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Research Article

Female Sex Is Not an Independent Risk Factor for Poor Prognosis of Patients with Acute Type A Aortic Dissection Undergoing Surgery

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Background and Aim of the Study. The effects of sex on the prognosis of patients with acute type A aortic dissection (ATAAD) have still remained controversial. This study aimed to explore the sex differences in outcomes of ATAAD patients undergoing surgery. *Methods*. Data of patients with ATAAD who were operated in our center from 2010 to 2018 were retrospectively collected. Data on pre-, intra-, and postoperative courses were analyzed. Propensity score weighting was performed to balance the baseline characteristics. Multivariable logistic regression was used to assess predictors of early mortality in overall female and male patients. *Results*. A total of 1448 patients were enrolled, including 352 (24.3%) female patients and 1096 (75.7%) male patients. Females were significantly older than males (56.0 vs. 47.8 years, $P < 0.001$). Dissection was less extensive (Fuwai Ct: 85.8% vs. 91.3%, $P = 0.003$) and malperfusion syndrome was less frequently diagnosed (Penn Ab: 19.3% vs. 29.7%, $P < 0.001$) in females. Males experienced more aortic root replacement (Bentall: 14.2% vs. 24.9%, $P < 0.001$) and total arch replacement combined with frozen elephant trunk (56.8% vs. 75.8%, $P < 0.001$) with the prolonged operation time (6.1 vs. 6.4 hours, $P = 0.001$). In contrast, early mortality was higher in females (9.4% vs. 6.1%, $P = 0.036$). No differences were found in long-term survival and reoperation rates. After propensity score weighting, sex suggested no influence on both early and long-term outcomes. Cardiopulmonary bypass time was an independent risk factor for early mortality in both overall and sex-related populations according to the multivariable logistic regression. *Conclusions*. In ATAAD, different presentations and surgical strategies were noted in male and female patients. However, there were no significant differences in early and long-term outcomes between sexes after propensity score weighting.

1. Introduction

Acute type A aortic dissection (ATAAD) is a lethal disease that requires timely surgical intervention. Although a great progress in surgical techniques has been achieved, the mortality rate of ATAAD remains as high as about 10% [1, 2]. To date, sex influences on the prognosis of ATAAD patients undergoing surgery have become a topic with contradictory results from different studies. A 2004 study by the International Registry of Acute Aortic Dissection (IRAD) reported that the in-hospital mortality rate of ATAAD in females was significantly higher than that in males (38.2% vs. 26.6%, $P = 0.002$) [3]. However, a 2021 study from the German Registry of Acute Aortic Dissection Type A (GERAADA) argued that there were no significant differences in in-hospital mortality between females and males (16.3% vs. 16.6%, $P = 0.180$) [4]. And a latest multicenter study also showed comparable in-hospital and long-term mortality rates between female and male ATAAD patients undergoing surgery [5]. Nonetheless, many other studies still failed to reach a consensus [6–10], which might, somehow, influence the choice of surgical strategies based on sexes. Therefore, the clarification of which sex should be taken into consideration in the selection of surgical strategies is necessary. And this present large-scale, single-center study aimed to use more recent data to illuminate the effects of sex on the early and long-term outcomes of ATAAD patients undergoing surgery through retrospective research and prospective follow-up, which was expected to provide more useful information for the selection of surgical strategies in both sexes.

2. Materials and Methods

2.1. Study Design. All patients who underwent surgery for ATAAD in Fuwai Hospital (Beijing, China) between 2010 and 2018 were retrospectively enrolled. The diagnosis was based on the patient history and clinical manifestations and was then confirmed by imaging examination and intraoperative visualization. The study was approved by the Institutional Review Board of Fuwai Hospital (no.: 2022-1745), and individual consent for this retrospective analysis was waived.

2.2. Data Collection and Follow-Up. Pre-, intra-, and postoperative data were collected from medical charts, laboratory test reports, and imaging examination reports with demographic information, cardiovascular risk profile, cardiovascular surgical history, dissection classification (Fuwai and Penn classification), details of the surgery, and postoperative outcomes. Patients were followed up for 2–10 years after discharge with long-term survival and reoperation evaluated by annual clinical reviews and telephone interviews with patients or their families.

2.3. Definitions of Variables. The Fuwai classification of TAAD, based on dissection propagation, subdivides the aortic arch into the proximal aorta, distal aorta, and total aorta as follows [11]: (i) Fuwai A is defined as TAAD (Stanford classification) that only involves the ascending aorta, (ii) Fuwai Cp is defined as TAAD (Stanford classification) that involves the proximal arch with innominate artery or combined with the left carotid artery, and (iii) Fuwai Ct is defined as TAAD (Stanford classification) that involves the total arch. The Penn classification of ATAAD is based on the ischemic pattern at clinical presentation as follows [12]: (i) Penn Aa (no ischemia) is defined as ATAAD with the absence of ischemia; (ii) Penn Ab (localized ischemia) is defined as ATAAD with branch vessel malperfusion producing clinical organ ischemia (e.g., stroke, renal failure, ischemic extremity, and mesenteric ischemia); (iii) Penn Ac (generalized ischemia) is defined as ATAAD with circulatory collapse, with or without cardiac involvement; and (iv) Penn Abc (combined ischemia) is defined as localized and generalized ischemia together. Stroke is defined as an acute episode of focal dysfunction of the brain, retina, or spinal cord lasting longer than 24 hours, or of any duration if imaging (computed tomography or magnetic resonance imaging) or autopsy shows focal infarction or hemorrhage relevant to the symptoms [13]. Paraplegia is defined as impairment in motor or sensory function of the lower extremities. Heart failure is defined as a complex clinical syndrome with symptoms and signs that result from any structural or functional impairment of ventricular filling or ejection of blood [14]. Multiple organ dysfunction syndrome (MODS) is defined as the acute and potentially reversible dysfunction of two or more organ systems that result from multiple different and clinically diverse factors.

2.4. Outcomes. The primary outcome of this study was the identification of differences between sexes in early mortality and long-term mortality and reoperation. Early mortality is referred to in-hospital death and/or death within 30 days after surgery (including intraoperative death), whichever is longer. Long-term mortality and reoperation are referred to all deaths and reoperations during the follow-up period. The secondary outcomes were independent risk factors of early mortality in overall and sex-related populations.

2.5. Statistical Analysis. Categorical variables were described as frequencies and percentages. Continuous variables were tested for normal distribution using Kolmogorov–Smirnov test first and were either expressed as mean and standard deviation or median and interquartile range (IQR). Categorical variables were compared using chi-squared or Fisher's exact tests. Continuous variables were compared using Student's *t* test for variables with normal distributions or Mann–Whitney *U* tests for variables with nonsymmetric distributions. Survival rate was estimated with the Kaplan–Meier method and compared using the log-rank test. Competing risk analysis using cumulative incidence functions of reoperation and death according to sex was performed and compared using Gray's test. The propensity score weighting (PSW) was administered to balance the baseline characteristics of male and female patients. The propensity score was calculated using logistic regression including all baseline data. A propensity score-matched cohort was then created using matching weight procedure. After matching, the quality of the PSW was assessed using a "love plot," which can graphically display the covariate balance before and after the adjustment, and by independent sample analysis. Multivariable logistic regression was performed to identify independent pre- and intraoperative risk factors for early mortality in overall and sex-related populations, which included all variables with a $P\ value < 0.20$ at univariable analysis. And a backward step-wise method was used for final models. Models are presented with adjusted odds ratio (OR) and 95% confidence interval (CI).

All analyses were conducted using *R* software (version 4.2.1). A two-tailed $P\ value < 0.05$ indicated statistical significance.

3. Results

3.1. Baseline Characteristics. Among 1448 patients undergoing surgery for ATAAD, 352 (24.3%) were female and 1096 (75.7%) were male (Table 1). Females were significantly older than males (56.0 vs. 47.8 years, $P < 0.001$). The majority of patients had a history of hypertension (81.0% vs. 77.6%, $P = 0.187$). According to the Fuwai classification, females were more likely to present with Fuwai Cp (7.7% vs. 2.6%, $P < 0.001$), whereas males were more frequently diagnosed with Fuwai Ct (85.8% vs. 91.3%, $P = 0.003$), which indicated that total arch dissection was more common in males. Few patients suffered from severe circulatory failure on the basis of the Penn classification (Penn Ac: 0.0% vs. 1.0%, $P = 0.125$ and Penn Abc: 0.6% vs. 0.6%, $P = 1$), but males were more likely to present with malperfusion syndrome (Penn Ab: 19.3% vs. 29.7%, $P < 0.001$).

3.2. Surgical Procedures. Significant differences were observed in surgical strategies between male and female patients (Table 2). Root replacement and total arch replacement (TAR) combined with frozen elephant trunk (FET) were less frequent in females (Bentall: 14.2% vs. 24.9%, $P < 0.001$ and TAR + FET: 56.8% vs. 75.8%, $P < 0.001$). However, the number of hybrid surgery and hemiarch replacement was almost 2-3 times higher in females than that in males, respectively (19.9% vs. 9.1%, $P < 0.001$ and 11.1% vs. 4.4%, $P < 0.001$, respectively). Moreover, females were less likely to experience hypothermic circulatory arrest (69.0% vs. 81.0%, $P < 0.001$). Operation time (6.1 vs. 6.4 hours, $P = 0.001$), cardiopulmonary bypass (CPB) time (160.0 vs. 174.0 minutes, $P < 0.001$), and aortic cross-clamped time (93.0 vs. 95.0 minutes, $P = 0.009$) were all longer in males.

3.3. Outcomes of Overall Population. Early mortality was higher in females of overall patients (9.4% vs. 6.1%, $P = 0.036$; Table 3). There were no significant differences in postoperative stroke, paraplegia, heart failure, pneumonia, re-exploration, tracheotomy, and MODS between sexes. Nevertheless, a higher requirement of postoperative continuous renal replacement therapy (CRRT) was noted in females (14.2% vs. 8.4%, $P = 0.001$) with a longer intensive care unit (ICU) stay (3.0 vs. 2.6 days, $P = 0.013$). The median follow-up period was 3.87 (2.34, 5.82) years, and a total of 32 patients (2.2%) were lost to follow-up. The Kaplan–Meier and competing risk analyses showed comparable long-term survival and reoperation rates in male and female patients ($P = 0.11$ and $P = 0.55$, respectively; Figure 1).

The results of multivariable logistic regression are shown in Table 4. In overall patients, sex revealed no influence on early mortality (OR = 0.736, 95% CI: 0.465–1.165, $P = 0.191$). Platelet count was the only protective factor (OR = 0.992, 95% CI: 0.987–0.998, $P = 0.006$). Age (OR = 1.056, 95% CI: 1.024–1.089, $P < 0.001$), white blood cell count (OR = 1.080, 95% CI: 1.012–1.153, $P = 0.021$), ascending aorta-femoral artery bypass (OR = 7.805, 95% CI: 1.475–41.304, $P = 0.016$), and CPB time (OR = 1.012, 95% CI: 1.006–1.018, $P < 0.001$) were suggested to predict early mortality. When analyzed by sex (Table 5), CPB time was still an independent risk factor in both female and male patients (OR = 1.013, 95% CI: 1.002–1.024, $P = 0.018$ and OR = 1.011, 95% CI: 1.004–1.019, $P = 0.003$, respectively).

3.4. Outcomes of Propensity Score Weighted Population. After PSW, the weighted number of female and male patients effectively matched was 261.5 and 250.5, respectively. No significant differences were observed between sexes in preoperative characteristics, and the P value was close to 1 (Table 1). The propensity score distribution and the love plot are shown in Figure 2. Previous differences in root procedures were still confirmed, but without differences in operation, CPB, and aortic cross-clamped time after PSW (Table 2). And early mortality was similar in both sexes (7.6% vs. 6.4%, $P = 0.569$; Table 3). There were still no significant differences in long-term survival and reoperation rates between sexes, as shown in Figure 3 ($P = 0.83$ and $P = 0.63$, respectively).

4. Discussion

Sex differences in cardiovascular surgeries have always been an important topic [15–17]. Clarification of the sex effects on the prognosis of surgery can help surgeons to better understand patients' medical status and develop a personalized treatment plan. Our study explored the sex effects on outcomes in ATAAD patients undergoing surgery and the following findings were mainly achieved: first, females were almost 9 years older than males with less extensive dissection and a lower rate of preoperative malperfusion syndrome. Second, surgical strategies notably differed between sexes. Relatively conservative strategies and shorter operation time were demonstrated in females. Third, there were no significant differences in early and long-term outcomes between sexes after PSW. Fourth, CPB time was an independent risk factor early mortality in both overall and sex-related populations.

Numerous studies have found that females were prone to develop ATAAD at older ages than males, which was consistent with our findings [18, 19]. The underlying mechanism has not been elucidated, which could be related to the protective effect of estrogen on females. Some studies suggested that estrogen could balance the synthesis of elastic and collagen fibers in the arterial media. Increased arterial stiffness in postmenopausal females could be partly ameliorated by estrogen replacement therapy [20, 21]. Tong et al. found that age-related decrease of the circumferential and longitudinal delamination strengths in elderly females with ascending aortic aneurysm was more prominent than that in elderly males (>65 years), which indicated that elderly females had a higher propensity for dissection occurrence compared with elderly males [22]. Similarly, GERAADA's study also confirmed a higher incidence of TAAD in females older than 75 years [4]. They suggested that the smaller initial aortic diameter in females might be a protective factor for aortic dissection at young ages, but its growth rate was faster than that in males, leading to an increased incidence of aortic dissection in females at older ages [23].

To summarize the preoperative characteristics of patients, Fuwai and Penn classifications were used to describe the extent of dissection involvement and preoperative malperfusion syndrome, respectively. It was found that the dissection in males was more extensive and more frequently

Table 1: Baseline characteristics.

	Unmatched				Weighted		
	Overall $n = 1448$	Female $n = 352$	Male $n = 1096$	P value	Female $n = 261.5$	Male $n = 250.5$	P value
Age (median (IQR), years)	49.0 (41.0, 58.0)	56.0 (47.3, 64.0)	47.8 (40.0, 55.0)	< 0.001*	52.0 (46.0, 61.0)	54.0 (45.0, 62.0)	0.631
BMI (median (IQR), kg/m^2)	25.7 (23.4, 28.2)	24.8 (22.6, 27.1)	26.0 (23.7, 28.7)	< 0.001*	25.4 (22.9, 27.1)	24.8 (22.9, 27.5)	0.955
Hypertension (%)	1136 (78.5)	285 (81.0)	851 (77.6)	0.187	205.3 (78.5)	196.1 (78.3)	0.934
Diabetes mellitus (%)	44 (3.0)	11 (3.1)	33 (3.0)	0.914	7.5 (2.9)	7.7 (3.1)	0.876
CAD (%)	39 (2.7)	13 (3.7)	26 (2.4)	0.183	8.4 (3.2)	8.2 (3.3)	0.972
COPD (%)	9 (0.6)	1 (0.3)	8 (0.7)	0.592	1.0 (0.4)	0.8 (0.3)	0.866
Marfan syndrome (%)	111 (7.7)	28 (8.0)	83 (7.6)	0.815	22.9 (8.8)	22.2 (8.9)	0.964
Smoking (%)	609 (42.1)	40 (11.4)	569 (51.9)	< 0.001*	38.8 (14.8)	38.7 (15.5)	0.807
Family history (%)†	24 (1.7)	4 (1.1)	20 (1.8)	0.379	4.0 (1.5)	4.6 (1.8)	0.766
History of cardiac surgery (%)	40 (2.8)	8 (2.3)	32 (2.9)	0.519	7.6 (2.9)	6.7 (2.7)	0.853
History of aortic surgery (%)	34 (2.3)	7 (2.0)	27 (2.5)	0.609	6.0 (2.3)	6.2 (2.5)	0.867
Hemoglobin (median (IQR), g/L)	134.0 (122.0, 146.0)	121.0 (112.0, 130.0)	139.0 (128.0, 148.0)	< 0.001*	124.0 (117.0, 132.0)	126.0 (111.8, 137.0)	0.281
White blood cell (median (IQR), $*10^9/L$)	11.4 (9.2, 13.9)	10.7 (8.8, 13.1)	11.7 (9.4, 14.3)	< 0.001*	10.9 (8.8, 13.3)	10.6 (8.6, 13.1)	0.318
Platelet (median (IQR), $*10^9/L$)	169.0 (135.0, 209.0])	174.0 (139.0, 218.0)	168.0 (134.0, 206.0)	0.063	171.0 (139.0, 213.5)	166.0 (131.9, 216.0])	0.401
Fuwai A (%)	90 (6.2)	23 (6.5)	67 (6.1)	0.392	17.4 (6.6)	16.2 (6.5)	0.925
Fuwai Cp (%)	55 (3.8)	27 (7.7)	28 (2.6)	< 0.001*	12.6 (4.8)	12.3 (4.9)	0.960
Fuwai Ct (%)	1303 (90.0)	302 (85.8)	1001 (91.3)	0.003*	231.5 (88.5)	222.0 (88.6)	0.970
Penn Aa (%)	1035 (71.5)	282 (80.1)	753 (68.7)	< 0.001*	201.1 (76.9)	190.5 (76.1)	0.794
Penn Ab (%)	393 (27.1)	68 (19.3)	325 (29.7)	< 0.001*	58.6 (22.4)	58.6 (23.4)	0.765
Penn Ac (%)	11 (0.8)	0 (0.0)	11 (1.0)	0.125	0.0 (0.0)	0.0 (0.0)	0.081
Penn Abc (%)	9 (0.6)	2 (0.6)	7 (0.6)	1	1.8 (0.7)	1.4 (0.6)	0.852

†Family history mainly included family history of thoracic aortic aneurysm or dissection; *statistically significant. BMI: body mass index; CAD: coronary artery disease; COPD: chronic obstructive pulmonary disease; IQ:, interquartile range.

Table 2: Operative details.

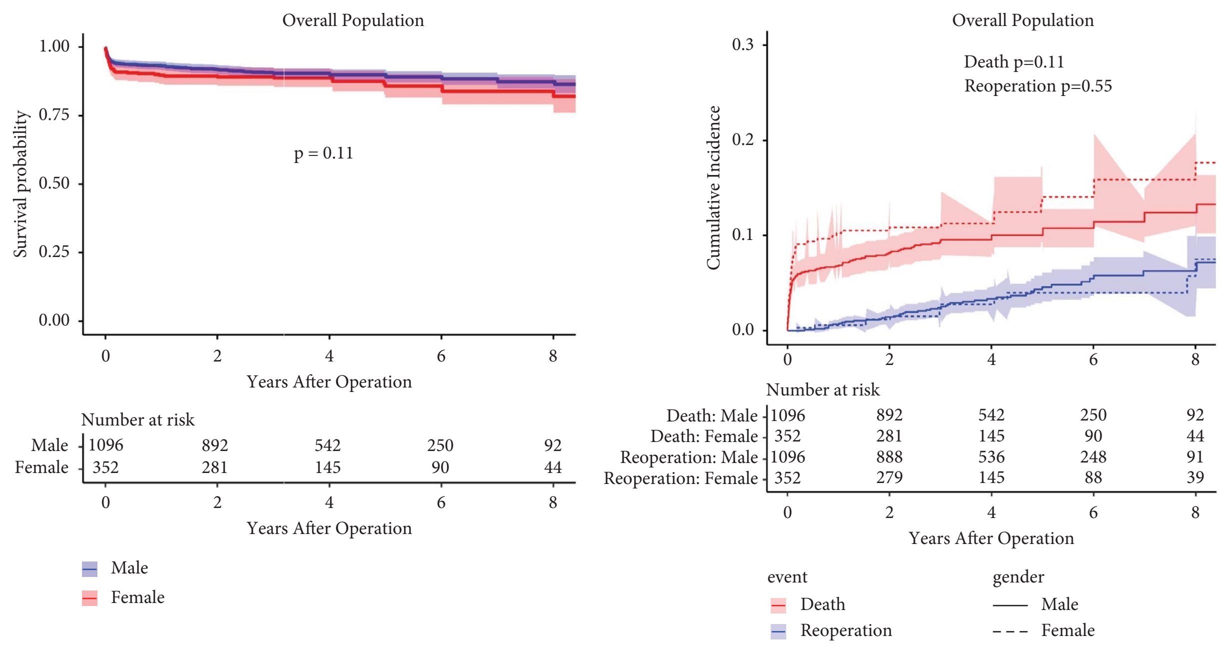
	Unmatched				Weighted		
	Overall $n = 1448$	Female $n = 352$	Male $n = 1096$	P value	Female $n = 261.5$	Male $n = 250.5$	P value
Aortic root sparing (%)	1102 (76.1)	298 (84.7)	804 (73.4)	< 0.001*	215.6 (82.5)	178.4 (71.2)	< 0.001*
Bentall (%)	323 (22.3)	50 (14.2)	273 (24.9)	< 0.001*	42.8 (16.4)	66.1 (26.4)	0.002*
David (%)	7 (0.5)	0 (0.0)	7 (0.6)	0.289	0.0 (0.0)	3.1 (1.2)	0.025*
Wheats (%)	16 (1.1)	4 (1.1)	12 (1.1)	1	3.1 (1.2)	3.0 (1.2)	0.968
Total arch replacement (%)	13 (0.9)	4 (1.1)	9 (0.8)	0.825	2.4 (0.9)	1.1 (0.4)	0.340
Total arch replacement + frozen elephant trunk (%)	1031 (71.2)	200 (56.8)	831 (75.8)	< 0.001*	162.5 (62.2)	164.7 (65.7)	0.334
Aortic balloon occlusion (%)	74 (5.1)	21 (6.0)	53 (4.8)	0.402	17.4 (6.7)	11.2 (4.5)	0.180
Hybrid (%)	170 (11.7)	70 (19.9)	100 (9.1)	< 0.001*	43.8 (16.8)	41.7 (16.6)	0.968
Hemiarch (%)	87 (6.0)	39 (11.1)	48 (4.4)	< 0.001*	24.3 (9.3)	18.7 (7.5)	0.412
Ascending aorta replacement (%)	73 (5.0)	18 (5.1)	55 (5.0)	0.943	11.0 (4.2)	13.1 (5.2)	0.519
Ascending aorta-femoral artery bypass (%)	23 (1.6)	5 (1.4)	18 (1.6)	0.772	5.0 (1.9)	4.8 (1.9)	0.997
Coronary artery bypass graft (%)	165 (11.4)	47 (13.4)	118 (10.8)	0.184	34.9 (13.4)	27.8 (11.1)	0.372
Hypothermic circulatory arrest (%)	1131 (78.1)	243 (69.0)	888 (81.0)	< 0.001*	189.2 (72.4)	184.5 (73.7)	0.705
Operation time (median (IQR), hours)	6.3 (5.3, 7.5)	6.1 (5.1, 7.1)	6.4 (5.4, 7.7)	< 0.001*	6.3 (5.2, 7.0)	6.3 (5.3, 7.4)	0.117
Cardiopulmonary bypass time (median (IQR), minutes)	172.0 (138.0, 208.0)	160.0 (128.0, 201.0)	174.0 (141.0, 212.0)	< 0.001*	172.0 (132.0, 197.2)	172.0 (138.0, 200.0)	0.344
Aortic cross-clamp time (median (IQR), minutes)	95.0 (76.0, 115.0)	93.0 (72.0, 112.0)	95.0 (79.0, 116.0)	0.009*	95.0 (74.0, 109.0)	94.0 (75.0, 112.0)	0.789

*Statistically significant. IQR: interquartile range.

Table 3: Postoperative outcomes.

	Unmatched				Weighted		
	Overall $n = 1448$	Female $n = 352$	Male $n = 1096$	P value	Female $n = 261.5$	Male $n = 250.5$	P value
Early mortality (%)	100 (6.9)	33 (9.4)	67 (6.1)	0.036*	20.0 (7.6)	16.0 (6.4)	0.569
Stroke (%)	42 (2.9)	11 (3.1)	31 (2.8)	0.773	7.5 (2.9)	4.7 (1.9)	0.313
Paraplegia (%)	37 (2.6)	10 (2.8)	27 (2.5)	0.696	8.1 (3.1)	6.9 (2.8)	0.794
CRRT (%)	142 (9.8)	50 (14.2)	92 (8.4)	0.001*	34.5 (13.2)	23.9 (9.5)	0.138
Heart failure (%)	39 (2.7)	11 (3.1)	28 (2.6)	0.565	5.7 (2.2)	5.8 (2.3)	0.884
Pneumonia (%)	261 (18.1)	69 (19.7)	192 (17.6)	0.379	45.6 (17.5)	39.0 (15.6)	0.483
Re-exploration (%)	52 (3.6)	18 (5.1)	34 (3.1)	0.078	15.7 (6.0)	8.3 (3.3)	0.097
Tracheotomy (%)	42 (2.9)	15 (4.3)	27 (2.5)	0.080	12.5 (4.8)	7.9 (3.2)	0.308
MODS (%)	29 (2.0)	10 (2.8)	19 (1.7)	0.197	9.0 (3.4)	4.1 (1.6)	0.126
In-hospital stay (median (IQR), days)	12.0 (9.0, 16.5)	13.0 (10.0, 18.0)	12.0 (9.0, 16.0)	0.250	13.0 (9.0, 18.0)	12.0 (10.0, 17.0)	0.673
ICU stay (median (IQR), days)	2.7 (1.5, 4.6)	3.0 (1.7, 5.0)	2.6 (1.5, 4.3)	0.013*	2.9 (1.7, 4.6)	2.9 (1.4, 4.5)	0.147

*Statistically significant. CRRT: continuous renal replacement therapy; IQR: interquartile range; ICU: intensive care unit; MODS: multiple organ dysfunction syndrome.



(a) (b)

Figure 1: Long-term outcomes for the overall population: (a) Kaplan–Meier analysis for long-term survival and (b) competing risk analysis for reoperation and death according to sex.

Table 4: Multivariable logistic regression for early mortality in the overall population.

	Odds ratio	95% confidence interval	*P* value
Overall population			
Sex	0.736	0.465–1.165	0.191
Age	1.056	1.024–1.089	<0.001
White blood cell	1.080	1.012–1.153	0.021
Platelet	0.992	0.987–0.998	0.006
Ascending aorta-femoral artery bypass	7.805	1.475–41.304	0.016
Cardiopulmonary bypass time	1.012	1.006–1.018	<0.001

Table 5: Multivariable logistic regression for early mortality in female and male patients.

	Odds ratio	95% confidence interval	*P* value
Females			
Platelet	0.991	0.983–1.000	0.045
Cardiopulmonary bypass time	1.013	1.002–1.024	0.018
Males			
Age	1.053	1.015–1.091	0.005
White blood cell	1.098	1.019–1.184	0.015
Cardiopulmonary bypass time	1.011	1.004–1.019	0.003

combined with malperfusion syndrome, which was consistent with the results of some other studies [4, 24]. Fuwai classification was developed to better distinguish the involvement of aortic arch dissection and guide different surgical strategies. Patients with Fuwai Ct had the most extensive dissection, and TAR was most frequently administrated in these patients [11]. The present study also showed that females presented with a lower rate of Fuwai Ct with less TAR + FET surgery but much more hemiarch replacement and hybrid surgery. Penn classification is a method for evaluating preoperative ischemic complications of ATAAD [12], which can effectively assess the surgical risk and help develop risk stratification for different patients. In this study, there were few patients presented with Penn Ac and Abc in both sexes. However, Penn Ab was more common in males, which indicated that males were more prone to develop preoperative localized ischemia.

Our findings noted that root replacement, especially the Bentall procedure, was more common in males, corresponding with the findings of some previous studies [7, 25].

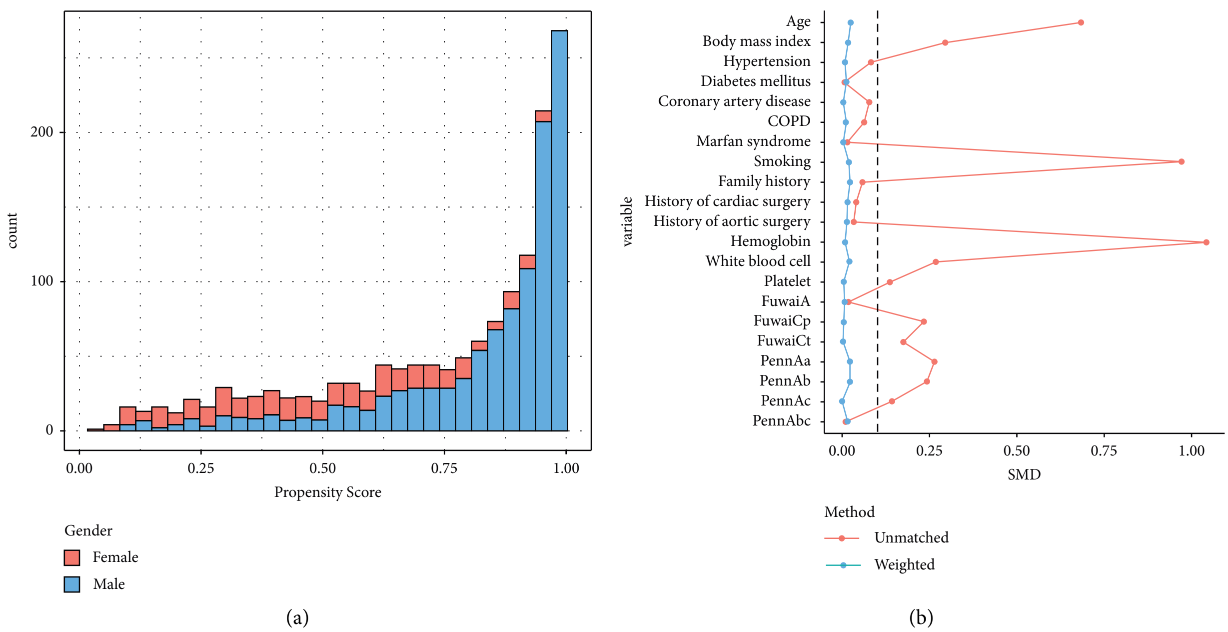


FIGURE 2: Results of propensity score weighting: (a) propensity score distribution and (b) love plot before and after propensity score weighting among baseline characteristics.

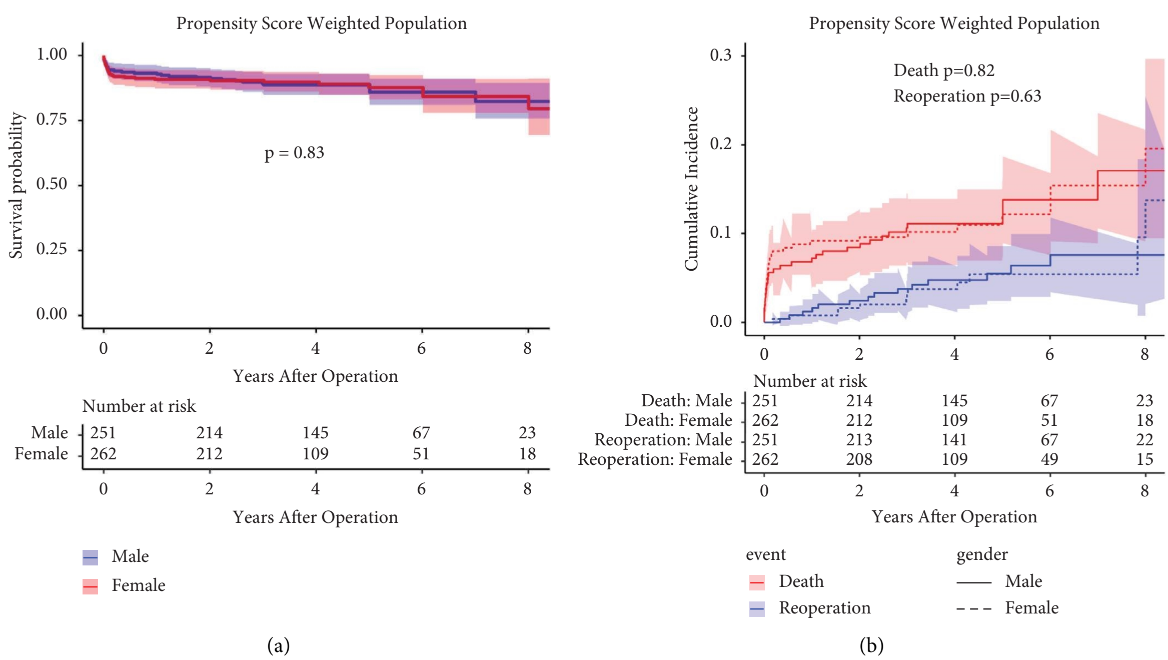


FIGURE 3: Long-term outcomes for the propensity score weighted population: (a) Kaplan–Meier analysis for long-term survival and (b) competing risk analysis for reoperation and death according to sex.

As described by Huckaby et al. from IRAD, the preoperative diameters of the aortic annulus, root, and sinotubular junction in males were significantly larger than those in females, and the proportion of aortic regurgitation more than mild was higher in males, which indicated that males were more frequently diagnosed with root involvement [25]. However, different from European and American centers [4, 8, 25], a total of 71.2% patients in our center in China underwent TAR + FET surgery for the aortic arch dissection, of which the number of male patients was significantly more, but both sexes exceeded 50% (56.8% vs. 75.8%, $P < 0.001$). Females were more conservative in surgery, which could be associated with the smaller propagation of dissection, less preoperative complications, and older age in females. One early study demonstrated that TAR surgery was an aggressive strategy that significantly increased the incidence of postoperative mortality and neurological complications [26]. However, after years of great progress in surgical techniques and improvement of the aortic prosthesis, recent studies showed no significant differences in patients' mortality and complications after TAR surgery compared with hemiarch surgery [27]. Besides, Wang et al. have recently revealed that TAR + FET surgery was equally safe in female patients, and even safer for younger females (≤55 years old) [9]. TAR + FET surgery has been applied in China for decades, and it has gradually become a widely used procedure for TAAD involving the aortic arch.

Despite more aggressive surgical strategies in male patients were noted in our findings, we did not observe any differences in early and long-term mortality between sexes after balancing the baseline characteristics. Multivariable analysis further confirmed that sex had no significant influence on early mortality, whereas some studies reported worse outcomes in female patients [3, 7, 28]. Nienaber et al. have earlier revealed a 10% higher in-hospital mortality rate in female ATAAD patients ($P = 0.013$) from IRAD. They concluded that females with older age and prolonged diagnosed time suffered from more severe preoperative complications and were less tolerant to surgery than males [3]. Li et al. also used the propensity score matching method to analyze sex differences in ATAAD patients, but they found that females had higher in-hospital and long-term mortality than males, especially when the operation time was longer than 12 hours [28]. However, these conclusions were not confirmed in most recent studies [6, 8, 18, 19, 24, 29]. The latest IRAD study reported that although females still experienced more preoperative complications, data from the last decade denied that female sex was an independent risk factor for in-hospital and long-term mortality. This change was closely related to the continuous progress of surgical techniques [25]. Chen et al. enrolled a total of 4,169 ATAAD patients undergoing surgery to investigate sex differences in outcomes, and no significant sex-related difference was found for the in-hospital mortality or accumulative all-cause mortality [29]. Some studies even suggested female sex to be a protective factor for early mortality of ATAAD surgery [9, 24], which could be related to the less extensive dissection in females. Future prospective studies with large-scale populations are required to further clarify the influence of female sex on the prognosis of ATAAD patients undergoing surgery.

4.1. Limitations. The present study has several limitations. First, this was a retrospective single-center study, hindering generalization of the findings of this study. However, we used propensity score weighting to balance potential confounding factors, so the results were relatively reliable. Second, only ATAAD patients undergoing surgery were included, which made it impossible to evaluate those who died before surgery or were treated conservatively.

5. Conclusions

In ATAAD, different presentations were noted in female patients, including older age and a lower incidence of malperfusion syndrome with localized dissection. Surgical strategies were more aggressive in male patients. However, there were no significant differences in early and long-term outcomes between sexes after balancing the baseline characteristics. CPB time was identified as a predictor of early mortality in both overall and sex-related populations. Therefore, conservative or aggressive surgical strategies should not be applied based on the sex.

Data Availability

All relevant data are included within the paper. The data used to support the findings of this study have not been made available due to privacy or ethical restrictions.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Authors' Contributions

Chenyu Zhou and Jinlin Wu conceptualised and designed the study; Cuntao Yu and Juntao Qiu were involved in administrative support; Chenyu Zhou and Jinlin Wu were responsible for statistics; Chenyu Zhou, Jinlin Wu, Enzehua Xie, Lu Dai, Jian Song, Rui Zhao, and Shiqi Gao collected the data; Jinlin Wu and Chenyu Zhou were involved in data analysis and interpretation; all authors prepared the original draft; all authors approved the article. Cuntaoyu secured funding. Chenyu Zhou and Jinlin Wu contributed equally to this work.

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