Early Extubation Following Open Heart Surgery in Pediatric Patients with Congenital Heart Diseases†

UNGKAB PRAKANRATTANA, M.D.*, SONGYOS VALAIRUCHA, M.D.*,
SOMCHAI SRIYOSCHATI, M.D.**, SAMPHANT PORNVILAWAN, M.D.**,
TEERAVIT PHANCHAIPETCH, M.D.**

Abstract

The study of tracheal extubation time in pediatric patients who underwent open heart surgery was performed in the period of 1990-1991 (group 1) and 1992-May 1994 (group 2), composed of 174 and 208 cases in group 1 and group 2 respectively. The criteria for extubation in these patients are convention regimens with considered subsequent standard of CPB, such as fully rewarmed, hemodynamic stable with adequate cardiac output with low-dose or no inotropes/ vasodilator, without significant dysrhythmias and no significant mediastinal bleeding. The difference of postoperative fluid management between the two groups include the regimens of total fluid intake of two-thirds of daily maintenance fluid in group 1, whereas, the total fluid therapy of group 2 depended on the patients' age and body weight.

The results show that, early extubation within 8 hours of ICU arrival were 20.5 per cent and 61.7 per cent in group 1 and group 2 respectively. All of the patients in group 2, after extubation, were discharged to the ward on the first postoperative day. The overnight ventilation was about 74.1 per cent and 30.6 per cent in the first and second groups respectively. The prolonged intubation (more than 24 hours) was almost the same in two groups. There was no significant complication of early extubation with the limitation of daily total fluid intake. The causes of tracheal reintubation in both groups were fluid overload and residual cardiac lesions. The prior etiology occurred in group 1 more than group 2.

It was concluded that, after the change in postoperative fluid therapy regimens, early extubation following open-heart pediatric surgery is highly successful with no significant complication. The benefits of early extubation include cost savings, patient comfort, early patient mobilization, improved cardiac function, reduced respiratory complications and reduction of case cancellation due to early ICU discharge.

* Department of Anesthesiology,
** Department of Cardiothoracic Surgery, Department of Surgery, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok 10700, Thailand.

† Presented at the 9th Asian Australasian Congress of Anesthesiologists, November 6-11, 1994, Bangkok, Thailand.

Most pediatric patients with congenital cardiac disease who have undergone open heart surgery usually have mechanical ventilatory support overnight. This action has been accepted by many anesthesiologists and surgeons, partly because of habit and partly due to the belief that overnight ventilation is somehow beneficial to the patients' respiratory and cardiovascular systems(1). The safety breathing was concerned when the analgesic and tranquilizer medication were administered(2). Nevertheless, continuation of the tracheal intubation might trigger many negative results, such as a decrease in cardiac output due to positive pressure ventilation, patient discomfort, a longer duration of stay in the intensive care unit and more respiratory complications(3). The problems might be associated with the tracheal tube itself, including displacement, disconnection and obstruction by either kinking or secretion(2).

Currently, Siriraj Hospital annually records more than 100 patients aged 12 years or younger, who undergo open heart surgery for congenital cardiac defects. Starting from 1991, a change was introduced in the amount of fluid intake given in the postoperative period. A research team noted that tracheal extubation could be made early without any increased risks. Therefore, a study was performed to compare the outcome of two groups of pediatric patients with different durations of tracheal intubation following open heart surgery as well as to compare the newly introduced regimen of postoperative fluid therapy with the previous one.

MATERIAL AND METHOD

A retrospective study was carried out among pediatric patients aged 12 years or younger who were admitted for open heart surgery to correct congenital cardiac defects from January 1990 to May 1994. All patients who died from surgical complications and those who had tracheostomy prior to the operation were excluded. Premedication was with chloral hydrate 50 mg/kg orally 1 hour preoperatively. The newborn patients were not premedicated. Monitoring of electrocardiogram and noninvasive blood pressure were commenced on arrival in the operating room. A 24-guage or 22-gauge venous cannula was inserted.

Anesthesia was induced with fentanyl 2 μg/kg, and thiopental 2 mg/kg. Atracurium 0.8-1 mg/kg, was administered to provide neuromuscular blockade and the lungs were ventilated with oxygen until intubation. A balanced technique was performed to maintain adequate anesthesia.

During cardiopulmonary bypass, the patient's core temperature was cooled to 18-25°C. Cardiac arrest was achieved with an antegrade crystalloid cardioplegic solution at 4°C. During or after cardiopulmonary bypass (CPB), mannitol and furosemide were given when required to maintain an adequate urine output. Discontinuation of cardiopulmonary bypass was attempted when nasopharyngeal temperature had reached 37.5°C. Hemodynamic stability was maintained by volume replacement with packed red cells and some fresh frozen plasma. Inotropic support was started with calcium gluconate 20-40 mg/kg intravenously and continuous intravenous infusion with dobutamine 5-10 μg/kg/min, except when the cardiac output was low, then adrenaline was administered. Pulmonary vascular hypertension was attenuated by intravenous infusion of nitroglycerin 0.5-4 μg/kg/min.

At the completion of surgery, no reversal of neuromuscular blockage was attempted. The patients were transferred to the cardiac surgery intensive care unit. Tracheal extubation was considered when signs and symptoms met the criteria for termination of mechanical ventilation and extubation(4) which are as follows :

1. The patient was awake, alert and moving all limbs.
2. The hemodynamic was stable in a normal for the age of the child with low-dose inotropes requirement.
3. The patient was well-perfused with adequate urine output.
4. The core temperature reached 36.5-37.5°C when the patient was fully rewarmed.
5. Mediastinal bleeding was less than 1 ml/kg/hr.
6. Arterial oxygen tension (PaO_2) was higher than 100 torr with FiO_2 = 0.4 for acyanotic child. For those with cyanosis, the PaO_2 should be approximately 40 torr with saturation more than 75 per cent with FiO_2 = 0.4 after the palliative procedures.
7. Chest X-rays showed no collapsed lung or pleural effusion.
8. Breath sounds were clear bilaterally and without wheeze.

Table 1. Amount of fluid intake among group 1 patients following open heart surgery, based on Holiday Segar's regimen.

Amount of fluid intake	
100% fluid intake (ml/day)	Actual amount of fluid intake in postoperative period
Body weight <10 kg :	2/3 of normal amount required
= 100 x weight (kg)	Example : A 15 kg child would received
Body weight 10-20 kg :	= 2/3 [1,000 + (5 x 50)] ml/day
= 1,000 + (weight - 10) x 50	= 833.3 ml/day
Body weight >20 kg :	$\approx$35 ml/hr
= 1,500 + (weight - 20) x 20	

Table 2. Daily fluid maintenance amount of 100% intake for children

Age	Total fluid intake (ml/kg/day)
5 days - 3 mos	150
3 - 6 mos	120
6 - 9 mos	100
9 - 12 mos	90
1 - 2 yrs	90
2 - 4 yrs	80
4 - 8 yrs	70
8 - 12 yrs	60

Table 3. Amount of postoperative fluid intake given to group 2 patients following open heart surgery.

Duration after surgery	Total fluid intake
Operative day	Weight <10 kg received 2 ml/kg/hr Weight >10 kg received 1 ml/kg/hr
Postoperative day	
1	60% of daily fluid intake shown in Table 2
2	70% of daily fluid intake shown in Table 2
3	80% of daily fluid intake shown in Table 2
4	90% of daily fluid intake shown in Table 2
5	100% of daily fluid intake shown in Table 2

The patients were divided into two groups according to different regimens of postoperative fluid management.

Group 1 consisted of 174 pediatric patients admitted from January 1990 to December 1991 for open heart surgery. In the ICU, during the first five postoperative days, the children received two-thirds of the total amount of fluid intake normally required daily, based on the Holiday Segar's regimen[5] (Table 1).

Group 2 patients consisted of 208 young children admitted for open heart surgery from January 1991 to May 1994. All patients had fluid therapy according to their age and body weight as shown in Tables 2 and 3.

The duration of endotracheal tube in place and postoperative complication were obtained, especially following tracheal extubation. Statistical analysis of the data was carried out using Student's *t*-test and chi-square to determine any significant differences between the groups. A P value of < 0.05 was considered statistically significant.

RESULTS

The demographic data, such as age, body weight, the period of circulatory arrest, aortic cross-clamp, CPB and surgery, of the patient groups were not significantly different between the groups in this study. There were ten and twelve deaths in Group 1 and Group 2 respectively. The etiologies of the deaths were related to surgery and patients' diseases themselves. After exclusion of the fatal cases, the study population remaining in Group 1 and Group 2 comprised 174 and 208 patients respectively. The majority of the population in each group had tetralogy of Fallot (TOF), ventricular septal defect (VSD), atrial septal defect (ASD) and transposition of the great arteries (TGA). The remaining 20 per cent of the children were diagnosed with double outlet of right ventricle (DORV), total or partial anomalous pulmonary venous connection (TAPVC, PAPVC), pulmonary atresia or stenosis, common atrioventricular canal and tricuspid atresia (TA).

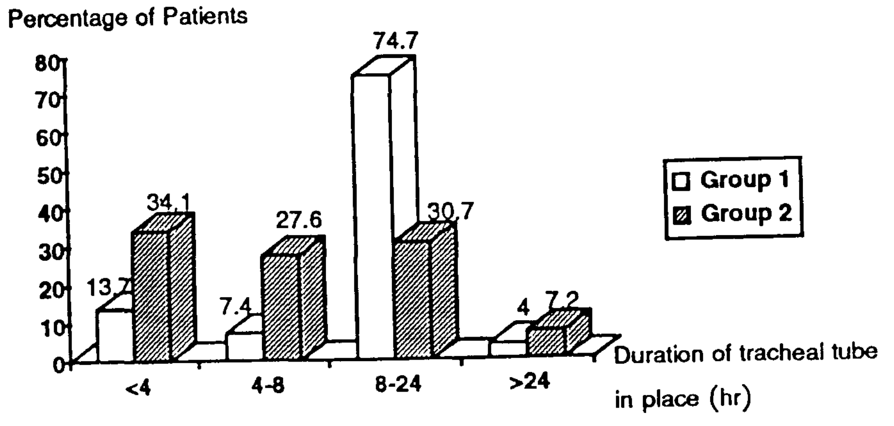

Fig. 1. Percentage of patients of the two groups having for different duration of tracheal tube in place.

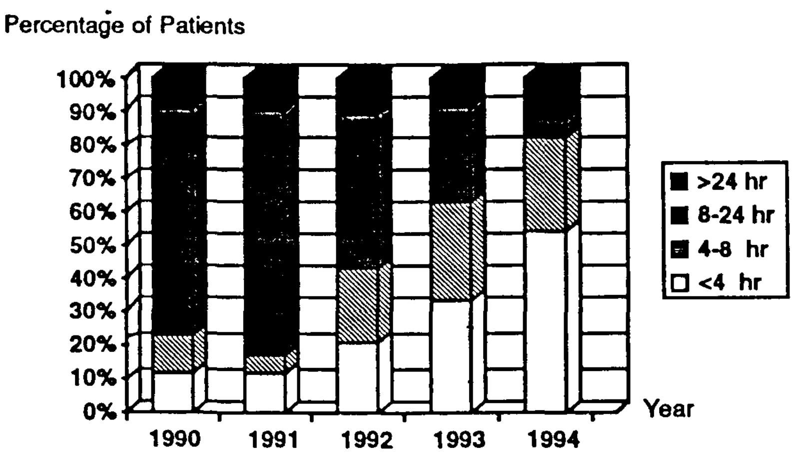

Fig. 2. Comparison of percentage of patients having tracheal tube in place for different durations by year.

The duration of endotracheal tube inplace were 15.9 ± 17.2 hours and 11.6 ± 16.3 hours in Group 1 and Group 2 respectively, with P value = 0.014. Within 4 hours postoperatively, 13.7 per cent and 34.1 per cent of patients in Group 1 and Group 2 respectively were extubated. The tracheal extubations were done in 4-8 hours postoperatively for 7.4 per cent and 27.8 per cent of Group 1 and Group 2 patients respectively. The percentages of those in Group 1 and Group 2 whose extubation was made during 8-24 hours postoperatively were 74.7 per cent and 30.7 per cent respectively. Only 4 per cent of patients in Group 1 and 7.2 per cent of those in Group 2 could be extubated after 24 hours post-operation (Fig. 1).

Fig. 2 shows the percentages of pediatric patients with remaining tracheal tube in place at different intervals of the postoperative period by year. It was found that early extubation was successful sooner each year, from 1990 to 1994.

When the analysis was separately performed on the patient groups according to their specific diseases, the results differed as shown in Fig. 3-Fig. 6.

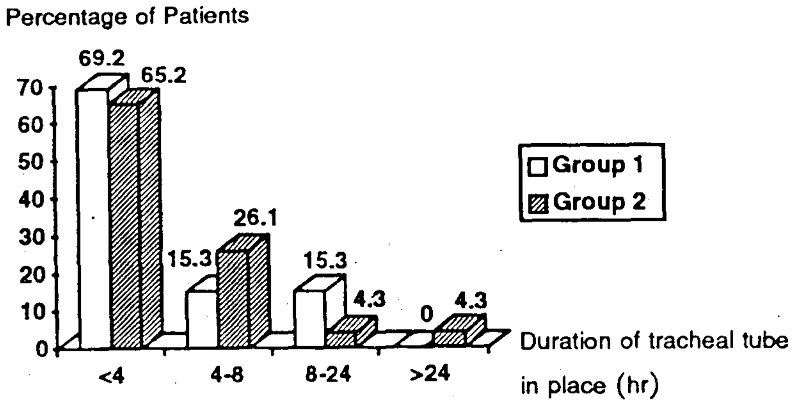

Fig. 3. Percentage of the two groups of patients with atrial septal defect (ASD) at different duration of tracheal tube in place.

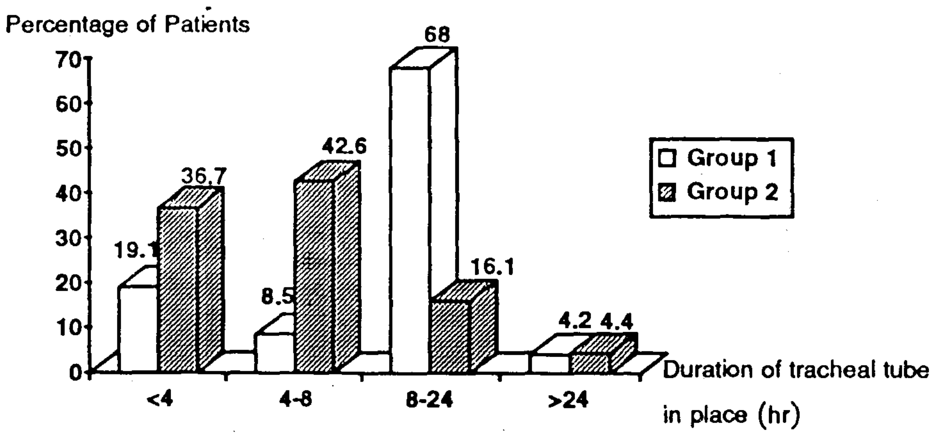

Fig. 4. Percentage of the two groups of patients with ventricular septal defect (VSD) at different duration of tracheal tube in place.

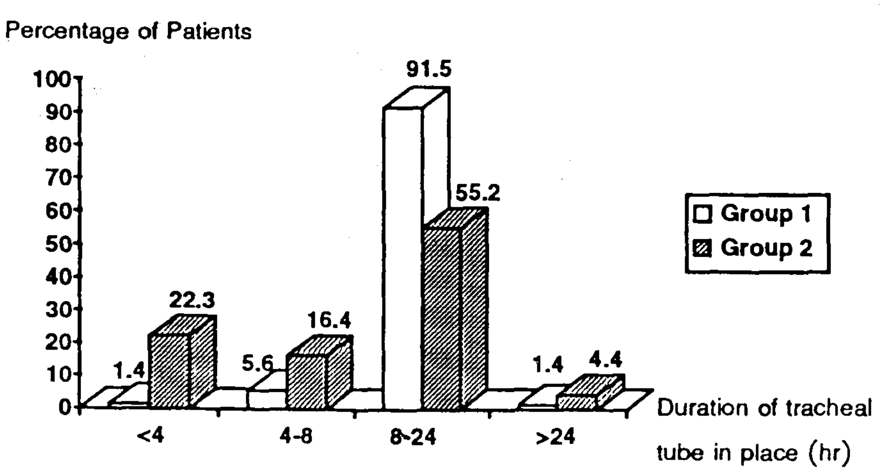

Fig. 5. Percentage of the two groups of patients with tetralogy of Fallot (TOF) at different duration of tracheal tube in place.

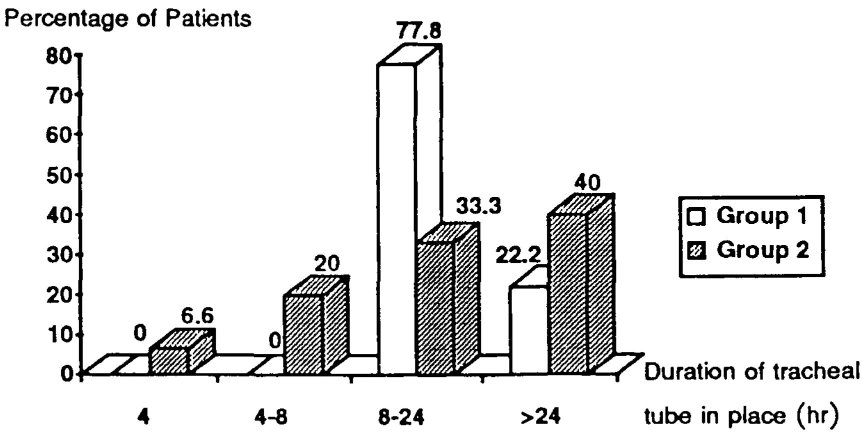

Fig. 6. **Percentage of patients of the two groups with transposition of the great arteries (TGA) at different duration of tracheal tube in place.**

Table 4. **Problems requiring tracheal reintubation after operation.**

Problems	Number of patients	
	Group 1	Group 2
Pulmonary congestion	3	1
Atelectasis	1	1
Arterial desaturation	1	1
Pleural effusion	1	-
Pneumonia	1	-
Residual VSD	1	1
Surgical bleeding	-	1
Left hemiparesis of diaphragm	-	1
Dislocation of tracheal tube	-	1

After tracheal extubation, there were 8 (4.6%) and 7 (3.3%) patients in Group 1 and Group 2 respectively, who experienced respiratory problems requiring reintubation and resumption of mechanical ventilatory support due to pulmonary congestion, atelectasis, arterial oxygen desaturation, pleural effusion, pneumonitis, mediastinal bleeding and left diaphragm hemiparesis (Table 4).

DISCUSSION

The results of this study revealed that following the change in postoperative fluid therapy for pediatric patients after open heart surgery to repair their congenital cardiac defects under CPB, the tracheal extubation could be made in Group 2 patients earlier than in Group 1 patients who received more fluid postoperatively. Approximately 21.1 per cent and 78.9 per cent of children in Group 1 were extubated within 8 hours and after 8 hours following surgery respectively. These results were compared to 6.2 per cent of those in Group 2 who were extubated within 8 hours postoperatively and only 38.1 per cent did so later than 8 hours. Increases in the number of patients whose early extubation was possible within 4-8 hours after cardiac surgery was likely to be the result of decrease in total fluid intake in the postoperative period. Since the mean accumulation per hour of fluid during CPB has been found to be 800 ml/m^2 of body surface area, the interstitial fluid accumulation was greater in the intestine, muscle, myocardium, and skin and was less in the kidney, lungs, and fat. Within 72 hours after the completion of CPB, there was translocation of large amounts of water into the intravascular space(6). Therefore, if the patients were given large amounts of fluid therapy, either intravenously or orally, the intravascular volume would then increase, leading to respiratory and cardiac dysfunction. That would further cause deteriorating pulmonary edema, low cardiac output and may progress to congestive failure. The appropriate management to improve cardiac performance included fluid restriction, furosemide intravenous, increased dosage of inotropic and vasodilator (nitroglycerin). Tracheal reintubation and mechanical ventilatory support would be required to maintain well oxygenation and adequate carbon dioxide elimination.

Since the appropriate timing of tracheal extubation following cardiac surgery also depends upon the type of cardiac diseases as well as surgical outcome, we analysed the patients according to their cardiac defects. Among the ASD patients, it was found that early tracheal extubation within 4 hours postoepratively was successful in both groups, due to the very short period of CPB to correct ASD and the less severe preoperative pathological condition. As a result, the new postoperative fluid therapy regimen was not influenced by early extubation (Fig. 3). In the past as well as currently, most of the ASD patients were very early extubated even in the operating room.

The VSD patients had left to right shunt and pulmonary hypertension. However, after the closure of VSD, a decreased pulmonary blood flow together with intravenous infusion of nitroglycerin as a pulmonary vasodilator induced reduction in pulmonary vascular resistance. Moreover, with a new postoperative regimen fluid intake attenuated an intravascular volume overloading, then tracheal extubation could be made sooner in Group 2 patients (Fig. 4). Therefore, the results from this study confirmed that the majority of VSD patients could be extubated at an early stage following CPB if the appropriate amount of fluid therapy was administered postoperatively.

Patients with TOF had less pulmonary blood flow from right ventricular outflow tract obstruction causing undergrowth of pulmonary vascular bed(7). Following the total repair of TOF, the pulmonary blood flow increased while the pulmonary vascular bed remained unchanged in this situation, reactive pulmonary hypertension may develop. The closure of VSD *via* right ventriculotomy could also contribute to an occurrence of right ventricular dysfunction as well. Such a medication for pulmonary vasodilator as nitroglycerin, tolazoline and PGE_1 would be helpful in relieving the problem(7). Moderate hypocarbia by using intermittent positive pressure ventilation (IPPV) would be beneficial to decrease pulmonary vascular resistance (PVR). However, a negative effect of IPPV itself, particularly when using high airway pressure ventilation or concomitant PEEP, is that the PVR would be increased(8). The reduction of total fluid intake following total repair of TOF in Group 2 patients made the tracheal extubation successful in 22.3 per cent of cases within four hours postoperatively, compared to only 1.4 per cent in Group 1 patients (Fig. 5). The limited amount of fluid intake could decrease pulmonary artery pressure as well as pulmonary congestion. Other contributing factors decreasing right ventricular dysfunction included dobutamine intravenous infusion and the surgical technique of closing VSD *via* atriotomy instead of right ventriculotomy.

Both groups of TGA patients admitted for surgical repair by Mustard's operation could be extubated successfully within 8 hours postoperatively due to the short duration of CPB. But for those TGA patients with arterial switch operation, we decided to continue positive pressure ventilation for another 1-3 days due to prolonged CPB duration and for prevention of increased pulmonary vascular resistance postoperatively. In 1994, there were more younger newborns aged 1-3 weeks undergoing arterial switch operation, so that we aimed to support their ventilation 24-72 hours postoperatively. Therefore, the change of postoperative fluid therapy regimen for the TGA patients did not significantly affect the difference in the duration of tracheal intubation.

Following the Fontan procedure for the children with tricuspid atresia or other complex anomalies, the venous pressure becomes the driving force for pulmonary blood flow. Venous pressure must be kept sufficiently great to provide adequate conduit flow. Spontaneous respiration would help decrease intrathoracic pressure and pulmonary arterial pressure resulting in better hemodynamic stability. Therefore, early extubation would be beneficial(2). Most of these patients were extubated within 8 hours postoperatively with inotropic support. In Group 1, patients had pleural effusion and ascites. The reduction of total fluid intake following Fontan procedure in Group 2 patients, to half of the daily maintenance fluid, made the children more comfortable with stable hemodynamic, less pleural effusion and no ascites.

The benefits of changing the regimen of fluid therapy postoperatively were not established in patients who had short duration of CPB such as ASD closure. Similarly, the reduction of fluid intake postoperatively was not evident among such patients with TGA admitted for arterial switch operation which prolonged the duration of CPB who generally intended to remain on the mechanical ventilation. However, in patients with VSD and TOF who experienced a high risk of pulmonary hypertension and pulmonary congestion postoperatively, the outstanding benefit of the reduced amount of fluid therapy postoperatively was clearly observed, in that a higher number of patients did have early tracheal extubation. The known benefits of early extubation include the cost saving, patient comfort, early patient mobilization, improved cardiac performance, decreased respiratory problem as well as reduction of case cancellation due to early ICU discharge.

The etiology of respiratory dysfunction following open heart surgery may be atelectasis, pulmonary congestion, pneumothorax, pleural effusion and hemiparesis of the diaphragm. The other causes may be cardiac in origin : residual shunt or low cardiac output[7]. The number of patients who had tracheal reintubation were 8 and 7 in Group 1 and Group 2 respectively. The major problem was pulmonary congestion, which occurred among 3 cases in Group 1 compared with only 1 in Group 2. However, the size of the population who had reintubation was too small for meaningful discussion.

(Received for publication on December 9, 1995)

REFERENCES

1. Higgins TL. Early endotracheal extubation is preferable to late extubation in patients following coronary artery surgery. J Cardiothorac Vasc Anesth 1992; 6 : 488-93.
2. Schuller JL, Bovill JG, Nijveld A, Patrick MR, Marcelletti C. Early extubation of the trachea after open heart surgery for congenital heart disease. Br J Anaesth 1984; 56: 1101-8.
3. Barash PG, Lescovich F, Katz JD, Talner NS, Stansel HC. Early extubation following pediatric cardiothoracic operation : a viable alternative. Ann Thorac Surg 1980; 29: 228.
4. Rothstein P. Congenital heart disease. In : Thomas ST, Kramer JL, eds. Manual of cardiac anesthesia, 2nd ed. New York : Churchill Livingstone, 1993: 237-43.
5. Bikhazi GB, Cook DR. Perioperative fluid therapy and blood replacement. In : Motoyama EK, ed. Smith's anesthesia for infants and children, 5th ed. St.Louis : CV Mosby, 1990: 331-44.
6. Uttley JR, Stephens DB. Fluid balance during cardiopulmonary bypass. In : Utley JR, ed. Pathophysiology and techniques of cardiopulmonary bypass. Baltimore : Williams & Wilkins, 1983: 23-35.
7. Willson DF. Postoperative respiratory function and its management. In : Carol LL, ed. Pediatric cardiac anesthesia. Norwalk : Appleton & Lange, 1988: 387-406.
8. Shapiro BA, Macmarek RM, Cane RD, Peruzzi WT, Hauptman D, eds. Clinical application of respiratory care, 4th ed. St.Louis : Mosby Year Book, 1991: 335-64.

การถอดท่อช่วยหายใจในเด็กภายหลังผ่าตัดหัวใจภายใต้เทคนิคใช้ปอด–หัวใจเทียม†

อังกาบ ปราการรัตน์, พ.บ., ทรงยศ วลัยฤาชา, พ.บ.**, สมชาย ศรียศชาติ, พ.บ.**, สัมพันธ์ พรวิลาวัณย์, พ.บ.**, ธีระวิทย์ พันธุ์ชัยเพชร, พ.บ.***

ศึกษาเกี่ยวกับระยะเวลาที่สามารถถอดท่อช่วยหายใจออกได้ภายหลังผ่าตัดหัวใจภายใต้เทคนิคใช้ปอด–หัวใจเทียมในผู้ป่วยเด็กอายุแรกเกิด ถึงอายุ 12 ปี ซึ่งเป็นโรคหัวใจพิการโดยกำเนิด 382 ราย ตั้งแต่ปี พ.ศ. 2533 ถึง พ.ศ. 2537. แบ่งกลุ่มตามปริมาณสารน้ำที่ให้แก่ผู้ป่วยภายหลังผ่าตัด : กลุ่มที่ 1 (ปี พ.ศ. 2533–2534) 174 ราย ได้รับสารน้ำปริมาณ 2/3 ของสารน้ำทั้งหมดที่ควรจะได้ตามปกติแบบของ Holiday Segar, กลุ่มที่ 2 (ปี พ.ศ. 2535–2537) 208 ราย ได้รับสารน้ำเพียง 1–2 มล./กก./ชั่วโมง ภายหลังผ่าตัดเสร็จวันแรก และวันต่อ ๆ มาได้รับสารน้ำเพียงร้อยละ 60, 70, 80 และ 90 ของปริมาณที่ควรได้ตามอายุและน้ำหนักตัว. ใช้หลักเกณฑ์หยุดเครื่องช่วยหายใจและถอดท่อช่วยหายใจออกตามมาตรฐานสากล. ผลของการศึกษา คือ ภายหลังเสร็จผ่าตัดหัวใจ 8 ชั่วโมง สามารถถอดท่อช่วยหายใจได้ร้อยละ 20.5 และ 61.7 ในผู้ป่วยกลุ่ม 1 และ 2 ตามลำดับ. มีผู้ป่วยร้อยละ 74.1 และ 30.6 ในกลุ่ม 1 และ 2 ตามลำดับที่ต้องช่วยหายใจข้ามคืน และถอดท่อช่วยหายใจออกได้ในเช้าวันแรกหลังผ่าตัด. ที่เหลือต้องช่วยหายใจนานกว่า 24 ชั่วโมง ซึ่งมีจำนวนผู้ป่วยใกล้เคียงกันทั้ง 2 กลุ่ม. ไม่พบภาวะแทรกซ้อนรุนแรงภายหลังถอดท่อช่วยหายใจออก. มีผู้ป่วย 8 และ 7 รายในกลุ่ม 1 และกลุ่ม 2 ที่ต้องช่วยใส่ท่อหายใจกลับเข้าไปใหม่ เนื่องจากปอดบวมน้ำ ถุงลมปอดแฟบ มีน้ำในช่องเยื่อหุ้มปอด ปอดติดเชื้อ เลือดออกมาก อัมพาตกะบังลมซ้าย มี VSD เหลืออยู่ และท่อช่วยหายใจเลื่อนหลุด. สรุปว่าการจำกัดปริมาณสารน้ำของผู้ป่วยเด็กภายหลังผ่าตัดหัวใจพิการโดยกำเนิดภายใต้เทคนิคใช้ปอด–หัวใจเทียม จะสามารถลดเวลาช่วยหายใจภายหลังผ่าตัดและสามารถถอดท่อช่วยหายใจออกได้เร็วมากโดยเฉพาะอย่างยิ่งในผู้ป่วยโรค ventricular septal defect และ tetralogy of Fallot.

* ภาควิชาวิสัญญีวิทยา,

** สาขาศัลยศาสตร์หัวใจและทรวงอก, ภาควิชาศัลยศาสตร์, คณะแพทยศาสตร์ศิริราชพยาบาล, มหาวิทยาลัยมหิดล, กรุงเทพ ฯ 10700.

† นำเสนอในการประชุมวิชาการ 9th Asian Australasian Congress of Anesthesiologists, 6–11 พฤศจิกายน 2537, กรุงเทพ ฯ.