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Predictive value of heart rate in patients with acute type A aortic dissection: a retrospective cohort study

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ABSTRACT

Objective Heart rate (HR) is a risk factor of mortality in many cardiovascular diseases but no clinical studies have focused on the association between HR and prognosis in patients with acute type A aortic dissection (ATAAD). This study aimed to evaluate the association between HR and long-term mortality and establish the criteria of HR in patients with ATAAD who underwent total aortic arch replacement combined with the frozen elephant trunk (TAR+FET).

Design, setting and participants Retrospective cohort study that studied all consecutive patients with ATAAD who underwent TAR+FET in the Fuwai Hospital between 2009 and 2015.

Main outcomes and measures 30-day postoperative, and estimated long-term mortality.

Results Overall, 707 patients with ATAAD who underwent TAR+FET were followed up for a median duration of 29 months (range, 5–77 months). In multivariate logistic analysis, HR (p<0.001), age (p<0.001), renal insufficiency (p=0.033), ejection fraction (p=0.005), cardiopulmonary bypass time (p<0.001) and intraoperative blood loss (p=0.002) were significantly associated with 30-day postoperative and estimated long-term mortalities. A hinge point with a sharp increase in estimated long-term mortality was identified at 80 beats/min (bpm), and compared with HR ≤80 bpm, HR >80 bpm was associated with an almost threefold higher long-term mortality. HRs ≤60, 60–70, 70–80, 80–90, 90–100, 100–110 and >110 bpm were associated with 3.9%, 4.0%, 3.8%, 7.2%, 9.5%, 10.1% and 14.4% yearly risks of death, respectively.

Conclusions HR is a powerful predictor of long-term mortality in patients with ATAAD undergoing TAR+FET. HR >80 bpm is independently associated with elevated long-term mortality for patients with ATAAD.

Strengths and limitations of this study

- First study to systematically evaluate the association between heart rate (HR) and long-term mortality in patient with acute type A aortic dissection (ATAAD).
- The importance of HR in short-term and long-term mortality was evaluated and a hinge point HR in patients with ATAAD was recommended.
- Convenient prediction tool based on preoperative risk factors was created to calculate the probability of long-term mortality.
- Did not include patients who did not undergo surgery or died before arriving in the operating room and the retrospective and observational nature of the study might bring confounding and bias. Did not consider preoperative treatment and therefore unable to decide whether preoperative HR control would improve long-term mortality.

INTRODUCTION

Many studies have demonstrated that heart rate (HR) is a risk factor of mortality in many cardiovascular diseases,[1–5] including type B aortic dissection.[6–8] However, to the best of our knowledge, no clinical studies have focused on the association between HR and long-term prognosis in patients with acute type A aortic dissection (ATAAD) who underwent total aortic arch replacement combined with the frozen elephant trunk (TAR+FET). Because of the urgency and fatalness of ATAAD, all of the current guidelines[9–12] highlight the importance of emergency surgery and blood pressure control. Most guidelines do not recommend a target HR in patients with ATAAD. Although the use of beta-blockers is suggested in all these guidelines, beta-blockers were mainly used for blood pressure control and reduction in dP/dt and not for HR reduction. In the 2011 Japanese Circulation Society guidelines,[10] pulse rate control is recommended as one of the most important aspects of treatment in acute aortic dissection, whereas no specific target of HR is suggested. Only the 2010 American College of Cardiology Foundation/American Heart Association guidelines[9] recommend titrating to a target HR of 60 bpm or less (class I, level of evidence: C). However, this was referenced only in a review published in 2005,[13] and the review did not provide any relevant clinical trials. Similarly, Nienaber and Powell[14] suggested a target HR of 60–80 bpm as the initial medical therapy for acute aortic syndromes in a review published in 2011, and they did not provide any relevant clinical

Table 1 Patient characteristics

	Total (N=707)	Survivors (n=612)	Non-Survivors (n=95)	P value
Age, years	46.6±10.4	46.0±10.1	50.2±11.0	<0.001
Male sex, %	552 (78.1)	486 (79.4)	66 (69.5)	0.041
BMI (kg/m^2)	25.6±4.00	25.6±4.07	25.5±3.50	0.704
Hypertension	512 (72.4)	441 (72.1)	71 (74.7)	0.674
Current/past smoker	296 (41.9)	257 (42.0)	39 (41.1)	0.951
Diabetes mellitus	15 (2.1)	13 (2.1)	2 (2.1)	1.000
Coronary artery disease	48 (6.8)	41 (6.7)	7 (7.4)	0.811
Aortic regurgitation	260 (36.8)	216 (35.3)	44 (46.3)	0.050
Renal insufficiency	35 (5.0)	24 (3.9)	11 (11.6)	0.003
Stroke	34 (4.8)	29 (4.7)	5 (5.3)	0.788
Pericardial effusion	99 (14.0)	85 (13.9)	14 (14.7)	0.744
Chest pain	623 (88.1)	540 (88.2)	83 (87.4)	0.997
Back pain	223 (31.5)	196 (32.0)	27 (28.4)	0.757
Abdominal pain	255 (36.1)	215 (35.1)	40 (42.1)	0.113
Time form onset of symptom to surgery (days)	7.1	7.0	7.4	0.755
Haemoglobin level, g/L	131.7±19.3	132±19.3	129±19.1	0.197
White cell count, ×10^9/L	11.1±4.13	11.1±4.06	11.3±4.60	0.692
EF <50%, %	32 (4.5)	20 (3.3)	12 (12.6)	<0.001
HR in ED, bpm	87.8±15.6	87.7±15.5	88.3±16.8	0.564
Preoperative HR, bpm	83.4±15.2	82.6±14.9	88.2±16.2	0.002
Systolic blood pressure, mm Hg	136±25.7	136±25.5	135.5±27.3	0.997
Diastolic blood pressure, mm Hg	61.2±15.8	61.2±15.4	61.2±18.0	0.803
Mean blood pressure, mm Hg	85.7±17.3	85.7±17.0	85.2±19.2	0.548
History of cardiac surgery	17 (2.4)	13 (2.1)	3 (3.2)	0.466
Concomitant procedures	301 (42.6)	252 (41.2)	49 (51.6)	0.072
CPB time, min	199.8±66.2	193±51.3	241±118	<0.001
Intraoperative blood loss, mL	959.0±766.1	959.0±766.1	959.0±766.1	0.019

Values are expressed as mean±SD or n (%), as appropriate.
BMI, body mass index; bpm, beats/min; CPB, cardiopulmonary by pass; ED, emergency department; EF, ejection fraction; HR, heart rate.

trials as well. Therefore, this study aimed to evaluate the association between HR and long-term all-cause mortality and explore the hinge point of HR among patients with ATAAD who underwent TAR+FET.

METHODS

Patients and data collection

After receiving approval from the Ethics Committees of Fuwai Hospital in Beijing, China, and under a waiver of informed consent, the authors conducted this retrospective observational study of all consecutive patients with ATAAD who underwent TAR+FET between December 2009 and December 2015. ATAAD was defined by observing an intimal flap separating two lumina in the ascending aorta that occurred within 14 days of symptom onset.[15] The TAR+FET surgical technique has been described previously in detail and is viewed as a standard therapy for ATAAD requiring repair of the aortic arch.[16] Patients were monitored using electrocardiography, pulse oximetry and the Intellivue MX700 monitor (Philips, Amsterdam, the Netherlands) (left radial and dorsalis pedis arterial pressures) in the operating room. Data related to demographic and in-hospital clinical variables were retrospectively collected from medical charts and electronic medical records, and patients were followed up by telephone and outpatient review.

HR was recorded every 5 min when a patient arrived in the operating room and the average of the first three values of HRs before anaesthesia induction was used in our study from electronic medical records. Long-term mortality was defined as 5-year postoperative mortality. Blood pressure was defined as the higher values between radial and dorsalis pedis pressure before anaesthesia

Table 2 Models for estimated long-term mortality

	Unadjusted OR (95% CI)	Adjusted OR (95% CI)	P value
Model 1: preoperative HR, age, sex, BMI			
Preoperative HR	1.02 (1.01 to 1.04)	1.03 (1.01 to 1.04)	<0.001
Age	1.04 (1.02 to 1.06)	1.05 (1.02 to 1.07)	<0.001
Model 2: model 2+HTN+DM+smoke+ST+CHD+RI+PE			
Preoperative HR	1.02 (1.01 to 1.04)	1.03 (1.01 to 1.04)	<0.001
Age	1.04 (1.02 to 1.06)	1.05 (1.02 to 1.07)	<0.001
RI	3.21 (1.52 to 6.79)	3.13 (1.41 to 6.94)	0.005
Model 3: model 3+AR+EF+HB+WBC count			
Preoperative HR	1.02 (1.01 to 1.04)	1.03 (1.02 to 1.05)	<0.001
Age	1.04 (1.02 to 1.06)	1.06 (1.03 to 1.09)	<0.001
RI	3.21 (1.52 to 6.79)	2.50 (1.08 to 5.80)	0.025
EF	0.23 (0.11 to 0.50)	0.20 (0.08 to 0.51)	0.001
Model 4: model 4+SBP+CPB+intraoperative BL+HR in ED+CS+PCS+T			
Preoperative HR	1.02 (1.01 to 1.04)	1.03 (1.01 to 1.05)	<0.001
Age	1.04 (1.02 to 1.06)	1.06 (1.03 to 1.09)	<0.001
RI	3.21 (1.52 to 6.79)	3.85 (1.58 to 9.35)	0.033
EF	0.23 (0.11 to 0.50)	0.25 (0.10 to 0.65)	0.005
CPB time	1.01 (1.00 to 1.01)	1.01 (1.00 to 1.01)	<0.001
Intraoperative BL	1.03 (1.01 to 1.05)	1.03 (1.00 to 1.05)	0.002

AR, moderate to severe aortic regurgitation; BL, blood loss; BMI, body mass index; CHD, coronary heart disease; CPB, cardiopulmonary bypass; CS, concomitant surgery; DM, diabetes mellitus; ED, emergency department; EF, ejection fraction; HB, haemoglobin; HR, heart rate; HTN, hypertension; PCS, prior cardiac surgery; PE, pericardial effusion; RI, renal insufficiency; SBP, systolic blood pressure; ST, stroke; T, time from onset of symptom to surgery; WBC, white blood cell.

induction (according to systolic blood pressure (SBP)). The four-variable Modification of Diet in Renal Disease equation was used to calculate the estimated glomerular filtration rate.[17] Renal insufficiency (RI) was defined as the preoperative estimated glomerular filtration rate <90 mL/min or dialysis.

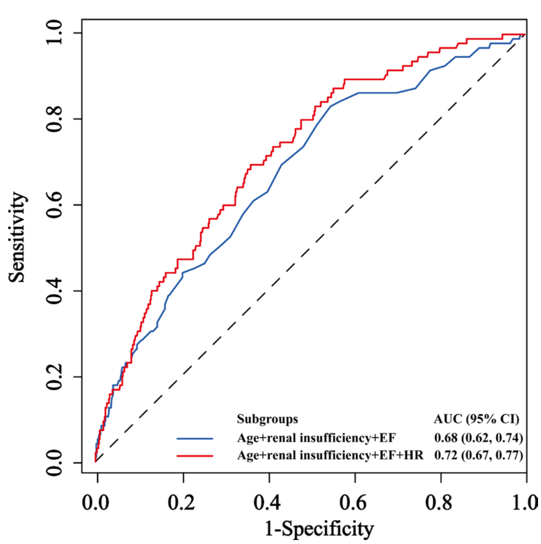
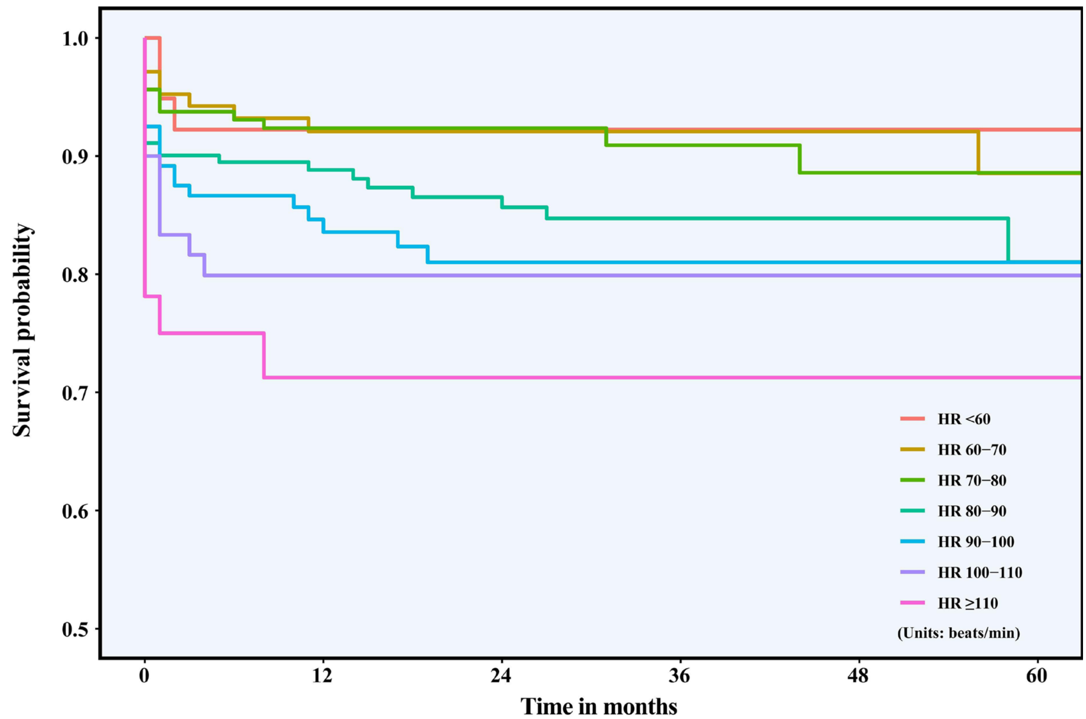


Figure 1 Receiver operating characteristic curve for multivariate logistic regression analysis. There is a significant improvement in the discrimination of the logistic regression model by introducing preoperative HR (an increase in AUC of 0.04, p=0.024). AUC, area under the receiver operating characteristic curve; EF, ejection fraction; HR, heart rate.

Statistical analysis

Values are expressed as mean±SD or number of patients (%), as appropriate. Multivariate logistic regression models were used to identify independent predictors of long-term mortality. To minimise selection bias and obtain comparable groups, propensity score matching (PSM) analysis was used to confirm the association between HR and long-term mortality. PSM of 1:1 ratio and 0.20 calliper by the 'nearest neighbour' method was performed with the 'Matching' package. The area under the receiver operating characteristic curve (AUC) was used to assess the discriminative performance of the logistic regression model. The long-term survival rate was analysed using the Kaplan-Meier analytical method and Cox regression analysis. The predictive models were built using the average of the predicted 5-year risk from the Cox proportional hazard model via the 'coxph' function of the 'survival' package in the R software package (R Foundation for Statistical Computing, Vienna, Austria). The Kaplan-Meir survival analyses were visualised using 'survminer' and 'ggplot2' packages in the R software package. The R software package,



Number at risk: n (%)

(Units: beats/min)	0	12	24	36	48	60
HR <60	39 (100)	27 (69)	20 (51)	15 (38)	11 (28)	6 (15)
HR 60–70	105 (100)	81 (77)	69 (66)	48 (46)	32 (30)	21 (20)
HR 70–80	160 (100)	115 (72)	82 (51)	55 (34)	33 (21)	19 (12)
HR 80–90	191 (100)	129 (68)	100 (52)	67 (35)	40 (21)	17 (9)
HR 90–100	120 (100)	79 (66)	58 (48)	35 (29)	28 (23)	12 (10)
HR 100–110	60 (100)	40 (67)	31 (52)	18 (30)	10 (17)	4 (7)
HR ≥110	32 (100)	19 (59)	15 (47)	13 (41)	8 (25)	3 (9)

Time in months

Figure 2 Kaplan-Meier analysis according to different HRs. Increased HR is significantly associated with a lower cumulative survival rate than decreased HR. A 5 beats/min increment of HR is associated with an 11.8% increased risk of all-cause mortality in the univariate Cox regression analysis. Additional adjustment for other variables did not change the significance of the association. HR, heart rate.

V.3.5.1 was used to analyse the data, and GraphPad Prism V.7.00 for Windows (GraphPad Software, San Diego, California, USA) was used for data analysis and visualisation. A two-tailed p value <0.05 was considered statistically significant.

Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

RESULTS

Clinical features and surgical data

From December 2009 to December 2015, 960 patients with ATAAD had surgeries in the Fuwai Hospital (online supplemental table 1). Of which, 746 patients underwent TAR+FET. After excluding, 39 of them for failure of follow-up, 707 patients were enrolled in this study. The clinical characteristics of the 707 patients are shown in table 1. Concomitant procedures included aortic valve repair in 22 patients, aortic root replacement in 227 patients, mitral valve operations in 9 patients, and coronary artery bypass grafting in 76 patients. Patients' mean age was 46.6±10.4 years, and male sex was predominant (78%). During a median follow-up of 29 months (range, 5–77 months) 95 patients died.

Association between HR and estimated long-term mortality

In the multivariate logistic regression analysis, HR (p<0.001), age (p<0.001), RI (p=0.033), ejection fraction (EF) (p=0.005), cardiopulmonary bypass time (p<0.001) and intraoperative blood loss (p=0.002) were identified as independent predictors of estimated long-term all-cause mortality. After adjusting for the

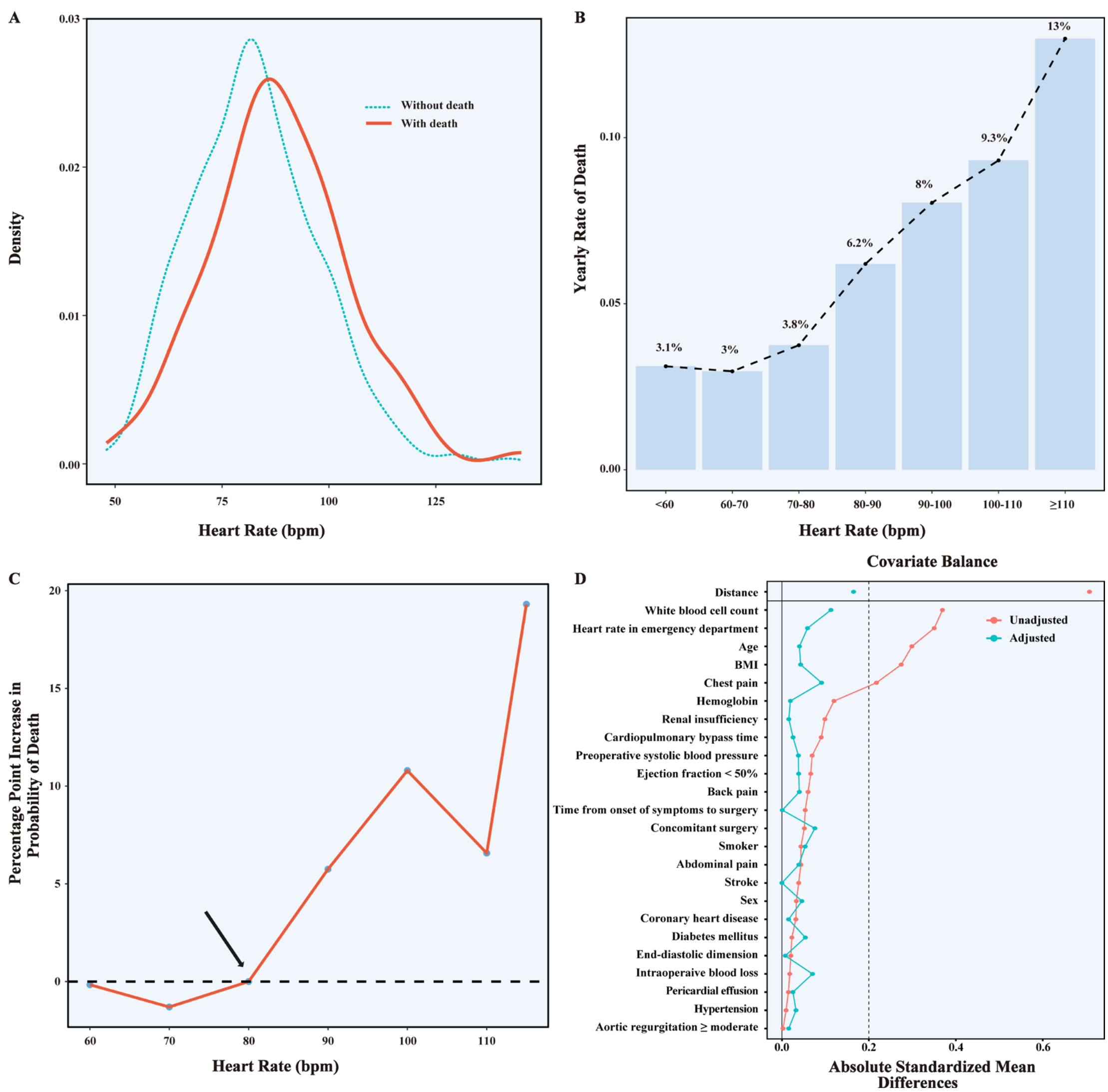


Figure 3 (A) Kernel density plots showing the distribution of HR. (B) Long-term mortality rates increase with increased HR. (C) Hinge plot. A cut-off HR of 80 bpm is observed and a sharp increase of estimated probability of long-term death occurs when HR >80 bpm. (D) Love plot showing absolute standardised differences before (red) and after (green) PSM comparing covariate values. BMI, body mass index; bpm, beats/min; HR, heart rate; PSM, propensity score matching.

demographic data, history of cardiac surgery and preoperative tests results, the above-mentioned six variables remained independently associated with long-term all-cause mortality (table 2). When we replaced SBP with diastolic blood pressure or mean blood pressure, the results were similar. There was a significant improvement in the discrimination of the logistic regression model by introducing HR (an increase in AUC of 0.04, p=0.024; figure 1). According to the Kaplan-Mieier curves, increased HR was significantly associated with lower cumulative survival rate than lower HR (figure 2). In addition, a 5-bpm increment of HR was associated with an 11.8% increased risk of all-cause mortality in the univariate Cox regression analysis, and additional adjustment for other variables did not change the significance of the association. However, we failed to find a significant relationship between heart rate in emergency department (defined as the heart rate from the first electrocardiograph when a patient arrived in emergency department) and long-term mortality.

Risk stratification based on HR

As illustrated in figure 3A, a significant 'rightward shift' of HR was observed in the long-term non-survivor group compared with that in the long-term survivor group (p<0.001). The long-term survival, estimated using Kaplan-Meier analysis as a function of preoperative HR, is shown in figure 2. HRs ≤60, 60–70, 70–80, 80–90, 90–100, 100–110 and >110 bpm were associated with a 3.9%, 4.0%, 3.8%, 7.2%, 9.5%, 10.1% and 14.4% yearly risk of death, respectively, which suggest that the risk of death sharply increased when HR >80 bpm.

To confirm an appropriate cut-off value of HR for risk prediction, a hinge point (HR of 80 bpm) was observed, that is, a sharp increase in the estimated probability of long-term death occurred when HR >80 bpm (figure 3B,C).

Table 3 Outcomes of propensity score matching

	Before matched			After matched		
	HR ≤80 (n=304)	HR >80 (n=403)	P value	HR ≤80 (n=266)	HR >80 (n=266)	P value
WBC, ×10^9	10.2±3.74	11.8±4.28	<0.001	10.6±3.76	11.1±4.15	0.238
Heart rate in ED	84.5±14.6	90.1±16.0	<0.001	85.8±14.5	86.7±14.5	0.281
Age	48.3±10.6	45.3±9.98	<0.001	47.1±10.4	46.7±9.97	0.699
BMI, kg/m^2	25.0±3.85	26.1±4.05	<0.001	25.2±3.92	25.4±3.61	0.510
Chest pain	257 (84.5)	366 (90.8)	0.0175	233 (87.6)	240 (90.2)	0.392
Haemoglobin, g/L	130±18.9	133±19.6	0.0522	131±19.2	131±19.7	0.674
Renal insufficiency	11 (3.6)	24 (6.0)	0.169	10 (3.8)	11 (4.1)	0.990
CPB time	196±57.2	203±72.1	0.369	197±58.8	199±66.3	0.981
Preoperative SBP	138±26.3	137±27.3	0.941	138±26.9	135±26.8	0.385
EF <50%	16 (5.3)	16 (4.0)	0.488	14 (5.3)	12 (4.5)	0.850
Back pain	91 (29.9)	132 (32.8)	0.466	82 (30.8)	87 (32.7)	0.693
Time from onset of symptom to surgery, days	7.76±8.63	7.28±9.11	0.188	7.65±8.73	7.65±9.86	0.434
Concomitant surgery	125 (41.1)	176 (43.7)	0.538	108 (40.6)	118 (44.4)	0.417
Smoker	131 (43.1)	165 (40.9)	0.606	108 (40.6)	115 (43.2)	0.595
Abdominal pain	106 (34.9)	149 (37.0)	0.568	96 (36.1)	101 (38.0)	0.704
Stroke	16 (5.3)	18 (4.5)	0.715	11 (4.1)	11 (4.1)	1.000
Sex, male	235 (77.3)	317 (78.7)	0.713	207 (77.8)	212 (79.7)	0.680
Coronary heart disease	22 (7.2)	26 (6.5)	0.762	20 (7.5)	19 (7.1)	0.990
Diabetes mellitus	7 (2.3)	8 (2.0)	0.779	7 (2.6)	5 (1.9)	0.764
Hypertension	219 (72.0)	293 (72.7)	0.860	192 (72.2)	189 (71.1)	0.852
LVEDD, mm	51.7±7.44	51.6±7.32	0.947	51.4±7.36	51.7±7.62	0.903
Intraoperative blood loss (mL/kg)	13.0±9.42	12.8±9.67	0.369	12.9±9.73	13.6±10.9	0.787
Moderate or more PE	42 (13.8)	57 (14.1)	0.907	34 (12.8)	37 (13.9)	0.799
Moderate or more AI	112 (36.8)	148 (36.7)	0.999	94 (35.3)	96 (36.1)	0.925
30-day postoperative mortality	15 (4.9)	47 (11.7)	<0.001	13 (4.9)	32 (12.0)	0.0025
Estimated long-term mortality	11.1%	19.7%	<0.001	7.70%	21.1%	<0.001

Data are means±SD or number (%).
AI, aortic regurgitation; BMI, body mass index; CPB, cardiopulmonary bypass; ED, emergency department; EF, ejection fraction; HR, heart rate; LVEDD, left ventricle end-diastolic dimension; PE, pericardial effusion; SBP, systolic blood pressure; WBC, white blood cell.

Two hundred and sixty-six pairs of patients were matched, and all covariates were well balanced (figure 3D). In the matched cohorts, the 30-day postoperative and long-term mortality were significantly higher among patients with preoperative HR >80 bpm than among those with HR ≤80 bpm (all, p<0.01). Results of the PSM analysis are displayed in table 3. Remarkably, preoperative HR >80 bpm was associated with an almost threefold long-term mortality compared with HR ≤80 bpm.

Convenient prediction tool for estimated long-term mortality

To categorise patients undergoing TAR+FET into different risk zones, we created a risk stratification nomogram (figure 4) based on all the preoperative independent risk factors (HR, age, RI and EF). We were able to calculate the probability of long-term mortality in patients undergoing TAR+FET with given values of HR, age, RI and EF. The AUC of the nomogram was 0.72 (95% CI 0.67 to 0.77).

Recalculation of 30-day postoperative mortality

To further consolidate our findings, we recalculated the results above with 30-day postoperative mortality, and found that our results remained stable (online supplemental table 2). In addition, to minimise the bias caused by the 39 patients who failed to undergo follow-up, we inputted their data as either long-term mortality or long-term survival, and the results were similar. Univariable

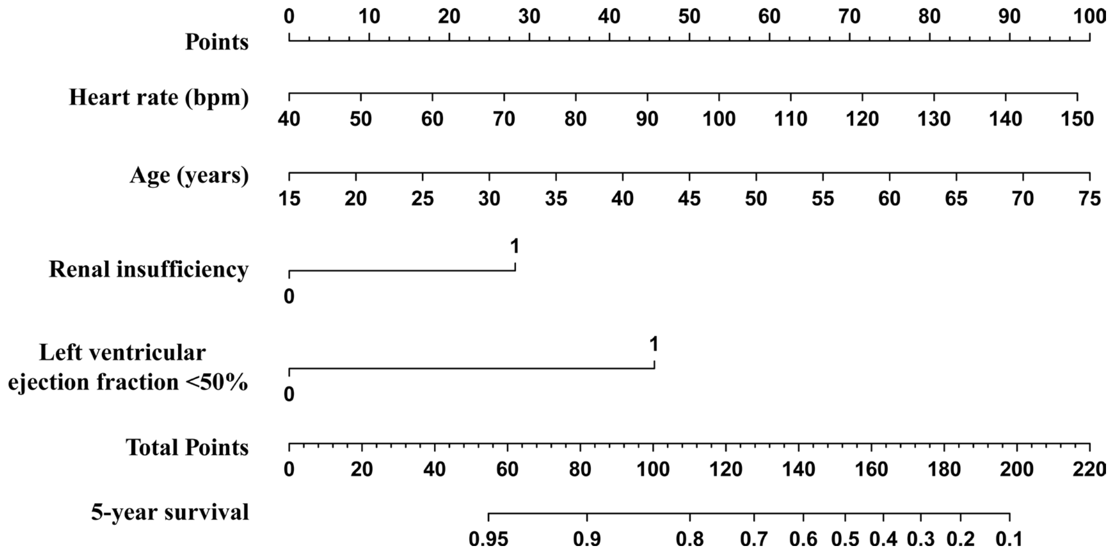


Figure 4 Nomogram for long-term mortality. We can calculate the probability of long-term mortality in patients undergoing TAR+FET with given values of HR, age, RI and EF. bpm, beats/min; EF, left ventricular ejection fraction; HR, heart rate; RI, renal insufficiency; TAR+FET, total arch replacement combined with the frozen elephant trunk.

and multivariable Cox regression analyses of long-term mortality showed similar results.

DISCUSSION

Our study is the first to systematically evaluate the association between HR and long-term mortality, and we found a cut-off HR and established a convenient predictive model of long-term mortality in patients with ATAAD who underwent TAR+FET. We also used comprehensive methods to further consolidate our findings.

In this study, we demonstrated that HR is an influential independent risk factor for long-term mortality in patients who underwent TAR+FET, and higher HR is associated with significantly increased long-term mortality. These findings are in agreement with those of Zhang *et al*'s[18] study that analysed 360 patients with acute aortic dissection and found that patients with slower HR had a higher in-hospital survival rate, although this was not statistically significant (p=0.064). Similarly, Suzuki *et al*[19] analysed 1301 patients with acute aortic dissection by analysing the International Registry of Acute Aortic Dissection global registry database and showed that the use of beta-blockers was associated with improved outcomes in both type A and type B aortic dissection patients. This finding supports our results. Importantly, we detected that a cut-off HR of 80 bpm was associated with a sharp increase in long-term mortality. Long-term mortality was almost threefold greater in patients with HR >80 bpm than in those with HR ≤80 bpm. Therefore, HR >80 bpm may be considered as an independent risk factor in patients with ATAAD undergoing TAR+FET.

Aggressive medical treatment of aortic dissection was first advocated in the 1960s.[20] The authors established the reduction of SBP and diminution of the rate of left ventricular ejection (dP/dt) as the two primary goals of pharmacological therapy. According to previous studies,[21] when HR decreases, both blood pressure and left ventricular dP/dt decrease. This may be the main reason that slower HR is associated with improved long-term mortality in patients with ATAAD. Besides, HR has been reported in association with the prognoses of various diseases.[22] One study[23] enrolled 112 680 subjects in 12 cohort studies and reported a continuous, increasing association between having a rest HR above approximately 65 bpm and the risk of both cardiovascular and all-cause mortalities. Similarly, Wang *et al*[4] analysed 92 562 participants in the Kailuan Study and demonstrated that elevated HR was independently associated with an increased risk of myocardial infarction and all-cause death. These large clinical investigations may help explain the benefit of a slower HR in our study from another viewpoint. It is generally believed that a faster HR is beneficial in severe aortic regurgitation (AR), as it potentially shortens the diastolic period during which AR occurs. In our study, 260 patients had moderate to severe AR but we did not find a significant association between preoperative HR and long-term mortality in patients with AR. This result was in line with that of Yang *et al*'s[1] study that investigated 820 patients with moderate to severe AR; they demonstrated a robust association between increased HR and elevated all-cause death, which was independent of demographics, comorbidities, guideline-based surgical triggers, the presence of hypertension and use of medications. Similarly, Sampat *et al*[24] conducted an observational study that included 756 consecutive patients with severe AR and found that beta-blocker therapy was an independent predictor of better survival for patients with higher HR.

In previous studies and guidelines,[9 12 25] blood pressure control was one of the main medical treatments in patients with aortic dissection. However, this study failed to demonstrate a significant relationship between blood pressure and long-term mortality. Because this study only included patients who underwent TAR+FET, we could not determine the effects of blood pressure on preoperative time. Indeed, many patients in our study received treatment for blood pressure control, and we defined blood pressure as the higher values between radial and dorsalis pedis pressures. In our study, patients had higher blood pressure than previous studies,[25] and patients with an SBP ≤100 mm Hg only accounted for 8.77% (62 cases). These differences might have caused different outcomes.

We did not include intraoperative risk factors in the development of predictive models because we wanted to determine the probability of long-term mortality in patients undergoing TAR+FET before the operation started.

In this study, we failed to find a significant relationship between HR in emergency department and long-term mortality. Therefore, we suggest that a patient can benefit from HR reduction if HR could be controlled to lower than 80 bpm no matter how the HR was when a patient arrived in emergency department.

Limitations

This study has several limitations. First, the retrospective and observational nature of the study might have caused bias. To reduce selection bias, only one type of surgery (TAR+FET) was chosen in this study and a PSM approach was used. Second, by design, we could not include patients who did not undergo surgery or died before arriving in operating room. Finally, this was an observational study, patients did not receive the same preoperative treatment, thereby we did not take preoperative medication into consideration. Prospective randomised trials are needed to reveal the association between preoperative control of HR and patients' outcomes to reduce long-term mortality in this population.

CONCLUSIONS

HR is a powerful predictor of long-term mortality and HR >80 bpm is associated with significantly increased long-term mortality for patients with ATAAD undergoing TAR+FET. We recommend combining HR, age, RI and EF to predict long-term mortality in patients undergoing TAR+FEF.

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