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Risk Factors for Permanent Neurological Dysfunction and Early Mortality in Patients with Type A Aortic Dissection Requiring Total Arch Replacement

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ABSTRACT

Background: Surgery is a definitive treatment for patients with type A aortic dissection. The aim of this study was to identify and analyze the risk factors for permanent neurological dysfunction (PND) and 30-day mortality in patients following total arch replacement and stented elephant trunk implantation in the descending aorta.

Methods: The clinical data of 85 consecutive patients who underwent this surgical procedure between December 2013 and May 2017 were reviewed. Multivariate logistic regression analysis was performed to determine the independent predictors of postoperative PND and 30-day mortality.

Results: There were 62 males and 23 females, with a mean age of 47.6 ± 11.7 years (range, 26-73 years). Ten patients (11.76%) developed PND after surgery. Postoperative 30-day mortality was 11.76% (10/85), including one death during hospitalization and nine deaths after discharge. Multivariate analysis showed that hypertension was independently associated with postoperative PND (OR = 4.407, 95% CI: 1.021-19.023, $P = .047$), and age and postoperative PND were independent predictors for 30-day mortality (OR, 1.120; 95% CI, 1.026-1.221; $P = .011$ and OR, 7.503; CI, 1.290-43.634; $P = .025$, respectively).

Conclusion: Hypertension was independently associated with postoperative PND, and age and postoperative PND were predictors for early mortality in patients who underwent total arch replacement and stented elephant trunk implantation.

INTRODUCTION

Type A aortic dissection is a life-threatening disease. Patients are at the greatest risk in the acute phase of this condition, and approximately 50% of patients die within 48 hours without surgery [Lauterbach 2001]. Appropriate surgical management of these lethal aortic diseases is critical for achieving a satisfactory outcome. Several surgical approaches have been introduced (ascending aorta/hemi-arch/total arch repair or replacement, and frozen elephant trunk technique), however, the optimal approach remains controversial [Kruger 2012; Sun 2011; Karck 2003; Fleck 2002].

Dr. Sun's team in China has reported a surgical technique (Sun's procedure) that is a therapeutic method for extensive dilating pathologies involving the ascending aorta, aortic arch and descending aorta [Sun 2013]. The technique integrates total arch replacement using a tetra-furcated graft with stented elephant trunk implantation in the descending aorta. This procedure provides an aggressive solution to type A aortic dissection, and has demonstrated favorable early and late outcomes in the reports from their team in the past decade [Ma 2014; Ma 2013; Sun 2011].

We have carried out this procedure since the end of 2013 in our department, and have reported some experiences with the cerebral perfusion in the extracorporeal circulation [Chen 2016]. The mortality and neurological dysfunction related to Sun's procedure is a hot topic in current research due to its higher technical complexity, longer operative time, and extended hypothermic circulatory arrest time, but data from Asian countries is very limited.

Herein, we reported 85 patients who underwent Sun's procedure, and investigated the possible perioperative risk factors influencing early mortality and postoperative permanent neurological dysfunction (PND).

MATERIALS AND METHODS

Patients

We performed a retrospective study of consecutive adult patients with type A aortic dissection who underwent Sun's procedure in Xinqiao hospital between December 2013 and May 2017. Preoperative diagnoses were based on the computed tomography angiography (CTA) and echocardiography (ECG) results. Surgical indications were any of following conditions: (1) primary entry located in the arch or descending aorta; (2) severe arch vessel pathologic features, including dissection, occlusion, stenosis, or aneurysm changes; (3) intimal intussusception in the arch; (4) concomitant Marfan syndrome; and (5) dissection in a dilated arch >4 cm in diameter and extending beyond the descending aorta [Ma 2014]. This study was approved by the Ethics Committee of Xinqiao Hospital.

Operation Techniques

All patients received standard general anesthesia. Midazolam or propofol, sufentanil, isoflurane, and vecuronium or

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Table 1. Univariate Analysis of Preoperative Risk Factors for Postoperative Permanent Neurological Dysfunction and Postoperative 30-Day Mortality

	Total	Permanent neurological dysfunction			Postoperative 30-day mortality		
	n=85	No (n=75)	Yes (n=10)	*P*	No (n=75)	Yes (n=10)	*P*
Age (year)	47.62 ± 11.74	47.2 ± 12.04	50.8 ± 9.09	.366	46.39 ± 11.58	56.90 ± 8.67	.007
Gender				.593			.196
Male	62 (72.94%)	54 (87.1%)	8 (12.9%)		53 (85.48%)	9(14.52%)	
Female	23 (27.06%)	21 (91.3%)	2 (8.7%)		22 (95.65%)	1(4.35%)	
BMI (kg/m^2)	24.06 ± 3.62	24.06 ± 3.79	24.04 ± 2.04	.992	24.05 ± 3.77	24.06 ± 2.25	.996
Hypertension				.010			.057
Yes	44 (51.76%)	35 (79.55%)	9 (20.45%)		36 (81.82%)	8(18.18%)	
No	41 (48.24%)	40 (97.56%)	1 (2.86%)		39 (95.12%)	2(4.88%)	
Diabetes mellitus				.601			.601
Yes	2 (2.35%)	2 (100%)	0 (0)		2 (100%)	0(0)	
No	83 (97.65%)	73 (87.95%)	10 (12.05%)		73 (87.95%)	10(12.05%)	
Hyperlipidemia				.057			.219
Yes	44 (51.76%)	36 (81.82%)	8 (18.18%)		37 (84.09%)	7(15.91%)	
No	41 (48.24%)	39 (95.12%)	2 (4.88%)		38 (92.68%)	3(7.32%)	
Coronary heart disease				.520			.520
Yes	3 (3.53%)	3 (100%)	0 (0)		3 (100%)	0(0)	
No	82 (96.47%)	72 (87.8%)	10 (12.2%)		72 (87.8%)	10(12.2%)	
Acute onset				.233			.233
Yes	64 (75.29%)	58 (90.63%)	6 (9.38%)		58 (90.63%)	6(9.38%)	
No	21 (24.71%)	17 (80.95%)	4 (19.05%)		17 (80.95%)	4(19.05%)	
Coronary malperfusion				.454			.015
Yes	4 (4.71%)	4 (100%)	0 (0)		2 (50%)	2(50%)	
No	81 (95.29%)	71 (87.7%)	10 (12.3%)		73 (90.1%)	8(9.9%)	
Renal malperfusion				.619			.390
Yes	10 (11.76%)	10 (100%)	0 (0)		8 (80%)	2(20%)	
No	75 (88.24%)	65 (86.7%)	10 (13.3%)		67 (89.3%)	8(10.7%)	
Lower extremity malperfusion				.390			.854
Yes	10 (11.76%)	8 (80%)	2 (20%)		9 (90%)	1(10%)	
No	75 (88.24%)	67 (89.3%)	8 (10.7%)		66 (88%)	9(12%)	
LVEF (%)	62 (59-65)	62 (59-65)	60 (58-62)	.105	62 (58.4-65)	61.5(59.8-66.4)	.656
Primary entry tear				.583			.424
Ascending aorta	40 (47.06%)	33 (82.5%)	7 (17.5%)		33 (82.5%)	7(17.5%)	
Aortic arch	13 (15.29%)	12 (92.31%)	1 (7.69%)		11 (84.62%)	2(15.38%)	
Descending aorta	2 (2.35%)	2 (100%)	0 (0)		2 (100%)	0(0)	
Multiple sites	22 (25.88%)	21 (95.45%)	1 (4.55%)		21 (95.45%)	1(4.55%)	
Unknown	8 (9.41%)	7 (87.5%)	1 (12.5%)		8 (100%)	0(0)	

Values are n (%), mean ± standard deviation, or median (interquartile range).
BMI indicates body mass index; LVEF, left ventricular ejection fraction.

Table 2. Univariate Analysis of Operative Risk Factors for Postoperative Permanent Neurological Dysfunction and Postoperative 30-Day Mortality

	Total	Permanent neurological dysfunction			Postoperative 30-day mortality		
	n=85	No (n=75)	Yes (n=10)	*P*	No (n=75)	Yes (n=10)	*P*
Emergency operation	23 (27.06%)	21 (78.26%)	2 (21.74%)	.593	19(82.61%)	4(17.39%)	.327
Operation time (h)	9.10 ± 1.64	9.06 ± 1.68	9.43 ± 1.31	.502	8.91 ± 1.49	10.54 ± 2.03	.003
CPB time (min)	271.25 ± 68.48	270.39 ± 71.77	277.7 ± 36.97	.753	260.96 ± 53.56	348.4 ± 112.64	.000
Cross-clamp time (min)	151.62 ± 41.89	149.88 ± 40.63	164.7 ± 50.9	.296	146.87 ± 38.94	187.3 ± 48.05	.004
SCP time (min)	45.14 ± 19.05	44.43 ± 18.31	50.5 ± 24.36	.347	45.11 ± 18.06	45.4 ± 26.55	.964
Cerebral perfusion vessel				.680			.274
Axillary artery	75 (88.24%)	65 (86.67%)	10 (13.33%)		66 (88%)	9(12%)	
Innominate artery	5 (5.88%)	5 (100%)	0 (0)		5 (100%)	0(0)	
Left common carotid artery	3 (3.53%)	3 (100%)	0 (0)		3(100%)	0(0)	
Superior vena cava	2 (2.35%)	2 (100%)	0 (0)		1 (50%)	1(50%)	
Crystal infusion, median (mL)	1950 (1500-2790)	1900 (1350-2780)	2000(1675-3400)	.332	1900(1350-2550)	3100(1675-4688)	.022
Transfusion (mL)	2970 ± 1525	2974 ± 1567	2941 ± 1231	.950	2891 ± 1510	3564 ± 1591	.192
Total infusion, median (mL)	4716 (3512-5858)	4600 (3320-5950)	4975(3885-6240)	.413	4475(3320-5635)	6103(4658-8988)	.020
Total output (mL)	3639 ± 1279	3625 ± 1288	3751 ± 1267	.772	3618 ± 1290	3796 ± 1247	.683
Bleeding (mL)	740 (490-1200)	730 (500-1200)	830 (454-1635)	.886	710 (480-1200)	935 (513-1987)	.230
Hyperfiltration (mL)	1509 ± 1125	1510 ± 1123	1500 ± 1191	.978	1549 ± 1146	1210 ± 945	.374
Urine volume (mL)	1157 ± 752	1142 ± 750	1274 ± 797	.605	1135 ± 770	1324 ± 616	.460

Values are n (%), mean ± standard deviation, or median (interquartile range).
CPB indicates cardiopulmonary bypass; SCP, selective cerebral perfusion.

rocuronium bromide were given to maintain anesthesia. The left radial artery and dorsal artery of the foot were cannulated for continuous measurement of systemic perfusion pressures during cardiopulmonary bypass (CPB). Temperature probes were placed for nasopharyngeal and rectal temperature monitoring.

All operations were performed through a median sternotomy. After heparinization, the right femoral artery, right axillary artery (occasionally innominate artery or left common carotid artery) and right atrium were cannulated. Patients were cooled on CPB; when the nasopharyngeal temperature reached 28 °C, the ascending aorta was clamped and cardioplegia was used for myocardial protection. Proximal aortic management was then accomplished including aortic valve replacement, Bentall procedure, and coronary artery bypass graft.

Circulatory arrest was initiated when the nasopharyngeal and rectal temperature reached 22-23 °C and 24-25 °C, respectively, and unilateral antegrade selective cerebral perfusion was executed. The flow rate was maintained at 5–10 ml/kg/min. Thereafter, implantation of the stented graft into the descending aorta, total arch replacement with a 4-branched vascular graft, and a specific sequence for aortic reconstruction (i.e., proximal descending aorta, then left carotid artery, ascending aorta, left subclavian artery, and finally innominate artery) were performed.

Methylprednisolone, magnesium sulfate, and mannitol were administered for neuroprotection during circulatory arrest. Inotropic support was implemented when necessary to maintain a normal cardiac index and vascular resistance. Blood components including packed red blood cells, fresh-frozen plasma, cryoprecipitate, and platelets, which were infused to maintain the post-CPB hematocrit and adjust coagulopathy.

Data Collection

Three categories of data were collected. First were preoperative variables, including demographic data such as gender, age and body mass index (BMI), primary diagnosis, medical history, urgent priorities, left ventricular ejection fraction (LVEF), dissection primary entry tear, and malperfusion syndromes. Second included intraoperative variables, including concomitant surgical procedures, operation time, CPB time, cross-lamp time, selective cerebral perfusion (SCP) time, cerebral perfusion vessels, infusion (crystal and blood components), and output (bleeding, urine and hyperfiltration). Third were postoperative variables, including length of mechanical ventilation, length of cardiac intensive care unit (CICU) stay, length of hospital stay, hypoxemia, postoperative 30-day mortality, postoperative acute kidney injury (AKI), liver damage, infection, and PND. Final clinical assessment was performed on day 30 post-operation.

Acute onset was defined as the beginning of clinical symptoms to ≤14 days. Malperfusion syndromes were defined according to symptoms from each arterial system and required

Table 3. Univariate Analysis of Postoperative Risk Factors for Postoperative Permanent Neurological Dysfunction and Postoperative 30-Day Mortality

	Total	Permanent neurological dysfunction			30-day mortality		
	n=85	No (n=75)	Yes (n=10)	*P*	No (n=75)	Yes (n=10)	*P*
Length of CICU stay (d)	9 (6-11)	8 (5-11)	12 (9-14.25)	.013	9(6-11)	8.5(1.75-14)	.702
Length of hospital stay (d)	25 (20-35.5)	25 (20-35)	24.5 (14-53.25)	.929	26(21-36)	11(5.5-23.25)	.001
Length of mechanical ventilation (h)	47 (32.5-84)	45 (30-68)	88(39.75-210)	.014	47(33-69)	69.5(23.75-210)	.309
Hypoxemia				.033			.546
Yes	50 (58.82%)	41 (82%)	9 (18%)		45 (90%)	5(10%)	
No	35 (41.18%)	34 (97.14%)	1 (2.86%)		30 (85.71%)	5(14.29%)	
AKI				.651			.249
Yes	54 (63.53%)	47 (87.04%)	7 (12.96%)		46 (85.19%)	8(14.81%)	
No	31 (36.47%)	28 (90.32%)	3 (9.68%)		29 (93.55%)	2(6.45%)	
Liver damage				.492			1.000
Yes	51 (60%)	46 (90.2%)	5 (9.8%)		45 (88.24%)	6(11.76%)	
No	34 (40%)	29 (85.29%)	5 (14.71%)		30 (88.24%)	4(11.76%)	
Infection				.169			1.000
Yes	34 (40%)	28 (82.35%)	6 (17.65%)		30 (88.24%)	4(11.76%)	
No	51 (60%)	47 (92.16%)	4 (7.84%)		45 (88.24%)	6(11.76%)	

Values are n (%), mean ± standard deviation, or median (interquartile range).
CICU indicates cardiac intensive care unit; AKI, acute kidney injury.

clinical evidence of lack of blood flow to a defined organ system, including cerebral, coronary, renal, spinal, mesenteric and lower extremity malperfusion, as described by Geirsson et al [Geirsson 2007]. Surgical or radiographical evidence of dissection flap in branch vessels without symptoms of malperfusion was not considered as malperfusion syndrome. AKI was diagnosed according to Acute Kidney Injury Network (AKIN) criteria [Mehta 2007]. We took an absolute increase in serum creatinine (sCr) of ≥0.3 mg/dL or a percentage increase in the sCr of ≥50% as the criteria of AKI. Liver damage was diagnosed by the standard classification of Child-Pugh score, and class B and class C were considered as liver damage [Jacob 2015]. Postoperative PND included stroke, coma, hemiplegia and paraplegia [Ergin 1994]. Postoperative hypoxemia was defined as an oxygen fraction (PaO_2/FiO_2) ≤200 mmHg under mechanical ventilation in the first 24 hours after surgery [Nakajima 2006].

Statistical Analysis

All statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) software version 16.0 (SPSS Inc., Chicago, IL, USA). Summary statistics are presented as frequencies and percentages for categorical variables, and as mean and standard deviation for continuous values. Continuous variables with asymmetrical distributions (skewed distributions) were presented as the median and interquartile ranges. The normality of the variables was assessed using Kolmogorov-Smirnov test. Comparisons of categorical variables between patients with and without postoperative PND and patients who died or survived were analyzed with the Pearson's chi-square test or Fisher's exact test, where appropriate. Comparisons between the means of continuous variables were assessed using Student's t-test for unpaired data, or the Mann–Whitney two-sample statistic, as appropriate. Age, gender, and BMI as adjusted factors, combined with all variables with a *P* value ≤ .05 in univariate analysis, were entered into a forward multivariate logistic regression model. Logistic regression result was presented as odds ratio (OR) with 95% confidence interval (95% CI) and *P* value. A *P* value ≤ .05 was considered statistically significant.

RESULTS

General Conditions

A total of 85 consecutive patients were included in our analysis. There were 62 males and 23 females, with a mean age of 47.6 ± 11.7 years (range, 26-73 years). Sixty-four (75.29%) patients were in acute phase of the disease. Massive pericardial effusion was found in one patient, and heart failure in four patients. Coronary malperfusion, renal malperfusion, and lower extremity malperfusion occurred in 4, 10, and 10 patients, respectively. No hypotension, stroke, coma, hemiplegia, paraplegia, or shock occurred at the onset of the diseases. Fifteen patients (17.65%) also had Marfan syndrome, while one (1.18%) also had bicuspid aortic valve. Hypertension, diabetes mellitus, hyperlipidemia, and coronary heart

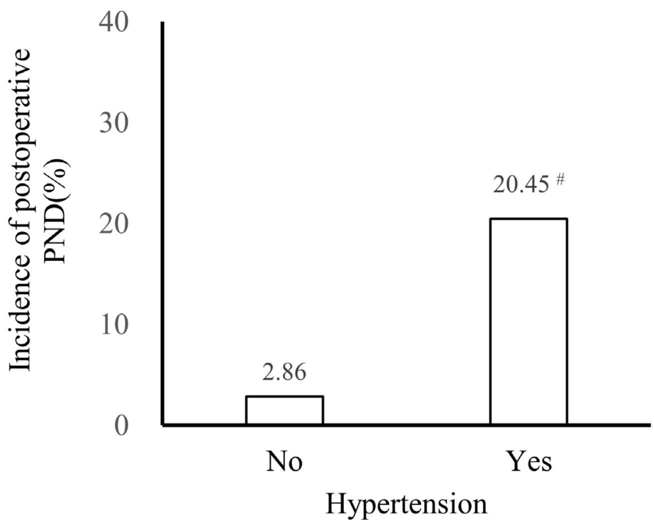

Figure 1. Incidence of postoperative permanent neurological dysfunction in patients with and without hypertension.
#*P* = .010.

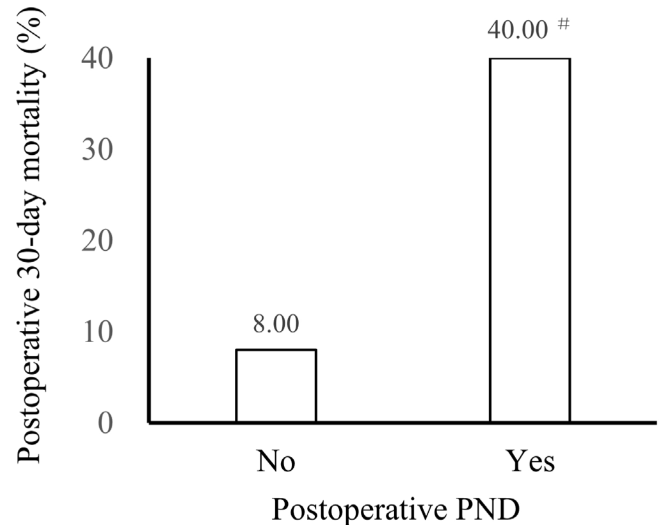

Figure 2. Postoperative 30-day mortality rate in patients with and without postoperative permanent neurological dysfunction.
#*P* = .003.

disease was diagnosed in 44 (51.76%), 2 (2.35%), 44 (51.76%) and 3 (3.53%) patients, respectively.

Ten patients (11.76%) developed PND after surgery. Postoperative 30-day mortality was 11.76% (10/85), including one death during hospitalization and nine deaths after discharge. An emergency operation was performed in 27.1% of patients (23/85). Concomitant procedures such as the Bentall procedure, coronary artery bypass graft, aortic valve replacement, and mitral valve plasty were performed in 40 patients (47.06%), 6 patients (7.06%), 1 patient (1.18%) and 1 patient (1.18%), respectively. The mean CPB time in all patients was 271.25 ± 68.48 min, cross-clamp time was 151.62 ± 41.89 min, and SCP time was 45.14 ± 19.05 min. Three patients (3.53%) were re-operated (two due to bleeding at the surgical site and one due to duodenal ulcer bleeding that could not be stopped by medical therapy after operation).

Risk Factors for Postoperative PND

By univariate analysis, four factors were significantly associated with postoperative PND: hypertension ($P = .010$), length of mechanical ventilation ($P = .014$), length of CICU stay ($P = .013$), and postoperative hypoxemia ($P = .033$). Incidence of postoperative PND was higher in patients with hypertension than in those without hypertension (20.45% versus 2.86%, $P = .010$) (Figure 1). Factors such as malperfusion, primary entry tear, CPB time, cross-clamp time, SCP time, and cerebral perfusion vessel had no effects on the incidence of postoperative PND ($P > .05$) (Tables 1, 2, and 3). Hypertension was found to be independently associated with postoperative PND using the multivariate analysis (OR, 4.407; 95% CI, 1.021-19.023; $P = .047$) (Table 4).

Risk Factors for 30-Day Mortality

Eight factors were significantly associated with the 30-day mortality of all patients by univariate analysis, including age ($P = .007$), coronary malperfusion ($P = .015$), intraoperative crystal infusion ($P = .022$), intraoperative total infusion ($P = .020$), operation time ($P = .003$), CPB time ($P < .001$), cross-clamp time ($P = .004$), and postoperative PND ($P = .003$) (Tables 1, 2, and 3). The 30-day mortality rate was higher in patients with postoperative PND than in those without postoperative PND (40% versus 8%, $P = .003$) (Figure 2). Age and postoperative PND were independently associated with mortality by multivariable analysis (OR, 1.120; CI, 1.026-1.221; $P = .011$ and OR, 7.503; CI, 1.290-43.634; $P = .025$, respectively) (Table 5).

DISCUSSION

The present study showed that hypertension was highly correlated with postoperative PND, and that age and postoperative PND were predictors for early mortality in patients who underwent Sun's procedure.

The prevalence of hypertension in China has been increasing for decades, and had reached 34% (about 337 million) in 2010 [Hou 2016]. However, the awareness of hypertension remains unsatisfactory, and its control rate is much lower than in the developed countries [Mohan 2009]. Thirty-four percent (15/44) patients diagnosed with hypertension in our study had regularly received hypotensive drugs, but only six patients had well-controlled blood pressure, which may explain why complications such as aortic dissection frequently occurred in these patients. Stroke was a major complication of hypertension in Chinese population. The mortality due to stroke has been increasing in rural areas and in younger people in cities, but has a declining trend in middle-aged and elderly population in cities [Liu 2011].

This study suggested that patients with hypertension had higher rates of postoperative PND compared to patients without hypertension. Also, a significantly higher mortality

Table 4. Multivariate Analysis of Risk Factors for Postoperative Permanent Neurological Dysfunction

	Odd Ratio	95% Confidence Interval	*P*
Age	0.995	0.927-1.069	.899
Gender	0.662	0.119-3.678	.638
BMI	0.956	0.776-1.177	.670
Hypertension	4.407	1.021-19.023	.047

BMI indicates body mass index.

Table 5. Multivariate Analysis of Risk Factors for Postoperative 30-Day Mortality

	Odd Ratio	95% Confidence Interval	*P*
Age	1.120	1.026-1.221	.011
Gender	0.161	0.015-1.665	.125
BMI	0.955	0.748-1.220	.713
Postoperative PND	7.503	1.290-43.634	.025

BMI indicates body mass index; PND, permanent neurological dysfunction.

rate was found in patients with postoperative PND than in patients without PND. Our study showed a clear association between hypertension, PND, and death in patients with type A aortic dissection who underwent Sun's procedure; this calls for attention to hypertension management in this disease.

Neurological deficit after surgical repair of type A aortic dissection is a frequent complication. Postoperative neurological symptoms varied widely between 16.5% and 47.5% in the reports of past two decades, and the incidence of new PND after surgery ranged from 5% to 13.5% in recent reports [Liu 2017; Kruger 2013; Ma 2013; Conzelmann 2012; Gaul 2007; Blanco 1999]. Our data showed that 11.76% patients developed PND after surgery, which was acceptable. The mean cross-clamp and SCP time was 152 min and 45 min in our patients, respectively, but 111 min and 24 min in Dr. Sun's report, which could be the reason why higher postoperative PND occurred at our institution [Ma 2014].

Perioperative neurological injury was most likely due to inadequate brain perfusion or protection during surgery. Conzelmann et al demonstrated that malperfusion syndrome, dissection of the supra-aortic vessels, and longer operating time were predictors for postoperative new neurological dysfunction [Conzelmann 2012]. Liu et al suggested that stroke was strongly associated with adverse outcomes [Liu 2017]. Ehrlich et al reported that preoperative hemodynamic instability was an independent predictor of adverse outcome [Ehrlich 2003].

Our study indicated that hypertension was the only predictor for postoperative PND. In our study, no cerebral malperfusion (stroke, coma hemiplegia, and paraplegia), hypotension, or shock was observed pre-operation. This was either due to the relatively small number of cases, or because many patients lived far away from our hospital and probably refused treatment when they had sudden stroke or coma, or died on the way. Therefore, patients that had preoperative neurologic deficits were absent.

Notably, we found a correlation between postoperative hypoxemia and PND by univariate analysis. Postoperative hypoxemia has been reported in 12.2–27.1% of patients after CPB, and as high as 49.5% in open heart aortic dissection surgery [Wang 2013; Ji 2008; Nakajima 2006]. Hypoxemia could induce prolonged ventilator support, longer stays in ICU, and organ dysfunctions other than the lung. Our research showed that postoperative hypoxemia played a role in PND, but was not an isolated risk factor for PND, which was likely due to multiple factors such as hypotension, low perfusion, microembolism, systemic inflammatory action, etc., which potentially influence neurological injury.

Whether cannulation strategy has an impact on neurological outcome remains controversial [Patris 2015]. Some studies have found that femoral and axillary artery cannulation had similar major complications and mortality, while others have shown that axillary and subclavian artery cannulation improved neurological outcome and decreased mortality as compared to femoral artery cannulation in patients undergoing acute type A aortic dissection repair [Klotz 2016; Ren 2015; Lee 2012; Moizumi 2005]. Combining femoral artery cannulation (to maintain the blood in lower part of the body) with axillary artery cannulation (for antegrade cerebral perfusion during circulatory arrest) is the routine procedure used at our hospital. Our data showed no significant difference in the cerebral perfusion vessels for postoperative PND and mortality.

Patients suffering from acute type A aortic dissection have high mortality. A 17-year observation from the International Registry of Acute Aortic Dissection (IRAD) group in 2015 reported that overall in-hospital mortality was 22–31%, surgical mortality was 18–25%, and the highest medical mortality was 65% in type A aortic dissection [Pape 2015]. A report from the German Registry for Acute Aortic Dissection Type A (GERAADA) in 2011 indicated that overall 30-day mortality was 15.9% [Kruger 2011]. In this study, the 30-day mortality with Sun's procedure was 11.76%, which was comparable to the western countries but higher than Dr. Sun's reports of 3.1–7.8% [Ma 2014; Ma 2013; Sun 2013]. There are two possible explanations for the mortality rate of our patients: first, the operation time was slightly longer, and second, death included the patients who were discharged from the hospital and died within 30 days after surgery. However, the major factors influencing mortality remain uncertain. Age and postoperative PND were predictors for early mortality in our study, which was in accordance with previous studies [Jussli-Melchers 2017; Rylski 2014; Conzelmann 2012; Olsson 2007]. Furthermore, PND significantly influenced the mortality of patients with type A aortic dissection, as seen in previous studies [Liu 2017; Kruger 2013; Ma 2013; Conzelmann 2012]. The only difference was that the mean age of our patients was 46.7 years, which was much younger than in the western countries: 1.18% of the patients in our study were ≥70 years, and 24.71% were <40 years, while the percentages were 30% and 7%, respectively, in the Rylski et al report [Rylski 2014; Olsson 2007].

Unhealthy lifestyles in young people were likely responsible for the etiology of hypertension in our country [Liu 2017; Ma 2014]. Some studies have shown that factors like acute heart failure, long CPB time, resuscitation, and longer operation time were associated with mortality [Conzelmann 2016; Ma 2013]. Interestingly, univariate analysis indicated that coronary malperfusion, intraoperative infusion, operation time, CPB time, and cross-clamp time were correlated with mortality, but these results were not found in multivariate analysis, perhaps due to the small number of cases in our study. Surgical procedure, such as operation time, surgical skill, circulatory arrest, and bleeding potentially influence early death. Sun's procedure required complex total arch replacement and stented elephant trunk implantation in the descending aorta, so the operation time and circulatory time may be longer than in hemi-arch or ascending aorta replacement, which could induce new PND and mortality.

This study had some limitations. First, a randomized controlled trial (RCT) would be a more robust study than this retrospective study. However, given the extreme emergency and catastrophic outcomes, conducting a large, prospective RCT is impossible in a single center. Second, the sample size was small; however, these clinical data will be useful for our future treatment. Further multi-center and prospective investigations with large sample sizes are required.

In conclusion, this study indicated that hypertension was independently associated with postoperative PND in patients with type A aortic dissection who underwent total arch replacement and stented elephant trunk implantation. Age and postoperative PND were found to be predictors for early mortality.

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REFERENCES

Blanco M, Diez-Tejedor E, Larrea JL, et al. 1999. Neurologic complications of type I aortic dissection. Acta Neurol Scand 99:232-5.

Chen XZ, Xiao YB, Wang Y, et al. 2016. Sun's procedure for acute type A aortic dissection using moderate hypothermia and unilateral selective antegrade cerebral perfusion in 38 patients-a single centre retrospective analysis. Chin J Ecc 14:73-6, 67.

Conzelmann LO, Hoffmann I, Blettner M, et al. 2012. Analysis of risk factors for neurological dysfunction in patients with acute aortic dissection type A: data from the German Registry for Acute Aortic Dissection type A (GERAADA). Eur J Cardiothorac Surg 42:557-65.

Conzelmann LO, Weigang E, Mehlhorn U, et al. 2016. Mortality in patients with acute aortic dissection type A: analysis of pre- and intraoperative risk factors from the German Registry for Acute Aortic Dissection Type A (GERAADA). Eur J Cardiothorac Surg 49:e44-52.

Ehrlich MP, Schillinger M, Grabenwoger M, et al. 2003. Predictors of adverse outcome and transient neurological dysfunction following surgical treatment of acute type A dissections. Circulation 108 Suppl 1:II318-23.

Ergin MA, Galla JD, Lansman SL, et al. 1994. Hypothermic circulatory arrest in operations on the thoracic aorta. Determinants of operative mortality and neurologic outcome. J Thorac Cardiovasc Surg 107:788-97; discussion 797-9.

Fleck T, Hutschala D, Czerny M, et al. 2002. Combined surgical and endovascular treatment of acute aortic dissection type A: preliminary results. Ann Thorac Surg 74:761-5; discussion 765-6.

Gaul C, Dietrich W, Friedrich I, et al. 2007. Neurological symptoms in type A aortic dissections. Stroke 38:292-7.

Geirsson A, Szeto WY, Pochettino A, et al. 2007. Significance of malperfusion syndromes prior to contemporary surgical repair for acute type A dissection: outcomes and need for additional revascularizations. Eur J Cardiothorac Surg 32:255-62.

Hou Z, Meng Q, Zhang Y. 2016. Hypertension prevalence, awareness, treatment, and control following China's healthcare reform. Am J Hypertens 29:428-31.

Jacob KA, Hjortnaes J, Kranenburg G, et al. 2015. Mortality after cardiac surgery in patients with liver cirrhosis classified by the Child-Pugh score. Interact Cardiovasc Thorac Surg:520-30.

Ji Q, Mei Y, Wang X, et al. 2008. Study on the risk factors of postoperative hypoxemia in patients undergoing coronary artery bypass grafting. Circ J 72:1975-80.

Jussli-Melchers J, Panholzer B, Friedrich C, et al. 2017. Long-term outcome and quality of life following emergency surgery for acute aortic dissection type A: a comparison between young and elderly adults. Eur J Cardiothorac Surg 51:465-71.

Karck M, Chavan A, Hagl C, et al. 2003. The frozen elephant trunk technique: a new treatment for thoracic aortic aneurysms. J Thorac Cardiovasc Surg 125:1550-3.

Klotz S, Bucsky BS, Richardt D, et al. 2016. Is the outcome in acute aortic dissection type A influenced by of femoral versus central cannulation? Ann Cardiothorac Surg 5:310-6.

Kruger T, Conzelmann LO, Bonser RS, et al. 2012. Acute aortic dissection type A. Br J Surg 99:1331-44.

Kruger T, Hoffmann I, Blettner M, et al. 2013. Intraoperative neuroprotective drugs without beneficial effects? Results of the German Registry for Acute Aortic Dissection Type A (GERAADA). Eur J Cardiothorac Surg 44:939-46.

Kruger T, Weigang E, Hoffmann I, et al. 2011. Cerebral protection during surgery for acute aortic dissection type A: results of the German Registry for Acute Aortic Dissection Type A (GERAADA). Circulation124:434-43.

Lauterbach SR, Cambria RP, Brewster DC, et al. 2001. Contemporary management of aortic branch compromise resulting from acute aortic dissection. J Vasc Surg 33:1185-92.

Lee HK, Kim GJ, Cho JY, et al. 2012. Comparison of the outcomes between axillary and femoral artery cannulation for acute type A aortic dissection. Korean J Thorac Cardiovasc Surg 45:85-90.

Liu H, Chang Q, Zhang H, et al. 2017. Predictors of Adverse Outcome and Transient Neurological Dysfunction Following Aortic Arch Replacement in 626 Consecutive Patients in China. Heart Lung Circ 26:172-8.

Liu LS, Writing Group of Chinese Guidelines for the Management of H. 2011. [2010 Chinese guidelines for the management of hypertension]. Zhonghua Xin Xue Guan Bing Za Zhi 39:579-615.

Ma WG, Zheng J, Dong SB, et al. 2013. Sun's procedure of total arch replacement using a tetrafurcated graft with stented elephant trunk implantation: analysis of early outcome in 398 patients with acute type A aortic dissection. Ann Cardiothorac Surg 2:621-8.

Ma WG, Zheng J, Zhang W, et al. 2014. Frozen elephant trunk with total arch replacement for type A aortic dissections: Does acuity affect operative mortality? J Thorac Cardiovasc Surg 148:963-70; discussion 970-2.

Mehta RL, Kellum JA, Shah SV, et al. 2007. Acute Kidney Injury Network: report of an initiative to improve outcomes in acute kidney injury. Crit care 11:R31.

Mohan S, Campbell NR. 2009. Hypertension management: time to shift gears and scale up national efforts. Hypertension. 53:450-1.

Moizumi Y, Motoyoshi N, Sakuma K, et al. 2005. Axillary artery cannulation improves operative results for acute type a aortic dissection. Ann Thorac Surg 80:77-83.

Nakajima T, Kawazoe K, Izumoto H, et al. 2006. Risk factors for hypoxemia after surgery for acute type A aortic dissection. Surg today 36:680-5.

Olsson C, Eriksson N, Stahle E, et al. 2007. Surgical and long-term mortality in 2634 consecutive patients operated on the proximal thoracic aorta. Eur J Cardiothorac Surg 31:963-9; discussion 969.

Pape LA, Awais M, Woznicki EM, et al. 2015. Presentation, diagnosis, and outcomes of acute aortic dissection: 17-year trends from the International Registry of Acute Aortic Dissection. J Am Coll Cardiol 66:350-8.

Patris V, Toufektzian L, Field M, et al. 2015. Is axillary superior to femoral artery cannulation for acute type A aortic dissection surgery? Interact Cardiovasc Thorac Surg 21:515-20.

Ren Z, Wang Z, Hu R, et al. 2015. Which cannulation (axillary cannulation or femoral cannulation) is better for acute type A aortic dissection repair? A meta-analysis of nine clinical studies. Eur J Cardiothorac Surg 47:408-15.

Rylski B, Hoffmann I, Beyersdorf F, et al. 2014. Acute aortic dissection type A: age-related management and outcomes reported in the German Registry for Acute Aortic Dissection Type A (GERAADA) of over 2000 patients. Ann Surg 259:598-604.

Sun L, Qi R, Zhu J, et al. 2011. Total arch replacement combined with stented elephant trunk implantation: a new "standard" therapy for type a dissection involving repair of the aortic arch? Circulation 123:971-8.

Sun LZ, Ma WG, Zhu JM, et al. 2013. Sun's procedure for chronic type A aortic dissection: total arch replacement using a tetrafurcate graft with stented elephant trunk implantation. Ann Cardiothorac Surg 2:665-6.

Wang Y, Xue S, Zhu H. 2013. Risk factors for postoperative hypoxemia in patients undergoing Stanford A aortic dissection surgery. J Cardiothorac Surg 8:118.