure (arch-first, 21.1% vs proximal-first, 3.8%, $P = .182$). One patient developed paraparesis whose lower-body ischemic time was 114 minutes with the lowest tympanic and bladder temperatures of 18.6 °C and 22.3 °C, respectively.

Survival and Aortic Intervention After Zone 2 Arch Repair

The mean follow-up duration was 2.0 ± 1.6 years in the arch-first group and 1.1 ± 0.6 years in the proximal-first group. Kaplan–Meier survival analysis showed that both

TABLE 1. Preoperative characteristics

Variable	All N = 45	Arch-first N = 19	Proximal-first N = 26	*P* value
Age, y	64 [55, 73.5]	66 [60, 74]	63 [55, 73]	.190
Male	32 (71.1%)	13 (68.4%)	19 (73.1%)	.734
Body surface area, m^2	2.04 [1.88, 2.23]	2.08 [1.87, 2.22]	2.00 [1.88, 2.25]	.558
Hypertension	40 (93.0%)	17 (89.5%)	23 (95.8%)	.833
Diabetes mellitus	7 (15.6%)	2 (10.5%)	5 (19.2%)	.706
Creatinine ≥1.5 mg/dL	4 (9.3%)	3 (15.8%)	1 (4.2%)	.439
Coronary artery disease	5 (11.1%)	2 (10.5%)	3 (11.5%)	1.00
Atrial fibrillation	2 (4.7%)	0	2 (8.3%)	.576
Cerebrovascular disease	3 (6.7%)	1 (5.3%)	2 (7.7%)	1.00
Connective tissue disease	2 (4.4%)	0	2 (8.3%)	.614
Prior TEVAR	3 (6.7%)	2 (10.5%)	1 (3.8%)	.778
Prior sternotomy	3 (6.7%)	1 (5.3%)	2 (7.7%)	1.00
Aortic insufficiency ≥2+	26 (57.8%)	12 (63.2%)	14 (53.8%)	.532
Ejection fraction, %	60 [60, 60]	60 [50, 60]	60 [60, 60]	.656
Intubation	4 (8.9%)	2 (10.5%)	2 (7.7%)	1.00
Cardiogenic shock	12 (26.7%)	6 (31.6%)	6 (23.1%)	.524
DeBakey I dissection	44 (97.8%)	19 (100%)	25 (96.2%)	1.00
Tear location				.022
Ascending	23 (51.1%)	5 (26.3%)	18 (69.2%)	
Ascending + arch	6 (13.3%)	5 (26.3%)	1 (4.2%)	
Arch	14 (31.1%)	8 (42.1%)	6 (23.1%)	
Descending	1 (2.2%)	0	1 (4.2%)	
Others/unknown	1 (2.2%)	1 (5.3%)	0	
Any malperfusion	19 (42.2%)	10 (52.6%)	9 (34.6%)	.187
Cerebral	12 (26.7%)	7 (36.8%)	5 (19.2%)	.245
Coronary	1 (2.2%)	0	1 (3.8%)	1.00
Mesenteric	3 (6.7%)	1 (5.3%)	2 (7.7%)	1.00
Arm	7 (15.6%)	3 (15.8%)	4 (15.4%)	1.00
Leg	4 (8.9%)	2 (10.5%)	2 (7.7%)	1.00
IA dissection	27 (61.4%)	11 (61.1%)	16 (61.5%)	.977
Right CCA dissection	15 (34.1%)	7 (38.9%)	8 (30.8%)	.576
Left CCA dissection	20 (46.5%)	9 (50.0%)	11 (44.0%)	.697
Left SCA dissection	17 (39.5%)	8 (44.4%)	9 (396.0%)	.576

Values are expressed in n (%) or median (first; third quantile). *TEVAR*, Thoracic endovascular repair; *IA*, innominate artery; *CCA*, common carotid artery; *SCA*, subclavian artery.

groups had comparable 1-year survival (arch-first, 89.5% ± 7.0% vs proximal-first, 92.0% ± 5.5%, $P = .739$) after Zone 2 arch repair (Figure 4).

There are 5 distal interventions. TEVAR was performed in 3 patients; the most recent patient underwent 1-branch TEVAR. Two patients received a "provisional extension to induce complete attachment" technique[5,7] to complete repair of the downstream aorta (Table E1). Two patients underwent open repair of the descending thoracic aorta; 1 patient developed dilatation of the descending aorta without enlargement of the distal aortic arch, and 1 patient required 2-stage repair using classic ET.

For proximal reoperation, 2 patients received aortic root replacement after Zone 2 arch repair. Because a bifurcated graft is anastomosed to the ascending graft just above the sinotubular junction, bilateral axillary artery cannulation was used to perfuse (1) the brain through the RAX to the bifurcated graft and (2) systemic body through the left axillary cannulation through the left SCA (Figure E2).

DISCUSSION

In the present study, we compared our proximal-first Zone 2 arch repair and our historical control (arch-first technique). Ascending or hemiarch replacement is our

TABLE 2. Operative details

Variable	All N = 45	Arch-first N = 19	Proximal-first N = 26	*P* value
Cardiopulmonary bypass, min	204 [172, 239]	230 [207, 290]	177.5 [157, 215]	.002
Lower-body circulatory arrest time, min	37 [27, 80]	87 [59, 134]	28 [24, 33.3]	<.001
Lowest bladder temperature, °C	23.0 [20.0, 25.0]	19.7 [18, 22.0]	24.9 [24.0, 25.0]	<.001
Myocardial ischemic time, min	106 [84, 146]	124 [113, 166]	91 [81.3, 116.5]	.001
Selective ACP time, min	55 [49, 72]	74 [56,114]	52 [47, 52]	.001
Bentall operation	9 (20.0%)	5 (26.3%)	4 (15.4%)	.597
Coronary artery bypass grafting	1 (2.3%)	1 (5.3%)	0	.906
Mitral or tricuspid valve procedure	2 (4.4%)	1 (5.3%)	1 (3.8%)	1.00
pRBC use	20 (44.4%)	12 (63.2%)	8 (30.8%)	.031
pRBC, units	0 (0, 3)	2 (0, 4)	0 (0, 2)	.048
Platelets, units	3 (2, 4)	4 (3, 5)	2 (2, 3)	.002
Fresh-frozen plasma, units	0 (0, 2)	0 (0, 2)	0 (0, 2)	.709
Cryoprecipitates, units	2 (0, 4)	2 (2, 4)	1 (0, 2.75)	.024

Values are expressed in n (%) or median (first; third quantile). *ACP*, Antegrade cerebral perfusion; *pRBC*, packed red blood cell.

standard approach as a lifesaving procedure in the setting of ATAD, which provides excellent survival.[16-20] On the other hand, a subset of patients may develop positive remodeling of the downstream aorta,[1,17-19] where the debate is ongoing as to which patients might benefit from extensive arch repair with or without endovascular repair and if the benefits outweigh risks in this acute setting.[3,4] In this regard, possible indications of extensive ATAD repair are as follows: complex tear in the aortic arch or descending thoracic aorta, complex dissection in neck vessels, arch aneurysm, cerebral malperfusion, or an expected residual compression of the true lumen in a distal aorta with potential requirement of distal intervention later on.[1,11,18] Although aortic reoperation after limited ATAD repair is safely performed in experienced centers,[18] it would be better to reduce the rate of distal reintervention (eg, open thoracoabdominal repair) by performing Zone 2 arch repair and subsequent endovascular repair to complete the distal repair.[11]

We previously reported the safety of the arch-first technique in elective, complex arch repair including redo cases.[14] However, the potential drawback of this approach, especially in the setting of ATAD, would be long lower-body ischemic time and deep hypothermia, which results in longer cardiopulmonary bypass time and can be associated with coagulopathy and end-organ dysfunction in critically ill patients.[15] Our present data showed that proximal-first Zone 2 arch repair significantly shortened the lower-body ischemic time and myocardial ischemic time by early perfusion of the lower body and heart where cardiopulmonary bypass time was approximately 50 minutes shorter in the proximal-first technique. By the time of completion of left CCA and IA anastomosis, the rewarming process is usually completed. In the early outcomes, several potential benefits were observed, such as less blood product use or lower mortality and morbidity rate. We introduced this technique for several reasons: The sequence is the same as our hemiarch repair where we

TABLE 3. Hospital outcomes

Outcome	All N = 45	Arch-first N = 19	Proximal-first N = 26	*P* value
Operative mortality	4 (8.9%)	2 (10.5%)	2 (7.7%)	1.00
Operative mortality + major morbidity	14 (31.1%)	11 (57.9%)	3 (11.5%)	.001
Permanent stroke	7 (15.6%)	5 (26.3%)	2 (7.7%)	.198
Reexploration for bleeding	3 (6.7%)	3 (15.8%)	0	.136
Tracheostomy	9 (20.0%)	7 (36.8%)	2 (7.7%)	.042
Renal failure	5 (11.1%)	4 (21.1%)	1 (3.8%)	.182
Deep sternal wound infection	0	0	0	1.00
Spinal cord ischemia	1 (2.3%)	1 (5.3%)	0	.906
Leg ischemia	4 (8.9%)	2 (10.5%)	2 (7.7%)	1.00

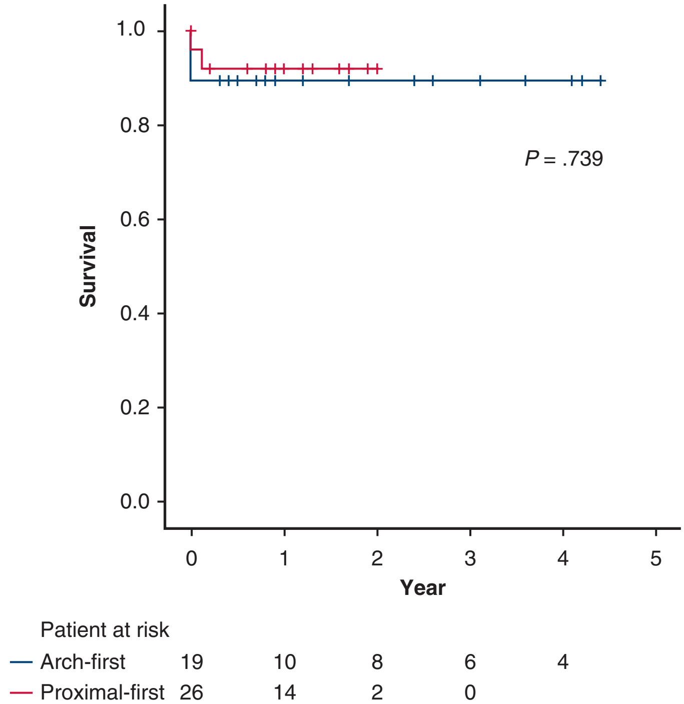

FIGURE 4. Kaplan–Meier survival curve.

consider proximal repair is crucial in ATAD surgery. Second, our technique does not require additional cannulation to neck vessels for selective ACP, which simplifies the procedure. Finally, when the Bentall operation is performed, there is no need for the arch-graft to Bentall graft anastomosis (single-piece of Bentall graft and bifurcated graft).[11] Sharma and colleagues[21] reported a "branch-first" technique, in which there are no periods of cerebral circulatory arrest or deep hypothermia. Although continuous brain perfusion using moderate hypothermia seems favorable,[7,8] we have not used this technique due to a concern of clamping the neck vessels during beating status and retrograde flow to the brain via the femoral artery without any right-sided brain perfusion during IA anastomosis. Similar outcomes could have been observed by using the distal first technique as other studies reported favorable outcomes in Zone 2 or total arch repair.[2,8-11] This includes direct cannulation of the supra-aortic vessels for selective ACP and restoration of the lower body and rewarming after distal anastomosis using a side-arm of the arch/ascending graft or separate cannulation using the femoral artery or left axillary artery.[8,9,12,22]

When using warmer temperature during distal aortic anastomosis as opposed to deep hypothermia, spinal cord ischemia is an important issue even in ATAD.[2,4] This devastating complication is not negligible after total arch repair with frozen or classic ET procedures with an incidence of 2.6% for ATAD.[4] In the proximal-first technique, the risk of spinal cord ischemia would be minimal because there is no need for ET with the lower-body circulatory arrest time of 28 minutes at 25 °C to 26 °C, which corresponds to true unilateral ACP time. This is in the safe limit of unilateral ACP under moderate or deep hypothermia (<50 minutes) described in the study by Angleitner and colleagues.[23] The overall stroke rate (15.6%) in this study was higher than in our previous series of all ATAD repairs (4.6%-8.4% including submitting data),[16,24] which is likely due to a high prevalence of neck vessels dissection and cerebral malperfusion in patients who underwent Zone 2 arch repair.[10-12] Another interesting result is that arch or ascending arch tear was higher in the arch-first group. This result suggests that we might have a lower threshold to perform proximal-first Zone 2 arch repair with growing experience. A decision for the cannulation site must be made before performing the proximal-first technique. As we previously reported, the RAX can be safely cannulated in patients with IA dissection, where our most recent experiences showed that the RAX is usable in approximately 95% of patients with ATAD.[16] An alternative approach if the RAX or IA is not available would be to perform the proximal-first Zone 2 arch repair using the left CCA cannulation or the other cannulation site using selective ACP from the orifice of the neck vessels.[8-13]

With regard to a proximal reoperation after Zone 2 arch repair, 2 patients successfully underwent the Bentall

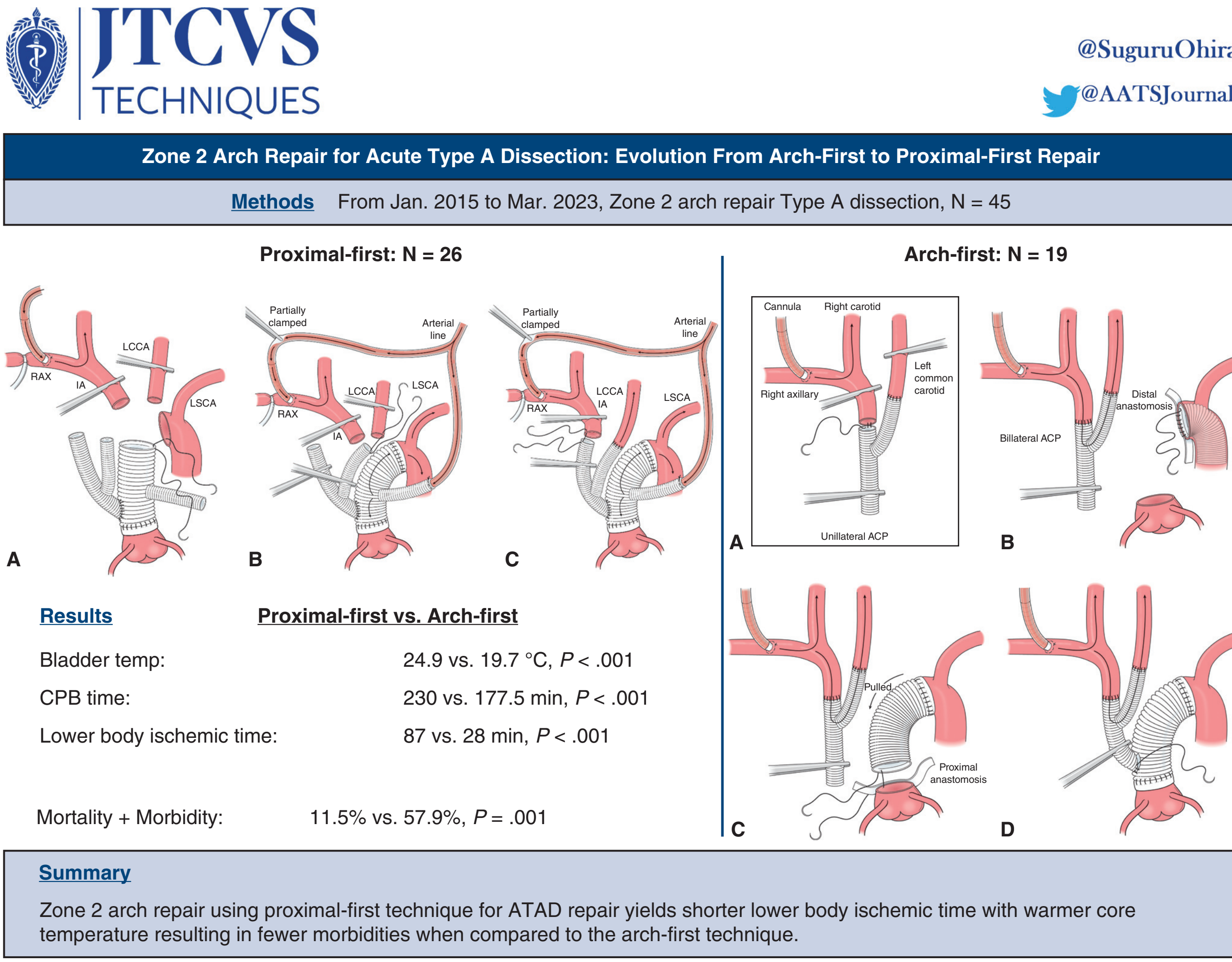

FIGURE 5. Proximal first-arch repair technique provides shorter lower body circulatory arrest time and cardiopulmonary bypass time with favorable early outcome. *LCCA*, Left common carotid artery; *RAX*, right axillary artery; *IA*, innominate artery; *SCA*, subclavian artery; *ACP*, antegrade cerebral perfusion; *ATAD*, acute type A aortic dissection.

procedure. In this setting, some patients require clamping of the ascending graft and bifurcated graft because proximal anastomosis of the bifurcated graft is located just above the sinotubular junction. Bilateral axillary cannulation is an effective option (Figure E2),[24] and left CCA to left subclavian bypass is also useful. Alternatively, Di Eusanio and colleagues[25] reported that a separate graft can be anastomosed to an 8-mm limb of a bifurcated graft after reentry to the sternum, which provides bilateral brain perfusion. We do not recannulate the old ascending graft in a redo scenario because of a concern of embolism.[18] For distal intervention, one of the potentials of Zone 2 arch repair would be an endovascular option that includes preemptive TEVAR to complete the total arch repair as described before.[10,12]

Study Limitations

We noted several limitations of this study. The main limitation of this single-center study is the small number of patients with a short follow-up period. The better outcomes with the proximal-first technique could have been due to the cumulative surgical experience because we switched to the surgical strategy of Zone 2 arch repair only in January 2021. One could argue that the rewarming process could be initiated after distal aortic anastomosis via the ascending ET graft or other cannulation site such as the femoral artery or left axillary artery.

CONCLUSIONS

Zone 2 arch repair using the proximal-first technique for ATAD repair yields a shorter lower-body ischemic time with warmer core temperature, resulting in shorter cardiopulmonary bypass time, less blood product use, and better operative mortality and morbidity outcomes when compared with the arch-first technique (Figure 5). If necessary, both proximal and distal interventions can be performed safely.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: aortic dissection, arch, Zone 2 arch, aorta/aortic, aortic arch, aortic operation

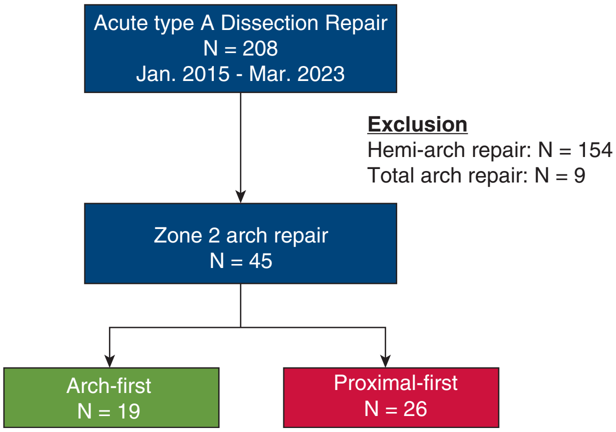

FIGURE E1. Flow chart of the study population.

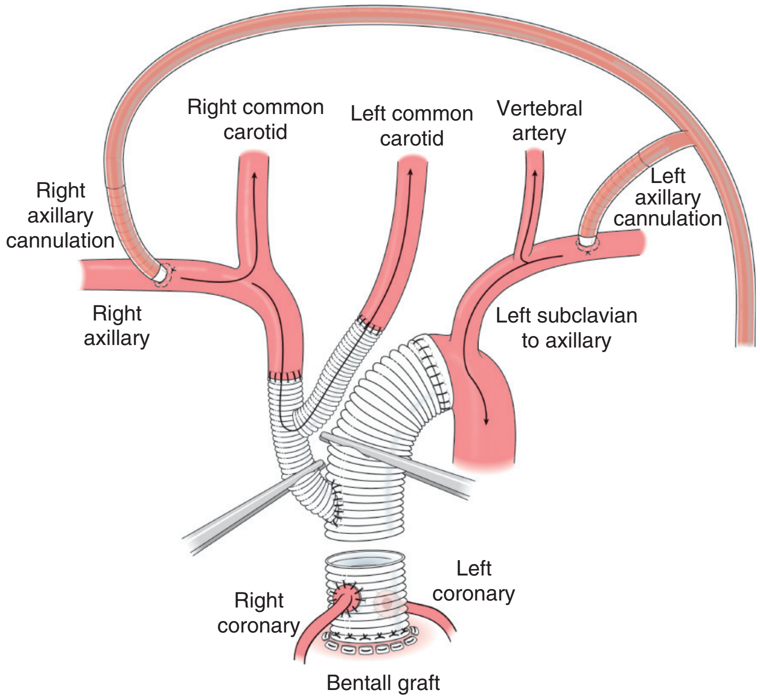

FIGURE E2. Proximal reoperation after Zone 2 arch repair. Bilateral axillary cannulation was used during the Bentall operation while the ascending graft and bifurcated graft were separately clamped.

TABLE E1. Distal intervention after Zone 2 arch repair

	Indication	Procedure	Interval from Zone 2 repair	Outcome
Arch-first technique				
66 y, female	Aneurysm of aortic arch and descending aorta	1. Reoperative total arch repair + ET	15 mo	
		2. Repair of descending aorta, left thoracotomy	18 mo	Alive
65 y, male	Enlarged false lumen	TEVAR (PETTICOAT) + left SCA-CCA bypass	2 mo	Alive
Proximal-first technique				
59 y, male	Enlarged false lumen	TEVAR (PETTICOAT) + left SCA-CCA bypass	3 mo	Alive
27 y, female	Aneurysm of descending aorta	Repair of descending aorta, left thoracotomy	8 mo	Alive
28 y, male	Enlarged false lumen	TEVAR (1-branch + PETTICOAT)	2 mo	Alive

ET, Elephant trunk; *TEVAR*, thoracic endovascular repair; *PETTICOAT*, Provisional Extension to Induce Complete Attachment; *SCA*, subclavian artery; *CCA*, common carotid artery.