0003-4975/$36.00
https://doi.org/10.1016/j.athoracsur.2024.02.026

Aorta: Research

Axillary vs Femoral Arterial Cannulation in Acute Type A Dissection: International Multicenter Data

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ABSTRACT

BACKGROUND Cannulation strategy in acute type A dissection (ATAD) varies widely without known gold standards. This study compared ATAD outcomes of axillary vs femoral artery cannulation in a large cohort from the International Registry of Acute Aortic Dissection (IRAD).

METHODS The study retrospectively reviewed 2145 patients from the IRAD Interventional Cohort (1996-2021) who underwent ATAD repair with axillary or femoral cannulation (axillary group: n = 1106 [52%]; femoral group: n = 1039 [48%]). End points included the following: early mortality; neurologic, respiratory, and renal complications; malperfusion; and tamponade. All outcomes are presented as axillary with respect to femoral.

RESULTS The proportion of patients younger than 70 years in both groups was similar (n = 1577 [74%]), as were bicuspid aortic valve, Marfan syndrome, and previous dissection. Patients with femoral cannulation had slightly more aortic insufficiency (408 [55%] vs 429 [60%]; $P = .058$) and coronary involvement (48 [8%] vs 70 [13%]; $P = .022$]. Patients with axillary cannulation underwent more total aortic arch (156 [15%] vs 106 [11%]; $P = .02$) and valve-sparing root replacements (220 [22%] vs 112 [12%]; $P < .001$). More patients with femoral cannulation underwent commissural resuspension (269 [30.9%] vs 324 [35.3%]; $P = .05$). Valve replacement rates were not different. The mean duration of cardiopulmonary bypass was longer in the femoral group (190 [149-237] minutes vs 196 [159-247] minutes; $P = .037$). In-hospital mortality was similar between the axillary (n = 165 [15%]) and femoral (n = 149 [14%]) groups ($P = .7$). Furthermore, there were no differences in stroke, visceral ischemia, tamponade, respiratory insufficiency, coma, or spinal cord ischemia.

CONCLUSIONS Axillary cannulation is associated with a more stable ATAD presentation, but it is a more extensive intervention compared with femoral cannulation. Both procedures have equivalent early mortality, stroke, tamponade, and malperfusion outcomes after statistical adjustment.

(Ann Thorac Surg 2024;117:1128-35)

Acute type A aortic dissection (ATAD) is a surgical emergency with an operative mortality of up to 20% even in the modern era.[1,2] Strategies for

The Supplemental Material can be viewed in the online version of this article [https://doi.org/10.1016/j.athoracsur.2024.02.026] on http://www.annalsthoracicsurgery.org.

Accepted for publication Feb 13, 2024.

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arterial cannulation and initiation of cardiopulmonary bypass (CPB) vary and include the femoral, axillary, innominate, direct aortic, and carotid arteries. The first 2 strategies are the most common.[3-6] Historically, femoral cannulation has been a preferred strategy because of technical simplicity and rapid initiation of CPB. In the last 2 decades, axillary cannulation has increased significantly in popularity because the axillary artery is often free of dissection and easily facilitates antegrade cerebral perfusion (ACP) for neuroprotection during circulatory arrest.[5]

Single-center ATAD studies suggest that axillary arterial cannulation is safe and may reduce neurologic injury.[7-10] Axillary cannulation simplifies antegrade cerebral protection and is particularly important for extended aortic arch reconstructions. Despite these potential benefits, surveys of cannulation strategy suggest that many surgeons routinely cannulate the femoral artery (30%) and often cite the urgent need to establish CPB in unstable patients or large body mass as impediments to axillary cannulation.[5] Overall, optimal cannulation strategy in ATAD remains unclear.

We sought to compare perioperative death and stroke in axillary vs femoral artery cannulation in a global cohort of patients with ATAD from the International Registry of Acute Aortic Dissection (IRAD).

PATIENTS AND METHODS

Demographic, intraoperative, and perioperative data were collected prospectively and retrospectively from the IRAD database between 1996 and 2021. All patients undergoing surgical repair for ATAD by axillary or femoral arterial cannulation and circulatory arrest were included regardless of surgical repair extent. After exclusion of patients undergoing innominate artery, direct aortic, carotid artery, and multiple artery cannulation strategies during the cooling phase, patients with type B aortic dissection, and patients without available procedural data, 2270 patients remained. The surgical strategy and judgment regarding the extent of repair indicated were chosen in accordance with surgeon or center preference. Primary outcomes were perioperative death and stroke. Secondary outcomes included perioperative neurologic complications, tamponade, renal failure, malperfusion, and respiratory complications. See the Supplemental Methods section for statistical and variable definition details.

RESULTS

PATIENT CHARACTERISTICS. Of the 2270 included patients, 1155 (51%) underwent axillary cannulation, whereas 1115 (49%) had femoral cannulation (Table 1). The proportion of patients undergoing femoral cannulation decreased over time: before 2010, more than 60% of patients underwent femoral cannulation; however, this proportion decreased below 50% from 2011 onward (Figure 1). Among patients who underwent axillary cannulation, male sex was more common (n = 816 [71%] vs n = 739 [66%]; P = .027). Age, hypertension, bicuspid aortic valve, Marfan syndrome, and mixed aortic valve disease were similar between the 2 groups. Average age generally increased moderately over time in both study arms except for a small drop in patient age in the axillary group around 2011 to 2015 (Supplemental Figure). A history of known aortic aneurysm was more common in patients in the axillary group (n = 159 [15%]; n = 119 [12%], respectively; P = .024). In general, patients in the femoral group presented in worse clinical condition compared with their axillary group counterparts. Although malperfusion syndromes overall occurred in 28% of the cohort at presentation with a similar incidence between the groups, renal malperfusion (axillary group: n = 60 [5%]; femoral group: n = 84 [8%]; P = .031) and coma (axillary group: n = 93 [8%]; femoral group: n = 123 [11%]; P = .02) were more common in the femoral group. Additionally, patients in the femoral group more frequently presented with aortic insufficiency, as noted on diagnostic imaging (n = 434 [55%]; n = 480 [61%]; P = .04).

INTRAOPERATIVE DETAILS. Axillary cannulation was associated with slightly shorter CPB duration than femoral cannulation (190 minutes [interquartile range {IQR}, 149-237 minutes]; 196 minutes [IQR, 159-247 minutes], respectively; P = .037) but longer aortic cross-clamp time (35 minutes [IQR, 25-48 minutes]; 33 minutes [IQR, 22-46 minutes], respectively; P = .006), and no clinically significant difference in median length of circulatory arrest. Axillary group patients were also more likely to undergo ACP (including both unilateral and bilateral approaches) 91% of the time (n = 845) compared with retrograde cerebral perfusion in only 9% (n = 87), whereas 48% of femoral group patients underwent retrograde perfusion (n = 331; P < .001). Axillary group patients were also more likely to undergo any cerebral perfusion (axillary group: n = 932 [87%]; femoral group: n = 692 [68%]; P < .001) and less likely to be subject to deep hypothermia in comparison with femoral group patients. Aortic root replacement and arch replacement were performed more frequently in patients with axillary cannulation. Intraoperative details are summarized in Table 1.

PERIOPERATIVE OUTCOMES. Overall, 335 patients died (axillary group: n = 174 [15%]; femoral group: n = 161 [14%]). In-hospital death rates remained stable over time, whereas the postoperative stroke rate increased slightly among both groups (Figure 2). Cannulation

TABLE 1 Baseline and Intraoperative Characteristics of Overall Cohort Compared by Cannulation Strategy

Baseline and Intraoperative Details	Axillary N = 1155	51%	Femoral N = 1115	49%	P Value
Region, continent					<.0001
North America	623	54	795	71	
Europe	401	35	281	25	
Asia	131	11	39	3	
Patient characteristics					
Male	816	71	739	66	.027
Age <70 y	838	73	820	74	.60
Atherosclerosis	164	16	173	17	.55
Diabetes	103	10	92	9	.55
Hypertension	836	76	798	75	.55
Aortic stenosis/insufficiency	118	11	108	11	.62
Aortic insufficiency	434	55	480	61	.04
Bicuspid aortic valve	40	4	39	4	1.00
Marfan syndrome	29	3	29	3	1.00
Previous aortic aneurysm	159	15	119	12	.024
Previous aortic dissection	41	4	43	4	.82
Iatrogenic dissection	17	1	29	3	.07
Previous cardiac surgery	117	11	95	9	.22
Shock presentation	54	5	78	8	.015
Stroke	67	7	61	7	.71
Malperfusion presentation					
Any	273	23	341	31	1.00
Visceral	32	3	33	3	.80
Renal	60	5	84	8	.031
Coronary	145	13	173	16	.75
Limb	205	18	171	15	.10
Coma	93	8	123	11	.02
Neurologic deficit	107	9	120	11	.24
Spinal ischemia	18	2	17	2	1.00
Extent of aortic repair					
Hemiarch repair	684	69	603	74	.01
Arch replacement intervention (any)	305	31	204	25	.01
Partial arch replacement	111	11	82	10	.49
Complete arch replacement	112	11	99	12	.56
Elephant trunk	82	9	23	3	<.0001
Commissural resuspension	275	27	325	31	.07
Valve replacement	327	54	315	49	.07
Mechanical valve replacement	134	22	154	24	.50
Biologic valve replacement	193	32	161	25	.0069
Root replacement intervention (any)	446	41	379	36	.0166
Valve-sparing root replacement	204	19	103	10	<.001
Composite valve graft	233	24	270	26	.26
Cerebral perfusion strategy (any)	932	87	692	68	<.0001
Antegrade cerebral perfusion	845	91	361	52	<.0001
Retrograde cerebral perfusion	87	9	331	48	<.0001
Use of deep hypothermia (<20°)	320	31	459	52	<.0001
Cross-clamp time, min, median and IQR	35	25-48	33	22-46	.0056
Circulatory arrest time, min, median and IQR	34	24-50	33	24-45	.0275
CPB time, min, median and IQR	190	149-237	196	159-247	.0372

Continuous variables are presented as mean and SD, and categorical variables as proportion and percentage unless otherwise specified. CPB, cardiopulmonary bypass; IQR, interquartile range (quartile 1 to quartile 3).

strategy was not associated with significant differences in any perioperative outcome, including mortality, stroke, tamponade, malperfusion, or respiratory complications. Perioperative outcomes for the overall cohort are presented in Table 2.

MULTIVARIABLE REGRESSION. Cannulation strategy did not significantly predict either of the 2 primary outcomes in the overall unmatched group (Table 3, Figure 3) and after propensity score adjustment (Supplemental Table).

Independent predictors of perioperative mortality included age greater than 70 years (odds ratio [OR], 1.04; 95% CI, 1.03-1.06; $P < .001$), year of operation (era 2014-2016 vs 1996-2007: OR, 0.41; 95% CI, 0.20-0.84; $P = .015$), preoperative shock (OR, 2.03; 95% CI, 1.07-3.84; $P = .029$), coronary malperfusion (OR, 1.74; 95% CI, 1.12-2.71; $P = .014$), limb ischemia (OR, 2.65; 95% CI, 1.65-4.27; $P < .0001$), cerebral perfusion strategy (antegrade vs retrograde: OR, 1.96; 95% CI, 1.08-3.58 $P = .028$; no perfusion vs retrograde perfusion: OR, 3.21; 95% CI, 1.55-6.62; $P = .002$), and CPB time (OR associated with 10-minute increase in CPB time, 1.11; 95% CI, 1.08-1.14; $P < .0001$).

Regarding perioperative stroke, independent predictors included presentation with stroke (OR, 4.40; 95% CI, 1.16-16.67; $P = .029$) and any aortic arch replacement intervention (OR, 1.93; 95% CI, 1.04-3.58; $P = .038$).

COMMENT

ATAD repair techniques have evolved notably: increased axillary cannulation, more aggressive extended arch reconstruction, and increased stent grafting of the proximal descending aorta.[1,3,5,6,11] Axillary cannulation has recently gained traction in North America and Europe; ATAD surgical guidelines now stipulate class IIa recommendations for axillary cannulation and class IIb for femoral cannulation.[12] In our series, one-half of patients with ATAD underwent axillary cannulation; however, the proportion tended to favor axillary cannulation over time. We observed a 15% risk of death and an 11% risk of stroke in the overall cohort, in line with ATAD outcomes of contemporary multicenter studies.[3,5,13]

Randomized data comparing cannulation strategies in ATAD are lacking. Retrospective series and meta-analyses suggest reduced mortality and stroke risk with axillary cannulation.[3-6,11] Establishing antegrade flow is purported to reduce neurologic events by avoiding the “sandblasting” effect and exposure to embolic debris in the brain potentially caused by retrograde, femoral flow. Axillary cannulation also facilitates cerebral perfusion, which is particularly important for extended arch reconstructions. A higher proportion of patients who had axillary cannulation received any cerebral protection, thereby confounding the effect of cannulation strategy on the incidence of stroke or neurologic injury. In our study, we found no difference in any outcome of interest on the basis of cannulation strategy even after propensity score adjustment and multivariable regression accounting for baseline and intraoperative differences and clustering by surgical center.

We speculate that aortic-specializing cardiac surgeons may perform fewer femoral cannulations, and thus patients with axillary cannulation may also be more likely to undergo aggressive aortic root and arch interventions because of the inherent experience of surgeons with these techniques in the elective context. This may explain the apparent discordance between the higher rates of aortic insufficiency in the femoral group with the lower rate of root and valve interventions. Additionally, despite matching, stroke risks associated with complex aortic arch operations more commonly performed on patients with axillary cannulation may have offset the increased risk of stroke among patients with femoral cannulation. This potentially explains similarities in perioperative outcome between the 2 groups in this study. Ultimately, given that this is a retrospective study from a database, additional study would be required to determine the relationship between practice patterns or preferences with patient outcomes. Although anecdotally femoral cannulation is considered to be best suited for hemodynamic instability as a result of time efficiency, some high-volume aortic surgeons perform axillary cannulation almost universally even on “unstable” patients. Furthermore, femoral cannulation may be challenging in patients with a large body habitus, femoral artery dissection, or severe atherosclerotic plaque.

We observed a counterintuitive discrepancy in complexity of operation (greater in the axillary cannulation group) and mean CPB duration (greater in the femoral cannulation group). We speculate that this finding may reflect increased efficiency of aortic surgeons in the axillary group and/or more time required weaning and performing hemostasis on patients in the femoral group who presented initially in more critical condition. An increased prevalence of more complex repairs, such as valve-sparing operations in the context of ATAD, within IRAD data has been previously reported.[14] Axillary group patients in this study underwent extensive repairs without substantially increased CPB and cross-clamp durations (only 6 minutes more in the femoral group and 2 minutes more in the axillary group). Decreased cooling time in axillary cannulated patients may have kept CPB duration relatively low because these patients were also less likely to undergo deep hypothermia. Aortic arch interventions, which were associated with doubled perioperative stroke risk, occurred more in axillary group patients. Conversely, aortic root intervention was not associated with any difference in risk of death or stroke.

We observed a 4-fold risk of postoperative stroke in patients with presenting with strokes. Although other multicenter ATAD studies of stroke have not reported this association,[3] it nevertheless warrants caution. Stroke rate increased over time among both the

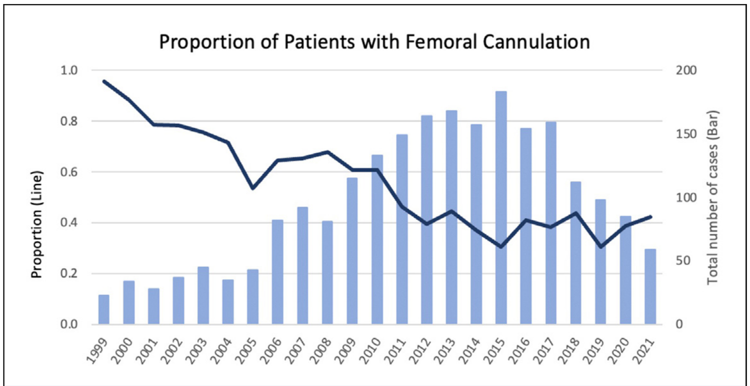

FIGURE 1 Proportion of type A dissection cases with femoral cannulation strategy over time.

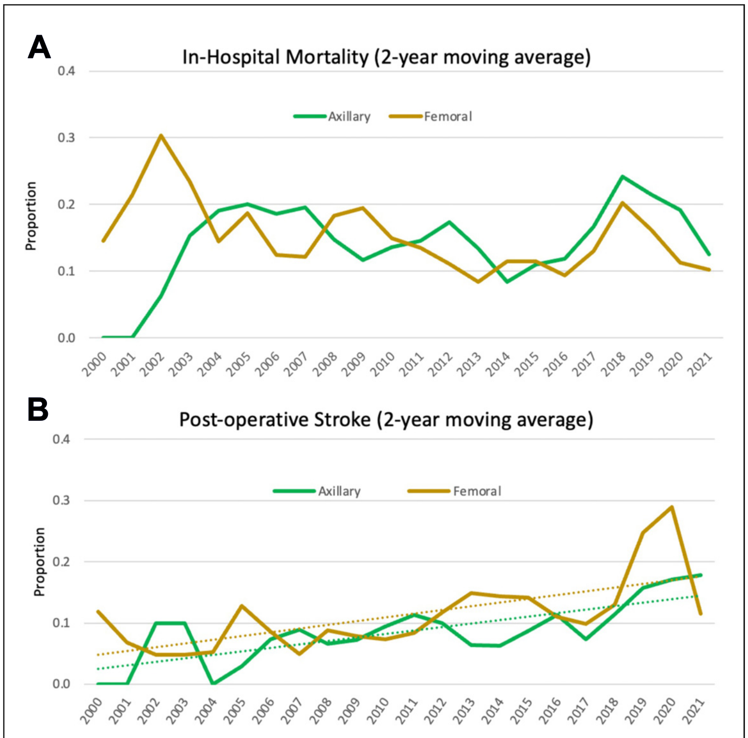

FIGURE 2 The 2-year moving average of (A) in-hospital death and (B) stroke.

TABLE 2 Perioperative Outcomes of Overall Cohort Compared by Cannulation Strategy

	Axillary		Femoral		
Perioperative Outcomes	N = 1155	51%	N = 1115	49%	*P* Value
Mortality	174	15	161	14	.72
Stroke	96	10	107	11	.37
Postoperative transient neurologic deficit	46	4.9	50	5.6	.53
Coma	31	3	35	4	.62
Spinal cord injury	17	2	20	2	.62
Mesenteric ischemia	37	4	24	2	.15
Acute renal failure	223	22	242	24	.17
Cardiac tamponade	78	8	77	8	1
Limb ischemia	56	6	39	4	.11
Respiratory insufficiency	219	28	156	27	.81
Length of hospital stay, d, median and IQR	11	7-19	12	8-19	.65

Values are n, %, or median and IQR. IQR, interquartile range (quartile 1 to quartile 3).

axillary and femoral cannulation groups, possibly a result of a greater propensity to perform technically complex repairs, a reduced threshold to operate on individuals presenting in critical condition,[15] and variable thresholds to perform neurologic imaging. The last factor remains a clinical problem: despite clinical diagnostic stroke rates of 4% to 7%, 70% of patients undergoing elective aortic surgery have magnetic resonance imaging lesions with up to 34% to 38% considered extensive or severe.[16,17] Previous studies investigating cannulation strategies in ATAD are limited by a single-center design,[7-10] thus raising questions about generalizability. Furthermore, some excluded patients with limited arch interventions.[10] Further study is required to clarify whether increases in stroke over time among IRAD patients are attributable to patient-related or technical reasons.

We affirm that cerebral protection significantly affects in-hospital death in ATAD[18]; lack of cerebral protection incurred a >3-fold risk of death in this study. We observed a counterintuitive survival benefit among patients undergoing retrograde vs antegrade cerebral protection. Despite the greater physiologic and metabolic support provided by ACP, the literature has not clearly shown a significant benefit of antegrade vs retrograde protection. A meta-analysis of ∼20,000 patients found similar rates of perioperative mortality and stroke in aortic surgical patients with antegrade vs retrograde perfusion,[19] and similar findings have been reported in studies of patients with ATAD only.[20] Nonetheless, differential cerebral perfusion strategies, often with more ACP use among patients with axillary cannulation, may confound perioperative stroke risks by cannulation strategy. Additionally, granular outcomes such as subclinical stroke and long-term neurocognitive function have yet to be assessed in detail after use of different strategies of cerebral protection.

Overall, femoral vs axillary perioperative safety in the context of ATAD repair seems similar. Nevertheless, we cannot exclude differences in cognitive function between the groups because baseline and follow-up neuropsychological tests were not performed, nor did all patients have brain imaging postoperatively. Although axillary cannulation facilitates cerebral perfusion, 13% of these patients in the axillary group had no cerebral perfusion in our study. It is conceivable that axillary cannulation and the continuation of nutritive blood flow to the brain during circulatory arrest are associated with improved cognitive function, but this remains to be proven. Choice of cannulation strategy must account for individual clinical and anatomic factors. In general, axillary cannulation has advantages over femoral, particularly in the context of extended arch operations. Nevertheless, given equivalent perioperative outcomes, femoral approaches seem appropriate when rapid initiation of CPB is warranted or if anatomic factors impede axillary access. Other cannulation techniques increasing in popularity include innominate artery and direct aortic cannulation under imaging guidance; however, further study regarding outcomes of these techniques is required.[4,21]

TABLE 3 Multivariable Regression for Mortality and Stroke[a]

Variable	OR (Mortality)	95% CI	*P* Value	OR (Stroke)	95%CI	*P* Value
Axillary vs femoral	1.23	0.82-1.85	.33	1.03	0.60-1.78	.92
Male	0.78	0.53-1.14	.20	1.03	0.61-1.74	.91
Age	1.04	1.03-1.06	<.0001	1.00	0.98-1.02	.75
Era[b]						
2 vs 1	1.03	0.54-1.96	.93	0.76	0.25-2.31	.63
3 vs 1	0.76	0.42-1.40	.38	1.35	0.53-3.45	.53
4 vs 1	0.41	0.20-0.84	.015	1.15	0.43-3.05	.78
5 vs 1	0.94	0.53-1.66	.84	1.89	0.76-4.66	.17
Hypertension	0.98	0.63-1.52	.93	0.91	0.53-1.56	.74
Stroke history	1.86	0.68-5.08	.22	4.40	1.16-16.67	.029
Marfan	0.61	0.14-2.66	.51	1.37	0.39-4.76	.62
Bicuspid aortic valve	0.53	0.15-1.81	.31	0.97	0.30-3.08	.95
Shock	2.03	1.07-3.84	.029	0.78	0.27-2.26	.65
Malperfusion						
Neurologic	0.57	0.23-1.43	.23	1.49	0.47-4.70	.50
Coronary	1.74	1.12-2.71	.014	0.74	0.37-1.48	.39
Visceral	2.02	0.82-4.97	.12	1.10	0.23-5.35	.90
Limb	2.65	1.65-4.27	<.0001	1.15	0.60-2.21	.67
Any arch intervention	0.92	0.61-1.38	.68	1.93	1.04-3.58	.038
Any root intervention	1.13	0.77-1.66	.52	1.16	0.70-1.91	.56
Cerebral perfusion						
Ante vs retrograde	1.96	1.08-3.58	.028	0.83	0.41-1.65	.59
None vs retrograde	3.21	1.55-6.62	.002	1.27	0.52-3.12	.60
Total bypass time	1.01	1.01-1.01	<.0001	1.00	1.00-1.01	.20

[a]Multivariable generalized linear model with random intercept for death and stroke; [b]Eras 1 to 5 are defined as follows: 1996-2007, 2008-2010, 2011-2013, 2014-2016, and 2017-2021. OR, odds ratio.

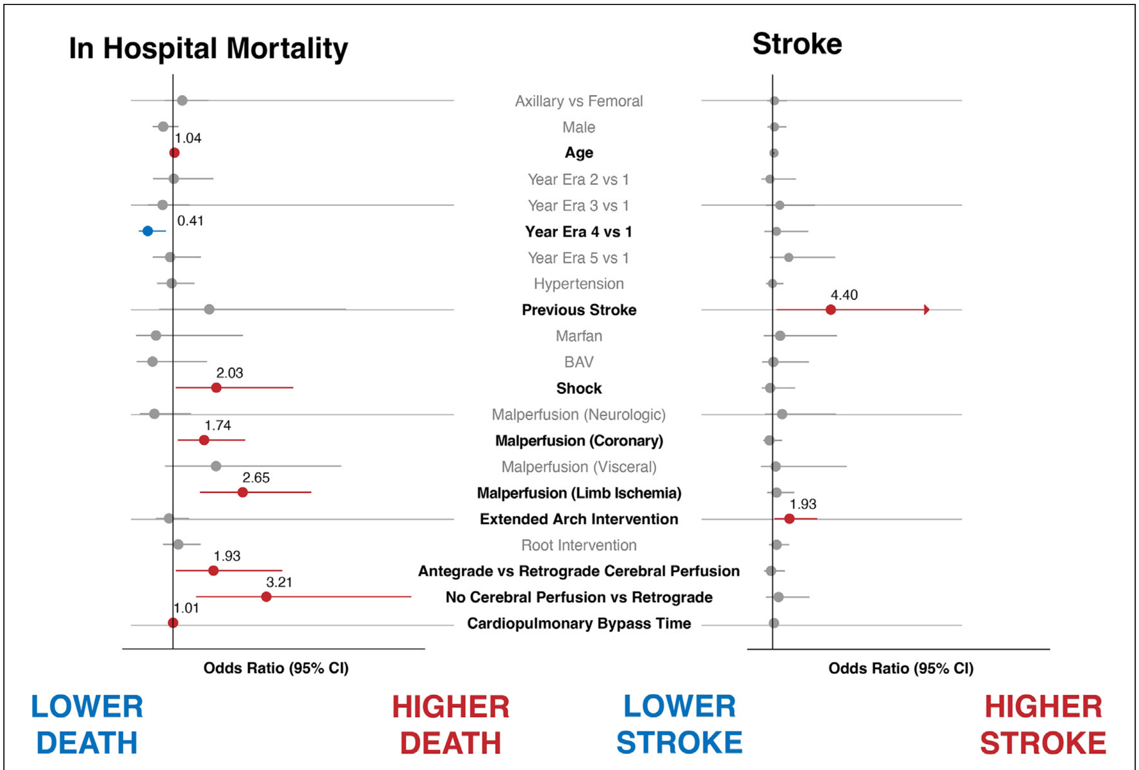

FIGURE 3 Multivariable generalized linear model with random intercept for (left) in-hospital death and (right) in-hospital stroke. Colored CIs are statistically significant, whereas CIs in gray are nonsignificant. Eras 1 to 5 are defined as follows: 1996-2007, 2008-2010, 2011-2013, 2014-2016, and 2017-2021. (BAV, bicuspid aortic valve.)

STUDY LIMITATIONS. Changes to surgical technique over time were partially mitigated by statistical adjustment. Despite standardized definitions for stroke and extent of surgical repair, variability remains in the context of self-reported registry data. Further, although some discrepancies existed in extent of surgical repair strategy between the 2 comparator groups, the registry did not capture exact indications for extent of repair to gauge appropriateness of operations performed between the 2 groups. Only 7% of patients were from outside North America or Europe. We did not study innominate, direct aortic, or carotid cannulation because of insufficient numbers. Changes to cannulation strategy during ATAD repair were not captured adequately by the database and therefore were excluded from the study. Despite statistical adjustment, unmeasured confounders remain possible. Nevertheless, this is an international study comparing axillary and femoral cannulation in ATAD that contributes important evidence, especially in the absence of randomized data.

CONCLUSION. In summary, we compared the 2 dominant arterial cannulation strategies in a large international cohort of ATAD repairs using more than 2 decades of experience. Both femoral cannulation and axillary cannulation appear to have equivalent perioperative safety in ATAD, although patients in the former group are more likely to present in critical condition and patients in the latter group are more likely to undergo extensive repair. Femoral cannulation is safe and effective for hemodynamically unstable patients, whereas axillary cannulation remains a valuable approach for providing physiologic antegrade flow and facilitating cerebral perfusion, particularly for extended aortic arch reconstruction.

Data Availability Statement: The manuscript and supplemental files contain all relevant data. Further material can be provided on reasonable request from the IRAD Coordinating Center at the University of Michigan.

FUNDING SOURCES

The International Registry of Acute Aortic Dissection has received generous support from W.L. Gore & Associates, participating IRAD aortic centers of excellence, Medtronic, the Varbedian Aortic Research Fund, the Hewlett Foundation, the Mardigian Foundation, UM Faculty Group Practice, Terumo, and Ann and Bob Aikens. Malak Elbatarny has received support from the Vanier Graduate Scholarship. Mark D. Peterson has received support from the Walter and Maria Schroeder Foundation. All other authors declare that they have no funding sources to disclose.

DISCLOSURES

The authors have no conflicts of interest to disclose.

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Published by Elsevier Inc.
0003-4975/$36.00
https://doi.org/10.1016/j.athoracsur.2024.03.029

Is There an Optimal Strategy for Cannulation and Cerebral Protection in Acute Type A Dissection?

INVITED COMMENTARY:

In the article "Axillary vs Femoral Arterial Cannulation in Acute Type A Dissection: International Multicenter Data" by Elbatarny and colleagues[1] in this issue of *The Annals of Thoracic Surgery*, cannulation strategies, more specifically, axillary and femoral arterial cannulation, were compared in a retrospective registry database, International Registry of Acute Aortic Dissection Interventional Cohort from 1996 to 2021. End points, including early mortality, neurologic, respiratory, and renal complications, malperfusion, and tamponade were assessed.

The authors have elegantly shown that there was no difference in the end points assessed between the 2