Risk factors of failed extubation after open-heart surgery in infants

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***Background*: Infants with congenital heart diseases undergoing open-hear surgery require mechanical ventilation. Failed extubation (FE) is statistically associated with prolonged mechanical ventilation. This study was undertaken to investigate the risk factors of FE after cardiac surgery in infants.**

***Mothods*: A total of 227 infants of less than 1 year old who had undergone congenital heart surgery (CHS) were enrolled in this study. Logistic regression analysis was used to assess the risk factors of FE. Odds ratio was used to assess the degree of relationship between FE and risk factors.**

***Results*: Out of the 227 infants undergoing CHS, 30 (13.22%) failed at the extubation. Risk factors for failed extubation included postoperative duration of mechanical ventilation (EOR = 12.0; 95% CI = 4.04-35.71; $P = 0.009$), postoperative pneumonia (EOR = 5.33, 95%CI = 1.81-15.68, $P = 0.002$), and preoperative pulmonary hypertension (EOR = 2.80, 95% CI = 1.21-10.45, $P = 0.041$). Postoperative pneumonia and preoperative pulmonary hypertension were the 2 independent risk factors for FE ($P < 0.05$).**

***Conclusions*: Postoperative pneumonia and preoperative pulmonary hypertension are the major risk factors for FE after CHS in infants. The prevention and treatment of postoperative pneumonia and pulmonary hypertensive crises are beneficial to the successful extubation.**

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***Key words*: infant;**
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Original article

Introduction

The incidence of failed extubation (FE) in infants with congenital heart diseases undergoing open-heart surgery is 10%-19%.[1-5] Rady et al[1-4, 6] have assessed the associated factors of FE after coronary artery bypass grafting (CABG), and found that FE after cardiac surgery is associated with patient age, duration of cardiopulmonary bypass, preoperative chronic obstructive pulmonary diseases, and grade of cardiac function. To improve the success rate of extubation after open-heart surgery in infants, avoid unnecessary prolongation of mechanical ventilation, decrease the incidence of complications, and save expenses, we viewed retrospectively 227 infants below 1 year old, who had failed initial extubation or required reintubation after congenital heart surgery (CHS) at the Children's Hospital, Zhejiang University School of Medicine. The aim of the study was to investigate variable risk factors relevant to FE after congenital heart surgery in infants.

Methods

Patients

A total of 809 patients including 227 infants underwent CHS at Children's Hospital, Zhejiang University School of Medicine. According to the definition of reintubation within 24 hours after extubation as FE,[7] 30 of the 227 infants failed to extubate after CHS. These patients constituted a group of failed extubation (FE group), and another 30 infants who had been successfully extubated were randomly enrolled in control group. In the FE group, 14 were male and 16 female, aged 6 ± 4 months, and weighed 6.4 ± 2.8 kg. The duration of cardiopul-

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monary bypass lasted 141 ± 35 minutes, and the aortic cross-clamping time was 81 ± 22 minutes. In the control group, 17 infants were male and 13 female, aged 6 ± 3 months and weighed 6 ± 1.1 kg. The duration of cardiopulmonary bypass was 135 ± 33 minutes and the aortic cross-clamping time was 89 ± 30 minutes. Congenital heart diseases included tetralogy of fallot (TOF) (4 patients), ventricular septal defect (VSD) (8), atrial septal defect (ASD) (2), VSD + pulmonary hypertension (PH) (4), transposition of the great arteries (TGA) (1), total anomalous pulmonary venous return (TAPVC) (3), ASD + VSD (4), VSD + patent ductus arteriosus (PDA) (1), VSD + ASD + PDA (2), and double outlet right ventricle (DORV) (1) in the EF group and TOF (4), VSD (6), ASD (3), VSD + PH (4), TGA (1), TAPVC (2), VSD + ASD (6), VSD + ASD + PH (2), VSD + PDA + PH (1), and atrioventricular canal defect (1) in the control group.

Treatment

In the intensive care unit (ICU), the patients were ventilated with a ServoVetilator 300 (Siemens, Germany) under pressure-regulated volume control (PRVC) with a tidal volume of 8-12 ml/kg. Once the patients awoke while breathing spontaneously and being hemodynamically stable for weaning, the mode of ventilation was switched to either pressure or volume-controlled, synchronized, and intermittent mandatory ventilation (SIMV). Two to four hours after cough and swallowing reflexs were confirmed normal without laryngeal edema, the patients were extubated after removal of secretions in the airway and empting of the stomach.

Preoperative, intraoperative and postoperative factors were likely to influence successful extubation in the two groups. Preoperative factors consisted of age, weight, underlying diseases, nutrition and growth condition, frequency of pneumonia, types of lesions, and asthma. Intraoperative factors consisted of duration of cardiopulmonary bypass and aortic cross-clamping. Postoperative factors consisted of hypotension, hypoxia, arrhythmia, pressure of the pulmonary artery, status and duration of mechanical ventilation, higher response of the airway, pulmonary hypertensive crisis, pneumonia pathogeny, and usage of vasoactive drugs.

Statistical analysis

Logistic regression anaysis was made to investigate the risk factors of FE in infants undergoing open-heart surgery, and the odds ratio was used to estimate the degree of relationship between FE and mentioned factors. Analysis was performed with SAS software after the establishment a FoxPro2.5 database. A $P<0.05$ was considered statistically significant.

Results

Of the 227 infants, 30 failed to extubate and were reintubated, giving a reintubation rate of 13.22%. In addition, 5 patients failed to extubate twice. The time of mechanical ventilation before initial extubation in the FE group was 3.4 ± 2.7 days, and the median time of mechanical ventilation was 5.2 ± 4.3 days. The mechanical ventilation time in the control group was 1.6 ± 1.4 days. Logistic regression univariate analysis (Table) demonstrated that high risk factors leading to postoperative FE and reintubation included time of postoperative mechanical ventilation (EOR = 12.1, 95% CI = 4.04-35.71, $P=0.0009$), postoperative pneumonia (EOR = 5.33, 95% CI = 1.81-15.68, $P=0.002$) and preoperative pulmonary hypertension (EOR = 2.80, 95% CI = 1.21-10.45, $P=0.041$).

Logistic regression multivariate

Analysis showed that postoperative pneumonia (95% CI = 1.43-30.45, $P=0.016$) and preoperative pulmonary hypertension (95% CI = 2.78-41.45, $P=0.0006$) were associated significantly with FE ($P<0.05$). Postoperative pneumonia and preoperative pulmonary hypertension were 2 independent risk factors for postoperative FE in infants with congenital heart diseases.

Table. The results of univariate logistic analysis of FE

Factors	Group	Sample/total sample	Odds ratio (95% CI)	*P* value
Gender	Female	16/29	0.729 (0.27-1.97)	0.5326
Time of mechanical ventilation	Below 1 year old	1/16	12.0 (4.04-35.71)	0.0009
Preoperative pneumonia	No pneumonia	7/12	1.37 (0.40-0.66)	0.6145
Postoperative pneumonia	Pneumonia	20/29	5.33 (1.81-15.68)	0.0020
Cardiac dysfunction	No cardiac dysfunction	13/19	2.039 (0.71-5.84)	0.1846
Pulmonary hypertension	No pulmonary hypertension	12/16	2.800 (1.21-10.45)	0.0410
High response of the airway	No high response of the airway	6/8	1.812 (0.46-7.18)	0.3969
Arrhythmias	No arrhythmias	3/8	0.622 (0.14-2.86)	0.5422
Hypouresis	Normal urine	4/12	0.481 (0.13-1.80)	0.2768
Acidosis	No acidosis	5/9	1.449 (0.35-5.99)	0.6080

Discussion

During open-heart surgery, the direct contact of plasma with artificial materials may activate the complement system as well as the kinin and fibrinolytic system. Nonpulse blood stream during cardiopulmonary bypass results in unbalanced perfusion in peripheral tissues, lesional anoxia and accumulation of toxic metabolites. In addition, stroke of surgery, reperfusion injury and change of temperature during cardiopulmonary bypass also activate the endotheliocyte system and granulocytes, induce the adherence of leukocytes penetrating blood vessels, and cause tissue damage and cardiopulmonary dysfunction. Furthermore, thoracotomy or sternotomy violates the chest wall integrity and disturbs respiratory muscle mechanics. These factors probably cause FE after open-heart surgery.[8-14] Clinical researchers[1-5] found that the incidence of FE was 10%-19% after open-heart surgery; but many studies[1-4,15-18] showed that the difference between prompt extubation and FE was not statistically significant. In adult patients with coronary artery bypass grafting (CABG), "fast-tracking" is feasible. Thus individualized therapy is essential to decrease the incidence of FE and reintubation. The patients who are indicated for weaning should be extubated early. And those patients having high risk for FE should be observed carefully and treated actively in order to utilize medical resources efficiently and be removed early from the ventilator.

The physiologic and pathophysiologic characteristics of infants with CHD are different from those of adult and pediatric patients with heart diseases.[10,11] They included low-weight, unstable physiologic conditions, depressed immunity caused by frequent preoperative pneumonia, and co-existence of pulmonary hypertension and malnutrition. Hence the postoperative risk factors of FE infants and their prevention differ from those in adult and pediatric patients. The patients with left to right shunt are prone to pulmonary hypertensive crisis, resulting in preoperative increase of pulmonary blood flow and muscularization of pulmonary capillaries. Once the malformed heart is corrected, the pulmonary pressure was lowered partly or totally. Nevertheless, systemic hypertension and pulmonary hypertensive crisis are likely to occur after surgery, thus resulting in hypoperfusion of pulmonary tissue during cardiopulmonary bypass. Finally, the resultant ischemia and hypoxia may induce the convulsion of pulmonary and systematic capillaries. Once the pulmonary pressure is equal or exceeds the systemic pressure, the latter might fall to a low level suddenly. Schulze-Neick and colleagues[19-21] found that the occurrence of pulmonary hypertensive crisis decreased the pulmonary compliance, which was the primary reason of FE.

The results of this study indicated that the risk factors of FE and reintubation in infants after open-heart surgery are probably associated with the time of mechanical ventilation, postoperative pneumonia, and preoperative pulmonary hypertension. Postoperative pneumonia and preoperative pulmonary hypertension are 2 independent risk factors for FE. In this series, the incidence of FE was 13.22%, which was not significantly different from that in adults with CABG and children with CHD (at age of 3 years). The fact that half of the patients in the control group were extubated successfully within 24 hours after surgery and a prominent longer period of mechanical ventilation in the FE group demonstrates that prompt extubation does not contribute to reintubation, and "fast-tracking" is feasible for patients with CHS efficiently and economically. It is suggested, however, that intensive care is needed in high-risk patients with PH and pneumonia. To increase the success rate of extubation and lower the postoperative mortality rate, control of pulmonary infection and hypertensive crisis are extremely important in postoperative intensive care. It has been reported[19-21] that the time of postoperative mechanical ventilation in patients with PH is longer than that in those without PH. Inhalation of NO could alleviate pulmonary hypertension and increase the success rate of extubation. The use of nasal continuous positive airway pressure in the treatment of acute respiratory failure could ameliorate respiratory conditions, decrease the work of breathing (WOB), promote the exchange of gases, and improve blood oxygen saturation. In conclusion, active measurements in the prevention and treatment of pulmonary hypertension and pneumonia are the key to increase the success rate of extubation and reduce the mortality rate.

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