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Determinants of Immediate Extubation in the Operating Room after Total Thoracoscopic Closure of Congenital Heart Defects

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Key Words
Thoracoscopy · Atrial septal defect · Ventricular septal defect · Ultra-fast-track anesthesia · Extubation

Abstract
Objective: This study was designed to assess the factors that influence immediate extubation following totally thoracoscopic closure of congenital heart defects. ***Subjects and Methods:*** Clinical and operational data of 216 patients (87 males, average age 13.6 ± 10.9 years) were retrospectively analyzed. Atrial (ASD, n = 90) or ventricular septal defects (VSD, n = 126) were closed via a totally thoracoscopic approach. Ultra-fast-track anesthesia (UFTA) was used in all patients. ***Results:*** Immediate extubation in the operating room was successfully performed in 156 (72.2%) patients. A delayed extubation was completed in the intensive care unit in the remaining 60 (27.8%) patients. There was no significant difference in the age, sex, body weight, or type of congenital heart defect between the immediate and delayed extubation groups ($p > 0.05$). However, more patients in the delayed extubation group had severe preoperational pulmonary hypertension [8 (13.3%) vs. 4 (2.3%), $p < 0.05$]. The cardiopulmonary bypass time, aortic clamp time, and total duration of the surgery in the immediate extubation group were shorter than in the delayed extubation group ($p < 0.05$). Multivariate logistic regression analysis showed that preoperational pulmonary hypertension, duration of the surgery or cardiopulmonary bypass, and dosage of fentanyl used during the surgery were independent predictors for immediate extubation. ***Conclusions:*** UFTA and immediate extubation in the operating room was feasible and safe in the majority of patients undergoing totally thoracoscopic closure of ASD or VSD. Preoperational pulmonary hypertension, duration of the surgery, and the dosage of fentanyl used for UFTA were the determining factors for immediate extubation.

Introduction

Thoracoscopic technologies have been used to repair atrial or ventricular septal defects (ASD or VSD) in children and young adults [1–6]. General anesthesia is required for thoracoscopic closures of ASD or VSD, and extubation was conducted in the intensive care unit (ICU) in the majority of the previously reported cases [1–6]. Fast-track anesthesia (FTA) is an anesthesia that enables patient extubation within 6 h after the cardiac surgery [7, 8], whereas with ultra-fast-track anesthesia (UFTA), ex-

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tubation is conducted while patients are still in the operating room [9]. Although UFTA appears feasible after coronary artery bypass grafting or cardiac valve replacement surgeries [10, 11], there has been limited information about the application of UFTA during thoracoscopic closures of congenital cardiac defects. The feasibility and safety of UFTA in patients undergoing totally thoracoscopic surgery have not been previously studied. Our earlier experience showed that approximately a third of the patients who were treated with totally thoracoscopic surgeries were extubated in the operating theater [12]. However, the factors that determine the immediate extubation were unknown [12]. The aim of this study was to investigate the factors that influence the immediate extubation in a larger cohort of patients following totally thoracoscopic closure of congenital heart defects.

Subjects and Methods

Selection of Patients

This retrospective study was approved by the Institutional Review Board of our hospital. The clinical and operational data of 216 patients who underwent totally thoracoscopic closure of a congenital heart defect between 2009 and 2011 were retrieved. There were 87 males and 129 females, with an average age of 13.6 ± 10.9 years (range 3–45) and an average body weight of 32.9 ± 14.3 kg (range 11–68). Preoperational echocardiography showed ASD in 90 patients, and VSD (membranous or perimembranous) in 126. Twelve patients had a preoperational pulmonary systolic pressure of 60–70 mm Hg. All patients had a New York Heart Association functional class I or II.

General Anesthesia

The thoracoscopic procedures in the present study were performed by the same operator (Z.M.) and the general anesthesia was performed by the same anesthetist (Z.Z.) using our recently reported methods [12]. For the induction of general anesthesia, midazolam, propofol, fentanyl, and vecuronium were administered intravenously. Single and double lumen intubation was performed in patients with a body weight <30 kg and ≥30 kg, respectively. Continuous infusion of remifentanil and intermittent inhalation of sevoflurane was used to maintain the general anesthesia.

Following the surgery, extubation was attempted in the operating room (immediate extubation group) if all of the following criteria were met [12]: (a) responding to verbal commands, (b) spontaneous respiration with Sp_{O_2} >95%, (c) stable blood pressure, (d) body temperature >36.5°C, and (e) arterial blood gas: pH >7.30, Pa_{O_2} >60–70 mm Hg, Pa_{CO_2} <45 mm Hg, and Fi_{O_2} <0.5. Those who did not meet the above criteria within 20 min of the surgery were transferred to the ICU for monitoring and extubation (delayed extubation group). To assess the immediate extubation rate at different learning curves of the operating team, the 216 patients were divided into 4 groups, and the extubation rate was calculated in each group.

Cardiopulmonary Bypass and Surgical Techniques

We have previously reported our techniques of totally thoracoscopic closure of ASD and VSD [5, 6]. Cardiopulmonary bypass was established by inserting a Carpentier double-lumen catheter (Medtronic, USA, or Kangxin, China) into the inferior and superior vena cava through the right femoral vein. Perfusion was performed through a second catheter in the abdominal aorta. Three small incisions (1–1.5 cm) were made on the right side of the chest, in the right 4th intercostal space, and in the right 5th and 6th intercostal space, respectively, for the placement of thoracoscopy (Olympus Corporation, Tokyo, Japan) and other surgical equipment. ASD or VSD were closed with either direct sutures or a bovine patch if a defect was large. Transesophageal echocardiography was performed after the closure to verify the integrity of the repair.

Statistical Analysis

All statistical analyses were performed with the SPSS software package (version 13.0; Chicago, Ill., USA). Data are expressed as means ± SD. Differences in continuous variables between groups were compared by one-way ANOVA. Categorical variables were compared by χ^2 or Fisher's exact test. Multivariate logistic regression analysis was performed to identify predicting factors for immediate extubation. Patient demographics, type of heart defect, presence of pulmonary hypertension, date of operation, total operation time, aortic clamp time, cardiopulmonary bypass time, and dose of fentanyl used during the surgery were entered into the regression model. p 0.05 was considered statistically significant.

Results

General Findings

The surgical procedures were successful in all patients. There were no postoperative mortalities or major complications, such as bleeding requiring reoperation or cerebrovascular events. The mean duration of cardiopulmonary bypass was 58 ± 29 min (range 23–192). The mean aortic clamp time was 30 ± 18 min (range 25–79).

Immediate Extubation Rate

Of the 216 patients, 156 (72.2%) met the immediate extubation criteria and were extubated in the operating room. In 2 (1.3%) patients, reintubation was performed in the operating room within 15 min of the initial extubation. One reintubation was due to a decline in consciousness level in the operating room shortly after extubation, and the other was due to arrhythmia and a reduction in blood pressure. Both patients had an uneventful postoperative recovery following a successful extubation 3 h after the ICU admission. In the remaining 60 (27.8%) patients, delayed extubation was performed in the ICU after a short period of mechanical ventilation (mean 85 ± 30 min). Immediate extubation was successfully performed in 4 of the 12 patients with a preoperational pulmonary

Table 1. Clinical and operational data of the immediate extubation and delayed extubation groups, and univariate logistic regression analysis

Indices	Immediate extubation (n = 156)	Delayed extubation (n = 60)	p value
Males, n (%)	66 (42)	24 (40)	0.538
Age, years	14.2±9.9	15.1±10.7	0.449
Body weight, kg	31.8±14.1	33.7±13.5	0.360
VSD, n (%)	96 (61.6)	33 (55.7)	0.948
Mean PASP, mm Hg	46.6±7.9	50.1±9.6	0.031
Pulmonary hypertension (PASP 60–70 mm Hg), n (%)	4 (2.3)	8 (13.3)	0.042
Dose of fentanyl, μg/kg	6.6±3.2	9.5±3.7	<0.001
Membrane oxygenator, n (%)	90 (58)	34 (56)	0.887
CPB, min	50±26	69±29	<0.001
Aortic clamp time, min	29±18	47±21	<0.001
Duration of the surgery, min	80±35	110±38	<0.001

PASP = Pulmonary arterial systolic pressure; CPB = cardiopulmonary bypass.

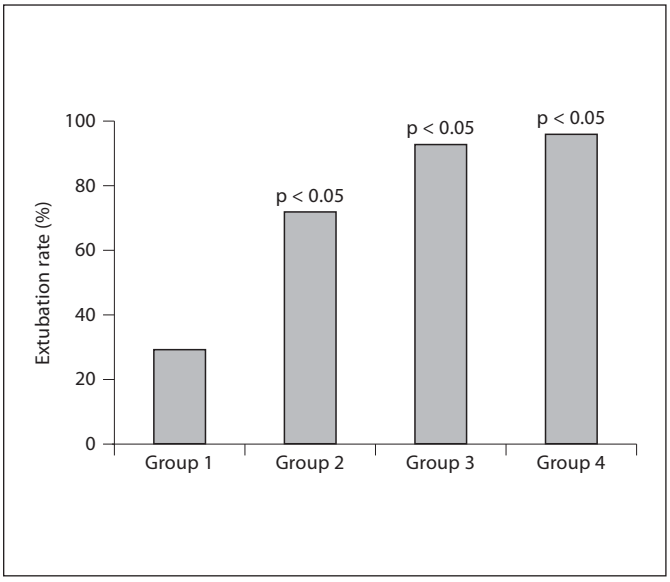

Fig. 1. Comparison of immediate extubation rates between the 4 groups. There was an increase in the successful extubation rate after the first 54 operations (group 1).

Table 2. Immediate extubation rate at different stages of the learning curve

Indices	First group (n = 54)	Second group (n = 54)	Third group (n = 54)	Fourth group (n = 54)
PASP 60–70 mm Hg, n (%)	0	2 (0.04)	4 (0.07)	6 (0.11)
Cardiopulmonary bypass time, min	80±26	62±23[a]	48±16[a, b]	45±14[a, b]
Aortic clamp time, min	55±28	42±21[a]	35±18[a]	30±12[a, b]
Duration of the surgery, min	115±35	90±21[a]	76±16[a, b]	70±17[a, b]

PASP = Pulmonary arterial systolic pressure. [a] $p < 0.05$ compared with the first group. [b] $p < 0.05$ compared with the second group.

pressure of 60–70 mm Hg. In 7 patients extubation was performed 240 min after the surgery, and in 1 patient it was performed 350 min after the surgery.

There was no statistically significant difference in age, sex, body weight, or type of heart defect (ASD or VSD) between the immediate and delayed extubation groups (table 1). However, the cardiopulmonary bypass time, aortic clamp time, and total duration of the surgery in the immediate extubation group (46.6 ± 7.9 mm Hg) were shorter than in the delayed extubation group ($p < 0.05$). The mean pulmonary systolic pressure in the immediate extubation group was lower than in the delayed extubation group (50.1 ± 9.6 mm Hg), and a smaller proportion of the patients in the immediate extubation group had preoperational pulmonary hypertension ($p < 0.05$). The dosage of fentanyl used in the immediate extubation group was lower than in the delayed extubation group ($p < 0.05$).

As shown in table 2, after the first 54 operations (the first group of patients), there was a statistically significant reduction in the cardiopulmonary time, aortic clamp time, and total duration of the surgery ($p < 0.05$). The immediate extubation rate also increased from 29 to 74% (fig. 1, $p < 0.05$). After the first 108 operations (the first and the second group), there was a further reduction in the cardiopulmonary bypass time, aortic clamp time, and total duration of the surgery (table 2, $p < 0.05$). The immediate extubation rate also increased to 93% (fig. 1, $p < 0.05$).

Clinical Outcomes

The clinical outcomes of patients with immediate and delayed extubation are shown in table 3. The proportion of the immediate extubation group who required postoperative analgesics (fentanyl) was lower than in the delayed extubation group ($p < 0.01$). The mean duration of ICU stays in the immediate extubation group was shorter ($p < 0.05$). However, there was no statistically significant difference in the rate of arrhythmia, postoperative pulmonary atelectasis, and duration of postoperative stay between the two groups ($p > 0.05$).

Factors Influencing Immediate Extubation

Multivariate logistic regression analysis also showed that preoperational pulmonary hypertension, dose of fentanyl, cardiopulmonary bypass time, aortic clamp time and total duration of surgery were independent predictors for immediate extubation (table 4).

Table 3. Clinical outcomes of the patients

Indices	Immediate extubation (n = 156)	Delayed extubation (n = 60)	p value
Postoperative analgesia, n (%)	21 (14)	17 (29)	<0.01
Volume of chest drainage, ml	110 ± 60	121 ± 69	0.249
Transient heart block, n (%)	0	1 (1.7)	0.644
Pulmonary atelectasis[a], n (%)	8 (5.1)	3 (5)	0.987
ICU stay, h	18 ± 4	24 ± 7	<0.01
Postoperative hospital stay, days	5.0 ± 0.9	5.5 ± 1.3	0.431

[a] Diagnosis was based on clinical symptoms and bedside chest X-ray.

Table 4. Multivariate logistic regression analysis of predicting factors for immediate extubation

Indices	OR	95% CI	p value
PASP 60–70 mm Hg	1.840	1.734–2.414	0.041
Dose of fentanyl	2.368	1.027–5.458	0.003
Cardiopulmonary bypass time (min)	2.104	1.029–5.184	0.006
Aortic clamp time (min)	2.614	0.853–5.981	0.002
Duration of the surgery (min)	1.019	1.003–1.035	0.016

PASP = Pulmonary arterial systolic pressure.

Discussion

This study demonstrated that UFTA can be safely used in patients undergoing totally thoracoscopic closure of ASD or VSD, and immediate extubation in the operating room can be achieved in the majority of the patients. More importantly, this study revealed that the rate of immediate extubation was related to the presence of preoperational pulmonary hypertension, the cardiopulmonary bypass time, the aortic clamp time, the total duration of the operation, and the dose of fentanyl used during the surgery.

Preoperational pulmonary hypertension is a major limiting factor for UFTA and immediate extubation [13, 14]. Some investigators consider severe preoperational pulmonary hypertension as a contraindication for UFTA [15], although this view has been debated by others [16]. In our early studies, patients with severe preoperational pulmonary hypertension (>60 mmHg) were excluded from these thoracoscopic procedures [5, 6]. As our surgical experiences improved, we began to operate on patients with a pulmonary pressure between 60–70 mm Hg and NYHA functional class II. As shown in this study, immediate extubation was achieved in approximately a third of the patients with severe pulmonary hypertension, and the majority of these patients required extubation in the ICU after approximately 4 h of mechanical ventilation. These results suggest that care should be taken in the application of immediate extubation in patients with severe preoperational pulmonary hypertension.

Previously retrospective analyses showed that total duration of surgery, cardiopulmonary bypass time and aortic clamp time were the independent predictors of immediate extubation [15, 16]. A longer cardiopulmonary bypass time is required for more complex cases or in cases with unexpected difficulties during the surgery. Longer cardiopulmonary bypass time was associated with an increased risk of inflammatory response syndrome with generalized edema, decreased respiratory compliance, acute lung injury, and coagulopathy, all of which affect the ability to extubate a patient immediately after surgery [15]. In the present study, the surgeries and the general anesthesia were performed by the same team, which allowed analysis of the immediate extubation rate at different stages of the learning curve. There was a statistically significant reduction in the total surgical time, cardiopulmonary bypass time, and aortic clamp time, after the first 108 operations. In the meantime, the rate of successful immediate extubation increased from 29 to 93–96%. There was no statistically significant difference in the

age, sex, body weight, types of the congenital defects, and types of the oxygenation methods used between the immediate extubation and delayed extubation groups. However, the cardiopulmonary time, aortic clamp time, and the total duration of the surgery in the immediate extubation group were shorter than in the delayed extubation group. Multivariate logistic regression analysis showed that total duration of surgery, cardiopulmonary bypass time and aortic clamp time were independent predictors for successful immediate extubation in the operating room. These results confirmed that the experiences of the surgical team play a critical role in reducing the operating times and in improving the rate of immediate extubation.

The dose of fentanyl used in the general anesthesia appears to play an important role in the duration of the surgery and in the success rate of immediate extubation. In patients undergoing coronary bypass surgery, a low intraoperative dose of fentanyl was an independent predictor of early extubation [17]. In the present study, the mean dose of intraoperative fentanyl in the immediate extubation group was lower than in the delayed extubation group. Furthermore, multivariate regression analysis demonstrated that the dose of fentanyl was an independent predictor for successful immediate extubation. These results suggest that minimization of the fentanyl use during the operation may facilitate immediate extubation following the endoscopic closure of congenital heart defects.

Although this study has demonstrated that early extubation is feasible and safe in the majority of patients undergoing totally endoscopic closure of ASD or VSD, it is worth noting that early extubation is not the ultimate outcome measure for this novel surgery, as early extubation is largely operator dependent.

Conclusion

This retrospective study demonstrated that UFTA and immediate extubation can be performed in the majority of patients undergoing totally thoracoscopic closure of ASD or VSD. The rate of success for immediate extubation is largely related to the severity of preoperational pulmonary hypertension, dosage of fentanyl, and the duration of the surgery or cardiopulmonary bypass.

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