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Hemodynamic effects of nasal continuous positive airway pressure after abdominal surgery

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Introduction

After major abdominal surgery, constant as well as episodic nocturnal hypoxemia is common, with an accumulation on the second and third postoperative nights [1]. Episodic hypoxemia is usually provoked by periods of central and/or obstructive apnea, most commonly occurring during sleep [1]. Thus, postoperative sleep disturbances could be of importance for the development of episodic hypoxemia [2]. Late postoperative oxygen treatment has no significant effect on the hypoxemic episodes [3], and currently there are no known possibilities for treatment of late postoperative episodic hypoxemia.

In nonsurgical patients with chronic obstructive sleep apnea syndrome (OSAS) and episodic hypoxemia, nasal continuous positive airway pressure (nCPAP) is the recommended treatment. Treatment with nCPAP has been shown to abolish episodes of obstructive apnea and episodic hypoxemia, to restore the drive for breathing to normal, and to allow unfragmented sleep [4].

The hemodynamic effects of nCPAP treatment have been investigated in nonsurgical patients with OSAS. Here it has been shown to cause a significant fall in the mean arterial blood pressure in normotensive [5,6] as well as in hypertensive patients [5], and to produce a reduction in the variability of blood pressure and a significant reduction in cardiac output [7]. In patients with stable severe congestive heart failure, nCPAP treatment furthermore caused a significant reduction in cardiac index and a significant increase in systemic vascular resistance [8]. Application of nCPAP to healthy normal subjects (without OSAS) caused a significant decrease in cardiac stroke volume and cardiac output [9]. Application of CPAP to patients after elective heart surgery has not shown any significant modification of the right ventricular indices [10]. A recent study in which nCPAP (10 cmH_2O) was given to patients during the first 12 h after abdominal vascular surgery did not find any changes in systolic or diastolic blood pressure [11]. There are no studies investigating other hemodynamic effects of nCPAP after major abdominal surgery, and no studies have included the late postoperative period, when the incidence of episodic hypoxaemia is highest [1].

The aim of this study was to investigate the hemodynamic effects of nCPAP in the late postoperative period in the general surgical ward, before implementation of the technique in further scientific studies as well as in clinical practice.

Patients and methods

The study was approved by the local ethics committee, and informed written consent was obtained from all patients before inclusion. The exclusion criteria were neurological, endocrine, pulmonary, or cardiac disease, including hypertension. Patients were tested on the second or third day after major abdominal surgery.

The study was conducted with the patient in a resting, supine position and was divided into three periods, each lasting 25 minutes. In the first period, the patient was wearing the mask but no airflow was applied (0 cmH_2O). In the second and third periods, nCPAP (5 and 10 cmH_2O using atmospheric air) was applied in random order. None of the patients had a gastric tube present during study periods, and they all received continuous epidural analgesia for pain (bupivacaine 2.5 $mg \cdot ml^{-1}$, 4 $ml \cdot h^{-1}$, and morphine 0.02 $mg \cdot h^{-1}$).

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CPAP was generated by a PB335 Respiratory Support System (Nellcor Puritan Bennett, Pleasanton, CA, USA). The hemodynamic parameters were monitored by a Cardioscreen, Noninvasive Hemodynamic Monitoring System (version 3.1, Medis, Ilmenau, Germany).

Previous studies have verified the reliability of the hemodynamic parameters determined noninvasively with this method of impedance cardiography and found good correlation when compared with invasive methods [12,13]. The hemodynamic monitoring involved measurements of thoracic electric impedance and ECG. The following hemodynamic parameters were recorded: mean arterial blood pressure (MAP), heart rate (HR), stroke volume (SV), cardiac output (CO), cardiac index (CI), end-diastolic index (EDI), ejection fraction (EF), index of contractility (IC), acceleration index (ACI), systemic vessels resistance index (SVRI), and left cardiac work index (LCWI).

Oxygen saturation was monitored noninvasively by a Nellcor N-3000 pulse oximeter (Nellcor Puritan Bennett). Blood pressure was measured with an arm cuff. The first 15 min of each period were regarded as necessary to obtain steady state. Therefore only the mean values of the data recorded in the last 10 min of each period were used for analysis. Blood pressure was measured after the first 15 min in each study period.

Data analysis was performed with SPSS statistical software (version 8.0). Friedman's two-way analysis was used for statistical analyses, and $P < 0.05$ was considered to indicate a statistically significant difference. All values are given as median (range).

Results

Twenty-three patients were included, of whom 11 were subsequently excluded. Six patients had nausea and vomiting that rendered application of nCPAP impossible. Two patients found it too uncomfortable to breathe against a pressure of 10 cmH_2O, two others found the mask too uncomfortable to wear, and one patient could not breathe through the nose because of congestion.

Twelve patients completed the study (seven women and five men). Then median age was 65 years (34–86), their height was 172 cm (157–179), and their weight was 74 kg (55–97). All patients had undergone a laparotomy (three explorative laparotomies, three low-anterior rectal resections, two abdomino-perineal rectal extirpations, one rectal resection with a coloanal reservoir, one rectal resection with ileoanal J-pouch, one Hartman's sigmoid resection, and one reversal of Hartman's resection).

Application of nasal CPAP (5 cmH_2O and 10 cmH_2O) did not significantly affect any of the measured hemodynamic parameters in our patients (Table 1), except for arterial oxygenation, which was slightly improved by nasal CPAP ($P = 0.01$, Friedman test).

Discussion

Previous studies have shown that approximately 30% of patients after major surgery (abdominal, thoracic, or orthopedic) have constant or episodic hypoxemia [14], in some probably associated with cardiac complications (ischemia, arrhythmias), mental dysfunction (delirium, confusion), and wound complications (reduced healing, infection) [1,14]. Constant hypoxemia is probably due to reduced lung volume after surgery and may be improved by oxygen therapy and mobilization [1,14]. Episodic hypoxemia primarily occurs when the patient is sleeping, especially on the second and third postoperative nights [1]. No effective treatment, however, is yet available.

Table 1. Hemodynamic and oxygenation parameters in the three periods of the study ($n = 12$)

Parameter	0 cmH_2O	5 cmH_2O	10 cmH_2O	P value
MAP (mmHg)	81 (62–103)	81 (64–100)	82 (63–112)	0.70
HR (min^{-1})	77 (62–94)	78 (62–101)	76 (61–95)	0.21
SV (ml)	82 (59–111)	74 (58–111)	77 (58–122)	0.56
CO ($l \cdot m^{-1}$)	6.1 (4.4–10.4)	5.5 (4.4–10.5)	6.4 (3.6–11.1)	0.52
CI ($l \cdot min \cdot m^{-2}$)	3.6 (2.4–5.3)	3.3 (2.2–5.3)	3.4 (1.8–5.6)	0.52
EDI ($ml \cdot m^{-}$)	67.9 (44.8–99.6)	68.1 (49.1–100.5)	65.0 (44.1–107.3)	0.56
EF (%)	69 (56–77)	65 (56–77)	65 (57–77)	0.92
IC (s^{-1})	0.05 (0.03–0.06)	0.05 (0.03–0.06)	0.05 (0.03–0.06)	0.54
ACI (s^{-2})	1.1 (7–1.8)	1.1 (0.5–1.8)	1.1 (0.7–2.0)	0.26
SVRI ($dyn*s \cdot cm^{-5}*m^{-2}$)	1971 (1193–2702)	1975 (1179–3002)	1902 (1070–3721)	0.72
LCWI ($kg*m \cdot m^{-2}$)	3.7 (2.5–5.6)	3.6 (2.4–6.7)	3.7 (2.0–5.7)	0.72
SpO_2 (%)	96 (91–99)	95 (91–99)	95 (93–100)	0.01

MAP, mean arterial blood pressure; HR, heart rate; SV, stroke volume; CO, cardiac output; CI, cardiac index; EDI, end-diastolic index; EF, ejection fraction; IC, index of contractility; ACI, acceleration index; SVRI, systemic vessels resistance index; LCWI, left cardiac work index; SpO_2, oxygen saturation by pulse oximeter

P-values are from Friedman tests. Values are median (range)

Part of the pathogenesis of episodic hypoxemia is probably due to postoperative sleep disturbances [2]. Changes in sleep early after major surgery are characterized by a decrease in total sleep time, with many awakenings, elimination of rapid eye movement (REM) sleep, a marked reduction in the amount of slow wave sleep, and increased amounts of non-REM sleep stage 2 [2]. On the second and third postoperative nights, REM sleep reappears with increased density and duration (rebound REM sleep). Rebound REM sleep causes intermittent hypoventilation as well as central and/or obstructive apneas, primarily because of reduced tone in the muscles of the pharynx during REM sleep [1,2], thereby causing episodic hypoxemia. The number of hypoxemic events associated with this REM sleep increases three times compared with the preoperative value [15]. Surgical trauma (pain and stress) combined with postoperative opioid treatment are probably the main causes of the development of postoperative sleep disturbances. However, it is not yet known specifically which factors in the surgical stress response cause the observed sleep changes [14].

Ventilatory patterns and associated arterial oxygenation have been studied postoperatively, showing that ventilatory disturbances are common and include periods of hypopnea and obstructive as well as central and mixed apneas often associated with episodes of oxygen desaturation [16]. The pathogenesis could be identical to that of obstructive sleep apnea syndrome, thus rendering nasal CPAP a possible treatment for postoperative episodic hypoxemia. However, applying positive airway pressure could have an effect on the intrathoracic pressure, thereby causing reduced cardiac output and hypotension if the heart is not able to compensate [8]. Because patients undergoing major surgery are under the influence of the surgical stress response and therefore have increased cardiac demands [14], rendering the adaptation of the heart more vulnerable, it is necessary to ensure that the hemodynamics will not be affected inappropriately when applying nCPAP. We have not been able to show any significant influence on the 11 hemodynamic parameters we investigated, thereby making nCPAP a possible treatment modality for late postoperative episodic hypoxemia in otherwise healthy cardiac patients. A recent study in patients undergoing abdominal vascular surgery used nCPAP (10 cmH_2O) during the first 12 h after operation [11]. It found no effects on systolic and diastolic blood pressure, but no other hemodynamic parameters were studied.

In summary, we found no significant effects ($P > 0.2$ for all values) of nasal CPAP (5 and 10 cmH_2O) on the measured hemodynamic parameters on the second and third days after laparotomy. Future studies may therefore evaluate the effects of nasal CPAP on episodic hypoxemia in the late postoperative period.

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