R. Gust
A. Gottschalk
H. Schmidt
B. W. Böttiger
H. Böhrer
E. Martin

Effects of continuous (CPAP) and bi-level positive airway pressure (BiPAP) on extravascular lung water after extubation of the trachea in patients following coronary artery bypass grafting

Abstract Objective: To evaluate the effects of continuous positive airway pressure (CPAP) and bi-level positive airway pressure (BiPAP) on extravascular lung water during weaning from mechanical ventilation in patients following coronary artery bypass grafting.

Design: Prospective, randomized clinical study.

Setting: Intensive care unit at a university hospital.

Patients: Seventy-five patients following coronary artery bypass grafting.

Interventions: After extubation of the trachea, patients were treated for 30 min with CPAP via face mask (n = 25), with nasal BiPAP (n = 25), or with oxygen administration via nasal cannula combined with routine chest physiotherapy (RCP) for 10 min (n = 25).

Measurements and results: Extravascular lung water (EVLW), pulmonary blood volume index (PBVI) and cardiac index (CI) were obtained during mechanical ventilation (T1), T-piece breathing (T2), interventions (T3), spontaneous breathing 60 min (T4) and 90 min (T5) after extubation of the trachea using a combined dye-thermal dilution method. Changing from mechanical ventilation to T-piece breathing did not show any significant differences in EVLW between the three groups, but a significant increase in PBVI from $155 \pm 5 \text{ ml/m}^2$ to $170 \pm 4 \text{ ml/m}^2$ could be observed in all groups ($p < 0.05$). After extubation of the trachea and treatment with BiPAP, PBVI decreased significantly to $134 \pm 6 \text{ ml/m}^2$ ($p < 0.05$). After treatment with CPAP or BiPAP, EVLW did not change significantly in these groups ($5.5 \pm 0.3 \text{ ml/kg}$ vs $5.0 \pm 0.4 \text{ ml/kg}$ and $5.1 \pm 0.4 \text{ ml/kg}$ vs $5.7 \pm 0.4 \text{ ml/kg}$). In the RCP-treated group, however, EVLW increased significantly from $5.8 \pm 0.3 \text{ ml/kg}$ to $7.1 \pm 0.4 \text{ ml/kg}$ ($p < 0.05$). Sixty and 90 min after extubation, EVLW stayed at a significantly higher level in the RCP-treated group ($7.5 \pm 0.5 \text{ ml/kg}$ and $7.4 \pm 0.5 \text{ ml/kg}$) than in the CPAP- or BiPAP-treated groups ($5.6 \pm 0.3 \text{ ml/kg}$ and $5.9 \pm 0.4 \text{ ml/kg}$) or BiPAP-treated groups ($5.2 \pm 0.4 \text{ ml/kg}$ and $5.2 \pm 0.4 \text{ ml/kg}$). No significant differences in CI could be observed within the three groups during the time period from mechanical ventilation to 90 min after extubation of the trachea.

Conclusions: Mask CPAP and nasal BiPAP after extubation of the trachea prevent the increase in extravascular lung water during weaning from mechanical ventilation. This effect is seen for at least 1 h after the discontinuation of CPAP or BiPAP treatment.
Further studies have to evaluate the clinical relevance of this phenomenon.

**Key words** Weaning · CPAP · BiPAP · Extravascular lung water · Cardiac surgery

**Introduction**

Postoperative weaning from mechanical ventilation in patients after coronary artery bypass grafting is frequently associated with complications. Changing from controlled mechanical positive-pressure ventilation to spontaneous breathing is accompanied by alterations in intrathoracic pressure and in lung volume [1, 2]. Generally, the alteration from mechanical ventilation to spontaneous breathing is characterized by a rapid decrease in intrathoracic pressure and an increase in abdominal pressure [2, 3]. Thus, the intrathoracic blood volume, which is the total blood volume of the lungs, heart and the large intrathoracic vessels, and the pulmonary blood volume increase. These changes induce complex cardiopulmonary interactions [4, 5], which result in an increase in left ventricular preload and afterload and an impairment of left ventricular function associated with the risk of increased extravascular lung water and the development of pulmonary oedema [2, 6]. Since left ventricular function in patients following coronary artery bypass grafting is frequently impaired, these patients have a relatively high risk of weaning failure [2, 6].

Continuous positive airway pressure (CPAP) and bi-level positive airway pressure (BiPAP) by mask are used in the treatment of patients with chronic pulmonary disease and acute respiratory failure to avoid intubation [7–11]. CPAP and BiPAP can improve pulmonary oxygen transfer by reestablishing functional capacity [12–15]. The aim of our study was to investigate whether treatment with mask CPAP or BiPAP for 30 min after extubation of the trachea prevents the increase in extravascular lung water (EVLW) due to an increase in pulmonary interstitial pressure, thus reducing the risk of pulmonary congestion and weaning failure in patients following coronary revascularization.

**Material and methods**

**Patients**

After approval by the local Ethics Committee and after informed consent had been obtained from each patient, 75 patients were included in the study. All patients underwent coronary artery bypass grafting. They suffered from coronary artery disease with stenosis greater than 75% of either the left anterior descending or the circumflex artery, which was documented by preoperative coronary artery catheterisation. In all patients, preoperative echocardiography studies showed normal cardiac valve function. Lack of regular sinus rhythm during the weaning period was an exclusion criterion for the study. Further exclusion criteria were abdominal aortic aneurysm, peripheral arterial occlusive disease, pulmonary arterial hypertension, iodine allergies and pre-existing pulmonary disease as determined by clinical examination, chest radiography, lung function tests and arterial blood gases. The demographic data of the patients are listed in Table I.

In all patients, coronary artery bypass surgery and anaesthetic management were performed uniformly according to standard procedures. For oral premedication, patients were administered dipotassium clorazepate 0.3 mg/kg in the evening, and flunitrazepam 0.03 mg/kg in the morning, before surgery. Fentanyl (0.1–15 μg/kg), flunitrazepam (5–10 μg/kg) and etomidate (0.2 mg/kg) were used for the induction of anaesthesia. In order to facilitate tracheal intubation (endotracheal tube I.D. 8.5 mm), pancuronium (0.1 mg/kg) was administered. Anaesthesia was maintained with additional doses of fentanyl and flunitrazepam. After tracheal intubation, patients were ventilated with an inspired oxygen to nitrous oxide (O₂ : N₂O) mixture of 1:1 at a tidal volume and ventilatory rate adequate to achieve normoventilation. Cardiopulmonary support was delivered using a pulsatile regimen with flow rates of 1.8 l/min per m² during normothermia and 1.1 l/min per m² during hypothermia. During cardiopulmonary bypass, the body core temperature was decreased to 27.5 ± 0.8 °C. Weaning from cardiopulmonary support was started after rewarming to the normal body core temperature. Postoperatively, all patients were mechanically ventilated in the Intensive Care Unit until complete haemodynamic stability and final rewarming was achieved.