

Changing the Institutional Practice of Prolonged Mechanical Ventilation after Coronary Artery Bypass Graft Surgery to Early Extubation

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Abstract

Since 1997 some of our cardiac anaesthetists have, whenever possible, extubated the patients early after cardiac surgery to improve their level of comfort, to allow an early return of the cardiopulmonary physiological function, and to help reduce health care costs. After a few months of implementing this practice, an audit was carried out to evaluate the success of early extubation after coronary artery bypass graft (CABG) surgery.

Over a 6-month period starting from May 1997, the perioperative data of 110 consecutive patients with good or moderate left ventricular function scheduled for elective CABG were prospectively collected and analysed. The anaesthetic regime was according to the preference of the anaesthetists. Initially consent was obtained from the surgeons when the extubation criteria were fulfilled, but subsequently as the practice became more accepted by the surgeons, extubation was initiated by the anaesthetists.

Within 4 hours of admission into the intensive care unit (ICU), 50 (45.5%) of the 110 patients satisfied the early extubation criteria and were extubated. The extubation criteria are described in the article. For the remaining patients, the median duration of mechanical ventilation was 14.3 hours. The profiles of the two groups of patients and the possible reasons for not extubating early are discussed.

Forty-five per cent of the patients with moderate to good ventricular function were extubated safely within 4 hours of admission into the ICU after CABG surgery. With gradual acceptance of the practice and a change in mindset amongst all the care givers, more patients can benefit from this practice. This article highlights the challenges associated with changing institutional practices with respect to the postoperative care of cardiac patients.

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Introduction

In the past, cardiac patients in this institution were ventilated postoperatively for a prolonged period, frequently overnight. Since 1997 some of our cardiac anaesthetists have, whenever possible, adopted the practice of early extubation after cardiac surgery to improve the patient's level of comfort and to allow an early return of the cardiopulmonary physiological function during the postoperative period. If the cardiac surgeons have given consent for early extubation, the patients were extubated as soon as they have fulfilled the extubation criteria.

After a few months of implementing this practice, an audit was carried out to evaluate the success of early extubation after coronary artery bypass graft (CABG) surgery. The duration of the patients' stay in the respec-

tive areas [intensive care unit (ICU), high dependency unit, and general ward] were also recorded to study the effects of early extubation in our hospital.

Materials and Methods

Over a 6-month period starting from May 1997, only patients with good or moderate left ventricular function scheduled for elective CABG [utilising cardiopulmonary bypass circuit (CPB)], anaesthetised by 1 of the 4 cardiac anaesthetists, and operated by 1 of the 3 surgeons were included in this audit. The 4 anaesthetists (A, B, C, and D, not in the order of authorship) had different anaesthetic regimes and these are shown in Table I.

All the patients in this audit had hypothermic cardiopulmonary bypass (oesophageal or nasopharyngeal and rectal temperatures maintained at about 28°C to 32°C

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TABLE I: THE FOUR DIFFERENT ANAESTHETIC REGIMES ARE REPRESENTED AS A, B, C, AND D

	A	B	C	D
Premedication	oral lorazepam 1 mg	intramuscular morphine 0.1 to 0.15 mg/kg, and hyoscine 0.2 mg	intramuscular morphine 0.1 to 0.15 mg/kg, and hyoscine 0.2 mg	oral lorazepam 1 mg midazolam 1 to 2 mg for insertion of lines
Anaesthesia				
Induction	fentanyl 20 to 25 µg/kg midazolam 1 to 2 mg	fentanyl 10 to 15 µg/kg etomidate 6 to 8 mg	fentanyl 10 to 15 µg/kg propofol infusion 2 mg/kg/h until loss of eyelash reflex	fentanyl 10 to 15 µg/kg etomidate 6 to 8 mg
Muscle relaxant	suxamethonium 100 mg pancuronium 0.1 mg/kg	pancuronium 0.1 mg/kg	pancuronium 0.1 mg/kg	pancuronium 0.1 mg/kg
Maintenance				
Prebypass	isoflurane	halothane	isoflurane	isoflurane
Bypass	morphine 5 to 10 mg, bolus doses of midazolam, and pancuronium 2 to 4 mg	propofol infusion 6 mg/kg/h, reducing to 4 mg/kg/h with core temperature less than 32°C	morphine 5 to 10 mg, and propofol infusion 5 mg/kg/h, reducing to 3 mg/kg/h with core temperature less than 32°C	morphine 5 to 10 mg, and propofol infusion 5 mg/kg/h
Postbypass	isoflurane	halothane, and fentanyl 1 to 1.5 µg/kg at chest closure	isoflurane	isoflurane
Muscle relaxant antagonist	none	neostigmine 1.25 mg with glycopyrrolate 0.2 mg	none	none
Thermoregulation and humidification	heat moisture exchanger, Bair Hugger®, heated water mattress	heated water bath humidifier, Bair Hugger®, heated water mattress	heated water bath humidifier, heated water mattress	heat moisture exchanger, Bair Hugger®, heated water mattress

depending on the preference of the surgeon), cardioplegia (using St. Thomas's cardioplegia solution) and topical hypothermia for myocardial protection. During the postbypass period, warming continued with the use of a thin heated water mattress that was positioned between the patient and the operating table. The inspired gases were humidified by either a heat-moisture exchanger or a heated water bath humidifier depending on the preference of the anaesthetists. Some patients were rewarmed with a convective warming blanket (Bair Hugger®) activated during the rewarming phase of CPB. For this, a Bair Hugger® blanket measuring approximately 200 x 20 cm was folded into two halves and applied to the lateral surfaces of the flexed lower limbs before the patient was cleaned and draped for the operation. The hose delivering the warm air was attached to the mid-point of the blanket at the feet-end of the operating table. All the patients were rewarmed to oesophageal or nasopharyngeal temperature of at least 36.5°C before the discontinuation of CPB.

The administration of tranexamic acid or aprotinin was according to the preference of the surgeons or the continued administration of aspirin up to the day before surgery. The regime of tranexamic acid administration in this institution was 500 mg before sternotomy, 500 mg during bypass, and 500 mg after protamine reversal of heparin. The regime of aprotinin administration was a loading dose of 1,000,000 Kallikrein Inactivator Units (KIU), started before sternotomy, followed by an infu-

sion of 500,000 KIU every hour, and 1,000,000 KIU added to the prime during bypass.

On admission to the ICU, the patients were routinely ventilated in the synchronous intermittent mandatory ventilation (SIMV) mode with pressure support of 10 cm H₂O, positive end-expiratory pressure of between 5 and 8 cmH₂O, and at a rate adjusted to achieve normocarbida. All the parameters were monitored continuously, and blood and fluids given as necessary.

For uniformity, the time of resumption of spontaneous breathing was recorded as the time from admission into the ICU, at which the respiratory rate was noted to be more than the preset ventilatory rate on the SIMV mode. If the patient started to breathe spontaneously before arriving in the ICU, then the time of onset of spontaneous breathing was taken to be zero minutes.

When spontaneous breathing was evident, weaning was first achieved by decreasing the SIMV rate and then to the continuous positive airway pressure (CPAP) mode with pressure support. In this cardiothoracic ICU, weaning the patient from the SIMV mode to the CPAP mode had always been the decision of either the surgical staff in the ICU or the surgeon in-charge of the patient. Since the introduction of the practice of early extubation after cardiac surgery, whenever possible, the anaesthetist who performed the anaesthesia helped in this phase of weaning.

The adequacy of ventilation and oxygenation was

routinely confirmed by an arterial blood gas analysis performed at 30 to 60 minutes after the patient had been on the CPAP mode. If the blood gas proved unsatisfactory, the SIMV mode with a lower preset ventilatory rate would be reinstituted. If the haemodynamics allowed, the patient would then be positioned to 20° to 30° head-up in bed (Fowler's position) to facilitate diaphragmatic breathing.

The time of awakening after admission to the ICU was documented as accurately as possible by either the anaesthetist or the attending nurse. A neurological assessment (based on the Glasgow Coma Scale) was performed for each patient after awakening. An infusion of morphine would then be started at 1 to 2 mg per hour for analgesia and the patient would be encouraged to breathe deeply.

The patients were allowed to be extubated only if the following criteria for early extubation were fulfilled:

1. The patient is fully rewarmed; having a core (rectal) temperature of more than 36.5°C and a core-peripheral temperature gradient of less than 2°C.
2. The hourly mediastinal blood loss is less than 50 ml.
3. The haemodynamic status should be satisfactory, as judged by the arterial blood pressure, filling pressure, peripheral circulation and the urine output. The continuation of inotrope per se is not a contraindication to early extubation.
4. The patient is responsive and able to obey commands.
5. The patient's pattern of breathing is regular, the rate of breathing is less than 20 breaths per minute, and the tidal volume is more than 7 ml/kg.
6. The arterial blood gas analysis is acceptable. A PaO_2 greater than 10 kPa with FiO_2 less than 0.5 and PaCO_2 less than 8 kPa.

After extubation, the patient received 40% to 60% oxygen administered by facemask.

During office hours, whenever possible, the anaesthetist in charge of the patient helped the surgical staff of the ICU decide on the timing of extubation. After office hours, the responsibility of weaning the patient off the ventilator was left to the discretion of the surgical staff managing the ICU, as was the conventional practice. If the surgeon in-charge had preferred to ventilate his patients overnight, the anaesthetist did not interfere with the pace of weaning from the ventilator.

The discharge times from the ICU were left to the decision of the surgeons and were not subjected to the influence of the anaesthetists.

For each patient, details such as demographic data, ventricular function, anaesthetic regime, duration of the anaesthesia, surgery, and cardiopulmonary bypass, intraoperative oesophageal and rectal temperatures were recorded. Postoperatively, the rectal temperature meas-

ured on admission to the ICU, time of awakening, time of resumption of spontaneous breathing, time needed to rewarm patient to a core temperature of 36.5°C in the ICU, hourly mediastinal blood loss, time of extubation, reason(s) for ventilating patient for more than 4 hours, and duration of stay in the ICU, high dependency unit and in the ward were recorded.

Statistical Analysis

Descriptive statistics were summarised as mean $\pm$ standard deviation with 95% confidence interval (95%CI) when the results were normally distributed and as median and range where they were not. Student's t-test and ANOVA test were used to determine the significance of normally distributed parametric values and Mann-Whitney U test and Kruskal-Wallis test for the non-normally distributed data. The chi-square test was used to compare the groups of patients with regards to left ventricular function, the anaesthetic agent used during bypass and the administration of neostigmine. The Spearman rank correlation coefficient was used to analyse the correlation between the temperatures maintained during bypass and postoperative mediastinal blood loss. Statistical significance was set at $P < 0.05$.

Results

Altogether data from 110 patients with moderate to good left ventricular function were prospectively collected and analysed. Sixty patients (54.5%) had good ventricular function with left ventricular ejection fraction of 50% or higher. Fifty patients (45.5%) had moderate ventricular function with ejection fraction between 30% and 49%. There were no differences with regard to the demographic data and the distribution of patients with moderate or good ventricular function amongst the anaesthetists and the surgeons. There were 25 female and 85 male patients. The mean age of the female patients was 63.6 (SD 8.2, 95% CI of 60.3-67.0) years, while that of the male patients was 58.8 (SD 9.0, 95% CI of 56.8-60.7) years ($P = 0.013$).

The median time of awakening following anaesthetic regimes A, B, C, and D were 1.50 hours (range 0 to 6.33), 0.71 hours (range 0 to 3.97), 1.25 hours (range 0 to 4.5), and 1.92 hours (range 0 to 6.5), respectively ($P > 0.05$).

The median time of resumption of spontaneous breathing was reduced from a median of 65 minutes (range 0 to 390 minutes, $n = 68$) to 5 minutes (range 0 to 170 minutes, $n = 42$) if neostigmine was administered ($P = 0.003$).

The median time of awakening for patients less than 50 years old was 1.17 hours (range 0 to 3.5, $n = 17$), 50 to 60 years old was 1.19 hours (range 0 to 6, $n = 36$), 60 to 70 years old was 1.25 hours (range 0 to 6.3, $n = 44$), and older than 70 years old was 1.5 hours (range 0 to 6.5, $n = 13$) after admission to the ICU ($P > 0.05$). The time to return of spontaneous breathing for the same groups of pa-

tients were 0.25 hours (range 0 to 2.83), 0.5 hours (range 0 to 6), 0.5 hours (range 0 to 3.9), and 0.88 hours (range 0 to 6.5), respectively ($P > 0.05$).

Fifty patients (45.5%) were extubated within 4 hours. The median time of extubation for these patients was 2.25 hours (range 0 to 4.0). For the remaining 60 patients, the median time of extubation was 14.33 hours (range 4.25 to 23). None of the patients were ventilated for more than 24 hours. Table II shows the number of extubations and the time of extubation after admission into the ICU.

TABLE II: NUMBER OF EXTUBATIONS AND THE TIME OF EXTUBATION AFTER ADMISSION INTO THE INTENSIVE CARE UNIT

No. of hours after admission into intensive care unit	Number of patients extubated	Percentage of patients extubated
0 to 2 hours	20	18.2
2 to 4 hours	30	27.3
4 to 6 hours	11	10.0
6 to 8 hours	4	3.6
8 to 10 hours	1	0.9
10 to 12 hours	1	0.9
12 to 14 hours	11	10.0
14 to 16 hours	15	13.6
16 to 18 hours	5	4.5
18 to 20 hours	7	6.4
20 to 22 hours	3	2.7
22 to 24 hours	2	1.8
Total	110	100

The median time of extubation following anaesthetic regimes A, B, C and D were 8.46 hours (range 0 to 23, $n = 22$), 3.54 hours (range 0.17 to 20.0, $n = 42$), 4.38 hours (range 1.33 to 20.33, $n = 26$), and 8.67 hours (range 0.67 to 20.17, $n = 20$), respectively ($P = 0.038$).

Figure 1 shows the influence of nursing shifts on the time of extubation of the patients.

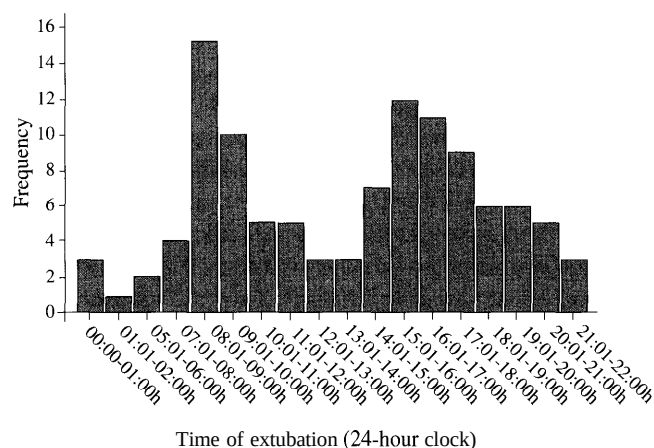


Fig. 1. The influence of nursing shifts on the time of extubation of the patients.

Table III compares the dosage of fentanyl administered, the duration of surgery and cardiopulmonary bypass, the degree of hypothermia during bypass, the number of grafts, the anaesthetic agents used during bypass, the rectal temperature recorded on admission to the ICU, the onset of spontaneous breathing, the time of awakening, the time of starting CPAP mode, the total mediastinal blood loss in the 4 hours, and the time of extubation between the patients who were extubated within 4 hours (group E) and the patients who were not (group N).

Although the degree of hypothermia during bypass and the duration of hypothermic bypass with rectal temperatures maintained under 30°C were statistically different between the patients who were extubated early and those who were not, rewarming of all the patients was adequate such that both the oesophageal and rectal temperatures of all the patients were similar by the end of chest closure ($P > 0.05$). There were no statistical correlation between the duration of bypass or the degree of hypothermia during bypass with the postoperative mediastinal blood loss.

Sixty patients received tranexamic acid and 12 patients received aprotinin during cardiac surgery. The number of patients who received tranexamic acid, aprotinin, or none of the above was 31/3/16 and 29/9/22 in groups E and N, respectively ($P > 0.05$). The total blood loss (median and range) from the mediastinal drains at the end of 4 hours for the tranexamic acid group and the aprotinin group of patients was 120 ml (range 20 to 1240 ml) and 130 ml (range 30 to 250 ml), respectively ($P > 0.05$). The remaining 38 patients did not receive tranexamic acid or aprotinin preoperatively. The median total blood loss at the end of 4 hours for this latter group of patients was 190 ml (range 60 to 800 ml), this amount was significantly more than that of the patients who received tranexamic acid or aprotinin ($P = 0.002$). Mediastinal blood loss in the first 4 hours did not correlate with the number of grafts ($P > 0.05$). Of the 14 patients who had excessive bleeding as a reason for not extubating early, 10 patients did not receive tranexamic acid or aprotinin and 1 of whom required exploration of the mediastinum for haemostasis. The other 4 patients had tranexamic acid preoperatively and all of whom returned to the operating theatre for exploration of the mediastinum for haemostasis.

By analysing the 6-month audit period in two three-month intervals, we found that the median time of extubation was 7.33 hours (range 0 to 23, $n = 62$) for the months of May to July, and 3.88 (range 0 to 19.92, $n = 48$), for the months of August to October ($P = 0.042$). While only 40.3% of the patients were extubated within 4 hours during May to July, this percentage increased to 52.8% during August to October. None of the patients required reintubation of the trachea after early extubation.

TABLE III: COMPARISON OF DATA OF PATIENTS WHO WERE EXTUBATED WITHIN 4 HOURS (E), AND THOSE WHO WERE NOT (N).

	E	N	P value
Number (%)	50 (45.5%)	60 (54.5%)	
Age (years)	58.6 ± 10.1 (55.7-61.5)	60.9 ± 7.9 (58.9-63.0)	ns
Gender (Male/Female)	39/11	46/14	ns
Number of patients with ejection fraction:			
30% to 49%	23	27	ns
50% or more	27	33	
Dosage of fentanyl (µg/kg)	13.1 (6.1-29.0)	16.3 (8.9-32.3)	<0.05
Anaesthetic agent used during bypass (n)			
midazolam/propofol	3 / 47	19 / 41	<0.005
Lowest rectal temperature during bypass (°C)	31.45 (28.8-34.9)	30.8 (27.3-33.5)	<0.05
Duration of bypass with rectal temperature <30.0°C (min)	0 (0-39)	0 (0-95)	<0.05
Number of grafts	3 (2-4)	3 (1-5)	ns
Cardiopulmonary bypass (minutes)	98.5 (58-160)	106.5 (32-235)	ns
Total duration of surgery (hours)	3.63 (1.95-5.42)	3.71 (2.17-6.67)	ns
Administration of neostigmine (n) [No/Yes]	25/25	43/17	<0.05
Rectal temperature on admission to CTICU (°C)	36.5 (34.4-37.9)	36.4 (35.3-37.4)	ns
Time of awakening (hours)	0.5 (0-2.5)	1.65 (0-6.5)	<0.005
Onset of spontaneous breathing (minutes)	3.5 (0-120)	65.0 (0-390)	<0.05
Time of starting CPAP mode (minutes)	85 (0-190)	260 (0-1320)	<0.005
Total mediastinal blood loss in 4 hours (ml)	120 (20-720)	140 (20-1240)	ns
Time of extubation (hours)	2.25 (0-4.0)	14.3 (4.2-23.0)	<0.005
Duration of stay in the intensive care unit (days)	1.9 (0.7-5.0)	2.05 (0.6-9.9)	ns
Duration of stay in the high dependency unit (days)	1 (0-6)	1 (1-9)	ns
Duration of stay in the hospital after discharge from ICU (days)	5 (3-15)	5 (3-29)	ns
Duration of stay in the ward before surgery (days)	1.5 (0.5-25.5)	1.79 (1-14.5)	<0.05

Values are in median (range) except for age in mean (SD, 95% CI).

Discussion

The use of controlled ventilation after cardiac surgery became widespread in the 1960s with the belief that it allowed a smoother and more stable recovery from surgery. Among the advantages cited for a period of postoperative ventilation included decreases in hypoxia, acidosis, hypercarbia, hypotension, and atelectasis.¹ The introduction of high-dose fentanyl anaesthesia (fentanyl 50 to 75 µg/kg) for coronary artery surgery contributed to the need for extended ventilatory support by causing prolonged respiratory depression.² A benefit of opioid anaesthesia is the cardiovascular stability obtained during induction and throughout operation, even in patients with severely impaired cardiac function.³ The primary considerations for justifying high-dose narcotic anaesthesia and prolonged mechanical ventilation after cardiopulmonary bypass have included (1) stability of patients relative to new ischaemic events, and (2) the decrease in myocardial work associated with mechanical ventilation.⁴ There is now evidence to show that perioperative ischaemia may be endothelially mediated and may not always be associated with the imbalance between myocardial blood flow supply and demand.⁵ With improvements in anaesthetic and surgical techniques, and refinement of the equipment for extracorporeal circulation, the incidence of postoperative

respiratory failure has been reduced.⁶ A number of studies have demonstrated the feasibility of early extubation after cardiac surgery in selected patients: early extubation (within 8 hours) did not impair haemodynamics or respiratory performances;⁷ postoperative improvements in cardiac index and oxygen uptake are unaffected by extubation within 1 hour of surgery;⁸ and earlier extubation does not appear to increase morbidity and mortality.⁹⁻¹¹

The factors that will affect the timing of extubation include metabolism and elimination of opioids and neuromuscular blocking agent, the adequacy of rewarming, the haemodynamic status of the patient, and whether there is a need to maintain an airway in an unstable patient who may need to return to the operating theatre due to tamponade or for control of bleeding.¹² From the data obtained in Table III, it appears that the anaesthetic regime plays an important role in facilitating early extubation. The patients who were extubated within 4 hours (group E) received a significantly lower dosage of fentanyl intraoperatively, 94% of them received propofol during bypass, and they had earlier awakening times. In addition, the recovery of respiratory muscle function at the end of surgery with the administration of neostigmine allowed the patients to resume spontaneous breathing earlier and this facilitated the CPAP mode of

ventilation earlier.

Fentanyl is a short-acting opioid. It has also been the practice in other centres advocating early extubation, to administer fentanyl 10 to 15 µg/kg at induction of anaesthesia, with no more opioid used during or after bypass period.^{11,13} Compared with the conventional high-dose fentanyl, this reduced dosage of fentanyl had been shown to reduce the incidence of postoperative respiratory depression and the need for prolonged ventilation.

The choice of the anaesthetic agent becomes important especially when the aim is to extubate the patients early. Propofol is an anaesthetic agent which does not accumulate and is associated with a rapid recovery without hangover. Propofol-based anaesthesia has been shown to provide good intraoperative haemodynamics.¹⁴ Propofol has been shown to be the anaesthetic agent of choice for the maintenance of anaesthesia during cardiopulmonary bypass to facilitate early extubation after cardiac surgery.^{10,15-17} A beneficial effect of infusing propofol during bypass is that being a direct vasodilator, when infused at a rate of 6 mg/kg/h during cardiopulmonary bypass, avoids the problem of hypertension that has been associated with hypothermia. As a result, the usage of the vasodilator, such as nitroglycerin, during bypass is greatly reduced.

Patients were able to resume spontaneous breathing earlier following the administration of only one dose of the muscle relaxant, pancuronium, at the beginning of surgery; and the routine recovery of neuromuscular function with neostigmine at the end of surgery. This is a radical change from past practice. In the past, small bolus doses of the long-acting pancuronium were topped-up at appropriate time intervals, such as at the onset of bypass, during bypass, and towards the end of bypass during rewarming, to maintain muscle paralysis. In addition, no attempt was also made to reverse the muscle paralysis at the end of surgery. Neostigmine is also administered in some other centres practising early extubation.^{11,13} One advantage of not administering any more muscle relaxant other than the dose given at the beginning of surgery (anaesthetic regime B) is that it is now possible to monitor the depth of anaesthesia during cardiac surgery without it being masked by the action of the muscle relaxant. If the neuromuscular blockade has worn off, an insufficient depth of anaesthesia during surgical stimulation may manifest itself as patient movement. This practice will help to reduce the risk of awareness that had been associated with the peri-bypass period.

Although 5 patients had to return to the theatre for the control of haemostasis, the total amount of mediastinal blood loss after 4 hours in the ICU was not significantly different between the patients in group E and group N. The common causes of postoperative mediastinal blood loss included surgical bleeding, dilutional coagulopathy, thrombocytopaenia, platelet dysfunction, inadequate

heparin reversal, excessive protamine administration, activation of the fibrinolytic system by heparin, and hypothermia.¹⁸⁻²² Recent evidence have shown that administration of excessive protamine prolongs the activated clotting time, alters adenine diphosphate-induced platelet aggregation and inhibits platelet function, and compromises clot structure resulting in coagulopathy.^{19,20,23} Hypothermia inhibits normal platelet function and prolongs prothrombin time and partial thromboplastin time.²⁴⁻²⁶ The inhibitory effect of hypothermia on coagulation is completely reversed by rewarming the blood to 37°C.²⁷ It is therefore imperative that the perfusionist, the surgeon and the anaesthetist realise that they can all participate actively in optimising thermoregulation and to reduce blood loss postbypass. The perfusionist should rewarm the patient thoroughly before weaning off bypass, the anaesthetist should maintain normothermia and titrate the dosage of protamine carefully for heparin reversal to optimise the coagulation profile, and the surgeon must ensure watertight suture lines. As hypothermia affects coagulation, the management of thermoregulation is discussed below.

All attempts should be made to maintain normothermia or to rewarm the patient as soon as possible to 36.5°C because failure of early extubation is most often related to persistent hypothermia.¹³ Hypothermia is responsible for coagulopathy, hypertension and shivering postoperatively.²⁴⁻²⁶ There are a few ways in which thermoregulation can be optimised. The patients need not be actively cooled during cardiopulmonary bypass, but the body temperature is allowed to drift to 32°C.¹³ Hypothermic cardiopulmonary bypass (rectal temperature of 27°C to 28°C) resulted in more pronounced alterations of platelet aggregation and endothelial related coagulation than normothermic cardiopulmonary bypass (rectal temperature more than 35°C).²⁸ Rewarming must be thorough and normothermia must be maintained throughout the postbypass period. Additional skin surface warming with a water mattress and forced warm air helped to preserve perioperative thermal balance and may contribute to reduced bleeding after cardiac surgery.²⁹ For our patients, this was achieved by a combination of warming mattress, convective warming blanket and by the inclusion of either a heat-moisture exchanger or a heated water bath humidifier in the breathing circuit to warm and humidify the dry anaesthetic gases delivered. The surgeon can also reduce heat loss from the thorax by closing the chest in an expeditious fashion as coagulation defects can result from ambient temperature-induced hypothermia.³⁰

We could not show any statistically significant differences in the times of awakening in the four age groups, although clinically it seemed that elderly patients took a longer time to wake up after cardiac surgery. The reasons for this insignificant difference could be due to the

differing anaesthetic regimes that were employed and relatively smaller number of patients in the more than 70-year-old group.

The initiation of ventilatory weaning can begin when the patient has begun to awake, is haemodynamically stable with minimal chest tube drainage and adequate urine output, and can maintain spontaneous tidal volume and respiratory rate, indicating sufficient reversal of both opioids and neuromuscular blocking agents.¹² The extubation criteria adopted by this ICU are similar to that used in other cardiac centres advocating early extubation after cardiac surgery.^{11,12,31,32} In a stable patient, the ability to maintain arterial pH greater than 7.35 while on the CPAP mode is a reliable test for the ability to sustain spontaneous respiration.³³ As early extubation was a fairly new experience for some of our surgeons, some of the anaesthetists and the ICU staff, initially, the gas exchange and acid-base balance were assessed 1 hour after the patient had been weaned to the CPAP mode. If the arterial blood gas result was satisfactory, the patient would be extubated. With more experience, some of the anaesthetists participated actively in weaning patients from SIMV mode to CPAP mode and the blood gases were analysed sooner, so that the patients could be extubated early.

One reason for choosing 4 hours as a cut-off time for analysis was that by this time, the patients should be awake, breathing and adequately rewarmed; and if there was cardiovascular instability or continuous mediastinal blood losses requiring immediate re-exploration, these would be obvious within this period of time. Another reason was that many advocates of early extubation after cardiac surgery had shown that the majority of their cardiac patients were extubated within 5 hours of admission to the ICU.^{6, 7,11,12,34} In an Oxford centre, more than 50% of the cardiac patients were extubated within 3 hours of admission to the cardiac recovery area." In a Toronto hospital, since the introduction of the early extubation programme, 65% of all cardiac patients and 85% of all first-time coronary artery bypass graft surgery patients were extubated within 2 to 6 hours after surgery.¹²

Some of the patients satisfied all the extubation criteria soon after surgery and were extubated in the operating theatre. They were transferred to the ICU slightly propped up, breathing 6 l/min flow of oxygen via a Hudson® facemask. However, for the majority of our patients, they were assessed for suitability of extubation in the ICU.

What were the other factors that were preventing more good risk patients from getting extubated early after cardiac surgery? Through this audit we realised that the experience and the cooperation of the surgical staff and the intensive care nursing staff were important. The night nurse to patient ratio in the ICU was less than

that in the day, and the night shift nurses and surgical staff had less experience with extubation in the night. Understandably, the night shift staff were not aggressive about extubation. During this audit period we noted that if the patients were not extubated by the time the night shift nursing staff went on duty, the nursing and the surgical staff preferred not to extubate the patients at night even if the patients had satisfied all the criteria for extubation (Fig. 1). In fact, to promote the practise, 1 of the authors (NCH) spent several nights in the cardiothoracic ICU to enable the surgical staff to work through the decision to extubate the patients. This is an area where continual education and the review of audit results may be able to change the attitude and mindset of the surgical and nursing staff managing the ICU.

The audit period coincided with the 6-month period of attachment of medical officers to the department of cardiothoracic surgery. The shorter median extubation times recorded in August to October as compared to the longer extubation times in the first three months of the posting (May to July) was hopefully the result of continual education, accumulation of experience in judgement, and acceptance of the practice.

The success of early extubation depends on a co-ordinated team approach involving the surgeons, anaesthetists, perfusionists and the intensive care surgical and nursing staff. Key factors such as good myocardial revascularisation, careful myocardial protection, uniform body rewarming, meticulous haemostasis, careful titration of protamine for heparin neutralisation, the use of anaesthetic agents that will allow rapid recovery of consciousness postoperatively, and the reduction in the total dose of short-acting opioids to reduce the duration of postoperative respiratory depression have been established as important factors in helping the patients achieve the extubation criteria early.^{11,35} However, the most important factor of all has to be education and changing the mindset of all concerned.³⁶ This consideration is especially important in this hospital where the traditional practice was to mechanically ventilate the cardiac patients overnight in the ICU.

It has been shown that the high cost of cardiac surgery is mainly due to the need of traditional postoperative care, that is, in the ICU.³⁷ Over 90% of patients undergoing cardiac surgery could recover safely and be treated effectively in a more economical area than the ICU.³⁷ Same-day or early extubation has been regarded as a principal component of reduced resource utilisation and cost.^{38,39}

Our audit data did not show that extubating within 4 hours resulted in an earlier discharge of the cardiac patients from the ICU. The reasons included: the actual time of discharge from the ICU was governed by other factors such as the availability of bed space in the high dependency unit, the discharge policy and practice of

the ICU, and the preference of the surgeons. The discharge of patients from the high dependency unit was in turn restricted by bed availability in the general ward, which at present is shared by another medical discipline. If the practice of early extubation can translate into the patients being discharged from the ICU earlier, then the reduction in health care costs to both the patient and the health care provider would be tremendous.

Conclusion

Numerous factors contribute to the success of the early extubation programme in our institution. The main factors are continuous education at various levels, meticulous attention to details, close cooperation amongst the surgeons, the anaesthetists, the perfusionists, and the ICU staff, flexibility and a commitment to excellence in patient care. Our next step will be to look into the discharging of patients from the ICU and to formulate the fast-track protocol for our institution.

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