

Early extubation and weaning with bilevel positive airway pressure ventilation after cardiac surgery (Weaning with BiPAP ventilation after cardiac surgery)

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ABSTRACT

Objective(s): To evaluate the use of bilevel positive airway pressure (BiPAP) ventilation in early extubation after fast-track cardiac surgery.

Design: Prospective observational study.

Setting: Postoperative intensive care.

Patients: Sixty consecutive patients eligible for early extubation after cardiac surgery. Patients were predominantly male (42 men [70%]) and middle aged (54.62 ± 10.66 years).

Interventions: Patients were randomly assigned to continuous pressure or BiPAP (Group I or Group II, respectively) and were extubated as soon as possible.

Measurements: Blood gases and haemodynamics were determined on arrival in the ICU (baseline, or T0) and 1, 2, 4, 6, 8, and 12 hours later. All data were expressed as (\pm SD) and analysed using the Student t-test and Mann-Whitney test (continuous data) or χ^2 test (categorical data). $P < 0.05$ was considered statistically significant.

Main results: PaCO₂ levels were statistically significantly higher in Group II than in Group I at 2, 4, 6, 8, and 12 hours ($P < 0.05$, $P < 0.01$). Within each group, PaCO₂ levels were statistically significantly higher at 4, 6, 8, and 12 hours than at baseline ($P < 0.01$).

Extubation time was significantly longer in Group I than in Group II 7.90 (7.90 [2.13] vs 3.83 [1.20], $P=0.001$). Respiratory rates were significantly higher in Group II than in Group I after 2, 4, and 6 hours ($P < 0.01$). Pmax was higher in Group I than in Group II after 1 hour but similar up to 4 hours.

Conclusions: Early extubation and weaning to BiPAP ventilation after cardiac surgery is safe and effective.

Introduction

Improving outcomes while reducing costs is a significant challenge in the postoperative care of cardiac surgery patients. Rapid ("fast-track") protocols designed to shorten length of stay (LOS) after cardiac surgery have become common place. As surgical and anaesthetic techniques have advanced, extubation within 4 to 6 hours after coronary artery bypass graft (CABG) surgery has become a preferred goal at many institutions. Nevertheless, how early to extubate remains a matter of debate.¹

There is ample evidence that early extubation after cardiac surgery is safe and well tolerated, provided that patient selection and surgical, anaesthetic, and postoperative management are carefully and diligently performed. Meanwhile, the role of respiratory management in successful early extubation has received little attention. Several clinical studies have aimed to identify the best approach to rapid postoperative weaning of patients from respiratory support.²

One potentially useful means of weaning patients from respiratory support is bilevel positive airway pressure (BiPAP). This noninvasive mode of ventilatory support combines pressure-controlled ventilation and spontaneous breathing to create 2 different positive airway pressure levels – inspiratory (IPAP) and expiratory (EPAP).³ These 2 levels of pressure change in response to the patient's respiratory cycle.³ Studies performed in the mid to late 1990s demonstrated that BiPAP ventilation is safe and effective in patients with many types of respiratory failure,⁴ in patients with chronic congestive heart failure,⁵ and in patients at high risk of postoperative complications.⁶ More recent studies have shown that BiPAP ventilation is safe and effective in mechanically ventilated patients who do not require total ventilatory support, even in the face of differences in

initiating and maintaining the inspiratory and expiratory phases, in breathing circuits, and in interventilator circuits.⁷ However, our search of the literature revealed no reports on the postoperative use of BiPAP to early weaning of cardiac surgery patients from ventilatory support. The aim of the present study was to evaluate the utility of BiPAP ventilation in achieving early extubation of eligible patients after cardiac surgery.

Methods

The study was designed as a prospective observational study. Between May 2005–December 2006 sixty patients were included in the study, eligible for early extubation after cardiac surgery. This study was approved by an institutional ethics committee, and all patients gave informed consent before participating. Only patients undergoing CABG surgery were eligible for inclusion in the study. Exclusion criteria were hypothermic circulatory arrest, recent myocardial infarction, aortic and mitral valve problems, and perioperative intra-aortic balloon pump insertion.

After enrolment and before undergoing CABG surgery, each patient was randomly assigned to one of 2 modes of ventilatory support: pressure support-continuous positive airway pressure (PS-CPAP) (Group I) or BiPAP (Group II). All patients were instructed in the purpose and use of both ventilatory support modes.

Preoperatively, all patients received diazepam orally the night before surgery and intramuscular midazolam (0.5–1 mg/kg) with scopolamine (0.5 mg) 1 hour before the induction of anaesthesia. Patient vital signs and other safety parameters were monitored by means of 5-lead electrocardiography, pulse oximetry, capnography, invasive measurement of radial artery pressure,

and measurement of central venous pressure via the right internal jugular vein. Ventilation was achieved by maintaining a tidal volume of 10 mL/kg and adjusting the respiratory rate to an end-tidal carbon dioxide level of 30–34 mmHg. Positive end-expiratory pressure (PEEP) was not used. Anaesthesia was induced and maintained by infusion of fentanyl (10 µg/kg) and propofol (2 mg/kg). Tracheal intubation was facilitated by intravenous bolus administration of rocuronium bromide (0.8 mg/kg). After intubation, intermittent positive pressure ventilation (IPPV) was initiated to achieve an inspired oxygen fraction (FiO₂) of 1, a respiratory rate of 12 breaths per minute, and a peak inspiratory pressure (Pmax) of 30 mmHg.

Upon arrival in the intensive care unit (ICU) after surgery, patients in both study groups were started on mechanical ventilation provided by a Servo 900C ventilator (Siemens Elema, AB, Sweden). Initially, the ventilator was set to operate in simultaneous intermittent mandatory ventilation (SIMV) mode to provide a tidal volume of 10 ml · kg⁻¹, a respiratory rate of 12–15 breaths per minute, a PEEP of 5 cmH₂O, and a FiO₂ of 1.0. Trigger sensitivity was set at -2 cmH₂O. The FiO₂ was reduced to 0.4 or less on the basis of blood gas levels and oxygen saturation as monitored by pulse oximetry (SpO₂). When spontaneous breathing reappeared, patients were treated in one of two ways. Each patient in Group I was switched to PS-CPAP mode at a pressure support level of 10 cmH₂O. Each patient in Group II had his or her endotracheal tube connected to a BiPAP ventilator operating in ST mode (BiPAP Vision, Respironics Inc., Murrysville, PA) at a preset inspiratory pressure of 15 cm H₂O and a preset expiratory pressure of 5 cmH₂O. In this way, the BiPAP ventilator was able to respond to the patient's respiratory cycle by alternating between a higher flow rate during inhalation and a lower flow rate during exhalation. The back-up flow rate was set at 12 breaths per minute. The circuit of a standard BiPAP S/T-D ventilator consists of a single limb for expiration and inspiration; oxygen was obtained via the central oxygen line.

Weaning from ventilatory support was achieved as follows. Patients in Group I were weaned while in CPAP mode by reducing the level of PS to 5 cmH₂O as tolerated. Once this level of support was achieved, patients were extubated and received nasal oxygen therapy. Patients in Group II were

weaned by reducing IPAP to 10 cmH₂O and EPAP to 5 cm H₂O. After extubation, BiPAP ventilatory support was continued through a special full-face mask for at least 30 minutes or as long as patient's need according to blood gases and haemodynamics.

Patients in the ICU were extubated only if they met the following criteria:

- Awake, cooperative, with no residual neuromuscular blockade
- Partial pressure of oxygen (PaO₂) > 80 mmHg (FiO₂ = 0.4)
- Partial pressure of carbon dioxide (PaCO₂) < 45 mmHg
- Stable haemodynamic and metabolic parameters
- Bleeding < 50 mL/hour
- Absence of shivering

Blood gas and lactate levels were measured and analysed. The oxygenation index (PaO₂/FiO₂) was calculated and recorded. Haemodynamics were measured and blood samples were taken at the following predetermined time points: on arrival in the ICU (T0) and 1, 2, 4, 6, 8, and 12 hours postoperatively.

All data were expressed with standard deviation (SD). Statistical analyses were performed using SPSS for Windows 10.0. Parametric data were compared between groups using the Student t-test and nonparametrics with Mann-Whitney test. Categorical data were compared against a chi-square distribution. A p value of less than 0.05 was considered to be statistically significant.

Results

Overall, the study population included 60 consecutive patients (42 men [70%] and 18 women [30%]) undergoing elective CABG surgery with CPB support. The mean (SD) patient age was 54.62 ± 10.66 years.

Both study groups were demographically similar (Table I). Clinically, they were also similar in terms of mean arterial pressure (MAP) (Table II), heart rate (Table III), total bypass and cross-clamp times (Table IV), and inotrope use (Table V). However, MAP did fall slightly in both groups (Table II) and heart rate increased in Group II (Table III, Figure 1) after 4 hours in the ICU.

Table I: Patient demographics and characteristics (n = 60)

Characteristic	Group I (PS-CPAP)	Group II (BiPAP)	χ ² and P values
	n (%)	n (%)	
Gender			
Men	23 (76.7)	19 (63.3)	χ ² = 1.270 P = 0.260
Women	7 (23.3)	11 (36.7)	
	Mean (SD)	Mean (SD)	
Age (years)	57.63 (12.02)	52.43 (8.42)	P = 0.057
Weight (kg)	77.47 (9.17)	82.33 (11.07)	P = 0.069
	n (%)	n (%)	
Medical history			
Diabetes mellitus	6 (20.0)	8 (26.7)	χ ² = 0.37 P = 0.542
Heart transplant	5 (16.7)	18 (60.0)	χ ² = 11.915 P = 0.001*
Myocardial infarction	14 (46.7)	14 (46.7)	χ ² = 0.000 P = 1.000

t: Student t test χ²: chi-square test

* P < 0.01.

Table II: Mean arterial pressure

	MAP (mmHg) ^a Group I (PS-CPAP)	Group II (BiPAP)	P value
Baseline	92.33 (14.42)	91.67 (10.49)	0.839
1 h	86.73 (18.02)	89.10 (15.34)	0.586
2 h	85.60† (12.13)	82.97† (13.88)	0.437
4 h	82.87†† (11.24)	85.50† (12.33)	0.391
6 h	83.23†† (14.87)	81.53†† (14.23)	0.653
8 h	83.17†† (11.66)	86.13† (11.17)	0.318
12 h	82.13†† (8.13)	81.87†† (12.23)	0.921

a Values shown are mean (SD)

† In group P < 0.05

†† In group P < 0.01

Table III: Heart rate

	Heart rate (bpm) ^a Group I (PS-CPAP)	Group II (BiPAP)	P value
Baseline	86.63 (20.91)	82.70 (14.08)	0.396
1 h	96.23†† (24.56)	88.57† (15.83)	0.156
2 h	95.90†† (20.91)	89.83†† (12.72)	0.180
4 h	93.60† (18.99)	97.03†† (17.16)	0.466
6 h	95.33†† (16.34)	87.00 (17.32)	0.060
8 h	91.43 (16.81)	88.23 (15.36)	0.445
12 h	89.47 (14.96)	88.43 (15.92)	0.796

a Values shown are mean (SD)

† In group P < 0.05

†† In group P < 0.01

Table IV: Mean Total Bypass and Cross-clamp Times

	Time (min) ^a		P value
	Group I (PS-CPAP)	Group II (BiPAP)	
Total bypass	88.70 (32.99)	85.29 (14.17)	0.679
Cross-clamp	55.25 (25.62)	60.06 (13.18)	0.469

a Values shown are mean (SD)

Table V: Extubation Times and Inotropic Agent Usage

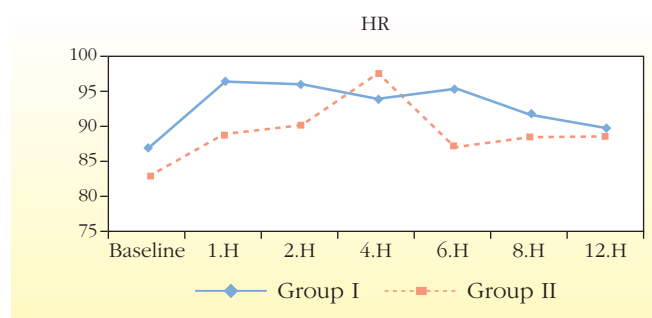
	Group I (PS-CPAP)	Group II (BiPAP)	P value
	Mean (SD)	Mean (SD)	
Time to extubation (h)	7.90 (2.13)	3.83 (1.20)	P = 0.001**
	n (%)	n (%)	
Inotrope			
None	24 (80.0)	29 (96.7)	$\chi^2 = 4.272$ P = 0.118
Dopamine	2 (6.7)	--	
Dobutamine	4 (13.3)	1 (3.3)	

t: Student t-test; χ^2 : chi-square test

*P < 0.05

**P < 0.01

Figure 1: Heart rate in BiPAP versus PS-CPAP patients



There were several significant differences between the groups. PaCO₂ levels were statistically significantly higher in Group II than in Group I at 2, 4, 6, 8, and 12 hours (P < 0.05, P < 0.01). Within both groups, PaCO₂ levels were statistically significantly higher at 4, 6, 8, and 12 hours than at baseline (P < 0.01) (Table VI, Figure 2). Extubation time was significantly longer in Group I than in Group II (Figure 3). None of all patients in both groups were re-intubated.

Respiratory rates were similar between groups at baseline and at 1, 2, 8, and 12 hours postoperatively (P > 0.05) but were significantly higher in Group II than in Group I at 2, 4, and 6 hours postoperatively (P < 0.01). Within both groups, respiratory rates were higher at all time points than they were at baseline (P < 0.05, P < 0.01) (Table VII, Figure 4).

Table VI: PCO₂

	PCO ₂ (mmHg) ^a		P value
	Group I (PS-CPAP)	Group II (BiPAP)	
Baseline	31.33 (5.26)	33.09 (4.47)	0.07
1 h	30.42 (4.88)	33.17 (6.94)	0.08
2 h	31.50 (4.83)	35.90 (7.20)	0.007**
4 h	33.82†† (4.96)	42.29†† (7.06)	0.001**
6 h	34.15†† (6.23)	40.67†† (4.04)	0.001**
8 h	36.23†† (4.97)	39.52†† (4.95)	0.013*
12 h	35.56†† (4.40)	39.31†† (4.34)	0.002**

t: Student t-test.
 a Values shown are mean (SD)
 * P < 0.05
 ** P < 0.01
 † In group P < 0.05
 †† In group P < 0.01

Figure 2: PaCO₂ in BiPAP versus PS-CPAP patients

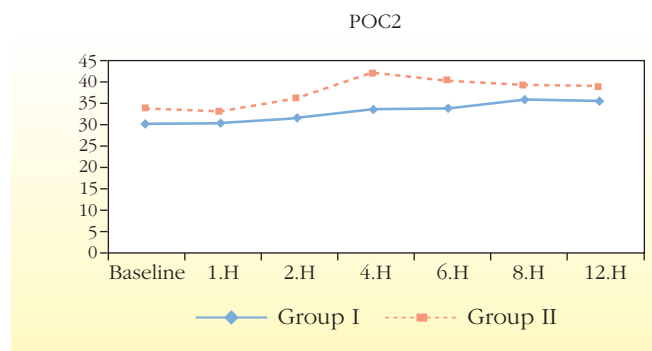


Figure 3: Extubation times in BiPAP versus PS-CPAP patients

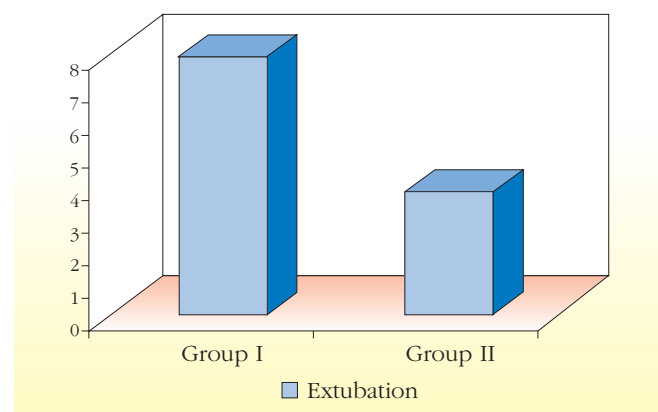


Table VII: Respiratory rate

	Respiratory rate (breaths per minute) ^a		P value
	Group I (PS-CPAP)	Group II (BiPAP)	
Baseline	11.83(0.46)	11.97(0.18)	0.146
1 h	13.20(3.99)	14.20†(5.95)	0.448
2 h	12.60†(1.97)	17.83††(5.05)	0.001*
4 h	13.00††(2.26)	17.93††(3.95)	0.001*
6 h	13.93††(2.93)	18.21††(3.37)	0.001*
8 h	16.00†† (3.74)	16.69†† (2.59)	0.416
12 h	17.28†† (2.90)	16.38†† (3.10)	0.260

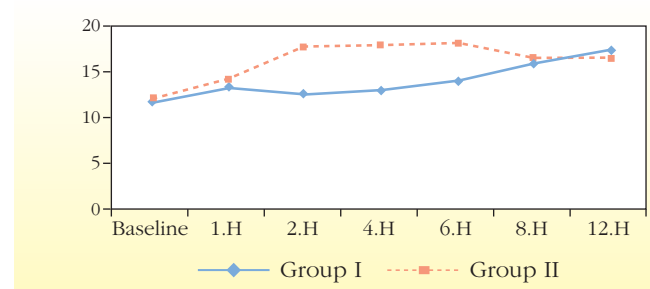
t: Student t-test

a Values shown are mean (SD)

* P < 0.01

† In group P < 0.05

†† In group P < 0.01

Figure 4: Respiratory rate in BiPAP versus PS-CPAP patients

One hour postoperatively, Pmax was higher in Group I than in Group II. At baseline and 2 hours postoperatively, Pmax was similar between groups. Four hours postoperatively, no between-group comparison of Pmax values was possible because patients in Group II were extubated at that time point. At 4, 6, 8, and 12 hours postoperatively, Pmax values declined progressively in Group I (Table VIII).

There was no significant difference in work of breathing (WOB) between groups at 1 and two hours postoperatively ($P > 0.05$). At 4 and 6 hours postoperatively, between-group comparisons of WOB were impossible, again because patients in Group II were extubated at those time points (Table IX).

Table VIII: Peak inspiratory pressure

	Pmax (mmHg) ^a		P value
	Group I (PS-CPAP)	Group II (BiPAP)	
Baseline	24.62 (4.10)	23.85 (3.88)	0.458
1 h	24.53(4.16)	22.00 (4.07)	0.026*
2 h	24.18(4.09)	25.00 (4.79)	0.649
4 h	23.14††(4.06)	--	
6 h	20.75††(3.82)	--	
8 h	21.22††(3.86)	--	
12 h	19.85(1.63)	--	

Pmax: peak inspiratory pressure;

t: Student t-test

a Values shown are mean (SD)

*P < 0.05

†† In group P < 0.01

Table IX: Work of breathing

	WOB ^a		P value
	Group I (PS-CPAP)	Group II (BiPAP)	
Baseline	1.48 (0.13)	1.51 (0.14)	0.294
1 h	1.28†† (0.13)	1.25†† (0.12)	0.457
2 h	1.22†† (0.32)	1.09†† (0.10)	0.294
4 h	3.03 (11.51)	--	--
6 h	3.63 (14.76)	--	--

WOB: work of breathing; t: Student t-test

a Values shown are mean (SD)

The PaO₂/FiO₂ values at baseline 1, 2, 4, 6, 8 and 12 hours are depicted in Table X.

Table X: PaO₂/FiO₂

	PaO ₂ /FiO ₂ ^a		P value
	Group I (PS-CPAP)	Group II (BiPAP)	
Baseline	354,53 (98,01)	380,23 (105,66)	p: 0,333
1 h	354,27(95,11)	400,45 (118,48)	p: 0,101
2 h	377,88 (89,56)	361,21 (117,70)	p:0,542
4 h	388,44 (98,22)	383,54 (83,81)	p:0,880
6 h	387,75 (99,80)	407,50	-
8 h	365,50 (86,42)	442,50	-
12 h	396,25 (96,62)	-	-

t: Student t-test.

a: Values shown are mean (SD)

Discussion

In the era of managed care, much emphasis has been placed on reducing the length of ICU stays after CABG surgery. Rapid (fast-track) weaning protocols have become increasingly popular because of their apparent cost-effectiveness and safety.⁸ However, the risk of respiratory complications after cardiac surgery remains high, mainly because of the complications classically associated with thoracic surgery, tracheal intubation, mechanical ventilation, and other factors such as age.

Recent well-documented data indicate that early extubation (i.e. less than eight hours) after cardiac surgery may be both clinically effective and cost effective. Reductions in ICU and overall hospital LOS are associated with lower costs in the postoperative period. However, the best time for early extubation remains open to debate, and the safety of very early or immediate extubation just after surgery remains controversial.

Postoperative ventilation and intubation times are influenced by several factors. In a study by Reis and colleagues,⁹ in which patients were extubated immediately after certain criteria were achieved (i.e. return to consciousness, normothermia, stable haemodynamics, acceptable respiratory function, and haemostasis), the researchers concluded that the success of fast-track extubation (FTE) depended strongly on postoperative monitoring, control of weaning from mechanical ventilation, and criteria-based endotracheal extubation.⁹

Postoperatively, complications including pneumonia, atelectasis, lobar collapse, increased total body water, and arterial blood gas deterioration occur more frequently in patients extubated more than 24 hours postoperatively than they do in patients extubated earlier. Higgins described a "window of opportunity" between the third and tenth hours after ICU admission during which cardiac surgery patients may be optimally extubated. He also noted that extubation should be preceded by a thorough physiologic and clinical evaluation in which careful attention is paid to haemodynamics, neurologic status, temperature and metabolism, hemostasis, and respiratory reserve.¹⁰

In a 30-day postoperative follow-up study of cardiac surgery patients, Cheng et al showed that early extubation diminished the incidence of intrapulmonary shunting but had no effect on postoperative mortality.¹¹ They also demonstrated that early tracheal extubation and anaesthetic management could reduce the total cost of CABG surgery by 25%.¹¹

In our present study, the mean (SD) time to extubation was 7.90 ± 2.13 hours in Group I versus 3.83 ± 1.20 hours in Group II. We hypothesise that the time to extubation in Group II was likely shorter because the BiPAP ventilator provides a more physiologic, unrestricted breathing pattern and has a more sensitive trigger mechanism. Thus, the FTE criterion of spontaneous breathing would have been met earlier in the BiPAP-supported group.

Weaning patients from mechanical ventilation may be problematic and difficult in the face of imposed work of breathing (WOBi). In performing the WOBi, the patient can trigger BiPAP ventilation and thus overcome the additional flow-resistant effects of the circuit and the endotracheal or tracheotomy tube. Indeed, WOBi is a recognised potential cause of weaning failure.

Nevertheless, the clinical significance of WOBi remains controversial. Its effect on the ability to wean patients from ventilatory support postoperatively may not be clinically significant in stable patients whose cardiopulmonary function is good, but it may be clinically significant in patients whose cardiopulmonary reserve is marginal and who may thus be kept unnecessarily ventilated. Several groups have implicated WOBi as a cause of failure to wean; others have argued that the work of breathing increases after extubation, possibly secondary to upper airway oedema, and that WOBi merely offsets this increase in work after extubation.¹²

In the present study, we observed no significant difference in WOB between our two study groups. In Group II, we avoided extubating any patient earlier than three hours after surgery in light of chest tube drainage and ventricular dysfunction. Even if a patient's spontaneous breathing was sufficient, the patient was connected to the BiPAP ventilator via his or her endotracheal tube, and no further adjustments to ventilator settings were made. In this way, we also aimed to reduce the patient's WOB. Ishaaya et al. reported that the mean WOB and pressure time product were significantly greater after extubation than during spontaneous breathing through an endotracheal tube.¹³ In the present study, we could not measure WOB after extubation (i.e. after four hours in the ICU).

In a prospective study, Kazmaier and colleagues compared the influences of BiPAP and CPAP on systemic haemodynamics and ventilatory parameters and found that BiPAP-ventilated patients, in contrast to CPAP-ventilated patients, were able to breathe spontaneously independently of the mechanical ventilatory cycle. Kazmaier's group concluded that the negative haemodynamic effects of BiPAP do not counterbalance its beneficial properties. They also found that Pmax differed between the groups during the period of sedation (i.e. increased in the CPAP-ventilated patients), but that hemodynamic parameters did not.¹⁴

In the present study, we also observed several notable differences between our PS-CPAP- and BiPAP-ventilated groups. First, Pmax was greater in Group I than in Group II at T1. Second, respiratory rate, PCO₂, PO₂, and PH differed significantly between the two groups at various time points. In particular, PCO₂ was significantly higher in Group II than Group I at all time points. We considered these differences to be due to the conditions imposed by the BiPAP machinery, which are similar to physiological conditions. Having a high respiratory rate 2, 4, and 6 hours postoperatively allowed extubation criteria to be reached more quickly. Conversely,

there was no difference between groups either in the respiratory rate at 8 and 12 hours postoperatively. Although there were statistically significant differences between groups in terms of base deficit and lactate levels, these differences were not considered clinically significant because all values fell within normal limits.

With the lone exception of heart rate, all other haemodynamic parameters were similar between groups. Heart rate was significantly higher in Group II than in Group I, 2nd and 4th hours postoperatively. It is possible, however, that the significant increase in heart rate in Group II patients at these two time points could have been due to early appearance of spontaneous breathing and haemodynamic alterations because of this situation.

Although there was a difference in the timing of extubation between groups, there was no difference in the timing of surgery, ICU LOS, or overall hospital LOS. The mean time to extubation postoperatively was twice as long in Group I than in Group II (7.9 ± 2.13 hours versus 3.83 ± 1.20 hours). The similarity in ICU and overall hospital LOS between groups was due to our surgery team's protocol for discharge.

After CABG surgery using hypothermic CPB, a prolonged period of analgesia and sedation is usually preferred to reduce stress-induced sympathetic activation. This is intended to decrease the risk of early postoperative myocardial ischaemia. Rathgeber and colleagues demonstrated that the type of ventilatory support can influence postoperative demand for analgesics and sedatives and that the application of BiPAP ventilation or SIMV instead of controlled mechanical ventilation can significantly decrease such demand. This suggests that BiPAP may be preferable for both short-term and long-term ventilation of patients after CABG surgery.¹⁵

In recent years, many groups have sought to develop new modes of weaning CABG patients from ventilatory support postoperatively in the ICU. The use of noninvasive ventilators for weaning has gained in popularity. For example, noninvasive positive pressure ventilation (NIPPV), which is primarily used to avoid intubation, has also been used to facilitate weaning. The pooled results from 2 prospective, randomised, controlled trials suggest that weaning via extubation to NPPV can reduce the duration of mechanical ventilation, ICU stays, mortality, and incidence of nosocomial pneumonia.^{16,17}

So far, there appears to be only one study reported in the literature to have examined the effects of BiPAP ventilation on intubated patients. In brief, Patel et al compared the effects of BiPAP S/T versus conventional ventilation on respiratory muscle performance, pulmonary mechanics, and gas exchange. They concluded that BiPAP S/T is safe and effective when used in patients who need mechanical ventilation via endotracheal tube or tracheostomy.⁷

Traditionally, the use of BiPAP in cardiac surgery has been limited to its use as a mode of conventional ventilation or as a means of providing respiratory support while avoiding reintubation. In studies performed by Eren and colleagues, 15 patients who underwent open heart surgery under CPB were weaned via extubation to NIPPV in the ICU.¹⁸ Five of these patients had to be reintubated after a relatively brief period of NIPPV support (mean [SD], 3 ± 0.5 hours) because of the reoccurrence of hypoxia, hypercapnia, and impaired haemodynamics. The other 10 patients experienced improvement in respiratory function and so were able to continue on NIPPV and avoid reintubation. One of these 10 patients, however, was reintubated.¹⁸

In other studies, Takami and colleagues demonstrated the useful effects of BiPAP in cardiac surgery patients.¹⁹ Theoretically, as the authors noted, EPAP provides physiological advantages similar to those of PEEP in mechanical ventilation, and IPAP creates further PS effects that permit passive ventilation. These two pressure levels, alternating at preset time intervals, improve lung mechanics by recruiting atelectatic alveoli, increasing pulmonary compliance, and reducing the WOB. As a result, in Takami's study, BiPAP ventilation not only increased the PaO₂/FiO₂ ratio in patients who were poorly oxygenated on arrival in ICU immediately after surgery and before extubation, but also allowed

postextubation PaO₂/FiO₂ levels in these patients to be maintained at levels similar to those in non-BiPAP-supported patients.

BiPAP ventilation offers several potential advantages to patients. First, it improves alveolar recruitment during both inhalation and exhalation. Second, CPAP increases oxygen uptake in the setting of impaired oxygen diffusion, which may result from acute lung injury during CPB. Third, by improving oxygenation, it may also increase tissue partial pressure of oxygen and thus promote wound healing and avoid surgical wound infection. Fourth, BiPAP ventilation, and especially its IPAP component, reduces the WOB, which may in turn reduce myocardial oxygen demand.¹⁹

In general, complications associated with BiPAP ventilation are uncommon. Gastric insufflation is rare at pressures of less than 30 cm H₂O. The incidence of aspiration of gastric contents is very low (5% or less) when the airway reflex is intact. Local complications such as skin abrasion, sinus complaints, and conjunctivitis are more common. In our study population there were no complications associated with BiPAP ventilation. None of all patients in both groups were re-intubated.

In conclusion, our study demonstrates that fast-track extubation and weaning to BiPAP ventilation after CABG surgery is safe and effective. BiPAP ventilation offers clinical benefits that warrant its earlier institution during the postoperative management of patients who have undergone cardiac surgery with CPB. In addition, our study suggests that BiPAP ventilation can be used safely not only for short-term support in patients who have undergone hypothermic CPB, but also for long-term support during periods of postoperative pulmonary dysfunction.

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