ORIGINAL ARTICLE

Risk Factors of Prolonged Postoperative Pleural Effusion After Repair of Tetralogy of Fallot

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Background: Tetralogy of Fallot (TOF) is the most common cyanotic congenital heart disease, and total correction is the definitive treatment. Chest tube drainage of pleural effusion (PE) is essential after surgery. Prolonged PE (> 7 days) is one of the complications; it may increase hospital stay and the risks of morbidity and mortality. The aim of this study was to investigate and analyze the possible risk factors for prolonged PE after total correction of TOF.

Methods: Thirty-seven patients who received total correction of TOF between July 1999 and April 2001 were included in this study. They were divided into 2 groups according to the duration of chest tube drainage for postoperative PE: Group I had postoperative PE ≤ 7 days; Group II had postoperative PE > 7 days. Detailed records were taken on patients' demographic characteristics, blood parameters, surgery, electrocardiographic and radiologic data, and angiographic and echocardiographic findings. The data of the 2 groups were compared using the Wilcoxon rank-sum test and Fisher's exact test. Risk factors were analyzed by logistic regression and model selection.

Results: Of the 37 patients, 16 were male and 21 were female. There were 32 patients (86.5%) in Group I and 5 (13.5%) in Group II. Mean patient age at repair was 1.82 ± 1.29 years (range, 0.53–3.11 years). Significant differences ($p < 0.05$) between the 2 groups were noted for gender, age at repair, body weight, presence of wound infection, duration on heart-lung machine (bypass time), oxygen saturation before surgery, duration of endotracheal intubation, length of hospital stay, and Nakata index. These risk factors were analyzed by logistic regression and model selection. Two models were set up: Model 1 – oxygen saturation before surgery, presence of wound infection, age at repair; Model 2 – oxygen saturation before surgery, presence of wound infection.

Conclusion: Prolonged PE is a significant morbidity after TOF repair. The risk factors for prolonged PE are gender, age at repair, body weight, bypass time, low oxygen saturation before surgery, wound infection after surgery, duration of endotracheal intubation, length of hospital stay, and Nakata index. Oxygen saturation before surgery and wound infection were major risk factors while age at repair was a confounder. [*J Chin Med Assoc* 2005;68(9):406–410]

Key Words: pleural effusion, tetralogy of Fallot

Introduction

Tetralogy of Fallot (TOF) is the most common cyanotic congenital heart disease, accounting for approximately 12% of congenital cardiac lesions. Definitive repair of TOF consists of closure of the ventricular septal defect (VSD) and relief of the right ventricle outflow tract (RVOT) obstruction. The technique to relieve RVOT obstruction is dictated by the type of obstruction that exists. Techniques range from simple pulmonary valvotomy/valvectomy to subpulmonary infundibular resection and patch augmentation of a hypoplastic pulmonary annulus, area of pulmonary artery hypoplasia, stenosis, or atresia (with RVOT reconstruction).[1] The best age to perform definitive repair depends on the individual anatomic features,

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particularly the size and distribution of the pulmonary artery tree (ex. McGoon ratio, Nakata index). Chest tube drainage of pleural effusion (PE) is essential after surgery. Many studies have found risk factors for mortality after total corrective surgery, including tricuspid regurgitation, pulmonary regurgitation, renal dysfunction, late ventricular dysfunction, and other late complications.[2–10] Prolonged PE after surgery for congenital heart disease is also an important morbidity factor, and it may result in extended hospitalization. The purpose of this retrospective study was to investigate and analyze the possible risk factors for prolonged PE after total surgical correction of TOF.

Methods

Thirty-seven patients who received total correction of TOF between July 1999 and April 2001 were included in this study. They were divided into 2 groups according to the duration of chest tube drainage for postoperative PE: Group I had postoperative PE ≤ 7 days; Group II had postoperative PE > 7 days.

Detailed records were taken on patients' demographic characteristics, blood parameters, surgery, electrocardiographic and radiologic data, as well as angiographic and echocardiographic findings. Demographic data included gender, age at repair, body weight and surface area, prior Blalock-Taussig (B-T) shunt, duration of follow-up, associated cardiac lesions, inotropic drugs used, and preoperative oxygen saturation. Blood laboratory parameters included white blood cell counts, hemoglobin, hematocrit, platelets, C-reactive protein, prothrombin time (PT), and activated partial thromboplastin time (APTT). Surgical data included patients' perioperative condition, duration on the heart-lung machine, aortic clamp time, pleural volume on days 1, 7, 14 and long term (> 1 month), length of hospital stay, duration of endotracheal intubation, and any wound infection. Electrocardiographic and radiologic data included mean RR interval, superior QRS axis, QRS duration, low QRS voltage, ventricular premature contractions (Lown grade), and C/T ratio. Angiographic data were the McGoon ratio and Nakata index, while echocardiographic findings included residual VSD, pulmonary stenosis, regurgitation, tricuspid regurgitation, ejection fraction (EF), and fraction of shortening (FS).

Statistical analysis

Descriptions of basic data, such as age and gender, were presented as mean ± standard deviation (SD), range, percentage or median. The data of the 2 groups were compared using the Wilcoxon rank-sum test for continuous data and Fisher's exact test for categorical data. Statistical significance was set at a p value of less than 0.05. Risk factors were analyzed by logistic regression and model selection.

Results

Of the 37 patients, 16 were male and 21 were female. There were 32 patients (86.5%) in Group I (postoperative PE ≤ 7 days) and 5 (13.5%) in Group II (postoperative PE > 7 days). Mean patient age at repair was 1.82 ± 1.29 years (range, 0.53–3.11 years). Five patients (13.5%) had a previous B-T shunt. The mean follow-up period was 1.2 ± 0.89 years (range, 0.08–3.0 years). Body weight at repair was 9.64 ± 2.78 kg (range, 1.75–17.5 kg), and body surface area at repair was 0.45 ± 0.97 kg/m^2 (range, 0.28–0.73 kg/m^2). Mean duration of hospital stay was 19.2 ± 12 days (range, 3–56 days) (Table 1).

Significant differences ($p < 0.05$) between the 2 groups were noted for gender, age at repair, body weight, presence of wound infection, duration on heart-lung machine (bypass time), oxygen saturation before surgery, duration of endotracheal intubation, length of hospital stay, and Nakata index. Tables 2 and 3 show these continuous and categorical data by group. These risk factors were then analyzed by logistic regression and model selection. Two models were

Table 1. Demographic data for Group I (postoperative PE ≤ 7 days) and Group II (postoperative PE > 7 days) patients

Group	*n* (%)	Age at repair (yr)	M/F (*n*)	Body weight (kg)	BSA (kg/m^2)	Previous B-T *n* (%)	Follow-up (yr)	Duration of hospital stay (d)
I	32 (86.5)	3.96 ± 1.06	12/20	9.27 ± 2.42	0.44 ± 0.08	4 (12.5)	1.18 ± 0.94	19.78 ± 12.77
II	5 (13.5)	2.53 ± 2.36	4/1	11.00 ± 4.28	0.49 ± 0.15	1 (20.0)	0.72 ± 0.45	24.60 ± 10.50
Total	37 (100)	1.82 ± 1.29	16/21	9.64 ± 2.78	0.45 ± 0.97	5 (13.5)	1.20 ± 0.89	19.24 ± 12.07

BSA = body surface area; B-T = Blalock-Taussig shunt; F = female; M = male; PE = pleural effusion.

Table 2. Continuous data in Group I (postoperative PE ≤ 7 days) and Group II (postoperative PE > 7 days) patients

	Group I (n = 32)	Group II (n = 5)	p
Age at repair (yr)	3.96 ± 1.06	2.53 ± 2.36	< 0.05
Body weight (kg)	9.27 ± 2.42	11.0 ± 4.28	< 0.05
Duration on heart-lung machine (d)	128.3 ± 35.8	119.4 ± 23.4	< 0.05
Preoperative oxygen saturation (%)	86.5 ± 9.0	72.8 ± 13.8	< 0.05
Duration of endotracheal intubation (d)	4.3 ± 10.8	7.2 ± 10.03	< 0.05
Length of hospital stay (d)	19.78 ± 12.77	24.60 ± 10.50	< 0.05
Nakata index	662.4 ± 261.6	491.24 ± 129.6	< 0.05

Table 3. Categorical data in Group I (postoperative PE ≤ 7 days) and Group II (postoperative PE > 7 days) patients

	Group I (n = 32)	Group II (n = 5)	p
Gender (M/F)	12/20	4/1	< 0.05
Presence of wound infection, n (%)	3 (9.4)	3 (60.0)	< 0.05

Table 4. Model 1 – risk factor analysis

	Value	SD	OR	95% CI for OR	p
Preoperative oxygen saturation	–0.27	0.12	0.76	0.60–0.97	< 0.05
Presence of wound infection	3.83	1.78	46.06	1.41–1,508.39	< 0.05
Age at repair	–0.14	0.07	0.87	0.76–1.00	< 0.05

CI = confidence interval; OR = odds ratio; SD = standard deviation.

Table 5. Model 2 – risk factor analysis

	Value	SD	OR	95% CI for OR	p
Preoperative oxygen saturation	–0.12	0.056	0.89	0.80–1.00	< 0.05
Presence of wound infection	2.90	1.33	18.17	1.34–246.36	< 0.05

CI = confidence interval; OR = odds ratio; SD = standard deviation.

set up: Model 1 – oxygen saturation before surgery, presence of wound infection, age at repair; Model 2 – oxygen saturation before surgery, presence of wound infection (Tables 4 and 5).

Discussion

Surgical repair of TOF has a reasonably low mortality rate. Tremendous results have been achieved after 1-stage correction compared with 2-stage correction in neonates.[11,12] Our study had only 1 case with 1-stage correction, so we could offer no further analysis and discussion. Long-term follow-up results, mortality and morbidity following repair are main areas of study.[13] Factors affecting the duration and amount of PE after open heart surgery have not been found. Prolonged PE after surgery for congenital heart disease is not an uncommon finding. Hemodynamics of fluid accumulation have been described after cardiac surgery in children.[14–16] Many factors, including prolonged cardiopulmonary bypass, hormonal changes and surgical technique, may affect fluid retention.[14–16] Most studies analyzed prolonged PE after the Fontan procedure, and the final model is of right heart failure commonly complicated by fluid retention and refractory PE.

Pleural fluid circulation is normally regulated by Starling pressure gradient between the pleura, the conductance of filtering and absorbing portions of the pleura, and the capacity and power of the lymphatic pump.[17,18] Any change in these factors can induce retention of pleural fluid. An increase in mean capillary hydrostatic pressure that occurs with systemic venous hypertension or pulmonary venous hypertension will also increase pleural drainage. Systemic venous hypertension increases resistance to the lymphatic flow and interferes with pleural fluid reabsorption.

The strong correlation between higher right atrial pressure (RAP) and the duration and volume of PE following repair of TOF confirms the importance of systemic venous hypertension in pleural fluid dynamics, but we did not find this relationship in our patients. On the other hand, the lower Nakada index in our Group II patients indicated poor development of the peripheral pulmonary arteries, which may lead to pulmonary hypertension, which in turn induces high-grade tricuspid regurgitation, high RAP, and even other signs of right heart failure. It also indicates that the Nakada index may be more sensitive than the McGoon ratio for evaluating outcome after TOF repair.[19]

Wound infection causing inflammation may increase mean capillary hydrostatic pressure, which then increases pleural drainage. The pulmonary vascular anatomy is usually abnormal in TOF.[20,21] Presence of RVOT obstruction and intracardiac right-to-left shunt lead to diminished pulmonary blood flow. Muscular pulmonary arteries are thin-walled and have medial atrophy; the lumens of pulmonary arteries, capillaries, and veins are dilated. Relieving the RVOT obstruction will cause an acute and marked increase in intravascular hydrostatic pressure and pulmonary blood flow, and considerably increase the gradient between the pleurae. Polycythemia increases blood viscosity, which inversely affects blood flow.[22,23] Low oxygen saturation before surgery and polycythemia are usually found in patients with cyanotic TOF, and acute hemodilution after repair of TOF adds to the increased pulmonary blood flow and may lead to development of PE.

Prolonged mechanical ventilation was associated with increased pleural drainage in this study. A rise in intrathoracic pressure by mechanical ventilation produces a net decrease in intrapleural pressure and an increase in systemic venous pressure. The pulmonary vascular resistance rises exponentially with lung inflation.[24] These mechanisms could decrease lymphatic drainage of pleural cavities and compromise pleural fluid reabsorption, which is present during prolonged endotracheal intubation.

Another potential factor in the development of prolonged PE after open heart surgery may involve the alteration in hormones that regulate fluid and electrolyte homeostasis, including atrial natriuretic factor, thyroid hormone, antidiuretic hormone, renin-angiotensin-aldosterone system, and cytokines. Since we did not examine patients' hormone changes in this study,[15,25] further investigations are necessary to establish the role of these different hormones in the development of PE following TOF repair. Right PE is prevalent in patients with heart failure.[26] Prolonged PE following TOF repair has a strong impact on postoperative morbidity and duration of hospital stay. Its pathophysiology appears to be multifactorial. Preoperative oxygen saturation and the presence of wound infection were major risk factors for prolonged PE in this study, which is somewhat different from a previous study;[19] this may be due to the small number of patients in our study. Early pleurodesis may be considered to decrease the duration of PE and hospitalization.[27] A thoracotomy for a palliative shunt is associated with reduced drainage after subsequent repair, which theoretically may be the previous palliative shunt increasing pulmonary flow before total repair, so pulmonary flow did not change too much after total repair. And we know that PE after total repair is associated with pulmonary flow.[17,18] On this basis, a right systemic-pulmonary arterial shunt should be constructed when staged repair is undertaken, but previous systemic-pulmonary arterial shunt may lead to stenosis of peripheral pulmonary arteries.

The odds ratio for the presence of wound infection was higher than that for other factors, so it may be a major risk factor for prolonged PE. Preoperative oxygen saturation may indicate a patient's condition before surgery (the degree of pulmonary stenosis). For example, low preoperative oxygen saturation may indicate that the patient is in a poor condition or that pulmonary flow is inadequate, so after surgery, the patient is prone to infection or there may be too much pulmonary flow, causing an increase in intravascular hydrostatic pressure and the pressure gradient between the pleurae, resulting in prolonged PE.

In conclusion, prolonged PE after TOF repair is a significant morbidity. The risk factors for prolonged PE are gender, age at repair, body weight, bypass time (duration on heart-lung machine), low oxygen saturation before surgery, wound infection after surgery, duration of endotracheal intubation, length of hospital stay, and Nakata index. Oxygen saturation before surgery and wound infection were major risk factors while age at repair was a confounder.

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