Predictors of Prolonged Mechanical Ventilation After Aortic Arch Surgery With Deep Hypothermic Circulatory Arrest Plus Antegrade Selective Cerebral Perfusion

Qian Lei, MD, Lei Chen, MD, Yi Zhang, MD, Nengxin Fang, MD, Weiping Cheng, MD, and Lihuan Li, MD

Objective: **The predictors of prolonged mechanical ventilation after aortic arch surgery with deep hypothermic circulatory arrest have not been comprehensively evaluated. The present study was designed to identify variables associated with prolonged ventilation in a group of aortic arch surgery patients from a single center.**

Design: **A retrospective study. Prolonged mechanical ventilation was defined as >72 hours.**

Setting: **Cardiovascular operating rooms and the intensive care unit.**

Participants: **Adults requiring aortic arch surgery with deep hypothermic circulatory arrest plus antegrade selective cerebral perfusion.**

Interventions: **None.**

Measurements and Main Results: **After 7 patients who underwent 1-stage total or subtotal aortic replacement were excluded, 255 patients were enrolled in the study. The average age of the patients was 44.7 ± 10.8 years with male predominance (74.1%). Two hundred twenty-nine patients were extubated within 72 hours postoperatively, and 26 patients needed prolonged mechanical ventilation. Patients with prolonged mechanical ventilation had higher incidences of in-hospital mortality, stroke, and renal failure requiring dialysis and reintubation and stayed longer in the intensive care unit and hospital than those without prolonged ventilation ($p < 0.05$). In multivariate analysis, predictors of prolonged ventilation were found to be prolonged cardiopulmonary bypass time, advanced age, emergency, and preoperative serum creatinine level ($p < 0.05$).**

Conclusion: **The authors identified 4 preoperative and intraoperative predictors associated with increased risk of prolonged mechanical ventilation. This is helpful to identify patients with increased risk for prolonged ventilation, develop preemptive strategies, and allocate medical resources.**

KEY WORDS: mechanical ventilation, deep hypothermic circulatory arrest, aortic arch surgery, risk factors

PROLONGED MECHANICAL VENTILATION after cardiovascular surgery is correlated with an increased risk of mortality and medical expenditure.[1-3] Previous studies have evaluated the risk factors for prolonged mechanical ventilation after coronary artery bypass graft (CABG) surgery, heart valve surgery, and congenital heart disease surgery.[4-8] Prolonged mechanical ventilation after thoracic aortic surgery with deep hypothermic circulatory arrest (DHCA) is common, with a published incidence of up to 19.1%.[9] However, the variables associated with prolonged mechanical ventilation after aortic arch surgery have not been comprehensively evaluated.

In China, the number of thoracic aortic surgeries performed, especially aortic arch repairs, has increased rapidly in recent years. Aortic arch surgery using DHCA plus antegrade selective cerebral perfusion (ASCP) through right axillary arterial cannulation has been a standard procedure for Stanford type-A aortic dissection and aneurysm of the aortic arch in the authors' center since 2004.[10] The aim of this study was to identify the preoperative and intraoperative parameters that were associated with prolonged mechanical ventilation after aortic arch surgery with DHCA plus ASCP.

METHODS

With the approval of the Institutional Review Committee, 262 consecutive adult patients undergoing aortic arch surgery from January 2005 to September 2007 were reviewed retrospectively. In order to reduce the heterogeneity of the subject population, 7 patients were excluded who underwent 1-stage total or subtotal aortic replacement because of different surgical incision and cardiopulmonary bypass (CPB) procedures.

General anesthesia was standardized for all patients. Patients were premedicated with morphine, 0.1 mg/kg, and scopolamine, 0.005 mg/kg, intramuscularly, 30 to 45 minutes before surgery and induced with midazolam (0.05-0.1 mg/kg), fentanyl (10 μg/kg), etomidate (0.2 mg/kg), and pipecuronium (0.1 mg/kg). Anesthesia was maintained with inhaled isoflurane, propofol infusion, and small additional doses of fentanyl and pipecuronium. The total amount of fentanyl used intraoperatively was approximately 30 μg/kg. Anesthetic monitoring included American Society of Anesthesiologists routine monitors, invasive blood pressure of the upper and lower extremities (typically via the radial artery and dorsal pedal artery), nasopharynx temperature, and bladder temperature; an 8.5F triple-lumen central venous catheter was placed via the right internal jugular vein to monitor central venous pressure, administer drugs and infuse fluids. Transesophageal echocardiography was used to confirm surgical diagnosis, guide hemodynamic management, and assess surgical intervention. Electroencephalography was used to guide the conduct of DHCA.

All operations were performed through a median sternotomy. The right axillary artery was isolated before sternotomy. After full anticoagulation with heparin given at a first dose of 400 IU/kg to maintain an activated coagulation time more than 480 seconds, CPB was instituted using right axillary arterial cannulation and right atrial venous cannulation. During DHCA, the brachiocephalic trunk was clamped, and antegrade selective cerebral perfusion through the right axillary arterial cannulation was performed in a standardized fashion at the authors' institution. Nasopharynx temperature was allowed to drift to approximately 15°C during total aortic arch replacement and 20°C during partial aortic arch replacement. After aortic arch repair, the aortic graft was cannulated and proximally clamped to recover circulation. The aortic root repair and cardiac procedures were then performed depending on the presenting pathology. The neuroprotective drugs administered during CPB included the following: methylprednisolone, 30 mg/

From the Department of Anesthesiology, Cardiovascular Institute and Fuwai Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, China.

Address reprint requests to Lihuan Li, MD, Department of Anesthesiology, Fuwai Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, 167 BeiLiShi Road, Beijing 100037, China. E-mail: lilhfw@gmail.com

1053-0770/09/2304-0010$36.00/0
doi:10.1053/j.jvca.2008.09.006

kg, magnesium sulfate, 1 g, and mannitol, 0.5 g/kg. Standard antegrade cold blood cardioplegia was used for myocardial protection. Heparin was reversed with protamine at a 1:1.5 ratio on weaning from CPB. Blood components including packed red blood cells, fresh-frozen plasma, and platelets were infused to maintain the post-CPB hematocrit and correct postprotamine coagulopathy.

The following preoperative variables were evaluated: age, sex, body mass index, aortic dissection, Marfan syndrome, history of hypertension, diabetes mellitus, chronic obstructive pulmonary disease (COPD), smoking, reoperation, New York Heart Association classification, hemoglobin, serum albumin, serum creatinine, international normalized ratio, and urgency of procedure. Intraoperative variables analyzed were inotropes, temperature nadir, DHCA time, myocardial ischemia time, CPB time, blood components transfused during surgery, and additional procedures. Major postoperative outcomes including in-hospital mortality, stroke, renal failure requiring dialysis, reintubation, re-exploration for bleeding, and intensive care unit (ICU) and in-hospital length of stay were also analyzed.

Perioperative data were collected from case files and a prospectively collected departmental patient database. Prolonged mechanical ventilation was defined as a requirement >72 hours for mechanical ventilation with an endotracheal tube. Patients were divided into group A (mechanical ventilation time ≤72 hours) and group B (mechanical ventilation time >72 hours) according to the duration of mechanical ventilation. A history of hypertension was defined as patients with a documented diagnosis of hypertension previously being treated with an antihypertensive agent. Reoperation was defined as any aortic procedure subsequent to a previous cardiac or thoracic aortic surgery. Serum creatinine was the most recent measurement value before operation. Some continuous variables were dichotomized at a clinically meaningful threshold. Advanced age was defined as age older than 60 years. Prolonged CPB time was defined as the duration of CPB longer than 180 minutes. Emergency surgery was defined as the necessity to take the patient to the operating room prior to the beginning of the next morning's operation schedule. Inotropes were defined as any inotropes used intraoperatively, the most common of which was dopamine. In-hospital mortality was defined as all mortalities within the same admission after aortic arch surgery regardless of their length of stay. Stroke was defined as a cerebrovascular accident evaluated by a neurologist and confirmed with a computed tomography scan or magnetic resonance imaging.

The decision to extubate was made by 1 of the 4 attending surgeons, 1 of the 2 anesthesiologists, and an intensivist. To be considered for extubation, patients had to be warm (>35°C), awake, and hemodynamically stable. Before extubation, patients were assisted with synchronized intermittent mandatory ventilation, and arterial blood gases had

Table 1. Demographic Characteristics and Preoperative and Intraoperative Data for Prolonged Mechanical Ventilation Patients and Nonprolonged Mechanical Ventilation Patients

Variable	Total (n = 255)	Group A (n = 229)	Group B (n = 26)	*p* Value
Preoperative variable				
Age (y)	44.7 ± 10.8	44.2 ± 10.7	48.9 ± 10.7	0.034
Advanced age	24 (9.4%)	18 (7.9%)	6 (23.1%)	0.048
Female	66 (25.9%)	60 (26.2%)	6 (23.1%)	0.73
BMI (kg/m^2)	24.6 ± 4.1	24.4 ± 4.1	26.2 ± 4.0	0.042
Aortic dissection	243 (95.3%)	219 (95.6%)	24 (92.3%)	0.35
Marfan syndrome	45 (17.6%)	43 (18.8%)	2 (7.7%)	0.12
History of hypertension	158 (62.0%)	137 (59.8%)	21 (80.8%)	0.037
Diabetes mellitus	11 (4.3%)	9 (3.9%)	2 (7.7%)	0.31
COPD	6 (2.4%)	5 (2.2%)	1 (3.8%)	0.48
Smoking	87 (34.1%)	74 (32.3%)	13 (50.0%)	0.071
Reoperation	16 (6.3%)	14 (6.1%)	2 (7.7%)	0.67
NYHA (class III, IV)	47 (18.4%)	37 (16.2%)	10 (38.5%)	0.013
Hemoglobin (g/L)	134.5 ± 15.4	135.0 ± 15.6	133.0 ± 14.5	0.49
Serum albumin (g/L)	40.0 ± 4.2	40.0 ± 4.3	40.0 ± 3.6	0.96
Serum creatinine (μmol/L)	85.0 (70.5, 105.6)	84.0 (70.0, 99.5)	116.9 (80.8, 157.3)	<0.001
INR	1.07 (1.02, 1.14)	1.07 (1.02, 1.13)	1.08 (1.04, 1.18)	0.14
Emergency	72 (28.2%)	54 (23.6%)	18 (69.2%)	<0.001
Intraoperative variable				
Inotropes	203 (79.6%)	177 (77.3%)	24 (92.3%)	0.076
Temperature nadir (°C)	17.9 ± 1.62	17.9 ± 1.67	17.9 ± 1.07	0.89
DHCA time (min)	22.2 ± 6.8	21.9 ± 6.2	24.5 ± 10.3	0.23
Myocardial ischemia time (min)	96.2 ± 30.2	95.0 ± 30.1	107.4 ± 29.2	0.046
CPB time (min)	180 (153, 201)	176 (150, 195)	213 (184, 236)	<0.001
Prolonged CPB time	119 (46.7%)	98 (42.8%)	21 (80.8%)	<0.001
Packed red blood cells (U)	6.6 ± 4.0	6.4 ± 3.8	8.0 ± 5.0	0.044
Fresh-frozen plasma (mL)	1,086 ± 723	1,065 ± 722	1,277 ± 716	0.16
Platelets (U)	1.7 ± 0.5	1.7 ± 0.5	1.6 ± 0.8	0.34
Aortic valve replacement	82 (32.2%)	77 (33.6%)	5 (19.2%)	0.14
Aortic valvuloplasty	15 (5.9%)	12 (5.2%)	3 (11.5%)	0.19
CABG	22 (8.6%)	18 (7.9%)	4 (15.4%)	0.26
Mitral valve replacement	5 (2.0%)	3 (1.3%)	2 (7.7%)	0.083

NOTE. Values are n (%), mean ± standard deviation, or median (interquartile range).

Abbreviation: BMI, body mass index; COPD, chronic obstructive pulmonary diseases; NYHA, New York Heart Association; INR, international normalized ratio; DHCA, deep hypothermic circulatory arrest; CABG, coronary artery bypass grafting.