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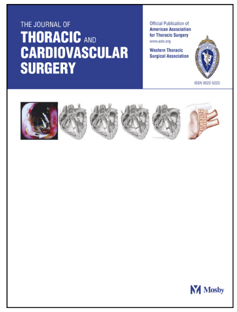

The Impact of Re-operation on Aortic Arch Reconstructive Surgery: Evidence from a Multicentre, National Registry

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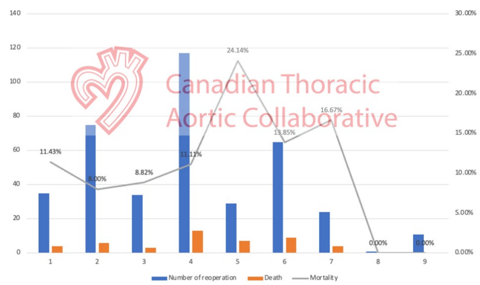

From 2002 to 2021, nine centers

- **Primary** (2107) mortality: 9.3%
- **Redo-aortic** (246) mortality: 11%
- **Redo-other** (128) mortality: 14%

HEMI-ARCH group

	Primary	Redo	*p*
N.	1800	266	
Mortality	8.8 %	14 %	0.014
MMOM	29 %	33 %	0.104

TOTAL-ARCH group

	Primary	Redo	*p*
N.	307	108	
Mortality	12 %	9.3 %	0.476
MMOM	42 %	42 %	0.976

Independent predictors of mortality and MMOMs

- Age over 65yrs
- Acute dissection or rupture
- Prolonged CPB time

Selected **aortic arch reoperations** can be performed safely in **experienced aortic centers** while further studies were needed for continuing optimization of surgical and patient management strategies.

JTCVS

@AATSHQ

The Impact of Re-operation on Aortic Arch Reconstructive Surgery: Evidence from a Multicentre, National Registry

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Central message.

Reoperative arch surgery is associated with similar operative mortality compared to primary surgery, but still remains risky in patients with advanced age, acute dissection and prolonged CPB time.

Perspective Statement

According to our multicenter, retrospective study, reoperative aortic arch reconstruction remains a high-risk and technically demanding operation, but can be performed safely and provides similar short-term outcomes to primary arch repair.

This study was presented as an oral presentation at the AATS 2025 annual meeting in Seattle, WA.

Glossary of Abbreviations

MMOM, a modified version of the Society of Thoracic Surgeons-defined composite endpoint for mortality and major morbidity;

CPB, cardiopulmonary bypass;

CTAC, Canadian Thoracic Aortic Collaborative;

HCA, hypothermic circulatory arrest;

ICU, intensive care unit;

LVEF, left ventricular ejection fraction;

Abstract

Objective: To analyze the in-hospital outcomes of patients undergoing re-operative aortic arch repair and identify risk factors for mortality and morbidity using data from a multicenter, national registry.

Methods: We collected data on patients undergoing aortic arch repair (hemiarch or total arch replacement with or without elephant trunk/frozen elephant trunk) under circulatory arrest between 2002 and 2021, including those with acute aortic dissection. Patients with a history of previous open-heart surgery were defined as the redo cases (aortic-redo group and other-redo group). The primary outcomes were operative mortality and a modified Society of Thoracic Surgeons composite endpoint for mortality and major morbidity (MMOM). The MMOM composite endpoint was defined as: operative mortality, stroke, dialysis-dependent renal failure, deep sternal wound infection, reoperation, prolonged ventilation of >40 hours. Blood transfusion rates were also analyzed.

Results: Overall, 374 (15%) of 2481 patients were in the redo cohort. The overall operative mortality of aortic arch reoperations was 12%. Although redo patients had a significantly higher comorbidity burden, no significant difference was identified for the operative mortality among primary, aortic-redo and other-redo groups (9.3% *vs.* 11% *vs.* 14%, $p = 0.132$), and for the MMOM incidence (30% *vs.* 34% *vs.* 39%, $p = 0.075$). Additionally, transfusion requirements and ICU/hospital stays were higher in both redo groups ($p < 0.001$). To further analyze the redo group, all patients were divided into four groups: Primary hemi-arch group (n = 1800), primary total-arch group (n = 307), redo hemi-arch group (n = 266) and redo total-arch group (n = 108). Operative mortality was significantly higher in the redo hemi-arch group (p = 0.014). In contrast, there was no significant difference in mortality or MMOM between primary and redo total-arch groups ($p > 0.05$). Multivariable analyses identified older age, acute aortic dissection, and prolonged CPB time (log-transformed) as independent predictors of both operative mortality and MMOM in reoperative arch repair.

Conclusions: This study of a national registry demonstrated that selected aortic arch reoperations can be performed with acceptable safety. Older age, acute aortic dissection, and prolonged CPB time are associated with worse operative outcomes. Further studies are needed to optimize surgical techniques and perioperative care, in addition to selecting patients who would benefit most from reoperative open arch surgery.

Key words:

Reoperation, aortic arch reconstruction, outcomes, mortality

Introduction

Reoperations on aortic arch following previous aortic or cardiac surgery are increasingly common but remain challenging, with significant associated mortality and morbidity[1,2]. With the advanced aging population and improved long-term survival of primary cardiac or aortic surgery, the number of patients requiring reoperative aortic arch repair is increasing. Although there have been many iterative improvements in surgical techniques, strategies for myocardial protection and cerebral perfusion, and overall perioperative management, all attempting to reduce surgical risk, aortic arch reoperations are still associated with high complexity and operative mortality[3].

Aortic arch reoperations are technically demanding due to several factors: redo sternotomy, adhesions from prior cardiac or aortic surgery, complexity of aortic anatomy, and an older patient population with more comorbidities. In addition, most reoperative aortic arch repair cases are associated with prolonged cardiopulmonary bypass time and circulatory arrest time, challenging cerebral protection strategies, and malperfusion/reperfusion injury[4]. All these features contribute to the higher incidence of adverse events, including major bleeding, neurological complications, acute kidney injury and other end-organ dysfunction. The operative mortality of aortic arch reoperation remains high, ranging from 7%-15%[1].

There are many previous studies examining reoperative aortic surgery, however, most consisted of small sample sizes, based on a single center or a single surgeon experience, which raises issues of reproducibility and generalizability.[4,5] We analyzed the short-term outcomes of all patients who had aortic arch reoperation from a multicenter, national registry . Patient characteristics and operative factors were also analyzed for identify independent predicators of mortality and morbidity.

Methods

Study population

The Canadian Thoracic Aortic Collaborative (CTAC) consists of nine participating centers and maintains a multicenter registry including inpatient data from all consecutive aortic procedures performed under circulatory arrest. Data is collected at local sites at the time of surgery and uploaded to the national registry periodically. Ethics approval was obtained locally from institutional review boards at individual participating institutions, with data-sharing agreements with Lawson Health Research Institute (IRB No. 119869; October 7, 2022).

All cases with aortic arch repair (hemiarch replacement, total arch replacement with or without elephant trunk) under circulatory arrest, including acute type A aortic dissection, were collected in our study from 2002 and 2021. Descending thoracic/thoracoabdominal aortic surgery using circulatory arrest were excluded. Hybrid aortic arch procedures were also included; however, details were not included for analysis. Redo cases were defined by any previous open heart surgery, including aortic, valvular, coronary artery, or other surgery . Specifically, patients with previous open aortic surgery were defined as the redo-aortic cohort and patients with open heart surgery, including valvular, coronary artery or other miscellaneous surgery under sternotomy or thoracotomy were defined as redo-other cohort.

Operative strategies

Cannulation strategies were carefully reviewed and reported in our previous study[6]. Briefly, strategies in our study included axillary, femoral, direct aortic, innominate and carotid artery cannulation. Each center selected the arterial cannulation site according to the patient specific pathological anatomy and institutional preference. Some patients (5%) had multiple cannulation strategies, including combining aortic cannulation, axillary cannulation and femoral cannulation.

Cerebral protection strategies were carefully reviewed and previously reported[7]. In general, most centers employed antegrade cerebral perfusion with moderate hypothermic circulatory arrest. Retrograde cerebral perfusion was used occasionally, and no brain perfusion was rarely employed. Neuromonitoring was used intra-operatively to further guide the brain protection strategies.

Outcomes

Two major outcomes were used in our study: operative mortality (in-hospital mortality or mortality within 30-days) and a modified version of the Society of Thoracic Surgeons-defined composite endpoint for mortality and major morbidity (MMOM). The MMOM composite endpoint was defined as the occurrence of one of the following endpoints: operative mortality, stroke, dialysis-dependent renal failure, deep sternal wound infection, reoperation, prolonged ventilation of >40 hours. Transfusion rates for patients undergoing arch reconstruction were also collected.

Statistics

Continuous variables were expressed as mean ± standard deviation (SD) or median (interquartile range), and categorical variables were expressed as frequencies (%). Factors associated with the outcomes were identified logistic regression models using least absolute shrinkage and selection operator (LASSO) selection methods to identify candidate variables. Variables assessed as potential risk factors included pre-operative baseline characteristics (i.e., age, aortic valve disease, aortic diameter, presence of dissection or rupture, urgent status of surgery, and comorbidities), as well as operative data (extent of aortic reconstruction, concomitant surgeries, surgical times, hypothermic circulatory arrest (HCA) temperatures, HCA times, and cerebral protection strategies). For variables that were not normally distributed (e.g., surgical times), a logarithmic transformation was used. To account for the effect of the individual centers, multivariable analyses using mixed effects regression models with logit link and a random effect of the center were then conducted using variables identified through LASSO (PROC GLIMMIX in SAS 9.4, SAS Institute, Cary, NC, USA). Variables were manually excluded in a backward selection process until all variables in the final model were significant.

Results

Overall, 374 of 2481 patients were included in the redo cohort. 246 patients had previous open-aortic surgery (redo-aortic group) and 128 had previous other open-heart surgery (redo-other group). The indications for reoperative aortic arch repair were analyzed and listed in the **Table 1**. The most common indication for reoperation on aortic arch repair was degenerated aortic aneurysm (50.7%). The contribution of each centre to our redo cohort and respective mortalities were shown in the **Figure 1 and Supplementary Table 1**.

Demographic characteristics were listed in the **Table 2**. Mean age was 63±13 years and 32% were female. Patients in the aortic-redo group were younger and more often had connective tissue disease. Patients in both redo groups had a significant higher comorbidity burden, while patients in the other-redo group had worse heart function.

Intra-operative and outcomes data is shown in the **Table 3-4** and **Supplementary Table 2**. No significant difference was identified for the operative mortality among primary, aortic-redo and other-redo groups (9.3% *vs.* 11% *vs.* 14%, $p = 0.132$). Although patients in other-redo group more often experienced prolonged ventilation and renal failure requiring dialysis, no significant difference was confirmed for MMOM (30% *vs.* 34% *vs.* 39%, $p = 0.075$).

In order to further analyze the redo group, all patients were divided into four groups: Primary hemi-arch group (n = 1800), primary total-arch group (n = 307), redo hemi-arch group (n = 266) and redo total-arch group (n = 108). Data was shown in the **Table 5** and **Supplementary Table 3-5**. In the hemi-arch cohorts, redo patients had significantly higher operative mortality compared primary patients (14% *vs.* 8.8%, $p = 0.014$). In the total-arch cohorts, no significant difference was found for operative mortality (12% *vs.* 9.3%, $p = 0.476$) and MMOM complication rates (42% *vs.* 42%, $p = 0.976$).

We performed multivariate analyses for independent predictors of operative mortality and MMOMs in both the whole cohort and redo cohort (Figure 2 and 3). Older age over 65, acute dissection or rupture and prolonged CPB time were identified as the independent predictors of operative mortality in patients with both primary and reoperative aortic arch repair.

Discussion

Most of the published evidence investigating outcomes in reoperative aortic arch surgery arise from a single center, often a single surgeon, which may reflect a specific and selective patient population, raising questions about generalizability. Our study analyzed 2481 patients who underwent aortic arch repair requiring circulatory arrest over the last two decades amongst nine Canadian centers with 374 patients identified as reoperative cases. The operative mortality rate was 12.3% and there were no significant differences in operative mortality between redo and primary aortic arch operations. Elderly patients (age over 65), acute dissection or rupture, and prolonged CPB time were identified as independent predictors of operative mortality in patients with both primary and reoperative aortic arch repair. This multi-center study from the major aortic centers in Canada included all patients with circulatory arrest arch repair. Our study represents real world results with generalizable outcomes for re-operative surgery from an unselected patient population. Our study is also useful as a reference study to compare the outcomes to the burgeoning field of endovascular aortic arch repair.

Reoperative surgery of the aortic arch presents multiple technical challenges and is often performed in older patients with more comorbid risks, particularly in patients with prior aortic surgery. Although the operative mortality in our study may seem high at 12%, this patient population included all-comers including acute aortic dissection, prosthetic graft infections, aortic pseudoaneurysms and patients with high burden of comorbidities. We feel this mortality rate is more reflective of an unselected patient populations consistent with other publications [1,4,8]. Some groups have published excellent results with reoperative aortic surgery, although patient selection may have been more stringent and the results are more reflective of single surgeon series. Ohira *et al.* recently reported their outcome of aortic reoperation after prior acute type A aortic dissection. A total of 123 reoperations were collected and revealed an average operative mortality rate of 2.4%, which included redo-sternotomy, left thoracotomy and endovascular approach[5]. Similar results were published by a high-volume center in China[9]. In our study, nine different volume centers were included and all patients requiring reoperative arch repair with redo-sternotomy were enrolled, including acute dissection, pseudoaneurysms and graft infections. Amongst the different centers, operative mortalities ranged from 0 to 24%. Not surprisingly, higher-volume centers demonstrated lower in-hospital mortalities, thus supporting the accruing evidence supporting the important volume-outcome relationship in aortic surgery. Our previous study also demonstrated improved outcomes over time with rapid evolving of surgical strategies and perioperative management [10].

Surprisingly, we found significantly higher operative mortality in redo hemi-arch group comparing with primary hemi-arch group while no significant difference between primary and redo total-arch cohort. We believe that this is largely related to the higher comorbidity in the redo hemiarch cohort. We hypothesize that the patients with higher comorbidity in the redo total-arch group were likely diverted to endovascular options, medical therapy or even towards hemiarch repair. The Bentall procedure for root repair, was also an independent predictor of operative mortality in our study. This is likely attributable to many factors, including more extensive aortic disease, complex aortic root re-operations, myocardial protection and technical challenges from re-operating on 'frozen' aortic roots [11,12]. Concomitant Bentall procedures were more common in the redo hemiarch group and may be another one of the reasons for the increased mortality seen in the redo hemiarch group compared to the redo total arch group.

In our study, the neurological complications remain high, ranging from 7.7% to 13%. However, we used a broad definition with included any neurological complications defined as stroke, TIA, seizures or any other central neurological complication. Several other studies also reported similar incidence of cerebrovascular event[13-15] Most patients received unilateral or bilateral antegrade cerebral perfusion during systemic hypothermic circulatory arrest. We did not identify any significant differences between antegrade and retrograde cerebral perfusion. Only a few patients received hypothermic circulatory arrest without cerebral perfusion and this strategy was an independent predictor of poor outcomes. In detail, our previous study about the impact of cerebral protection strategies confirmed that antegrade cerebral perfusion was a predictor of improved survival and neurological outcomes[7]. As for the impact of initial cannulation strategy on neurological outcomes, although the current study did not identify any significant difference, our previous study found that axillary cannulation should be the preferred strategy in experienced centers if anatomy and stability allow[6].

Recent studies have shown a higher reoperation rate after hemi-arch repair for acute type A aortic dissection[16]. Our group previously demonstrated that extended arch replacement can be performed with similar perioperative mortality and permanent neurologic risk as hemiarch repair in type A aortic dissection[17]. However, extended arch replacement should be offered to carefully selected patients due to increased risk of composite adverse events[17]. In order to further address these issues, our group initiated the first randomized trial in acute type A aortic dissection, the treatment in thoracic aortic aneurysm: hemiarch vs extended arch in aortic dissection—a systematic analysis by randomized trial (TITAN:HEADSTART), to provide evidence to determine the optimal arch strategy in acute type A dissection[18].

Consistent with previous studies, we also found that older age, aortic dissection or rupture, and prolonged CPB time and were independent predictors of operative mortality[8,12,19-21]. Elderly patients have more comorbidities and frailty resulting in a lower reserve for withstanding complex aortic reconstructive surgery. Prolonged CPB time reflects the increased complexity of the operations and has been associated with both short-term and long-term clinical outcomes[22-24]. We also performed our analysis using a composite outcome of MMOM, and found no significant differences between the primary and reoperative aortic arch repair.

Our study has several limitations. Firstly, the CTAC database focuses on short-term, in-hospital data that may have been prone to many known or unknown biases with no long-term follow-up data. Secondly, we lacked granular data on the specific details of the previous operations. There was also no central adjudication of adverse events such as neurological complications. Thirdly, the absolute number of mortalities (46) in the redo setting was relatively low, hence, limiting our ability to perform a more comprehensive multivariable analysis.

In conclusion, this multicenter study from the major aortic centers in Canada demonstrated the real-world operative mortality of aortic arch reoperations to be 12.3%, without significant differences compared to primary arch operations. We found that older age, acute dissection or rupture and prolonged CPB time as independent predictors for both operative death and MMOMs. Reoperative arch surgery with concomitant a Bentall procedure was also an independent predictor for operative mortality. These high-risk patients would benefit from careful counselling in the shared-decision making process and consideration to alternative treatment strategies including endovascular or medical management. We believe that selected aortic arch reoperations can be performed safely in experienced aortic centers. Further studies are needed to identify specific surgical techniques and patient ch062aracteristics who would benefit the most from complex, reoperative aortic surgery.

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Figure legends

Figure 1. (**a**) Proportion of indications for reoperative aortic arch reconstructions. (**b**) distribution and mortalities of nine participating centers in CTAC database.

Figure 2. Forest plot of multivariable logistic regression model for predictors of operative mortality. Odds ratios (OR) with 95% confidence intervals (CI). (**a**) multivariate analyses for operative mortality in the whole population; (**b**) multivariate analyses for MMOM in the whole population.

Figure 3. Forest plot of multivariable logistic regression model for predictors of operative mortality. Odds ratios (OR) with 95% confidence intervals (CI). (**a**) multivariate analyses for operative mortality in the redo setting; (**b**) multivariate analyses for MMOM in the redo setting.

Figure 4. Graphical Abstract.

Central picture. No significant difference was identified among primary and redo groups.

Supplementary video legend. Reoperative total arch replacement with carotid artery cannulation

Audio:

You can listen to the audio recording of the presentation and discussion associated with this paper in supplementary materials.

Table 1. The indications for reoperative aortic arch repair.

	INDICATIONS					
	Degenerated aneurysm	Chronic or residual dissection	Pseudoaneurysm	Endocarditis	Acute dissection	Others
Total	190 (51%)	45 (12%)	34 (9.0%)	26 (7.0%)	64 (17%)	15 (4.1%)
HEMI-ARCH	153 (57%)	9 (3.2%)	19 (7.3%)	25 (9.3%)	46 (17%)	14 (5.3%)
TOTAL-ARCH	36 (34%)	38 (35%)	14 (13%)	1 (1.0%)	18 (16%)	1 (1.0%)

Table 2. Demographic characteristics.

Variable	OVERALL (N=2481)	PRIMARY (N=2107)	REDO-AORTIC (N=246)	REDO-OTHER (N=128)	P
Age, years	63 ± 13	64 ± 13	58 ± 16	65 ± 13	<.001
Female gender	32% (784)	33% (702)	25% (61)	16% (21)	<.001
Height, cm	1.7 ± 0.1	1.7 ± 0.1	1.7 ± 0.1	1.7 ± 0.1	0.008
Weight, kg	83 ± 19	83 ± 20	81 ± 18	82 ± 16	0.650
Body mass index	28 ± 6	28 ± 6	27 ± 5	28 ± 7	0.026
Hypertension	67% (1665)	68% (1428)	63% (156)	63% (81)	0.247
Diabetes	13% (313)	13% (272)	8.9% (22)	15% (19)	0.153
Dyslipidemia	45% (1112)	44% (928)	41% (101)	65% (83)	<.001
Preoperative renal failure	4.6% (114)	4.3% (90)	6.9% (17)	5.5% (7)	0.155
Cerebrovascular disease	7.1% (177)	6.2% (131)	13% (31)	12% (15)	<.001
Peripheral vascular disease	11% (268)	10% (216)	14% (35)	13% (17)	0.107
Ever smoker	45% (1107)	46% (960)	41% (101)	36% (46)	0.052
Chronic obstructive pulmonary disease	12% (298)	12% (250)	14% (35)	10% (13)	0.449
Preoperative atrial fibrillation	12% (297)	11% (227)	15% (37)	26% (33)	<.001
Coronary artery disease	21% (516)	19% (408)	22% (53)	43% (55)	<.001
Prior myocardial infarction	7.5% (185)	7.0% (147)	8.5% (21)	13% (17)	0.025
Congestive heart failure	11% (275)	10% (214)	16% (39)	17% (22)	0.002
Connective tissue disorder					<.001
- None	95% (2350)	96% (2017)	85% (209)	97% (124)	

Variable	OVERALL (N=2481)	PRIMARY (N=2107)	REDO-AORTIC (N=246)	REDO-OTHER (N=128)	P
- Confirmed	3.2% (79)	2.1% (44)	13% (33)	1.6% (2)	
- Suspected	2.1% (52)	2.2% (46)	1.6% (4)	1.6% (2)	
Left ventricular ejection fraction, %	56 ± 9	56 ± 9	56 ± 10	52 ± 11	<.001
Ascending aorta aneurysm	75% (1860)	74% (1562)	83% (204)	73% (94)	0.010
Acute Dissection or Rupture	30% (756)	34% (714)	6.9% (17)	20% (25)	<.001
PREOPERATIVE STATUS					
Urgency status					<.001
- Elective	57% (1411)	55% (1153)	73% (180)	61% (78)	
- Urgent (same hospital stay)	11% (264)	9.4% (199)	18% (44)	16% (21)	
- Emergent or salvage	32% (806)	36% (755)	8.9% (22)	23% (29)	
Preoperative NYHA class III or IV	18% (445)	17% (349)	21% (51)	35% (45)	<.001

Table 3. Intra-operative surgical details and perfusion data.

Variable	OVERALL (N=2481)	PRIMARY (N=2107)	REDO-AORTIC (N=246)	REDO-OTHER (N=128)	P
Concomitant aortic valve surgery	75% (1856)	77% (1617)	61% (149)	70% (90)	<.001
- Aortic valve replacement	20% (490)	20% (419)	17% (42)	23% (29)	0.403
- Bentall	27% (663)	26% (547)	30% (74)	33% (42)	0.107
- Ross	0.36% (9)	0.28% (6)	0.81% (2)	0.78% (1)	0.308
- Valve sparing root replacement	7.6% (189)	8.4% (177)	3.3% (8)	3.1% (4)	0.002
Ascending aorta replacement	87% (2163)	88% (1855)	79% (194)	89% (114)	<.001
Aortic arch surgery					<.001
- Hemiarch	83% (2066)	85% (1800)	61% (151)	90% (115)	
- Total arch	17% (415)	15% (307)	39% (95)	10% (13)	
Elephant trunk					<.001
- No elephant trunk	90% (2231)	92% (1928)	74% (181)	95% (122)	
- Conventional elephant trunk	4.6% (115)	3.9% (83)	12% (30)	1.6% (2)	
- Frozen elephant trunk	5.4% (135)	4.6% (96)	14% (35)	3.1% (4)	
Concomitant surgery	28% (684)	26% (543)	35% (87)	42% (54)	<.001
- Mitral valve replacement	2.1% (52)	1.4% (30)	4.9% (12)	7.8% (10)	<.001
- Mitral valve repair	2.1% (53)	1.9% (40)	3.7% (9)	3.1% (4)	0.143
- CABG	19% (475)	19% (400)	16% (39)	28% (36)	0.015
- ASD or VSD closure	1.5% (36)	1.5% (32)	1.2% (3)	0.78% (1)	0.755
PERFUSION DETAILS					

Variable	OVERALL (N=2481)	PRIMARY (N=2107)	REDO-AORTIC (N=246)	REDO-OTHER (N=128)	P
Arterial canulation site					
- Axillary, innominate or carotid	74% (754)	74% (662)	71% (65)	75% (27)	0.724
- Aortic	30% (303)	30% (268)	24% (22)	36% (13)	0.323
- Femoral	14% (146)	13% (119)	25% (23)	11% (4)	0.009
Cardiopulmonary bypass time, min.	174 [129, 231]	170 [125, 222]	199 [162, 276]	206 [150, 266]	<.001
Myocardial ischemia time, min.	100 [67, 143]	99 [66, 140]	117 [67, 163]	106 [78, 154]	0.003
Deep hypothermic cardiac arrest time, min.	20 [13, 32]	20 [13, 31]	23 [15, 38]	19 [12, 29]	<.001
Lowest temperature, Celcius	24 [20, 26]	24 [20, 26]	22 [18, 25]	23 [19, 26]	<.001
Cerebral perfusion strategy					0.163
- No cerebral perfusion	15% (361)	14% (297)	15% (37)	21% (27)	
- Unilateral antegrade	75% (1863)	75% (1582)	76% (187)	73% (94)	
- Bilateral antegrade	4.0% (100)	4.1% (86)	4.5% (11)	2.3% (3)	
- Retrograde	6.3% (157)	6.7% (142)	4.5% (11)	3.1% (4)	

Table 4. Outcomes data.

Variable	OVERALL (N=2481)	PRIMARY (N=2107)	REDO-AORTIC (N=246)	REDO-OTHER (N=128)	P value
POSTOPERATIVE OUTCOMES					
- Hospital mortality	10% (241)	9.3% (195)	11% (28)	14% (18)	0.132
- Cardiac reoperation for tamponade or bleeding	9.4% (233)	9.0% (190)	12% (29)	11% (14)	0.306
- Prolonged ventilation (> 40h)	19% (473)	18% (382)	22% (55)	28% (36)	0.008
- Dialysis dependent renal failure	5.6% (138)	5.2% (109)	5.7% (14)	12% (15)	0.007
- Deep sternal wound infection	0.69% (17)	0.62% (13)	0.41% (1)	2.3% (3)	0.061
- Any cerebrovascular accident	10% (255)	10% (220)	7.7% (19)	13% (16)	0.288
- STS modified composite endpoint (death, stroke, reop, renal failure, DSWI, long vent. > 40h)	31% (776)	30% (642)	34% (84)	39% (50)	0.075

Table 5. Outcomes of subgroup analysis.

Variable	PRIMARY-HEMI (N=1800)	REDO-HEM (N=266)I	P value	PRIMARY-TOTAL (N=307)	REDO-TOTAL (N=108)	P value
POSTOPERATIVE OUTCOMES						
- Hospital mortality	8.8% (159)	14% (36)	0.014	12% (36)	9.3% (10)	0.476
- Cardiac reoperation for tamponade or bleeding	8.3% (149)	10% (27)	0.306	13% (41)	15% (16)	0.713
- Prolonged ventilation (> 40h)	17% (302)	23% (61)	0.014	26% (80)	28% (30)	0.741
- Dialysis dependent renal failure	4.7% (85)	7.9% (21)	0.028	7.8% (24)	7.4% (8)	0.884
- Deep sternal wound infection	0.67% (12)	1.1% (3)	0.408	0.33% (1)	0.93% (1)	0.440
- Any cerebrovascular accident	10% (182)	10% (26)	0.867	12% (38)	8.3% (9)	0.250
- STS modified composite endpoint (death, stroke, reop, renal failure, DSWI, long vent. > 40h)	29% (515)	33% (89)	0.104	41% (127)	42% (45)	0.976
INTENSIVE CARE AND HOSPITAL STAY						
ICU length of stay (first stay), d	2.0 [1.0, 5]	2.9 [1.2, 6]	0.002	3.0 [1.1, 6]	3.1 [1.5, 8]	0.545
Hospital length of stay (first stay), d	8 [6, 14]	9 [6, 18]	0.007	10 [7, 21]	13 [7, 18]	0.290

Table 1. The indications for reoperative aortic arch repair.

	INDICATIONS					
	Degenerated aneurysm	Chronic or residual dissection	Pseudoaneurysm	Endocarditis	Acute dissection	Others
Total	190 (51%)	45 (12%)	34 (9.0%)	26 (7.0%)	64 (17%)	15 (4.1%)
HEMI-ARCH	153 (57%)	9 (3.2%)	19 (7.3%)	25 (9.3%)	46 (17%)	14 (5.3%)
TOTAL-ARCH	36 (34%)	38 (35%)	14 (13%)	1 (1.0%)	18 (16%)	1 (1.0%)

Table 2. Demographic characteristics.

Variable	OVERALL (N=2481)	PRIMARY (N=2107)	REDO-AORTIC (N=246)	REDO-OTHER (N=128)	P
Age, years	63 ± 13	64 ± 13	58 ± 16	65 ± 13	<.001
Female gender	32% (784)	33% (702)	25% (61)	16% (21)	<.001
Height, cm	1.7 ± 0.1	1.7 ± 0.1	1.7 ± 0.1	1.7 ± 0.1	0.008
Weight, kg	83 ± 19	83 ± 20	81 ± 18	82 ± 16	0.650
Body mass index	28 ± 6	28 ± 6	27 ± 5	28 ± 7	0.026
Hypertension	67% (1665)	68% (1428)	63% (156)	63% (81)	0.247
Diabetes	13% (313)	13% (272)	8.9% (22)	15% (19)	0.153
Dyslipidemia	45% (1112)	44% (928)	41% (101)	65% (83)	<.001
Preoperative renal failure	4.6% (114)	4.3% (90)	6.9% (17)	5.5% (7)	0.155
Cerebrovascular disease	7.1% (177)	6.2% (131)	13% (31)	12% (15)	<.001
Peripheral vascular disease	11% (268)	10% (216)	14% (35)	13% (17)	0.107
Ever smoker	45% (1107)	46% (960)	41% (101)	36% (46)	0.052
Chronic obstructive pulmonary disease	12% (298)	12% (250)	14% (35)	10% (13)	0.449
Preoperative atrial fibrillation	12% (297)	11% (227)	15% (37)	26% (33)	<.001
Coronary artery disease	21% (516)	19% (408)	22% (53)	43% (55)	<.001
Prior myocardial infarction	7.5% (185)	7.0% (147)	8.5% (21)	13% (17)	0.025
Congestive heart failure	11% (275)	10% (214)	16% (39)	17% (22)	0.002
Connective tissue disorder					<.001
- None	95% (2350)	96% (2017)	85% (209)	97% (124)	

Variable	OVERALL (N=2481)	PRIMARY (N=2107)	REDO-AORTIC (N=246)	REDO-OTHER (N=128)	P
- Confirmed	3.2% (79)	2.1% (44)	13% (33)	1.6% (2)	
- Suspected	2.1% (52)	2.2% (46)	1.6% (4)	1.6% (2)	
Left ventricular ejection fraction, %	56 ± 9	56 ± 9	56 ± 10	52 ± 11	<.001
Ascending aorta aneurysm	75% (1860)	74% (1562)	83% (204)	73% (94)	0.010
Acute Dissection or Rupture	30% (756)	34% (714)	6.9% (17)	20% (25)	<.001
PREOPERATIVE STATUS					
Urgency status					<.001
- Elective	57% (1411)	55% (1153)	73% (180)	61% (78)	
- Urgent (same hospital stay)	11% (264)	9.4% (199)	18% (44)	16% (21)	
- Emergent or salvage	32% (806)	36% (755)	8.9% (22)	23% (29)	
Preoperative NYHA class III or IV	18% (445)	17% (349)	21% (51)	35% (45)	<.001

Table 3. Intra-operative surgical details and perfusion data.

Variable	OVERALL (N=2481)	PRIMARY (N=2107)	REDO-AORTIC (N=246)	REDO-OTHER (N=128)	P
Concomitant aortic valve surgery	75% (1856)	77% (1617)	61% (149)	70% (90)	<.001
- Aortic valve replacement	20% (490)	20% (419)	17% (42)	23% (29)	0.403
- Bentall	27% (663)	26% (547)	30% (74)	33% (42)	0.107
- Ross	0.36% (9)	0.28% (6)	0.81% (2)	0.78% (1)	0.308
- Valve sparing root replacement	7.6% (189)	8.4% (177)	3.3% (8)	3.1% (4)	0.002
Ascending aorta replacement	87% (2163)	88% (1855)	79% (194)	89% (114)	<.001
Aortic arch surgery					<.001
- Hemiarch	83% (2066)	85% (1800)	61% (151)	90% (115)	
- Total arch	17% (415)	15% (307)	39% (95)	10% (13)	
Elephant trunk					<.001
- No elephant trunk	90% (2231)	92% (1928)	74% (181)	95% (122)	
- Conventional elephant trunk	4.6% (115)	3.9% (83)	12% (30)	1.6% (2)	
- Frozen elephant trunk	5.4% (135)	4.6% (96)	14% (35)	3.1% (4)	
Concomitant surgery	28% (684)	26% (543)	35% (87)	42% (54)	<.001
- Mitral valve replacement	2.1% (52)	1.4% (30)	4.9% (12)	7.8% (10)	<.001
- Mitral valve repair	2.1% (53)	1.9% (40)	3.7% (9)	3.1% (4)	0.143
- CABG	19% (475)	19% (400)	16% (39)	28% (36)	0.015
- ASD or VSD closure	1.5% (36)	1.5% (32)	1.2% (3)	0.78% (1)	0.755
PERFUSION DETAILS					

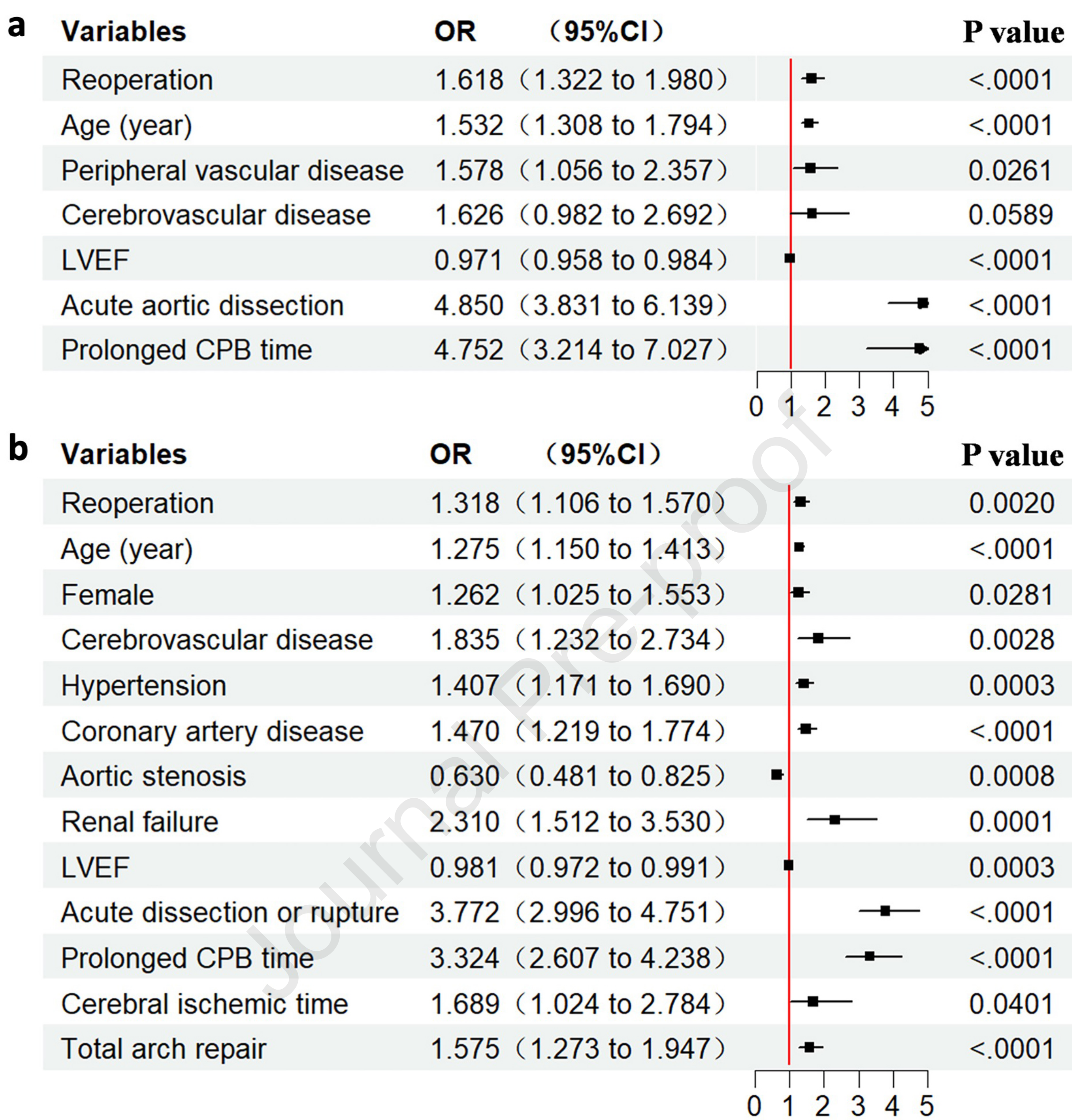
Variable	OVERALL (N=2481)	PRIMARY (N=2107)	REDO-AORTIC (N=246)	REDO-OTHER (N=128)	P
Arterial canulation site					
- Axillary, innominate or carotid	74% (754)	74% (662)	71% (65)	75% (27)	0.724
- Aortic	30% (303)	30% (268)	24% (22)	36% (13)	0.323
- Femoral	14% (146)	13% (119)	25% (23)	11% (4)	0.009
Cardiopulmonary bypass time, min.	174 [129, 231]	170 [125, 222]	199 [162, 276]	206 [150, 266]	<.001
Myocardial ischemia time, min.	100 [67, 143]	99 [66, 140]	117 [67, 163]	106 [78, 154]	0.003
Deep hypothermic cardiac arrest time, min.	20 [13, 32]	20 [13, 31]	23 [15, 38]	19 [12, 29]	<.001
Lowest temperature, Celcius	24 [20, 26]	24 [20, 26]	22 [18, 25]	23 [19, 26]	<.001
Cerebral perfusion strategy					0.163
- No cerebral perfusion	15% (361)	14% (297)	15% (37)	21% (27)	
- Unilateral antegrade	75% (1863)	75% (1582)	76% (187)	73% (94)	
- Bilateral antegrade	4.0% (100)	4.1% (86)	4.5% (11)	2.3% (3)	
- Retrograde	6.3% (157)	6.7% (142)	4.5% (11)	3.1% (4)	

Table 4. Outcomes data.

Variable	OVERALL (N=2481)	PRIMARY (N=2107)	REDO-AORTIC (N=246)	REDO-OTHER (N=128)	P value
POSTOPERATIVE OUTCOMES					
- Hospital mortality	10% (241)	9.3% (195)	11% (28)	14% (18)	0.132
- Cardiac reoperation for tamponade or bleeding	9.4% (233)	9.0% (190)	12% (29)	11% (14)	0.306
- Prolonged ventilation (> 40h)	19% (473)	18% (382)	22% (55)	28% (36)	0.008
- Dialysis dependent renal failure	5.6% (138)	5.2% (109)	5.7% (14)	12% (15)	0.007
- Deep sternal wound infection	0.69% (17)	0.62% (13)	0.41% (1)	2.3% (3)	0.061
- Any cerebrovascular accident	10% (255)	10% (220)	7.7% (19)	13% (16)	0.288
- STS modified composite endpoint (death, stroke, reop, renal failure, DSWI, long vent. > 40h)	31% (776)	30% (642)	34% (84)	39% (50)	0.075

Table 5. Outcomes of subgroup analysis.

Variable	PRIMARY-HEMI (N=1800)	REDO-HEM (N=266)I	P value	PRIMARY-TOTAL (N=307)	REDO-TOTAL (N=108)	P value
POSTOPERATIVE OUTCOMES						
- Hospital mortality	8.8% (159)	14% (36)	0.014	12% (36)	9.3% (10)	0.476
- Cardiac reoperation for tamponade or bleeding	8.3% (149)	10% (27)	0.306	13% (41)	15% (16)	0.713
- Prolonged ventilation (> 40h)	17% (302)	23% (61)	0.014	26% (80)	28% (30)	0.741
- Dialysis dependent renal failure	4.7% (85)	7.9% (21)	0.028	7.8% (24)	7.4% (8)	0.884
- Deep sternal wound infection	0.67% (12)	1.1% (3)	0.408	0.33% (1)	0.93% (1)	0.440
- Any cerebrovascular accident	10% (182)	10% (26)	0.867	12% (38)	8.3% (9)	0.250
- STS modified composite endpoint (death, stroke, reop, renal failure, DSWI, long vent. > 40h)	29% (515)	33% (89)	0.104	41% (127)	42% (45)	0.976
INTENSIVE CARE AND HOSPITAL STAY						
ICU length of stay (first stay), d	2.0 [1.0, 5]	2.9 [1.2, 6]	0.002	3.0 [1.1, 6]	3.1 [1.5, 8]	0.545
Hospital length of stay (first stay), d	8 [6, 14]	9 [6, 18]	0.007	10 [7, 21]	13 [7, 18]	0.290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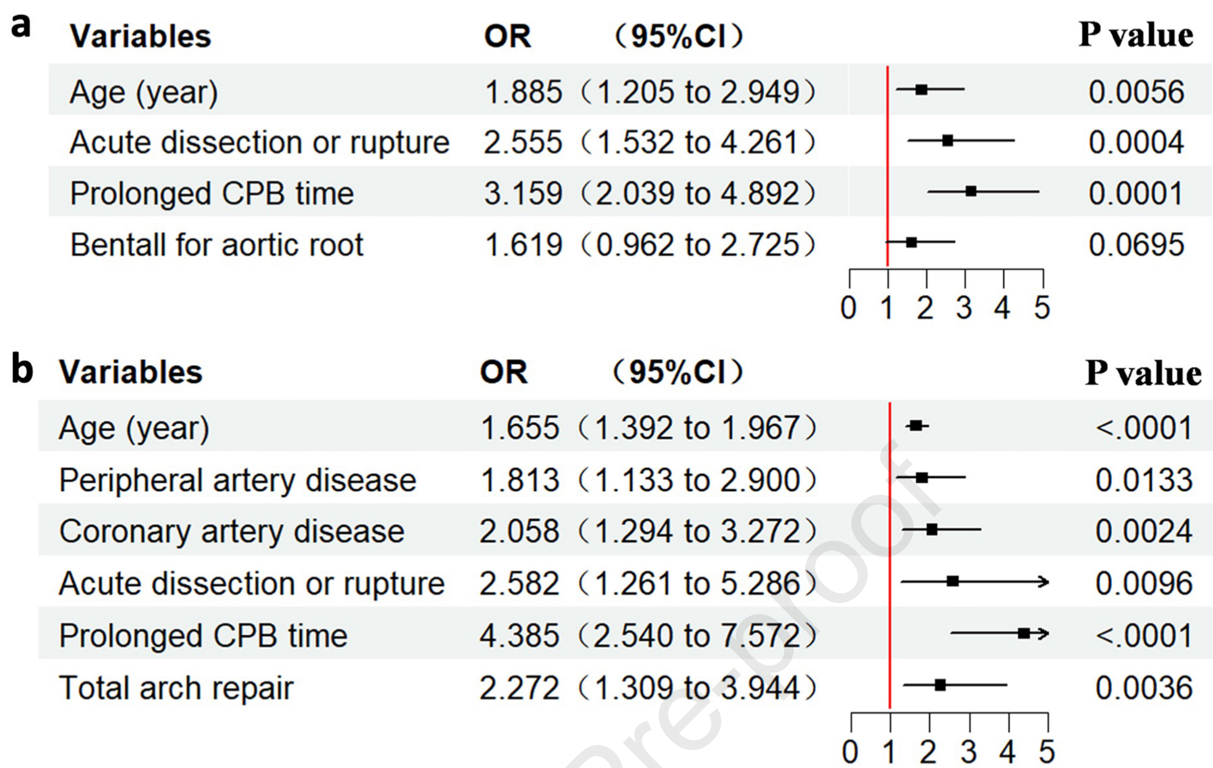
Variables
OR
(95%CI)
P value
Reoperation 1.618 (1.322 to 1.980) <.0001
Age (year) 1.532 (1.308 to 1.794) <.0001
Peripheral vascular disease 1.578 (1.056 to 2.357) 0.0261
Cerebrovascular disease 1.626 (0.982 to 2.692) 0.0589
LVEF 0.971 (0.958 to 0.984) <.0001
Acute aortic dissection 4.850 (3.831 to 6.139) <.0001
Prolonged CPB time 4.752 (3.214 to 7.027) <.0001
0 1 2 3 4 5
b
Variables
OR
(95%CI)
P value
Reoperation 1.318 (1.106 to 1.570) 0.0020
Age (year) 1.275 (1.150 to 1.413) <.0001
Female 1.262 (1.025 to 1.553) 0.0281
Cerebrovascular disease 1.835 (1.232 to 2.734) 0.0028
Hypertension 1.407 (1.171 to 1.690) 0.0003
Coronary artery disease 1.470 (1.219 to 1.774) <.0001
Aortic stenosis 0.630 (0.481 to 0.825) 0.0008
Renal failure 2.310 (1.512 to 3.530) 0.0001
LVEF 0.981 (0.972 to 0.991) 0.0003
Acute dissection or rupture 3.772 (2.996 to 4.751) <.0001
Prolonged CPB time 3.324 (2.607 to 4.238) <.0001
Cerebral ischemic time 1.689 (1.024 to 2.784) 0.0401
Total arch repair 1.575 (1.273 to 1.947) <.0001
0 1 2 3 4 5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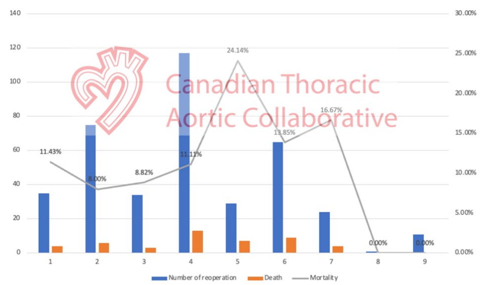
Variables
OR
（95%CI）
P value
Age (year)
1.885（1.205 to 2.949）
0.0056
Acute dissection or rupture
2.555（1.532 to 4.261）
0.0004
Prolonged CPB time
3.159（2.039 to 4.892）
0.0001
Bentall for aortic root
1.619（0.962 to 2.725）
0.0695
0 1 2 3 4 5
b
Variables
OR
（95%CI）
P value
Age (year)
1.655（1.392 to 1.967）
<.0001
Peripheral artery disease
1.813（1.133 to 2.900）
0.0133
Coronary artery disease
2.058（1.294 to 3.272）
0.0024
Acute dissection or rupture
2.582（1.261 to 5.286）
0.0096
Prolonged CPB time
4.385（2.540 to 7.572）
<.0001
Total arch repair
2.272（1.309 to 3.944）
0.0036
0 1 2 3 4 5

The Impact of Re-operation on Aortic Arch Reconstructive Surgery: a Multicentre, National Registry



From 2002 to 2021, nine centers

- **Primary** (2107) mortality: 9.3%
- **Redo-aortic** (246) mortality: 11%
- **Redo-other** (128) mortality: 14%

HEMI-ARCH group

	Primary	Redo	*p*
N.	1800	266	
Mortality	8.8 %	14 %	0.014
MMOM	29 %	33 %	0.104

TOTAL-ARCH group

	Primary	Redo	*p*
N.	307	108	
Mortality	12 %	9.3 %	0.476
MMOM	42 %	42 %	0.976

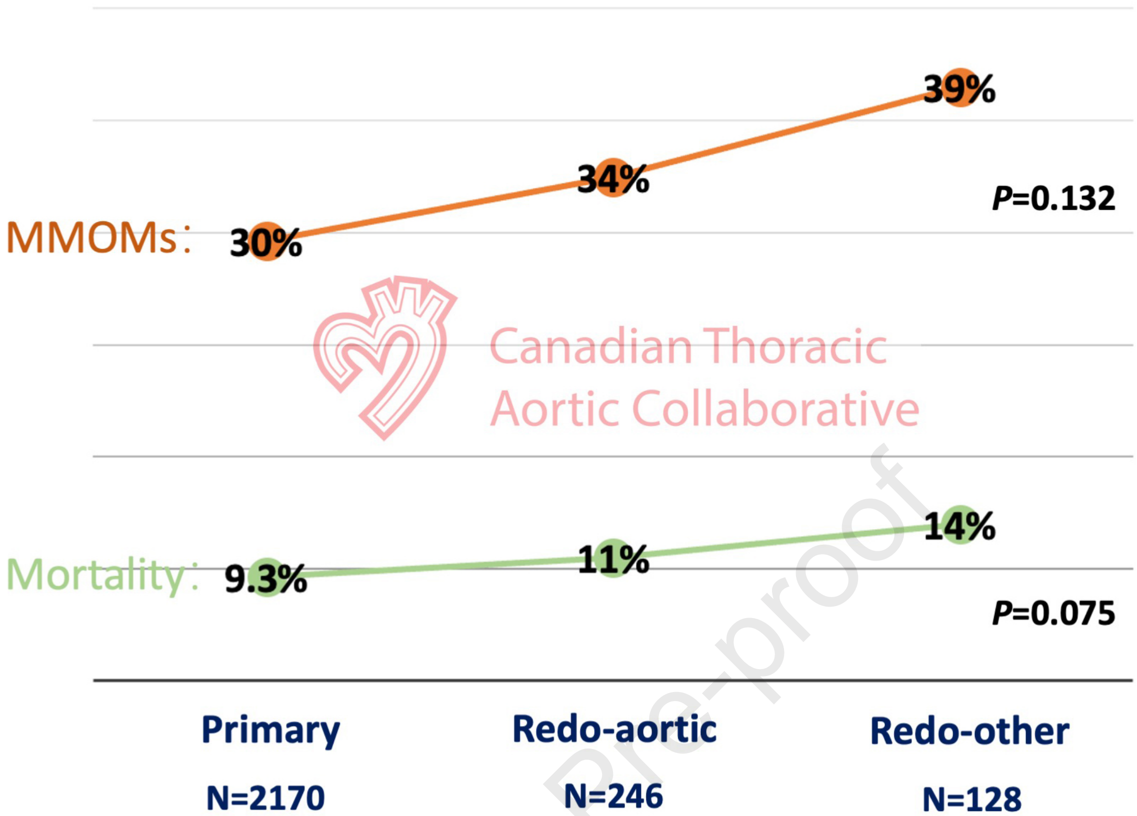
Independent predictors of mortality and MMOMs

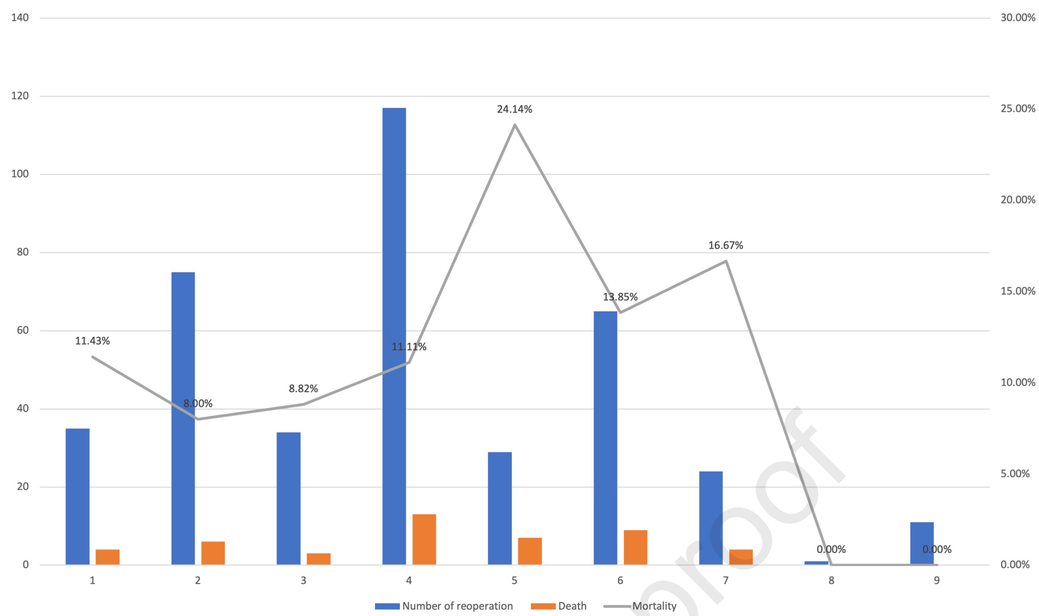
- Age over 65yrs
- Acute dissection or rupture
- Prolonged CPB time

Selected **aortic arch reoperations** can be performed safely in **experienced aortic centers** while further studies were needed for continuing optimization of surgical and patient management strategies.

JTCVS

@AATSHQ


39%
34%
P=0.132
MMOMs:
30%
Canadian Thoracic
Aortic Collaborative
14%
Mortality:
9.3%
11%
P=0.075
Primary
N=2170
Redo-aortic
N=246
Redo-other
N=128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80
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40
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20.00%
15.00%
10.00%
5.00%
0.00%
11.43%
8.00%
8.82%
11.11%
24.14%
13.85%
16.67%
0.00%
0.00%
1
2
3
4
5
6
7
8
9
Number of reoperation
Death
Mortality