Differential outcomes of open and clamp-on distal anastomosis techniques in acute type A aortic dissection

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ABSTRACT

Objectives: Open-distal anastomosis is the preferred technique over clamp-on technique for surgical repair of acute type A aortic dissection (ATAAD). The aim of this study was to define how outcomes of ATAAD were affected by the use of either technique.

Methods: Nordic Consortium for Acute Type A Aortic Dissection includes 8 academic cardiothoracic hospitals in 4 Nordic countries. The cohort consisted of 1134 patients, 153 clamp-on and 981 open-distal, from 2005 to 2014.

Results: Patients who underwent operation with the clamp-on were younger, more frequently had coronary artery disease, bicuspid aortic valve, hypotension/shock or syncope, and a greater PennClass than open-distal patients. Postoperative cerebral vascular accident occurred less frequently in clamp-on (14/153, 10%) compared with the open-distal group (190/981, 20%). Clamp-on had greater 30-day mortality (39/153, 25%) than the open-distal group (158/981, 16%), and 5-year survival was also worse in clamp-on ($61.8\% \pm 4.4\%$) compared with the open-distal group ($73.0\% \pm 1.6\%$). The open-distal technique was used more frequently in greater-volume hospitals but was not independently associated with 30-day mortality. Preoperative condition was an independent risk factor whereas hospital volume and later year of operation were beneficial in regard to short-term outcome. Open-distal was independently associated with improved mid-term survival.

Conclusions: Patients who underwent operation with the clamp-on were sicker on presentation and had worse short- and mid-term survival compared with the open-distal group. Patients in the open-distal group had greater rates of cerebrovascular complications. The results support the routine use of open-distal anastomosis as the primary operative strategy for ATAAD, although clamp-on can be performed successfully in select cases. (J Thorac Cardiovasc Surg 2019;157:1750-8)

Superior mid-term survival with open-distal anastomosis in acute type A aortic dissection.

Central Message

Open-distal anastomosis is the preferred technique to use for acute type A aortic dissection, but the clamp-on technique can be used successfully in selected cases.

Perspective

The strategy for distal anastomosis in acute type A aortic dissection includes open-distal with hypothermic circulatory arrest and, less commonly, anastomosis done with crossclamp in place. Open-distal was associated with better survival but greater rates of cerebrovascular events. This supports the routine use of open-distal technique, although clamp-on can be performed successfully in selective cases.

See Commentaries on pages 1759 and 1761.

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Abbreviations and Acronyms

ATAAD	= acute type A aortic dissection
CI	= confidence interval
CPB	= cardiopulmonary bypass
CVA	= cerebral vascular accident
HCA	= hypothermic circulatory arrest
HR	= hazard ratio
NORCAAD	= Nordic Consortium for Acute Type A Aortic Dissection
OR	= odds ratio

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Acute type A aortic dissection (ATAAD) is a rare condition, with high mortality and morbidity, where emergent surgical repair is the only proven treatment modality.¹⁻⁴ There is a general consensus that the distal anastomosis should be performed using an open-distal technique where the anastomosis suturing is performed under hypothermic circulatory arrest (HCA), without the application of an aortic cross-clamp, rather than leaving the aortic cross-clamp in place for the duration of the operation (clamp-on). The rationale for open-distal anastomosis includes better visualization of the dissected aorta in quiescent operative field, allowing more accurate suture placement, proper exclusion of the false lumen, as well as identification of the primary tear and longitudinal arch tears (Video 1).

The potential drawbacks, however, include longer operative times for cooling and rewarming as well as increased bleeding complications.⁵ In addition, the techniques required to do an open-distal anastomosis, such as HCA and cerebral perfusion strategy, are more complex and require greater experience and specific training. With the clamp-on technique, there is more residual dissected aorta left in place, which might compromise the integrity of the anastomosis. There is potential for greater rates of persistent false lumen patency as well as distal aneurysm formation requiring later reoperations.⁶⁻⁸

Few studies have compared the outcomes of clamp-on with open-distal anastomosis techniques in ATAAD. This is mostly due to the general adaptation of the open-distal technique, therefore not allowing for adequate number of patients to perform meaningful comparison with clamp-on technique. A study by David and colleagues⁹ 1999 was the first to suggest that open-distal anastomosis was associated

VIDEO 1. Example of a distal anastomosis technique for acute type A aortic dissection using moderate hypothermia and antegrade cerebral perfusion. Video available at: [https://www.jtcvs.org/article/S0022-5223\(18\)32521-2/fulltext](https://www.jtcvs.org/article/S0022-5223(18)32521-2/fulltext).

with lower hospital mortality, lower risk of stroke, more favorable long-term survival, and greater rate of false lumen thrombosis, and the study resulted in a paradigm change in how the distal anastomosis was performed in ATAAD. Interestingly, that study reported on only 163 patients, including 54 who underwent operation with the open-distal technique. Therefore, selection bias could have accounted for some of the reported beneficial effect of the open-distal technique. This is in line with later studies that showed no difference in outcome when comparing open-distal with closed-distal anastomosis; however, it should be stressed that most of these studies had insufficient power to detect any statistical difference (potential type II error).¹⁰⁻¹³

The Nordic Consortium for Acute Type A Aortic Dissection (NORCAAD) is a collaborative effort of 8 small- to medium-sized academic cardiothoracic centers in Denmark, Finland, Iceland, and Sweden. A total of 1159 patients operated on for ATAAD from 2005 to 2014 were included in the registry. We have recently reported improved short-term outcome correlating with later year of operation and increased number of operations performed in the NORCAAD cohort.¹⁴ Mid-term survival has improved in these centers, and it appears to be associated with the use of open-distal anastomosis techniques.¹⁵ A variety of operative techniques were used by surgeons participating in NORCAAD, of which the distal anastomosis was performed in 163 cases with the clamp-on technique, allowing for substantial number of cases to be analyzed for the purpose of this study. The aim of this study was to define the specific influence of distal anastomosis techniques on early mortality and postoperative complications as well as mid-term survival after ATAAD repair.

METHODS**Study Design**

Data were retrospectively collected for patients who underwent an operation for ATAAD from January 1, 2005, to December 31, 2014 at the 8 participating centers. All participating sites are tertiary cardiac surgery

referral centers. The study design and setup has been previously described in detail.¹⁶ The primary outcomes measures for the study were short-term mortality, mid-term survival, and distal reoperation rate. Short-term mortality included intraoperative mortality, defined as death in the operating room; 30-day mortality; and hospital mortality, defined as death during index hospital stay. Mid-term survival included all-cause mortality during the follow-up time of the study until December 31, 2014. The national identity registries in the Nordic countries allow for complete capture of survival status so patients are not lost to follow-up after hospital discharge. Distal reoperation was defined as any reoperation at or beyond the distal anastomosis occurring after the index ATAAD operation. This included pseudoaneurysm of distal anastomosis, critical dilatation of chronic type B dissection-related thoracoabdominal aneurysm, graft infection, and other indications. Patients were coded before inclusion into the database. Because individual patients were not identified, obtaining individual consent for the study was waived.

Surgical Procedures

The decision to operate for ATAAD and the specific techniques employed were at the discretion of the responsible surgeons at each center. Standard median sternotomy, cardiopulmonary bypass (CPB), and intermittent cardioplegic arrest were routinely used as described previously.¹⁶ Cannulation sites varied by center, patient, and surgeon. In cases in which a crossclamp was not used, resection and inspection of the aortic arch was performed under HCA, with or without the use of antegrade or retrograde cerebral perfusion. The method of ascending aorta or aortic arch replacement depended on the location of the intimal tear and the extent of dissection; a root replacement was performed when it involved the coronary ostia or aortic valve, or in the presence of an aortic root aneurysm. Operations that involved the aortic arch entailed reimplantation of any supra-aortic branch. The extent of aortic replacement was determined by the location of the distal anastomosis. Hemiarach and total arch replacement always included replacement of the ascending aorta. When required, the competence of the aortic valve was restored as feasible via subcommissural plication, commissural resuspension, or valvuloplasty. Concomitant procedures (eg, coronary artery bypass grafting) were performed when required.

Statistical Analysis

Continuous variables were expressed as mean $\pm$ standard deviation and categorical variables as percentages. Continuous variables were not normally distributed as determined by Shapiro–Wilk test; therefore, nonparametric the Mann–Whitney U test was used for continuous variables. χ^2 was used for categorical variables. The results of logistic regression for outcome measures are presented as odds ratios (OR) with 95% confidence intervals (CIs). Multivariable logistic regression with backward and forward elimination was performed for 30-day mortality using previously described independent variables,¹⁴ including age, chronic obstructive pulmonary disease, preoperative arrest, hypotension or shock, any malperfusion syndrome, PennClass, CPB time, total hospital volume, and year of surgery adding to the model open-distal anastomosis and proportional use of open-distal anastomosis for each hospital center.

Actuarial survival was estimated using the Kaplan–Meier method and is expressed as medians with 95% CI. Log-rank test was used in univariable analysis for survival and distal technique. Cox proportional hazard regression was used for univariable and multivariable analysis of independent predictors associated with mid-term survival and freedom from distal reoperation with backward and forward elimination in model selection, reported with hazard ratio (HR) and 95% CI. The proportionality assumption was tested using Schoenfeld residuals. Multivariable Cox for mid-term survival was conducted in the same fashion as previously described,¹⁵ using age, chronic renal disease, previous aortic operation, open-distal anastomosis, connective tissue disease in addition to center-specific total number of cases, and proportional use of open-distal anastomosis technique.

The fixed-effect model was used for both logistic and Cox regression since intracluster correlation coefficient was low (0.016–0.05) for all outcome measures tested. In multivariable modeling, cases with missing values were excluded from the analysis. From the original database of 1159 cases, we excluded 15 cases where values were missing for open-distal anastomosis, mid-term survival, hospital mortality, or 30-day mortality. An additional 10 cases were excluded, where hemiarach or total arch replacement was performed using complex perfusion techniques, without the use of HCA, resulting in total of 1134 cases. For all the variables used, there were 4.5% missing case values. Data were collected using Microsoft Excel (Microsoft, Redmond WA), and statistical calculation was performed using R.¹⁷

RESULTS

Throughout the study period, the mean use of open-distal anastomosis technique in the NORCAAD cohort was 86.5% (981/1134). Its use increased significantly throughout the study period, or from an annual rate of 73.2% (61/83) in 2005 to 91.8% (135/147) in 2014 (OR 1.12 for each consecutive year, 95% CI 1.05–1.19, $P < .001$).

Baseline Characteristics

There were 153 patients in the clamp-on group and 981 patients in the open-distal anastomosis group. The patients in the clamp-on group had greater prevalence of coronary artery disease and more often had a bicuspid aortic valve compared with patients in the open-distal anastomosis group (Table 1). On presentation to the hospital, patients in the clamp-on group more frequently had evidence of hypotension or shock and syncope, and their PennClass was of a greater grade than in the open-distal anastomosis group (Table 1). The clamp-on group more often had a root replacement, and greater rates of ascending aorta replacement, compared with the open-distal group. Primary tear was excised in majority of cases in both groups. CPB time was shorter, crossclamp time was longer, and lowest mean temperature greater, in the clamp-on compared to open-distal group (Table 2).

Short-Term Outcomes

Postoperative complications were more common in the open-distal group, including postoperative cerebral vascular accident (CVA), acute kidney injury, renal-replacement therapy, pneumonia, and new-onset atrial fibrillation (Table 3).

Short-term mortality, which included intraoperative, hospital, and 30-day mortality, was greater in the clamp-on group (Table 3). There was marked variability in the use of the 2 distal techniques between the 8 individual hospital centers (Table 4). Greater-volume centers were more likely to use open-distal anastomosis technique than lower-volume centers (OR 1.001 use of open-distal per 1 case increase in total hospital volume, 95% CI 1.001–1.002, $P < .001$). Independent predictors for 30-day mortality included age, chronic obstructive pulmonary disease, any malperfusion syndrome, PennClass C and B&C, and CPB

TABLE 1. Preoperative demographics and symptoms on presentation

	Total (N = 1134)	Clamp-on (n = 153)	Open-distal (n = 981)	P value	Missing cases
Age, y, mean (SD)	61.5 (12.2)	58.9 (15.4)	61.9 (11.6)	.094	0
Male	764 (67)	105 (69)	659 (67)	.792	0
HTN	583 (52)	68 (45)	515 (52)	.105	2
PVD	33 (3)	3 (2)	30 (3)	.625	13
Previous type B dissection	17 (2)	1 (1)	16 (2)	.572	13
Resternotomy	30 (3)	3 (2)	27 (3)	.783	190
DM	26 (2)	7 (5)	19 (2)	.081	5
Hyperlipidemia	135 (12)	18 (12)	117 (12)	.999	7
History of stroke	46 (4)	3 (2)	43 (4)	.231	3
History of TIA	17 (1)	1 (1)	16 (2)	.568	3
History of CKD	21 (2)	1 (1)	20 (2)	.388	3
COPD	69 (6)	12 (8)	57 (6)	.419	4
History of CAD	47 (4)	15 (10)	32 (3)	<.001	3
Active smoking	256 (24)	31 (23)	225 (24)	.823	64
History of TAA	109 (10)	13 (8)	96 (10)	.711	4
Marfan syndrome	48 (4)	8 (5)	40 (4)	.634	3
Bicuspid aortic valve	68 (6)	20 (13)	48 (5)	<.001	10
Sudden pain	959 (85)	126 (83)	833 (85)	.505	6
Hypotension or shock	243 (23)	57 (38)	186 (21)	<.001	85
Syncope	220 (20)	41 (29)	179 (19)	.008	34
Preoperative arrest	54 (5)	8 (5)	46 (5)	.937	3
Pericardial effusion	465 (42)	70 (46)	395 (41)	.298	23
Cardiac tamponade	186 (17)	25 (16)	161 (17)	.999	23
Any malperfusion	314 (28)	38 (25)	276 (28)	.423	7
Cardiac malperfusion	87 (9)	16 (11)	71 (8)	.287	129
Renal malperfusion	63 (6)	8 (6)	55 (6)	.901	128
Cerebral malperfusion	88 (9)	15 (11)	73 (8)	.503	127
DeBakey type 1	825 (73)	108 (71)	717 (73)	.799	6
PennClass				<.001	10
A, no ischemia	697 (62)	81 (54)	616 (63)		
B, localized	240 (21)	25 (17)	215 (22)		
C, generalized	122 (11)	27 (18)	95 (10)		
B&C, both	65 (6)	18 (12)	47 (5)		

Values are n (%) unless otherwise noted. *SD*, Standard deviation; *HTN*, hypertension; *PVD*, peripheral vascular disease; *DM*, diabetes mellitus; *TIA*, transient ischemic attack; *CKD*, chronic kidney disease; *COPD*, chronic obstructive pulmonary disease; *CAD*, coronary artery disease; *TAA*, thoracic aortic aneurysm.

time. Total hospital volume and later calendar year of surgery predicted lower 30-day mortality (Table 5). Use of open-distal technique and its proportional use in each center were not significant predictors for short-term mortality and were dropped out of final model during stepwise elimination. In subgroup analysis of open-distal patients, 30-day mortality was not dependent on cannulation site ($P = .423$) or HCA technique ($P = .499$). Postoperative CVA rates did not change during the study period

($P = .551$) and were not affected by cannulation site ($P = .117$) or HCA technique ($P = .912$).

Mid-Term Outcomes

Cumulative follow-up was 3496 patient years with mean follow-up of 3.1 year (standard deviation 2.9, range 0-10.2 years). On univariable Cox regression, mid-term survival was significantly better in the open-distal group compared with the clamp-on group (HR 0.64, 95% CI

TABLE 2. Operative data

	Total (N = 1134)	Clamp-on (n = 153)	Open-distal (n = 981)	P value	Missing cases
Arterial cannulation site				.005	10
Femoral artery	867 (77)	107 (72)	760 (78)		
Ascending aorta	107 (10)	25 (17)	82 (8)		
Subclavian artery	150 (13)	17 (11)	133 (14)		
Aortic root replaced	291 (26)	65 (43)	226 (23)	<.001	0
Distal surgery				<.001	23
Ascending aorta	807 (73)	146 (100)	661 (69)		
Hemiarch	244 (22)		244 (25)		
Total arch	60 (6)		60 (6)		
HCA technique*					17
HCA only			422 (44)		
SACP			284 (29)		
RCP			251 (26)		
SACP and RCP			7 (1)		
Primary tear excised	862 (93)	121 (95)	741 (93)	.409	210
Location of primary tear				.139	35
Aortic root	141 (13)	21 (14)	120 (13)		
Ascending aorta	664 (60)	95 (64)	569 (60)		
Aortic arch	115 (10)	6 (4)	115 (12)		
Descending aorta	12 (1)	2 (1)	10 (1)		
Unknown	161 (15)	24 (16)	137 (14)		
CPB time, min, mean (SD)	207.4 (78.5)	174.3 (75.5)	211.8 (77.9)	<.001	94
XC time, min, mean (SD)	105.2 (56.4)	112.0 (46.9)	104.3 (57.5)	.002	124
Temp, °C, mean (SD)	20.9 (4.8)	28.9 (5.7)	20.3 (4.1)	<.001	113
HCA time, min, mean (SD)		N/A	30.2 (18.0)		90*

Values are n (%) unless otherwise noted. HCA, Hypothermic circulatory arrest; SACP, selective antegrade cerebral perfusion; RCP, retrograde cerebral perfusion; CPB, cardiopulmonary bypass; SD, standard deviation; XC, crossclamp; N/A, not available. *Open-distal group.

0.48-0.85, $P = .002$, reference: clamp-on group), with 1-year survival of $80.6\% \pm 1.3\%$ vs $68.5\% \pm 3.8\%$; 2-year survival of $78.4 \pm 1.4\%$ vs $66.9 \pm 3.9\%$; and 5-year survival of $73.0\% \pm 1.6\%$ vs $61.8\% \pm 4.4\%$, for open-distal vs clamp-on, respectively (Figure 1). Using multivariable Cox regression, independent predictors of medium-term mortality in the final model were age, chronic renal disease, and previous aortic aneurysm surgery. Use of open-distal anastomosis was protective (adjusted HR 0.36, 95% CI 0.15-0.82, $P = .015$, reference: clamp-on group) whereas proportional use open-distal was not a significant predictor of mid-term mortality (Table 6). Freedom from distal reoperation was not statistically significantly different between the 2 groups, $95.9\% \pm 1.0\%$ versus $92.8 \pm 3.2\%$, for open-distal versus clamp-on, respectively, at 5 years (HR 0.60, 95% CI 0.25-1.48, $P = .269$, reference: clamp-on group).

DISCUSSION

The primary findings of this study are that the use of open-distal anastomosis compared with the clamp-on technique is associated with better short-term and mid-term

survival; however, it also is associated with greater rates of postoperative complications, including CVA, acute kidney injury, pneumonia, and postoperative atrial fibrillation, in patients operated for ATAAD. Use of open-distal technique increased over the study period and greater-volume hospitals used open-distal technique more commonly than lower-volume hospitals.

Studying the effects of specific changes in operative management of a complex condition such as ATAAD is difficult because multiple uncontrollable factors and biases can affect the outcome. It is particularly challenging to obtain useful contemporary data on the subject of distal anastomosis techniques, since the predominant distal operative technique in large aortic centers that have contributed to the literature of ATAAD was open-distal anastomosis. In the NORCAAD cohort, we had access to a relatively large number of patients operated on with the clamp-on technique, which allowed for the analysis presented here. Patients undergoing operation via the clamp-on technique were sicker and presented to the hospital in more critical condition, with greater rates of hypotension/shock and syncope as well as greater PennClass. Perfusion and cerebral

TABLE 3. Postoperative complications and outcomes

	Total (N = 1134)	Clamp-on (n = 153)	Open-distal (n = 981)	P value	Missing cases
Any complication	843 (75)	103 (69)	740 (76)	.103	8
Reoperation for bleeding	222 (20)	25 (17)	197 (21)	.376	28
Perioperative MI	69 (6)	10 (7)	59 (6)	.891	30
Postoperative CVA	204 (18)	14 (10)	190 (20)	.005	26
Coma	102 (10)	12 (9)	90 (10)	.798	139
DSWI	22 (2)	1 (1)	21 (2)	.377	28
Sepsis	110 (10)	10 (7)	100 (10)	.224	27
Acute kidney injury	397 (37)	40 (28)	357 (39)	.019	80
Renal replacement	128 (12)	9 (6)	119 (12)	.042	31
Ventilator >48 h	345 (32)	40 (28)	305 (32)	.615	41
Tracheostomy	94 (9)	6 (4)	88 (9)	.061	32
Pneumonia	180 (16)	13 (9)	167 (17)	.013	32
Postop tamponade	154 (14)	20 (14)	134 (14)	.99	28
GI complications	55 (6)	6 (4)	49 (6)	.793	147
Multisystem organ failure	58 (6)	6 (4)	52 (6)	.684	153
Postoperative atrial fibrillation	428 (39)	42 (29)	386 (41)	.010	39
PRBC, units, mean (SD)	9.3 (12.3)	8.8 (10.9)	9.4 (12.5)	.486	120
PLT, units, mean (SD)	4.4 (6.0)	5.1 (5.9)	4.2 (6.0)	.357	109
FFP, units, mean (SD)	8.9 (15.9)	8.1 (13.3)	9.0 (16.3)	.216	120
Intraoperative mortality	71 (6)	20 (13)	51 (5)	<.001	0
30-d mortality	197 (17)	39 (25)	158 (16)	.006	0
Hospital mortality	181 (16)	37 (24)	144 (15)	.004	0
Distal reoperation	30 (3)	6 (4)	24 (2)	.431	0

Values are n (%) unless otherwise noted. *MI*, Myocardial infarction; *CVA*, cerebral vascular accident; *DSWI*, deep sternal wound infection; *GI*, gastrointestinal; *PRBC*, packed red blood cells; *SD*, standard deviation; *PLT*, platelets; *FFP*, fresh-frozen plasma.

protection techniques were variable in the open-distal but not in the clamp-on group and therefore the open-distal group was more heterogeneous. These 2 groups are therefore not directly comparable and that should be kept in mind in the ensuing interpretation of our outcomes.

We considered performing propensity score matching in attempt to control for those differences but judged that

treatment assignment could not be ignored by factors such as patient condition, location of tear, time to diagnosis and surgery, complexity of arch dissection, as well as experience of the operating surgeon. The use of open-distal technique increased in later years of the study, and there was a significant difference in the use of each technique between hospitals, where greater-volume centers were more likely to

TABLE 4. Distal anastomosis use and short-term mortality by hospital center

	Cases		30-d mortality	
	Clamp-on	Open-distal	Clamp-on	Open-distal
Hospital 1	172 (15)	5 (3)	167 (97)	23 (13)
Hospital 2	59 (5)	22 (37)	37 (63)	20 (34)
Hospital 3	54 (5)	41 (76)	13 (24)	21 (39)
Hospital 4	29 (3)	18 (62)	11 (38)	7 (24)
Hospital 5	259 (23)	9 (3)	250 (97)	32 (12)
Hospital 6	222 (20)	22 (10)	200 (90)	32 (14)
Hospital 7	100 (9)	20 (20)	80 (80)	22 (22)
Hospital 8	239 (21)	16 (7)	223 (93)	40 (20)

Values are n (%).

TABLE 5. 30-day mortality – multivariable logistic regression (n = 957)

	OR (95% CI)	P value
Age	1.02 (1.00-1.04)	.012
Chronic obstructive lung disease	2.06 (1.04-3.94)	.033
Preoperative arrest	1.81 (0.87-3.65)	.103
Hypotension/shock	0.63 (0.36-1.07)	.092
Any malperfusion syndrome	2.23 (1.23-4.09)	.009
PennClass B (localized ischemia)	1.20 (0.60-2.36)	.602
PennClass C (general ischemia)	4.08 (2.16-7.74)	<.001
PennClass B&C (both)	4.21 (1.78-9.93)	.001
CPB time, minutes	1.01 (1.00-1.01)	<.001
Hospital volume, total	0.99 (0.99-0.99)	<.001
Year of surgery*	0.88 (0.82-0.94)	<.001

OR, Odds ratio; age as continuous variable; CI, confidence interval; CPB, cardiopulmonary bypass time. *Each calendar year from 2005 to 2014.

use open-distal anastomosis techniques, indicating that adaptation of open-distal and/or increased experience played a role in selection of distal operative technique. The clamp-on technique was generally, but not exclusively, used in lower-volume hospitals (Table 4) for sick patients with proximal aortic disease, where primary tear could be excised, indicating that it was either used as specific operative strategy or based on operative experience of the surgeon.

As would be expected, based on the presence of comorbidities and worse clinical condition on presentation, we observed a greater hospital, 30-day and intraoperative mortality in the clamp-on group. Short-term mortality was primarily determined by preoperative patient condition, CPB

TABLE 6. Mid-term mortality – multivariable Cox proportional hazard analysis (n = 937)

	HR (95% CI)	P value
Age	1.06 (1.04-1.08)	<.001
Chronic renal disease	2.93 (1.28-6.72)	.011
Previous aneurysm surgery	3.93 (1.97-7.81)	<.001
Open-distal anastomosis	0.36 (0.15-0.82)	.015
Proportional use of open-distal	3.17 (0.83-12.09)	.091

Likelihood ratio $\chi^2 = 61$. Schoenfeld residuals: $P = .222$. HR, Hazard ratio; age as continuous variable; CI, confidence interval.

time, hospital volume, and later calendar year of operation whereas the use of open anastomosis did not have significant effects in our multivariable regression model. Patient selection and preoperative factors play an important role in short-term surgical outcome after repair of ATAAD, which is well outlined by the PennClass stratification system.¹⁸⁻²⁰ PennClass was significantly greater in the clamp-on group.

Certainly, a strategy to do a quicker, less complex operation in compromised patients can be valid in some circumstances. The notion that clamp-on technique could decrease bleeding complications is not supported by our result since the use of blood products and rate of reoperation for bleeding did not differ between groups. Unexpectedly, however, despite the patients being in better clinical condition on presentation, the rates of complications were greater in the open-distal group. It should be noted that the results of short-term outcome other than mortality are descriptive. Some of the difference observed could be explained by greater rates of intraoperative and earlier death in the clamp-group, thereby excluding specific complications before death. When accounting for rate of postoperative complications, intraoperative mortality cases were excluded, thereby reducing the denominator for complications rate, and can at least in part explain the difference observed.

Especially concerning was the greater rates of CVA in the open-distal group, which could indicate that the use of HCA was associated with worse neurologic outcome.²¹ We did not appreciate any significant effects of cannulation, HCA technique or later year of operation, on postoperative CVA in the open-distal group. The current version of NORCAAD is not granular enough to differentiate between different cerebral protection methods, hypothermic arrest protocols related to flow rates and pressure, as well as cerebral monitoring adjuncts, to determine whether that could account for this outcome. Overall, the rate of neurologic complications was quite high in the NORCAAD cohort. It is, however, similar to other European studies, which generally report greater rates of stroke than studies from the United States.^{19,22-25}

FIGURE 1. Actuarial survival of patients undergoing repair for acute type A aortic dissection, using either cross clamp-on or open-distal anastomosis technique. Shaded area shows 95% confidence interval. Lower panel shows number at risk for each group. Time in years. Log-rank $P = .002$.

We observed more favorable mid-term survival in the open-distal group, which is in agreement with a previous report from our group based on the same study population.¹⁵ It should be noted that the survival benefit appears primarily in the first few months after surgery, after which the curves are near parallel. Use of open-distal anastomosis as well as more extensive arch repair has been proposed to improve the freedom from distal reoperations.^{7,26} In this study, there was no difference in rates of distal reoperation between groups, although there was a trend toward lower rates of reoperation in the open-distal group. The rates were quite low compared with other studies, but our follow-up is quite short and probably of insufficient length to allow for demonstration of difference in aneurysm changes of the residual dissected aorta.²² As has been described in a recent publication from NORCAAD, the extent of primary repair did not influence the rates of distal or proximal reoperations.²⁷

Limitations of this study include weaknesses that are inherent to all retrospective studies, such as incomplete datasets, sampling error, unmeasured or missing potential confounders, and treatment selection biases. There was significant heterogeneity within the open-distal group, such as degree of hypothermia as well as the use and method of cerebral perfusion. In addition, the current version of the NORCAAD database does not contain sufficient details on perfusion techniques, such as flow rates, pressures and cerebral monitoring techniques, or surgeon-specific data. The strength of the NORCAAD include the uniform health care systems in the Nordic countries with relatively stable homogeneous populations of which follow-up is nearly complete through centralized national identity registries. NORCAAD contains data from low- to medium-volume academic cardiac surgery hospitals and may therefore better reflect real-world experience and outcomes of ATAAD.

In conclusion, patients undergoing operation for ATAAD with the clamp-on technique were sicker and had worse short and mid-term survival compared with patients operated on with the open-distal technique. Patients in open-distal group had greater rates of complications, including CVA. These results should be interpreted cautiously, taking into account that the outcomes are inherently affected by selection bias, since the clamp-on group had relatively sicker patients. Lower-volume hospitals used the open-distal anastomosis technique less commonly, which may reflect operative experience that does affect outcomes.¹⁴ The results should also not be generalized for all patients undergoing operation for ATAAD, since preoperative condition of the patient, hospital volume, and later year of operation were the primary determinant of short-term outcome but not distal operative technique. Use of open-distal is associated with improved mid-term survival, but no significant difference was noted in freedom from distal reoperations, although the length of follow-up is short. The results

support the routine use of open-distal anastomosis as the primary operative strategy for ATAAD. Treatment of ATAAD should be tailored for each patient, with the primary aim of saving patient's life. Patients with evidence of arch malperfusion, complex intimal tear, as well as younger patients with or without connective tissues disease are probably better served with open-distal anastomosis. In selected circumstances, such as in very sick patients or at lower-volume hospitals where surgeons might have less experience, the clamp-on technique can be used with acceptable results.

Conflict of Interest Statement

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