Outcomes of acute type A aortic dissection operations performed by early-career cardiovascular surgeons

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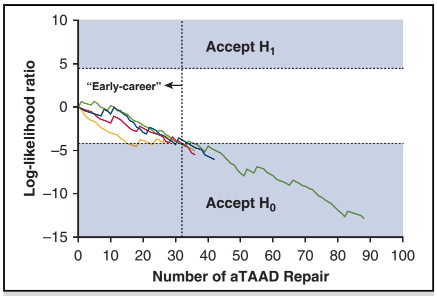
ABSTRACT

Objective: Surgical outcomes of acute type A aortic dissection have been recognized to be associated with the surgical volume of individual hospitals and surgeons. In this study, we aimed to investigate the results and learning curves of acute type A aortic dissection operations performed by early-career cardiovascular surgeons.

Methods: A total of 248 surgical repairs of acute type A aortic dissections were conducted at a tertiary medical center between 2010 and 2018. By using the cumulative sum test, cardiovascular surgeons in their early career were identified, and their performances were assessed. The outcomes of patients who were operated by early-career cardiovascular surgeons were compared with those by experienced or senior surgeons.

Results: During the study period, 202 (81.5%) of the 248 acute type A aortic dissection operations were performed primarily by the 4 newly appointed attending cardiovascular surgeons. In cumulative sum curves, all surgeons exhibited a steady performance throughout the study period. On the basis of our institutional result of acute type A aortic dissection operation, early career was defined as performing fewer than 32 acute type A aortic dissection operations. The 30-day mortality rates of acute type A aortic dissection operations performed by early-career surgeons were equivalent to those performed by experienced/senior surgeons (10.9% vs 12.5%, $P = .844$). There was also no difference in mid-term overall survival and aortic event-free survival between the 2 groups ($P = .638$ and $P = .574$, respectively).

Conclusions: In a center with a well-established program, cardiovascular surgeons could accomplish surgical repair of acute type A aortic dissection with adequate early- and mid-term results from the initiation of their careers. (JTCVS Open 2021;6:1-10)



Performance curves of aTAAD operations performed by 4 junior cardiovascular surgeons.

CENTRAL MESSAGE

Surgical repair of acute type A aortic dissection could be performed independently and safely by cardiovascular surgeons trained in well-established programs early in their career.

PERSPECTIVE

The outcome of high-risk operations such as surgical repair of acute type A aortic dissection should be inspected prudently, especially in cases performed by surgeons at the beginning of their careers. Compatible outcomes should be anticipated and encouraged for every aortic surgeon regardless of the stage of their career.

See Commentaries on pages 11 and 13.

Acute type A aortic dissection (aTAAD) is a high-risk surgical emergency, and its surgical outcomes have improved significantly in recent years.[1,2] Excellent results have been reported by some experienced multidisciplinary referral centers, and both surgeon volume and institutional volume have been shown to be important detrimental factors for the outcome.[3-6] Whether patients with aTAAD should be routinely transferred to experienced centers is controversial, and opinion on this varies across the world.[3-6] The referral policy might depend on the cardiovascular surgical capacity within a specific region as well as a country's overall health care system.[4,6] In

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Abbreviations and Acronyms

aTAAD = acute type A aortic dissection
CUSUM = cumulative sum
IRAD = International Registry of Acute Aortic Dissection
OR = odds ratio
SACP = selective antegrade cerebral perfusion
SPRT = sequential probability ratio test

Taiwan, there is no stipulation regarding where or by whom aTAAD operations should be performed, and there is no aortic supercenter. In most situations, surgical repairs for aTAAD cases are performed by general cardiovascular surgeons taking the emergency call, including less-experienced surgeons in their early career. Ideally, in an institution with a well-established aortic program, the seniority of the surgeon should not be a factor affecting the outcome of aTAAD operations. Meanwhile, the performance of early-career cardiovascular surgeons when managing this lethal surgical emergency must be monitored continuously. In this study, we aimed to analyze the learning curves of aTAAD operations at the initiation of clinical practice of cardiovascular surgeons using cumulative sum (CUSUM) methods, and to compare the surgical outcomes of aTAAD repair performed by early-career surgeons with those of experienced or senior surgeons.

METHODS

Study Population

We retrospectively reviewed the charts of patients who underwent surgery for aTAAD between January 2010 and December 2018. During the study period, all aTAAD operations were performed exclusively by 6 attending cardiovascular surgeons. Two of them were senior surgeons who were attending surgeons for more than 10 years before 2010. The other 4 junior surgeons were cardiovascular fellows who had completed training courses at our institution and were certificated recently. Only after 2010 did the junior attendees begin receiving emergency calls for surgical consultation of aortic dissections independently (successively since 2010, 2012, 2013, and 2016).

The primary safety outcomes of interest were 30-day mortality in the short term and overall and aortic event-free survival rates in the long term. The secondary outcomes included duration of cardiopulmonary bypass, aortic crossclamp and selective antegrade cerebral perfusion (SACP) times, amounts of postoperative blood transfusion, major complications (re-exploration for bleeding, newly developed dialysis, deep sternal wound infection, prolonged mechanical ventilation or requiring tracheostomy, and permanent stroke), intensive care unit length of stay, and length of hospital stay. The institutional review board of the National Cheng Kung University Hospital (IRB No. A-ER-110-055) approved this retrospective study and waived the requirement for patient informed consent.

Operative Technique

The operative techniques of aTAAD repair in our institute have been standardized as previously described.[7,8] Right axillary artery cannulation for cardiopulmonary bypass was the most commonly used method in aTAAD operations, with the exception of cases with significant hemodynamic instability caused by cardiac tamponade, severe aortic regurgitation, or aortic rupture, which were managed by emergency cardiopulmonary bypass establishment through femoral access. During distal aorta or arch branch reconstruction, SACP as a brain-protection strategy under moderate (25°C) hypothermic circulatory arrest was used. Alpha-stat acid–base management was used throughout the cardiopulmonary bypass period. No patient received retrograde cerebral perfusion during hypothermic circulatory arrest. The modified sandwich technique was used for both proximal and distal aortic reconstruction, unless root replacement was performed. To obliterate the false lumen, a tailored Teflon patch was placed into the dissected space between the media and the adventitia, followed by external reinforcement using a Teflon strip surrounding the entire circle of the aortic anastomosis site.

The extent of aortic reconstruction was classified depending on whether the aortic arch or aortic root was replaced. Aortic arch replacement was defined as the reconstruction extending to the greater curvature of the aortic arch along with one or more brachiocephalic arteries replaced, with or without distal aortic stenting (frozen elephant trunk technique). Aortic reconstructions limited to the lesser curvature of the aortic arch were referred to as "hemiarch replacement" and were not included in the arch replacement group. Aortic root replacement was defined as the need for the entire sinus of Valsalva to be replaced, including the Bentall procedure and its modifications, valve-sparing root replacements, and the Ross procedure, but not including the sinus of Valsalva repair.

CUSUM Analysis

Risk-adjusted CUSUM analysis was performed to assess the primary safety outcome and learning curve of surgeons as previously described.[9-11] The predictors of mortality were retrieved and modified from the latest International Registry of Acute Aortic Dissection (IRAD) data and incorporated into the CUSUM curve reconstruction,[12] by means of the risk-adjusted cumulative log-likelihood ratio (known as the risk-adjusted sequential probability ratio test [SPRT] chart).[11]

The acceptable unadjusted outcome (p_0) was set at an early mortality rate of 16.8% after aTAAD repair on the basis of the latest results from the IRAD database.[12] The inferior outcome (p_1) was set as double (odds ratio [OR] = 2.0) in the odds of mortality compared with p_0. Type I (α) and II (β) errors were both set at 0.05. Lower and upper boundary lines (h_0 and h_1, respectively) were constructed as previously described to test the null hypothesis (H_0: cumulative outcome = p_0) against the alternative hypothesis (H_1: cumulative outcome = p_1), where

$$h_0 = -\frac{\ln\left(\frac{1-\alpha}{\beta}\right)}{\ln(OR)}$$

and

$$h_1 = \frac{\ln\left(\frac{1-\beta}{\alpha}\right)}{\ln(OR)}$$

To obtain a risk-adjusted p_0 for each aTAAD case in this study, 3 well-recognized preoperative predictors were incorporated, including age >65 years, systolic blood pressure ≤80 mm Hg, and the presence of any pulse defect. The corresponsive ORs for the aforementioned predictors were 2.39, 1.9, and 1.73, respectively.[12] Intraoperative and postoperative predictors of mortality, such as postoperative mesenteric ischemia and myocardial infarction, were not included in the risk-adjustment model. For X_i denoting the outcome for procedure i, with $X_i = 1$ if a failure (30-day mortality in this study) occurred and $X_i = 0$ if it did not, we could obtain the graph of risk-adjusted cumulative log-likelihood ratio T_i, where

$$T_i = T_{(i-1)} + (X_i - S_i) = \sum_{j=1}^{i} (X_j - S_j),\ with\ T_0 = 0$$

where

$$S_i = \frac{\ln\left(\frac{1-P_{0i}}{1-P_{1i}}\right)}{\ln(OR)}$$

Defining "Early Career" of the Junior Surgeons

We considered that junior surgeons could continuously gain experience with a greater number of aTAAD operations performed. Thus, we defined the "early-career" period as performing less than a specific number of aTAAD operations, by using a procedure- and institution-specific estimation of the SPRT chart. As the concept of the SPRT chart described in previous studies,[9-11] when the lower boundary line (h_0) was crossed by the cumulative outcome curve (T_i), the null hypothesis was accepted, which indicated that an acceptable performance was achieved. Thus, we can define this number i by solving the equation

$$h_0 = T_i$$

using an institutional specific SPRT curve based on the institutional average results by graphing

$$T_i = \sum_{j=1}^{i} (X_j - S_j) = i \times \left(\overline{X} - \overline{S}\right)$$

For instance, in a hospital with an average early mortality rate ($\overline{X}$) of 16.8% equal to the latest IRAD result, along with average patient risks, we have

$$\overline{S} = \frac{\ln\left(\frac{1-P_0}{1-P_1}\right)}{\ln(OR)} \cong 0.224$$

By solving the above equation $h_0 = T_i$, we can obtain $i \cong 75.8$ when the SPRT curve crosses the lower boundary line. That is, we could define surgeons as being in their "early career" in that hospital before performing 75 consecutive aTAAD operations.

Statistical Analysis

After defining the early-career cardiovascular surgeons in our institute, we further compared the operative variables of aTAAD operations performed by surgeons with different experiences. Categorical variables were evaluated using the χ^2 or the Fisher exact tests, and numerical variables were evaluated using the Student t test and the Mann–Whitney U test. The measures of effect size among each variable were phi coefficient (φ), Cohen's d, and eta squared (η^2), respectively. The Kaplan–Meier survival curve and log-rank test were used to evaluate the estimated overall survival and aortic event-free survival during follow-up. Statistical analyses were performed using PASW Statistics for Windows, version 18.0 (SPSS, Inc, Chicago, Ill).

RESULTS

A total of 248 patients with aTAAD underwent surgical repair during the study period, in which 46 (18.5%) operations were performed by 1 of the 2 senior surgeons and 202 (81.5%) were performed by 1 of the 4 junior cardiovascular surgeons. The average surgical volume of aTAAD repair by the four junior surgeons was 13.04 ± 4.62 cases per year. In the SPRT curves for the 4 junior surgeons, none of the surgeons' curves crossed the upper boundary line to detect an inappropriate outcome where the OR of early mortality was twice the IRAD result. In contrast, all curves crossed the lower boundary line within the study period which indicated an adequate outcome, with an average run length of 27.8 ± 7.9 cases (Figure 1).

The overall 30-day mortality rate of the entire study group was 11.7% (29/248) during the study period. On the basis of the parameters defined in the Methods section, we obtained our institutional average risk adjusted $p_0 \cong 18.9\%$ and average risk adjusted $\overline{S} \cong 0.249$ (Table 1). To obtain our institutional specific number of aTAAD operations to define "early-career" period of the junior surgeons, we solved the equation $h_0 = T_i$. We have

$$h_0 = -\frac{\ln\left(\frac{1-\alpha}{\beta}\right)}{\ln(OR)} = -\frac{\ln\left(\frac{0.95}{0.05}\right)}{\ln(2)} \cong -4.25$$

and

$$T_i = \sum_{j=1}^{i} (X_j - S_j) = i \times \left(\overline{X} - \overline{S}\right) \cong i \times (-0.132)$$

we got $i \cong 32.1$. Thus, we determined that these 4 junior surgeons were in their "early career" in this study before performing 32 consecutive cases of aTAAD operations (Table 1 and Figure 2).

All 4 junior surgeons performed more than 32 aTAAD operations during the study period. Therefore, there were 32 × 4 = 128 aTAAD operations performed by the early-career surgeon group, accounting for 51.6% of all cases during the study period. The remaining 120 aTAAD

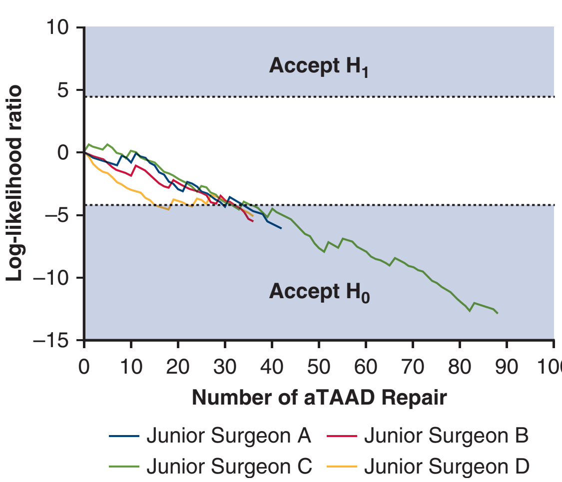

FIGURE 1. Risk-adjusted cumulative sum analysis using the cumulative log-likelihood ratio (risk-adjusted sequential probability ratio test) chart with an odds ratio = 2.0 for 4 newly appointed cardiovascular surgeons during the study period. *aTAAD*, Acute type A aortic dissection.

TABLE 1. Parameters of institute-specific estimation of risk-adjusted SPRT curves to define "early-career" cardiovascular surgeon performing an aTAAD operation

	$\overline{X}$	Risk-adjusted p_0	$\overline{S}$	i
NCKUH	11.7%	18.9%	0.249	32.1
Institute X	16.8%	16.8%	0.224	75.8

NCKUH, National Cheng Kung University Hospital; *Institute X*, hypothetic institute with average outcome ($\overline{X}$ = 16.8%) and risks (risk-adjusted p_0 = unadjusted p_0 = 16.8%) equal to latest IRAD results.

operations, which were performed either in the later career of the 4 junior surgeons or by the 2 senior surgeons, were defined as the experienced/senior surgeon group for comparison. The number of annual aTAAD operations stratified by 2 groups is illustrated in Figure 3. There was no significant difference in the patients' baseline characteristics between the 2 groups, as shown in Table 2.

Operative details and postoperative outcomes of both groups are shown in Table 3. Notably, only 7 (5.5%) aTAAD operations performed by the 4 early-career surgeons were assisted by other experienced/senior surgeons. The proportions of different aortic reconstructive and other associated procedures did not differ between the groups. The early-career surgeons group had a longer SACP time compared with the experienced/senior surgeon group (median [interquartile range], 53.5 [45-77.25] minutes vs 48 [34-67.75] minutes P = .038), although the effect size was small (η^2 = 0.017). The cardiopulmonary bypass time, aortic crossclamp time, and other outcome variables were not different between the 2 groups. Both early-career and experienced/senior surgeons achieved acceptable 30-day survival rates (89.1% vs 87.5%, P = .844, φ = 0.024), and there was no significant difference in the incidence of major postoperative complications (37.5% vs 40.0%, P = .698, φ = –0.026).

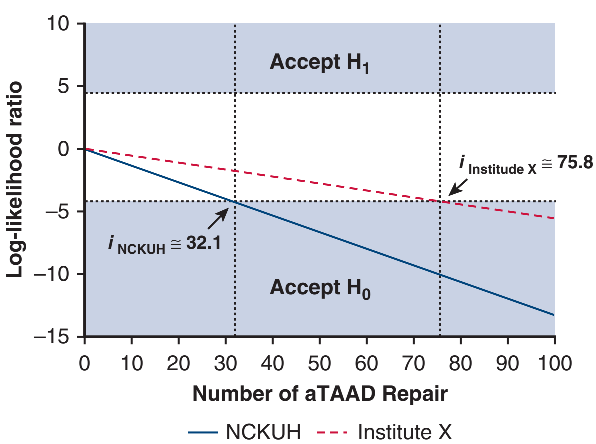

FIGURE 2. Institutional outcome-based estimation of risk-adjusted SPRT curves to define "early-career" surgeons. When the SPRT curve (T_i) cross the lower boundary line (h_0), we get the number i, and we define that surgeons are in their "early-career" period when performing less than i consecutive aTAAD operations. *Solid line*: estimated SPRT curve of our institute (NCKUH); *dash line*: estimated SPRT curve of a hypothetical institute with average outcome and risks based on IRAD results (*Institute X*). *NCKUH*, National Cheng Kung University Hospital; *aTAAD*, acute type A aortic dissection.

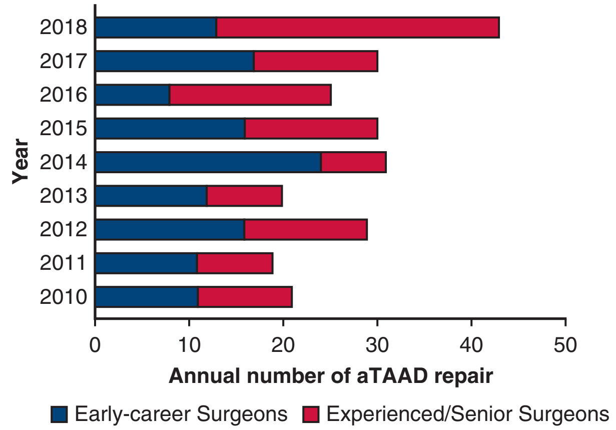

FIGURE 3. Case numbers of aTAAD operations performed by early-career surgeons or experienced/senior surgeons according to year. *aTAAD*, Acute type A aortic dissection.

In subgroup analyses for those with preoperative predictors of poor outcomes (age >65 years, hemodynamic instability, and presence of any malperfusion syndrome), the short-term outcomes of the early-career surgeon group were still noninferior to those of the experienced/senior surgeon group (Tables E1, E2, and E3). By contrast, for patients ≤65 years of age with stable hemodynamics and no preoperative malperfusion, both groups had no 30-day mortality, and there was also no difference in the incidence of major postoperative complications (12.5% vs 12.1%, P > .999, φ = 0.006) (Table E4).

In the Kaplan–Meier curves, both groups demonstrated compatible mid-term overall and aortic event-free survivals (Figure 4, *A* and *B*). The estimated 5-year aortic event-free survival rates in the early-career surgeons and experienced/senior surgeon groups were 79.1 (95% confidence interval, 70.8%-85.3%) and 77.3 (95% confidence interval, 68.4%-84.0%), respectively.

DISCUSSION

Several previous studies had shown that surgical outcome was better for aTAAD operations performed in high volume institutes or by high volume surgeons.[3-6] Even in experienced aortic referral centers, surgeons with less annually operated aTAAD cases were still associated with both worse short-term and mid-term outcomes.[6] In this study, however, we demonstrated that surgical repair of aTAAD could be performed by early-career cardiovascular surgeons with good results. We attribute this finding to the comprehensive cardiovascular surgical training program in

TABLE 2. Characteristics and clinical presentations of patients undergoing aTAAD surgical repair from January 2010 to December 2018 (n = 248)

	Early-career surgeons (n = 128)	Experienced/senior surgeons (n = 120)	*P* value	Effect size
Age, y	60.55 ± 12.69	61.13 ± 13.41	.723	−0.045
Male sex	84 (65.6)	78 (65.0)	>.999	0.007
Hematocrit, %	38.33 ± 6.88	37.71 ± 6.30	.459	0.094
LVEF, %	66.20 ± 8.29	66.03 ± 12.80	.961	0.016
Diabetes mellitus	12 (9.4)	12 (8.3)	.826	0.018
Chronic kidney disease	30 (26.1)	28 (29.2)	.645	−0.034
Dialysis	4 (4.3)	3 (2.7)	.703	0.046
Chronic lung disease	6 (4.7)	1 (0.8)	.121	0.116
Peripheral arterial disease	4 (3.1)	4 (3.3)	>.999	−0.006
Redo operation	3 (3.3)	3 (2.7)	>.999	0.019
Hemodynamic instability	43 (33.6)	40 (33.3)	>.999	0.003
Cardiac tamponade	29 (22.7)	29 (24.2)	.881	−0.018
CPCR	8 (6.3)	13 (10.8)	.255	−0.082
Malperfusion syndrome	40 (31.3)	40 (33.3)	.786	−0.022
Myocardial infarction	12 (9.4)	6 (6.7)	.490	0.050
Cerebral malperfusion	19 (14.8)	18 (15.0)	>.999	−0.002
Extremity malperfusion	20 (15.6)	20 (16.7)	.864	−0.014
Mesenteric malperfusion	4 (3.1)	6 (5.0)	.529	−0.048

Data are presented as mean ± standard deviation or n (%). Effect sizes are presented as phi coefficient (φ) among categorical variables and Cohen's d based on differences between means of numerical variables. *LVEF*, Left ventricular ejection fraction; *CPCR*, cardiopulmonary cerebral resuscitation.

our institute. In Taiwan, we do not adopt an integrated cardiothoracic or cardiovascular surgical residency training program. All cardiovascular surgeons are eligible to appear in the board examination after being a board-certified general surgeon (after minimum 4 years of general surgery residency training) and a minimum of 2 years of cardiovascular surgery subspecialty training. The National Cheng Kung University Hospital is a university hospital located

TABLE 3. Procedural and outcome variables of aTAAD surgical repair from January 2010 to December 2018 (n = 248)

	Early-career surgeons (n = 128)	Experienced/senior surgeons (n = 120)	*P* value	Effect size
Aortic root replacement	30 (23.4)	33 (27.5)	.470	−0.047
Aortic arch replacement	52 (40.6)	59 (49.2)	.202	−0.086
Concomitant CABG	7 (5.5)	9 (7.5)	.609	−0.041
Hybrid procedure	7 (5.5)	11 (9.2)	.330	−0.071
Cardiopulmonary bypass time, min	252 (203-325)	259 (218-337.75)	.426	0.003
Aortic crossclamp time, min	150 (123-213)	159 (110.5-214.25)	.644	0.001
SACP time, min	53.5 (45-77.25)	48 (34-67.75)	.038	0.017
ECMO	14 (10.9)	13 (10.8)	>.999	0.002
Re-exploration for bleeding	14 (10.9)	15 (12.5)	.844	−0.024
DSWI	4 (3.1)	7 (5.8)	.364	−0.066
Acute kidney injury	36 (28.1)	37 (30.8)	.677	−0.030
Newly developed dialysis	22 (17.2)	18 (15.0)	.730	0.030
Respiratory failure*	20 (15.6)	17 (14.2)	.859	0.020
Permanent stroke	27 (21.1)	25 (20.8)	>.999	0.003
ICU stay, d	5 (3-11)	6 (3-9.75)	.926	<0.001
Hospital stay, d	15 (11-29.75)	16 (10.25-25)	.847	<0.001
Major complications†	48 (37.5)	48 (40.0)	.698	−0.026
30-d survival	114 (89.1)	105 (87.5)	.844	0.024

Data are presented as median (interquartile range) or n (%). Effect sizes are presented as phi coefficient (φ) among categorical variables, and eta squared (η^2) for nonparametric tests. *CABG*, Coronary artery bypass graft; *SACP*, selective antegrade cerebral perfusion; *ECMO*, extracorporeal membrane oxygenation; *DSWI*, deep sternal wound infection; *ICU*, intensive care unit. *Defined as prolonged mechanical ventilation >7 days or requiring tracheostomy. †Defined as composite adverse outcomes including re-exploration for bleeding, newly developed dialysis, DSWI, respiratory failure, and permanent stroke.

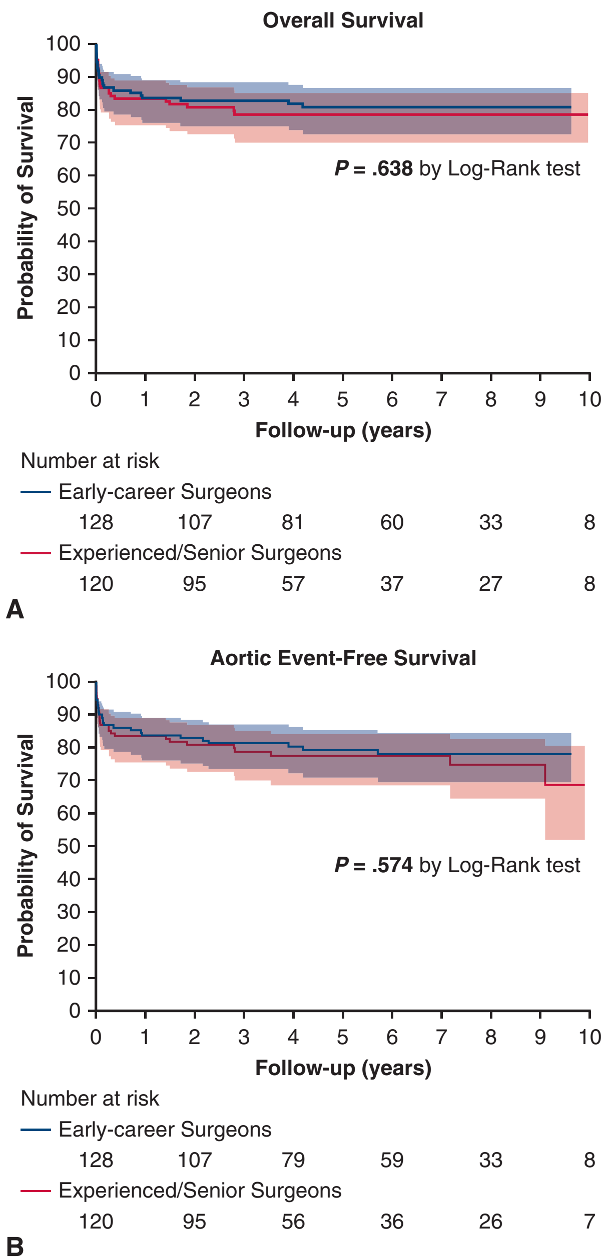

FIGURE 4. Kaplan–Meier survival curves of (A) overall survival and (B) aortic event-free survival of acute type A aortic dissection (aTAAD) operations performed by early-career surgeons or experienced/senior surgeons. The survival curves are truncated when fewer than 10 patients at risk remain.

in southern Taiwan and also the tertiary referral medical center responding to the Tainan Metropolitan area and the "Yun-Chia-Nan" region, with a total population of 3 million people.[13,14] Although annually there are only 300 cases requiring major cardiac operations using cardiopulmonary bypass in our hospital, their complexity and severity are considerable. As shown in our previous literature, approximately 50% of our adult cardiac surgical cases were nonelective, 25% involved the thoracic aorta, and 20% required hypothermic circulatory arrest.[15] The mean estimated mortality rate using the EuroScore II of all patients who underwent surgery was above 7% in out institute.[15] The operated cases (those requiring cardiopulmonary bypass) performed by each trainee in the fellow year will be more than 200 cases and significantly outnumber the minimum requirement announced by the Accreditation Council for Graduate Medical Education of the United States and also the regulations provided by other countries.[16] Specifically, although it was our institutional policy that all aTAAD repairs and other aortic emergency operations should be performed primarily by the attending surgeons in our institute, we have tried to help our trainees achieve adequate preparedness by allowing them to perform as many elective aortic cases as possible. During the fellowship year, the trainees could be the primary operators in about 25 elective aortic operations. This intensive training process indeed results in our young cardiovascular giving steady performances from the initiation of their career.

The well-established, standardized surgical approach to aTAAD patients along with the well-cooperated surgical teams, including anesthesiologists, perfusionists, scrub nurses, surgical assistants, and postoperative intensive care staffs, contributed to our institute's steady and consistent performance in aTAAD operations. Our cardiac surgical team is thus confidently able to accept every referred aTAAD with the exception of the rare occurrence when the surgical intensive care unit is fully occupied or overwhelmed. Since more than 50% of the aTAAD operations were performed by early-career surgeons with most of them performed independently and solely by these surgeons, our results showed that confined manpower would not compromise the outcome of surgical repairs for aTAAD in a well-established program. In addition, the efficient support from our multidisciplinary team also invigorated these junior surgeons to perform aTAAD operations independently since their early-careers. As junior surgeons could accumulate experience in surgical repair of aTAAD quickly, balanced duty calls for aortic dissection consultation could be taken by each aortic surgeon and not be confined to only one or two senior surgeons.

Elimination of the intima tear site was essential for determining the extent of aortic segment replacement at our institute.[7,8] Beyond this, decisions regarding a more aggressive aortic reconstructive procedure extending to the aortic root or the arch in aTAAD operations, such as the diameter of the aortic root or arch, severity of distal aortic true lumen compromise, and presence of end-organ malperfusion, were similar for each surgeon in our institute.[17-20] The consensus of the extent of aortic reconstruction in patients with aTAAD might also explained the equivalent midterm aortic event-free survival rate in both groups.

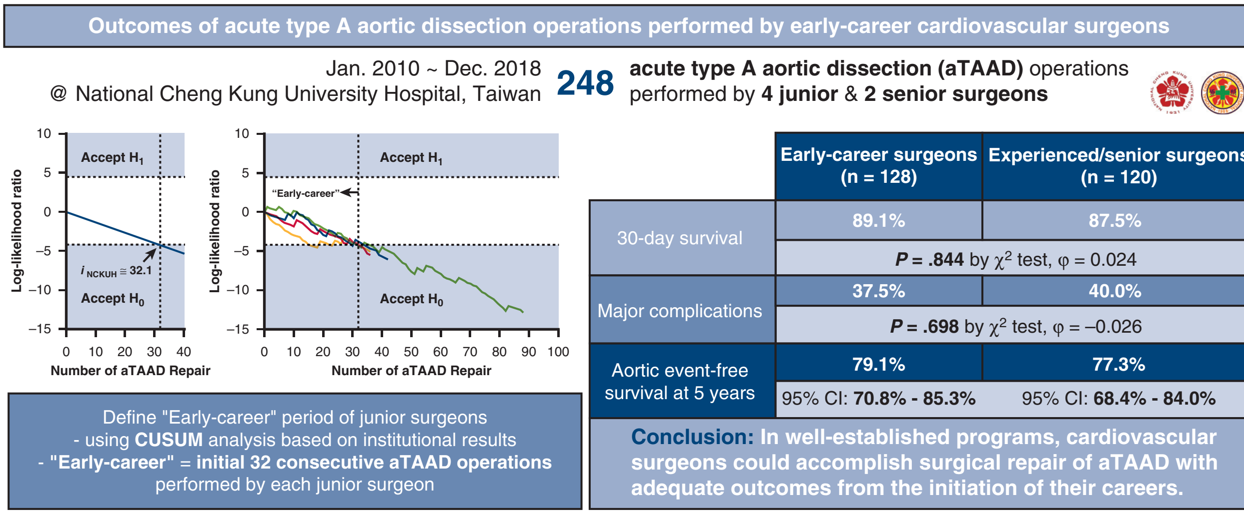

FIGURE 5. Outcomes of acute type A aortic dissection operations performed by early-career cardiovascular surgeons. *CI*, Confidence interval; *CUSUM*, cumulative sum.

The CUSUM analysis is a valuable method to provide continuous outcome monitoring used for quality control and has been widely applied in assessing the performance of individual surgeons performing various cardiac surgeries.[21,22] Along with other retrospective measures, this study uses CUSUM analysis to evaluate the surgical outcome of aTAAD repair performed by individual cardiovascular surgeons. When considering the aTAAD operations, the definitions of "low-volume" surgeons in previous studies varied.[3-6] For the junior surgeons in this study, their mean annual aTAAD operated case number was 13.04 ± 4.62, which could be defined as "high-volume" in most previous studies.[6] Although these surgeons gained experience by performing a considerable number of aTAAD cases since their early career, we believe that close monitoring and timely intervention is required for every surgeon in their initial period of clinical practice. Our study defines "early-career" surgeons by a specific cases number of operations performed at their initiation of their career using the CUSUM chart based on our institutional average outcome. By this procedure- and institution-specific definition, we can continuously monitor the performance of future early-career aortic surgeons before they perform consecutive ∼30 aTAAD operations and can take interventions once the performance curve approaches the alarm boundary of worse outcomes in their early-career. Since the defined number is institutional result-based, we also encourage other institutes to use this method to define their "early-career" surgeons, and also to monitor these surgeons' performance at the beginning of their careers.

As the outcome of aTAAD repair has continuously improved and many excellent results have been reported from experienced centers, all surgeons, including those in their early career, should be expected to have an even greater standard, in terms of not only constantly improving short-term survival but also making efforts to diminish complications, to ameliorate the quality of life of the survivors. Although the institutional volume, experience, and policy could still have an impact on the surgical outcome of aTAAD operations, equivalent outcomes should be persuaded for every aortic surgeon within a single institute, regardless of the stage of his or her career.

Limitations

The small number of cases was a major limitation of this study, and the statistical analyses might falsely not detect significant differences in some variables between the groups (type II errors), despite that we reported the effect sizes among each variables to clarify the statistical results. While the SPRT curve, and also the SPRT-based definition of "early career," were determined by p_0, α, β, and OR, the OR (= 2.0) was defined subjectively in this study because the precise distribution of mortality rates among individual surgeons and institutions is unknown. Although outcome prediction models for aTAAD repair have been described with validated discriminatory powers,[23-26] we used a simplified model in our CUSUM analyses by adapting only preoperative variables, and some important predictors of death might have been omitted.

CONCLUSIONS

By using the proposed institutional outcome-based CUSUM test, junior cardiovascular surgeons in the early career could be defined and their performances could be monitored. Early-career cardiovascular surgeons trained in well-established cardiovascular surgical programs could perform aTAAD repairs with a satisfactory early survival rate from the initiation of their clinical practice (Figure 5).

Conflict of Interest Statement

The authors reported no conflicts of interest.

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Key Words: acute type A aortic dissection, early-career surgeons, outcome, CUSUM analysis

TABLE E1. Thirty-day survival and major complications rates of aTAAD surgical repair in elder patients (>65 years) from January 2010 to December 2018 (n = 103)

	Early-career surgeons (n = 50)	Experienced/senior surgeons (n = 53)	*P* value	Effect size
Major complications*	19 (38.0)	28 (52.8)	.167	−0.149
30-d survival	40 (80.0)	41 (77.4)	.813	0.032

Data are presented as n (%). Effect sizes are presented as phi coefficient (φ). *Defined as composite adverse outcomes including re-exploration for bleeding, newly developed dialysis, DSWI, respiratory failure and permanent stroke.

TABLE E2. Thirty-day survival and major complications rates of aTAAD surgical repair in patients with preoperative hemodynamic instability* from January 2010 to December 2018 (n = 83)

	Early-career surgeons (n = 43)	Experienced/senior surgeons (n = 40)	*P* value	Effect size
Major complications†	23 (53.5)	25 (62.5)	.506	−0.091
30-d survival	36 (83.7)	28 (70.0)	.192	0.163

Data are presented as n (%). Effect sizes are presented as phi coefficient (φ). *Defined as preoperative systolic arterial blood pressure ≤80 mm Hg or requiring cardiopulmonary cerebral resuscitation. †Defined as composite adverse outcomes including re-exploration for bleeding, newly developed dialysis, DSWI, respiratory failure and permanent stroke.

TABLE E3. Thirty-day survival and major complications rates of aTAAD surgical repair in patients with preoperative malperfusion syndromes* from January 2010 to December 2018 (n = 80)

	Early-career surgeons (n = 40)	Experienced/senior surgeons (n = 40)	*P* value	Effect size
Major complications†	27 (67.5)	23 (57.5)	.489	0.103
30-d survival	33 (82.5)	36 (90.0)	.518	−0.109

Data are presented as n (%). Effect sizes are presented as phi coefficient (φ). *Defined as the presence of laboratory or clinical evidence of end-organ ischemia, isolated organ-supplying branch arteries dissection on imaging study not included. †Defined as composite adverse outcomes including re-exploration for bleeding, newly developed dialysis, DSWI, respiratory failure and permanent stroke.

TABLE E4. Thirty-day survival and major complications rates of aTAAD surgical repair in patients ≤65 years of age with stable hemodynamics* and no preoperative malperfusion syndrome† from January 2010 to December 2018 (n = 73)

	Early-career surgeons (n = 40)	Experienced/senior surgeons (n = 33)	*P* value	Effect size
Major complications‡	5 (12.5)	4 (12.1)	>.999	0.006
30-d survival	40 (100.0)	33 (100.0)	–	–

Data are presented as n (%). Effect sizes are presented as phi coefficient (φ). *Defined as preoperative systolic arterial blood pressure >80 mm Hg without inotrope/vasopressor. †Defined as the presence of laboratory or clinical evidence of end-organ ischemia, isolated organ-supplying branch arteries dissection on imaging study not included. ‡Defined as composite adverse outcomes including re-exploration for bleeding, newly developed dialysis, DSWI, respiratory failure and permanent stroke.