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ORIGINAL RESEARCH

The Guidance of Head-Neck-Aorta CT Angiography in Acute Type A Aortic Dissection Patients

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ABSTRACT

BACKGROUND The benefit of preoperative craniocervical artery imaging has not been elucidated for decision-making during the surgical repair of acute type A aortic dissection (ATAAD).

OBJECTIVES The purpose of this study was to explore the clinical implication of a preoperative extended head-neck-aorta computed tomography angiography (CTA) among ATAAD patients.

METHODS ATAAD patients undergoing surgical repair were retrospectively enrolled. Preoperatively, 215 patients underwent aortic CTA (conventional group) and 220 underwent extended CTA (extended group). In the extended group, the surgical team was informed of assessment of craniocervical arteries before the operation. The primary endpoint was postoperative transient neurological deficit and permanent neurological deficit. A 1:1 propensity score matching analysis was performed to account for baseline differences between groups, resulting in 154 pairs.

RESULTS In the extended group, 135 patients were free of preoperative neurological symptoms, but 35 (25.9%) presented with severely stenosed or occluded common carotid artery. Common carotid artery reconstruction and cannulation combined with femoral artery cannulation (24.1% vs 5.1%; $P < 0.001$) and bilateral antegrade selective cerebral perfusion during hypothermic circulatory arrest (56.4% vs 19.1%; $P < 0.001$) were more adopted in the extended group. In the matched cohort, the extended CTA was significantly associated with fewer postoperative permanent neurological deficit (adjusted OR: 0.186; 95% CI: 0.059-0.587; $P = 0.004$) after adjustment with logistic regression.

CONCLUSIONS The extended head-neck-aorta CTA protocol provided additional anatomical clarity preoperatively for modified surgical strategies and may subsequently improved the neurological outcomes of ATAAD. (JACC Asia. 2025;5:679-688) © 2025 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

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The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

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ABBREVIATIONS AND ACRONYMS

ATAAD = acute type A aortic dissection

bi-ASCP = bilateral antegrade selective cerebral perfusion

CCA = common carotid artery

CoW = circle of Willis

CTA = computed tomography angiography

NIRS = near-infrared spectroscopy

NS = neurological symptom(s)

PND = permanent neurological deficit

TND = transient neurological deficit

u-ASCP = unilateral antegrade selective cerebral perfusion

Acute type A aortic dissection (ATAAD) involving the common carotid artery (CCA) is associated with cerebral malperfusion and increased risk of stroke.[1-3] ATAAD patients with CCA involvement experience postoperative neurological deficits and worse long-term prognoses even without preoperative neurological symptoms (NS).[4] Although improved surgical techniques have effectively reduced the postoperative mortality of ATAAD in the past decade,[5,6] the prognosis remains suboptimal for those with preoperative cerebral malperfusion. For ATAAD patients with CCA involvement, expert consensus recommends early perfusion to restore the blood supply of the branches and direct reconstruction of the involved CCA.[7] Despite a few specific brain salvage strategies proposed,[8,9] consensus is lacking with regard to the management strategy for ATAAD with CCA involvement.

Aortic computed tomography angiography (CTA) is the preferred method for evaluating ATAAD patients[10,11] and has become crucial in patient selection, surgical planning, and prediction of potential complications, such as postoperative neurological deficits. Notably, direct imaging evidence on craniocervical vessels in ATAAD patients is rare in the existing literature. Surgery is typically performed immediately after ATAAD diagnosis, and surgeons are accustomed to intraoperative monitoring or exploration of the craniocervical vessel status. Previous studies have demonstrated that internal carotid artery involvement may be a surrogate marker for dismal neurological outcomes,[12] and anatomical variation of the circle of Willis (CoW) may affect intraoperative cerebral perfusion.[13,14] However, the limited scan range of conventional aortic CTA restricts the important craniocervical arteries from objective evaluation before surgery. In light of this limitation, a previous study has confirmed the feasibility of the 1-stop combined CTA of the aorta and craniocervical arteries; specifically, the extended CTA protocol would provide the required diagnostic image quality without delaying timely diagnosis.[15]

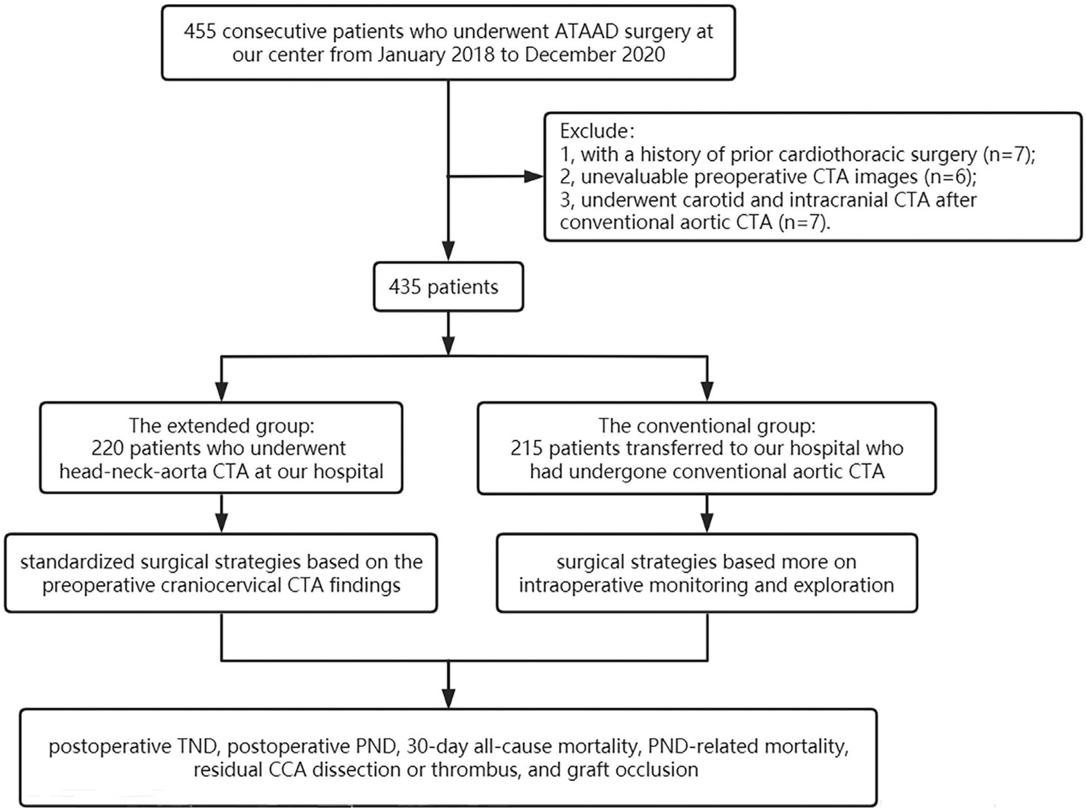
We hypothesize that the extended CTA scan may help surgical strategy decision-making and improve clinical outcomes. Therefore, in our center, patients who were initially screened for suspected ATAAD by echocardiography were scanned with the extended CTA protocol. This study aims to evaluate the surgical implications and prognostic impact of the extended CTA protocol in ATAAD patients by comparing them to transferred patients who have already completed conventional aortic CTA.

METHODS

STUDY POPULATION. This retrospective study included patients enrolled in the Sino-RAD registry from January 2018 to December 2020 at our center. Ethics approval (KY20151104-1) was obtained from the local Institutional Review Board (ethics committee of Xijing hospital), and all patients provided written informed consent. A total of 455 consecutive patients who underwent ATAAD surgery at our center were reviewed. ATAAD was defined as a dissection involving the ascending aorta (proximal to the brachiocephalic artery) presenting within 14 days of symptom onset regardless of the location of primary entry.[7] All patients underwent preoperative CTA examinations at our hospital or 2 designated transferring hospitals. Patients with a history of prior cardiothoracic surgery (n = 7), those with unevaluable preoperative CTA images (n = 6), and those who underwent carotid and intracranial CTA after conventional aortic CTA (n = 7) were excluded. Finally, 435 ATAAD patients were included for further analysis (Figure 1).

Patients were divided into 2 groups depending on the preoperative CTA scanning range. The extended group comprised 220 patients who underwent head-neck-aorta CTA at our hospital, whereas the conventional group comprised 215 patients transferred to our hospital who had undergone conventional aortic CTA in the designated hospitals. Despite our hypothesis on the benefit of the extended CTA, an additional craniocervical CTA scan at our center was not justified for the transferred patients considering the emergency risks. Data on patient demographics, medical history, echocardiography results, aortic CTA characteristics, and intraoperative details and postoperative outcomes were recorded. Blinding rules were adhered during data extraction. The researchers extracting the basic characteristics and comorbidities of the study population were not the same individuals who are extracting the postoperative results. They were also blinded to the study design and did not communicate with each other. Specifically, a radiologist (R.X.) extracted patients' demographics, medical history, echocardiography results, and aortic CTA characteristics. The intraoperative details and

FIGURE 1 Study Flowchart



All patients underwent preoperative computed tomography angiography (CTA) examinations at our hospital or 2 designated transferring hospitals. Patients with a history of prior cardiothoracic surgery (n = 7), those with unevaluable preoperative CTA images (n = 6), and those who underwent carotid and intracranial CTA after conventional aortic CTA (n = 7) were excluded. Finally, 435 acute type A aortic dissection (ATAAD) patients were included for further analysis. CCA = common carotid artery; PND = permanent neurological deficit; TND = transient neurological deficit.

postoperative outcomes were recorded by a cardiothoracic surgeon (C.X.). In case of any ambiguity, the senior surgeon (W.D.) adjudicated the final outcome.

CTA IMAGE ACQUISITION. In the extended group, all CTA examinations were performed in high-pitch mode using a second-generation dual-source CT scanner (SOMATOM Definition Flash, Siemens Healthineers). In the conventional group, aortic CTA was performed using various scanners (all with configurations of ≥64-row detectors). The scan parameters and contrast protocol were adopted from a previous study;[16] details are further described in the Supplemental Appendix.

CRANIOCERVICAL ARTERY EVALUATION AND RECOMMENDED SURGICAL STRATEGIES. Two cardiovascular radiologists with 15 years of experience performed the image interpretation in consensus preoperatively. In the extended group, the craniocervical vessel anatomy was structurally reported to describe CCA involvement, location and extent of the dissection, status of the false lumen, phenotypical variants of CoW, and other noteworthy findings (Central Illustration). Detailed CW variation types were described in a previous study.[15] Briefly, hypoplasia of cerebral artery was defined as a diameter <1 mm.[17] Both hypoplasia and absence were considered as hemodynamically significant and

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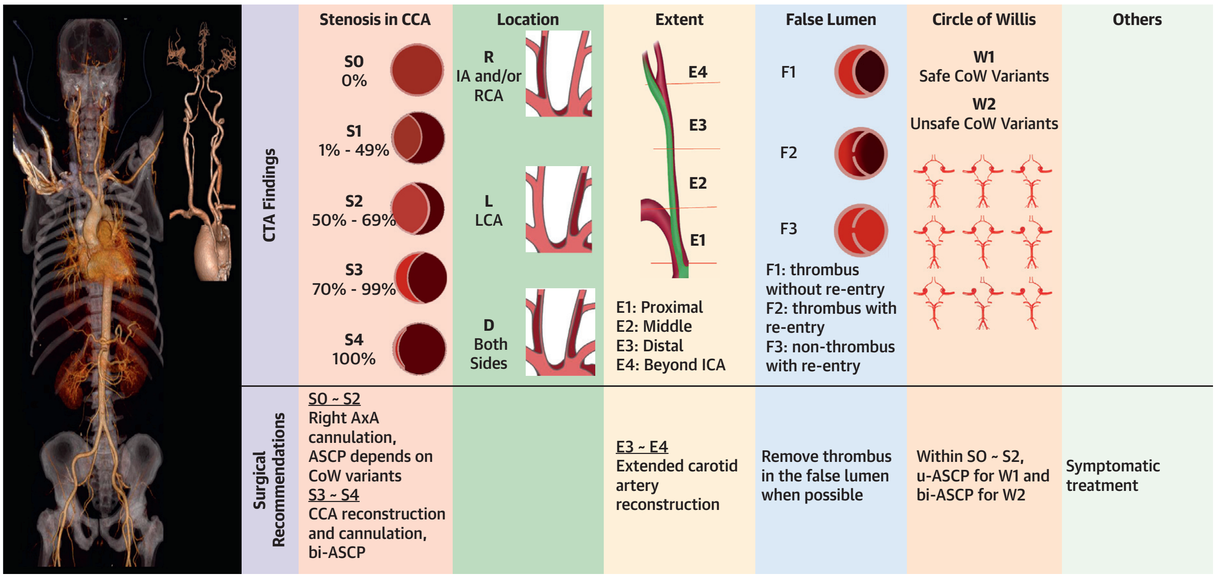
CENTRAL ILLUSTRATION Extended Head-Neck-Aorta Computed Tomography Angiography Protocol With a Structured Report



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In the extended group, the craniocervical vessel anatomy was structurally reported to describe common carotid artery (CCA) involvement, location and extent of the dissection, status of the false lumen, phenotypical variants of circle of Willis (CoW), and other noteworthy findings. AxA = axillary artery; bi-ASCP = bilateral antegrade selective cerebral perfusion; IA = innominate artery; ICA = internal carotid artery; LCA = left common carotid artery; RCA = right common carotid artery; u-ASCP = unilateral antegrade selective cerebral perfusion.

unsafe. In the case of none-to-moderate CCA involvement (S0-S2), right axillary artery (AxA) cannulation for cardiopulmonary bypass was recommended, and the choice of antegrade selective cerebral perfusion (ASCP) during hypothermic circulatory arrest should depend on CoW variants. For instance, unilateral antegrade selective cerebral perfusion (u-ASCP) and bilateral antegrade selective cerebral perfusion (bi-ASCP) should be preferred for safe and unsafe CoW variants, respectively. We followed the method of early direct reperfusion and direct reconstruction described by Gomibuchi et al[9] combined with bi-ASCP for severely involved or occluded CCA (S3-S4) regardless of CoW phenotypes. Furthermore, the reconstruction of carotid arteries should be extended according to the extent of dissection. Surgeons should also consider removing thrombus in the false lumen as much as possible if the clinical conditions allow. Details are shown in Supplemental Figure 1.

SURGICAL PROCEDURE. Our standard operation protocol comprises sternotomy with cardiopulmonary bypass and deep hypothermic circulatory arrest (DHCA) with antegrade cerebral perfusion. A standard cardiopulmonary bypass was established with right AxA, innominate artery, CCA reconstruction and cannulation, or femoral arterial cannulation. The specific strategy was based on conventional aortic CTA and the surgeon's intraoperative evaluation in the conventional group. In the extended group, the arterial cannulation site was decided according to the recommended structured report (Central Illustration) of preoperative craniocervical CTA and intraoperative evaluation. Near-infrared spectroscopy was used in all patients to monitor cerebral oxygenation. For patients who were started on u-ASCP, if the near-infrared spectroscopy value on either side reduced by >20% of the baseline value during the procedure, cerebral perfusion was then switched to bi-ASCP. Antegrade del Nido cold blood cardioplegia was used for myocardial protection. Bladder and nasopharyngeal temperatures were routinely monitored.

INTRAOPERATIVE DETAILS AND POSTOPERATIVE OUTCOMES. A review of procedural notes yielded information on arterial cannulation sites, cerebral perfusion strategies, and operative time. Data on postoperative neurological complications and 30-day all-cause mortality were collected from electronic

TABLE 1 Baseline Patient Characteristics

	Extended (Original, n = 220)	Conventional (Original, n = 215)	*P* Value (Original)	Extended (Matched, n = 154)	Conventional (Matched, n = 154)	*P* Value (Matched)	SMD
Age, y	49.2 ± 9.7	48.5 ± 10.5	0.475	48.3 ± 9.9	48.9 ± 10.1	0.640	-0.055
Male	182 (82.7)	167 (77.7)	0.186	131 (85.1)	131 (85.1)	1.000	0.000
Hypertension	151 (68.6)	158 (73.5)	0.265	110 (71.4)	113 (73.4)	0.702	-0.042
Diabetes	4 (1.8)	6 (2.8)	0.721	3 (1.9)	1 (0.6)	0.623	0.097
Coronary artery disease	11 (5.0)	11 (5.1)	0.956	8 (5.2)	6 (3.9)	0.584	0.060
Prior cerebrovascular accident	18 (8.2)	16 (7.4)	0.774	12 (7.8)	11 (7.1)	0.828	0.024
Tamponade/hypotension/shock	26 (11.8)	26 (12.1)	0.930	8 (5.2)	8 (5.2)	1.000	0.000
Preoperative neurological symptom	85 (38.6)	69 (32.1)	0.154	57 (37.0)	52 (33.8)	0.551	0.067
Interval from symptoms to surgery, h	16.1 ± 8.9	15.6 ± 8.8	0.574	16.2 ± 8.7	15.8 ± 8.8	0.718	0.040
Surgeon			0.543			1.000	
Surgeon 1	104 (47.3)	91 (42.3)		70 (45.5)	70 (45.5)		0.000
Surgeon 2	59 (26.8)	60 (27.9)		43 (27.9)	43 (27.9)		0.000
Surgeon 3	57 (25.9)	64 (29.8)		41 (26.6)	41 (26.6)		0.000
Echocardiography							
Aortic valve insufficiency (moderate or severe)	41 (18.6)	44 (20.5)	0.631	33 (21.4)	28 (18.2)	0.475	0.083
LVEF ≤40%	11 (5.0)	9 (4.2)	0.685	6 (3.9)	7 (4.5)	0.777	-0.030
Aortic CTA characteristics							
Dissection involved the aortic root	156 (70.9)	147 (68.4)	0.565	106 (68.8)	109 (70.8)	0.710	-0.043
Dissection involved the iliac artery	143 (65.0)	133 (61.9)	0.497	100 (64.9)	98 (63.6)	0.812	0.027
Entry tear in the aortic arch	31 (14.1)	37 (17.2)	0.371	26 (16.9)	26 (16.9)	1.000	0.000
Intimal flap plaque	76 (34.5)	66 (30.7)	0.392	50 (32.5)	51 (33.1)	0.903	-0.014
Aberrant right subclavian artery	5 (2.3)	3 (1.4)	0.746	3 (1.9)	3 (1.9)	1.000	0.000
Left VA originate from aortic arch	11 (5.0)	8 (3.7)	0.514	7 (4.5)	8 (5.2)	0.791	-0.030
Common carotid artery dissection	100 (45.5)	99 (46.0)	0.978	71 (46.1)	76 (49.4)	0.568	-0.065

Values are mean ± SD or n (%).
CTA = computed tomography angiography; LVEF = left ventricular ejection fraction; SMD = standardized mean difference; VA = vertebral artery.

medical records. Transient neurological deficit (TND) was defined as postoperative confusion, agitation, delirium, and prolonged obtundation without any new structural abnormality on imaging.[18] Permanent neurological deficit (PND) was defined as the presence of deficits, including stroke or spinal cord ischemia that persisted at discharge.[18]

Carotid-aortic CTA was performed in all postoperative survivors before discharge to evaluate the rates of persistent CCA dissection and graft occlusion. A definite diagnosis of persistent CCA dissection was established only when the intimal flap was visible on at least 2 sections (1 transverse and 1 longitudinal) or there was false lumen thrombosis with a true lumen stenosis of ≥70%.[19] Occlusion of the CCA graft was defined as nonvisualization of the CCA graft vessel on postoperative CTA.

The primary endpoint was the occurrence of postoperative TND and PND. The secondary endpoint was 30-day all-cause mortality. Neurologic examination was performed by cardiac surgeons and neurologists, before and after surgery. All endpoints were adjudicated by cardiac surgeons, neurologists and radiologists altogether.

STATISTICAL ANALYSIS. The normality of data distribution was determined using the single-sample Kolmogorov-Smirnov test. Continuous variables with normal distribution are presented as the mean ± SD, and variables with non-normal distribution are expressed as the median and IQR. Categorical variables are expressed as percentages and were compared using the Fisher exact test or chi-square test according to the size of the data unit. Student's *t*-test was used for normally distributed data, while the Mann-Whitney *U* test was used for non-normally distributed data. A 2-sided *P* value <0.050 was considered statistically significant. Binary outcomes were explored by multivariable logistic regression. All statistical analyses were performed using Statistical Package for the Social Sciences (SPSS Statistics 24, IBM) and R version 4.0.0 (R Foundation for Statistical Computing). Because of the nonrandomized design of the study, propensity score matching (PSM) was used to adjust for baseline confounding variables between the extended and conventional group. The following characteristics were included into the PSM analysis: age, sex, hypertension, diabetes, coronary artery disease, prior cerebrovascular accident,

TABLE 2 Craniocervical CTA Findings in the Combined CTA Group

	All (N = 220)	CCA S0 ~S2 (n = 154)	CCA S3 ~S4 (n = 66)
CCA involvement			
S0: 0%	120 (54.5)	120 (77.9)	/
S1: 1%-49%	10 (4.5)	10 (6.5)	/
S2: 50%-69%	24 (10.9)	24 (15.6)	/
S3: 70%-99%	54 (24.5)	/	54 (81.8)
S4: >99%	12 (5.5)	/	12 (18.2)
Location			
R: IA and/or RCA	48 (21.8)	18 (11.7)	30 (45.5)
L: LCA	17 (7.7)	12 (7.8)	5 (7.6)
D: Both sides	35 (15.9)	4 (2.6)	31 (47.0)
Extent			
E1: Proximal	17 (7.7)	4 (2.6)	13 (19.7)
E2: Middle	26 (11.8)	14 (9.1)	12 (18.2)
E3: Distal	52 (23.6)	15 (9.7)	37 (57.6)
E4: Beyond ICA	5 (2.3)	1 (0.6)	4 (13.6)
False lumen			
F1: Thrombus without re-entry	30 (13.6)	11 (7.1)	19 (28.8)
F2: Thrombus with re-entry	42 (19.1)	4 (2.6)	38 (57.6)
F3: Nonthrombus with re-entry	28 (12.7)	19 (12.3)	9 (13.6)
CoW variant			
W1: Safe	128 (58.2)	94 (61.0)	34 (51.5)
W2: Unsafe	92 (41.8)	60 (40.0)	32 (48.5)
Others			
Aberrant right SA	3 (1.4)	2 (1.3)	1 (1.5)
Left VA abnormally originate from AA	11 (5.0)	9 (5.8)	2 (3.0)
Aneurysm	2 (0.9)	2 (1.3)	0 (0)
Preoperative neurological symptom			
Present	85 (38.6)	54 (35.1)	31 (47.0)
Absent	135 (61.4)	100 (64.9)	35 (53.0)

Values are n (%).

AA = aortic arch; CCA = common carotid artery; CoW = circle of Willis; IA = innominate artery; ICA = internal carotid artery; LCA = left common carotid artery; RCA = right common carotid artery; SA = subclavian artery; VA = vertebral artery.

tamponade/hypotension/shock, preoperative neurological symptom, interval from symptoms to surgery, surgeon, aortic valve insufficiency (moderate or severe), left ventricular ejection fraction ≤40%, dissection involving the aortic root, dissection involving the iliac artery, entry tear in the aortic arch, intimal flap plaque, aberrant right subclavian artery, left vertebral artery originating from aortic arch, and common carotid artery dissection. The 1-to-1 nearest neighbor method with no replacement and a caliper of 0.22 were used for propensity score matching with the R package MatchIt. Balance between the groups was estimated using standardized mean differences (SMDs) and variance ratios, and SMD <0.1 were considered as an acceptable balance between covariates.

RESULTS

PATIENT POPULATION. The baseline characteristics of all patients are presented in Table 1. Although patients in the conventional group were transferred from designated hospitals, the time interval from symptoms to operation (15.6 ± 8.8 hours vs 16.1 ± 8.9 hours; $P = 0.574$) were comparable between the 2 groups. The groups exhibited no significant differences in demographics, medical history, echocardiography results, or aortic CTA characteristics (all $P > 0.050$). The matched cohort consisted of 154 patients each (total n = 308). All absolute values of SMD were <0.10, indicating balance between the cohorts (Table 1, Supplemental Figure 2).

CRANIOCERVICAL CTA FINDINGS. In the extended group, 54.5% (120 of 220) patients had no CCA dissection and 45.5% (100 of 220) had CCA involvement. The location and extent of CCA dissection are presented in Table 2. Thrombus in the false lumen was observed in 72 patients, among which re-entry occurred in 42 patients. Furthermore, 58.2% (128 of 220) patients had safe CoW, whereas the remaining 92 patients had unsafe CoW. Preoperative NS was present in 38.6% (85 of 220) of the studied population, but a significant proportion of patients presented radiographical discrepancies with the symptom-based evaluation. Of the 154 patients with none-to-moderate CCA involvement, 54 (35.1%) exhibited NS; meanwhile, in the 66 patients whose CCA was severely stenosed or completely occluded, preoperative NS was absent in 35 (53.0%) patients. More importantly, these 35 patients would account for 25.9% (35 of 135) of neurologically asymptomatic ATAAD patients and would lead to an underdiagnosis of cerebral malperfusion had the extended CTA protocol not been performed.

RECOMMENDED SURGICAL STRATEGIES AND INTRAOPERATIVE INFORMATION. Intraoperative data are listed in Table 3. In the unmatched cohort, for the arterial cannulation site for cardiopulmonary bypass, the overall difference was statistically significant ($P < 0.001$). Although most patients in both groups underwent right AxA cannulation or combined femoral artery cannulation, its selection was markedly more frequent in the conventional group than in the extended group (201 of 215 [93.5%] vs 162 of 220 [73.6%]; $P < 0.001$). Innominate artery cannulation or combined femoral artery cannulation was adopted to a similar extent in both groups (3 of 215 [1.4%] vs 5 of 220 [2.3%]). CCA reconstruction and cannulation combined with femoral artery cannulation were performed significantly more often in the extended group than in the conventional group (53 of 220 [24.1%] vs 11 of 215 [5.1%]; $P < 0.001$). Furthermore, the choice of antegrade cerebral perfusion during hypothermic circulatory arrest also varied

TABLE 3 Intraoperative Cerebral Protection and Surgical Details

	Extended (Original, n = 220)	Conventional (Original, n = 215)	*P* Value (Original)	Extended (Matched, n = 154)	Conventional (Matched, n = 154)	*P* Value (Matched)
Arterial cannulation site			<0.001			<0.001
Right AxA cannulation or combined FA cannulation	162 (73.6)	201 (93.5)		116 (75.3)	144 (93.5)	
IA cannulation combined FA cannulation	5 (2.3)	3 (1.4)		4 (2.6)	2 (1.3)	
CCA reconstruction and cannulation combined with FA cannulation	53 (24.1)	11 (5.1)		34 (22.1)	8 (5.2)	
Antegrade cerebral perfusion:			<0.001			<0.001
u-ASCP	96 (43.6)	174 (80.9)		73 (47.4)	123 (79.9)	
bi-ASCP	124 (56.4)	41 (19.1)		81 (52.6)	31 (20.1)	
Bentall procedure	92 (41.8)	87 (40.5)	0.774	60 (39.0)	62 (40.3)	0.816
Aortic valve repair	64 (29.1)	61 (28.4)	0.868	46 (29.9)	47 (30.5)	0.901
CABG	29 (13.2)	25 (11.6)	0.623	21 (13.6)	17 (11.0)	0.488
Operative time:						
CPB time, min	217.3 ± 31.6	220.7 ± 41.5	0.362	215.8 ± 28.7	221.5 ± 45.6	0.187
DHCA time, min	30.5 ± 6.8	31.2 ± 5.1	0.176	30.8 ± 7.2	31.4 ± 5.2	0.407
Aortic cross-clamp time, min	101.4 ± 24.6	100.1 ± 20.7	0.535	102.0 ± 19.8	99.9 ± 21.2	0.390

Values are n (%) or mean ± SD.

AxA = axillary artery; bi-ASCP = bilateral antegrade selective cerebral perfusion; CABG = coronary artery bypass grafting; CPB = cardiopulmonary bypass; DHCA = deep hypothermic circulatory arrest; FA = femoral artery; IA = innominate artery; u-ASCP = unilateral antegrade selective cerebral perfusion.

significantly between groups ($P < 0.001$). Bi-ASCP was adopted significantly more often in the extended group than in the conventional group (124 of 220 [56.4%] vs 41 of 215 [19.1%]; $P < 0.001$). These differences were maintained after matching. Before and after matching, no significant variation was observed between the 2 groups in the frequency of adoption of the Bentall procedure, aortic valve repair, and coronary artery bypass grafting and operative time (all $P > 0.050$) (**Table 3**). A representative case is shown in **Figure 2** to illustrate craniocervical vessel findings, corresponding surgical procedures, and clinical and radiologic outcomes.

CLINICAL OUTCOMES. Postoperative TND occurred in 12.4% (54 of 435) of all patients, but the difference between the 2 groups was not significant (19 of 220 [8.6%] vs 35 of 215 [16.3%]; $P = 0.477$). Postoperative PND occurred in 7.6% (33 of 435) of all patients, and it was more prevalent in the conventional group than in the extended group (23 of 215 [10.7%] vs 10 of 220 [4.5%]; $P = 0.027$). The 30-day all-cause mortality rate did not differ significantly between the 2 groups (27 of 220 [12.3%] vs 32 of 215 [14.9%]; $P = 0.361$). Major causes of postoperative death did not differ significantly between the 2 groups ($P > 0.050$) (**Table 4**). In the matched cohort, based on multivariable regression analysis, the extended CTA was significantly associated with fewer postoperative PND (adjusted OR: 0.186; 95% CI: 0.059-0.587; $P = 0.004$) (**Table 4**).

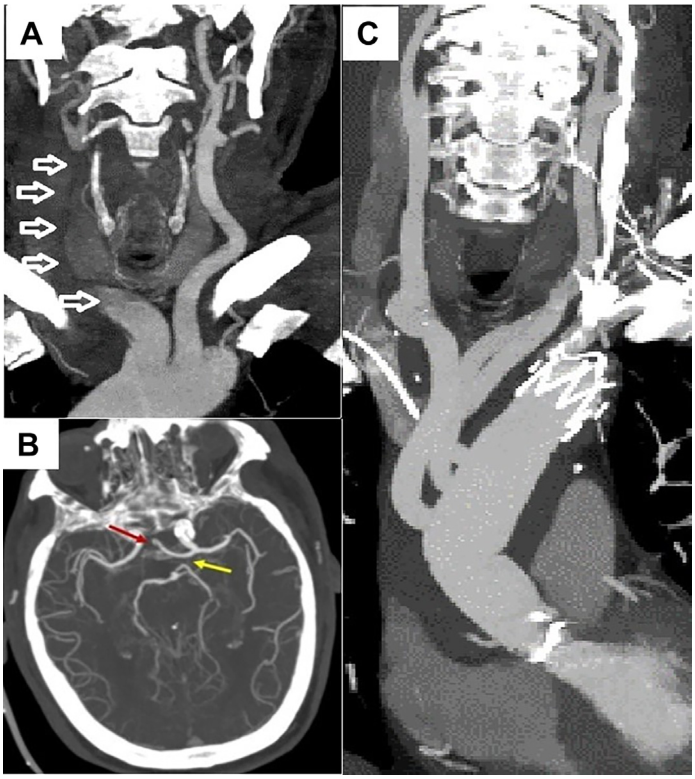
Postoperative carotid-aortic CTA was reviewed before discharge in 429 patients (218 and 211 patients in the extended and conventional groups, respectively). Compared with the conventional group, the incidence rate of persistent CCA dissection in the extended group was significantly lower (15 of 218 [6.9%] vs 31 of 211 [14.7%]; $P = 0.009$). Furthermore, 5 of 211 (2.4%) patients in the conventional group developed graft occlusion, but none in the extended group.

DISCUSSION

This retrospective cohort study proposed an extended head-neck-aorta CTA protocol for the work-up of ATAAD. Among the 220 patients who underwent the extended scan, a mismatch was observed between CCA involvement and preoperative NS, potentially indicating an underdiagnosis of cerebral malperfusion with the current symptom-based evaluation before surgery. Compared with the conventional imaging work-up, the extended CTA provided additional anatomical information on craniocervical arteries and allowed surgeons to optimize surgical strategies comprising the arterial cannulation site, cerebral protection, and extent of reconstruction. Guided by the proposed imaging technique, surgeons could mitigate postoperative neurological complications, neurologically related mortality, and imaging-confirmed persistent CCA dissection.

Cerebral malperfusion is an often-witnessed comorbidity of ATAAD; however, physical examination and symptom-based preoperative evaluation lack diagnostic sensitivity and specificity, potentially leading to an underdiagnosis of the dreadful complication.[20] According to data from the International

FIGURE 2 A Representative Example



A 58-year-old man presented with chest and back pain for 6 hours and was diagnosed with acute type A aortic dissection. Intraoperative cerebral protection strategies included right common carotid artery reconstruction and cannulation combined with femoral artery cannulation and bilateral antegrade selective cerebral perfusion. No postoperative neurological deficiency occurred in this patient. Preoperative extended computed tomography angiography showed (A) dissection involving innominate artery and right common carotid artery with severe stenosis to occlusion of the true lumen (arrows). (B) Intracranial circle of Willis: The horizontal segment of the right anterior cerebral artery (red arrow) and bilateral posterior communicating arteries (yellow arrow) were absent. (C) Two weeks postoperatively, aortic computed tomography angiography showed that the 3 supra-aortic grafts were patent, without stenosis in the true lumen of the right CCA.

Registry of Acute Aortic Dissection (IRAD), Sultan et al.[21] found that 15.1% of ATAAD patients presented with clinical signs and symptoms of cerebral malperfusion. However, several commentaries cited the absence of imaging evidence of cerebral malperfusion as a limitation of IRAD. Additionally, based on a retrospective analysis of 775 ATAAD patients conducted by Fukuhara et al,[12] cerebral malperfusion had an incidence of 10%. Unfortunately, craniocervical vessel imaging was only performed in 45 patients. In this study, preoperative NS was present in 38.6% (85 of 220) and 32.1% (69 of 215) of patients in the extended and conventional groups, respectively. With direct imaging evidence of craniocervical arteries, a discrepancy was observed between CCA involvement and preoperative NS. More than 50% of the 66 ATAAD patients with severely stenosed or occluded CCA were neurologically asymptomatic, and the absence of craniocervical vessel imaging would have underestimated cerebral malperfusion in 25.9% (35 of 135) of neurologically asymptomatic ATAAD patients.

CTA has been recommended as a diagnostic and prognostic imaging modality for ATAAD in the 2022 American Heart Association/American College of Cardiology Guideline for the Diagnosis and Management of Aortic Disease,[22] and the conventional CTA protocol extends from the thoracic inlet to the level of the femoral arteries. Although the conventional scanning range provides a sufficient assessment of most malperfusions, such as cardiac, mesenteric, and limb malperfusion, the lack of craniocervical arteries would prohibit a comprehensive preoperative evaluation of cerebral malperfusion. High-pitch extended CTA covering the entire aorta and the craniocervical arteries can be appealing in emergency settings because it would not incur additional scan time, contrast media, or excessive radiation dose. Additionally, the extended CTA protocol is not limited to dual-source CT scanners, as it may also be accomplished by other scanners with configurations of ≥64-row detectors. The wide availability, high spatial resolution, and fast acquisition speed would collectively enable the proposed method as the preferred preoperative imaging solution to ATAAD over magnetic resonance imaging and echocardiography.

ATAAD with CCA involvement may cause not only preoperative cerebral malperfusion but also exacerbation of malperfusion during cardiopulmonary bypass. Several surgical strategies based on the extent of surgery, antegrade cerebral protection, and arterial cannulation site have been extensively advocated to decrease neurological complications. Inoue et al[4] reported a strategy involving direct reperfusion and direct reconstruction along with thrombectomy in the CCA false lumen. Sultan et al[23] suggested that concomitant carotid artery replacement was a feasible and safe technique. u-ASCP could potentially cause malperfusion in the case of right carotid artery stenosis[24] or incomplete closure of CoW, which is detected in 15% of the population.[25] In contrast, bi-ASCP, with an expected long DHCA duration, is more complex and poses a risk of embolic injury during manipulation of the left CCA. However, bi-ASCP is deemed to be a safer method by most surgeons.[26] Collectively, decision-making on surgery strategies lacks criteria. Surgeons often resort to

TABLE 4 Multivariable Logistic Regression of the Extended CTA for Postoperative Outcomes

	Extended (Original, n = 220)	Conventional (Original, n = 215)	*P* Value (Original)	OR (95% CI) (Original)	Extended (Matched, n = 154)	Conventional (Matched, n = 154)	*P* Value (Matched)	OR (95% CI) (Matched)
Postoperative TND	19 (8.6)	35 (16.3)	0.477	0.747 (0.335-1.667)	15 (9.7)	27 (17.5)	0.909	0.945 (0.361-2.478)
Postoperative PND	10 (4.5)	23 (10.7)	**0.027**	0.345 (0.134-0.888)	6 (3.9)	18 (11.7)	**0.004**	0.186 (0.059-0.587)
30-d all-cause mortality	27 (12.3)	32 (14.9)	0.361	0.755 (0.413-1.380)	17 (11.0)	25 (16.2)	0.112	0.559 (0.273-1.145)
Causes of mortality:								
PND	4 (1.8)	12 (5.6)	0.236	0.433 (0.108-1.729)	3 (1.9)	10 (6.5)	0.143	0.305 (0.062-1.493)
Postoperative cardiac arrest	8 (3.6)	7 (3.3)	0.963	1.025 (0.354-2.973)	5 (3.2)	7 (4.5)	0.591	0.720 (0.218-2.383)
Multiorgan failure	8 (3.6)	9 (4.2)	0.825	0.890 (0.318-2.491)	6 (3.9)	5 (3.2)	0.899	1.088 (0.297-3.985)
Pneumonia	4 (1.8)	2 (0.9)	0.635	1.542 (0.258-9.223)	2 (1.3)	2 (1.3)	0.901	0.876 (0.108-7.087)

Values are n (%). Note: All multivariable regression analyses were adjusted for age, gender, preoperative neurological symptom (NS), interval from symptoms to surgery (h), surgeon, dissection involved the iliac artery, common carotid artery dissection, and the extended group.

TND = transient neurological deficit; PND = permanent neurological deficit.

intraoperative monitoring; various preoperative imaging modalities, such as aortic CTA, plain CT, and echocardiography; or individual preferences. Extended CTA scans of the aorta and craniocervical arteries might enable a standardized surgery strategy based on objective evaluation, thereby addressing perioperative cerebral malperfusion.

Although the modern perioperative mortality of ATAAD repair has decreased to the 10% to 20% range at centers of excellence and evolving surgical strategies have improved the durability of aortic repair,[5,6] the incidence of postoperative stroke has not changed (>10%) in the past 2 decades.[1] In the German Registry for Acute Aortic Dissection type A, the 30-day mortality rate of 2,137 patients after ATAAD surgery was 16.9%.[27] Another study on surgically managed ATAAD patients from the IRAD reported an in-hospital mortality rate of 14.0%.[21] Our findings showed comparable 30-day all-cause mortality (13.6%). Furthermore, the postoperative neurological complications in this study, including TND and PND, were comparable with those reported in previous studies.[28-30] More importantly, rates of TND and PND incidence, postoperative PND-related mortality, and postoperative persistent dissection of CCA were significantly lower in the extended group (where surgeons adopted modified surgical strategies based on the preoperative craniocervical CTA findings) than in the conventional group (where surgeons relied more on intraoperative detection and exploration). CCA reconstruction and cannulation combined with femoral artery cannulation and bi-ASCP were adopted significantly more often in the extended group. Without imaging information on craniocervical arteries before surgery, it is reasonable to assume that the surgeon would be less inclined to extensively reconstruct CCA, remove thrombus in the false lumen extensively, or adopt bi-ASCP to reduce DHCA time. This may partially explain the more residual dissection and thrombus in CCA in the conventional group, thereby causing more postoperative neurological deficits.[1] These results support the implication that additional anatomical information on craniocervical vessels obtained from the extended CTA may be essential in ATAAD surgical decision-making and reduction of neurological complications.

STUDY LIMITATIONS. First, this is a single-center retrospective study. Although all patients underwent surgery at our institution, those in the conventional group were transferred from the designated hospitals, thus leading to inevitable selection bias. Although we have used propensity score modeling to overcome heterogeneity, there may still be unknown heterogeneity contributing to the surgical outcomes between groups. Second, we only evaluated a specific scan protocol from 1 commercial computed tomography scanner. Craniocervical artery imaging can be performed through various imaging modalities, and future efforts can be directed to expand the generalizability of this study. Third, our CTA reporting system relied on common imaging features but did not account for the less frequent conditions, such as left subclavian artery dissection or vascular variants. Finally, long-term follow-up results are lacking; thus, future multicenter prospective studies are warranted to confirm the value of our findings.

CONCLUSIONS

Extended head-neck-aorta CT angiography provided additional preoperative anatomical information on craniocervical arteries. The imaging-guided surgical repair strategy may improve the neurological outcomes of patients with acute type A aortic dissection.

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APPENDIX For an expanded Methods section and supplemental figures, please see the online version of this paper.