EPISODIC ARTERIAL OXYGEN DESATURATION AND HEART RATE VARIATIONS FOLLOWING MAJOR ABDOMINAL SURGERY

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Preliminary investigations [1] have shown that severe episodic oxygen desaturation (< 80% saturation) occurs in the first 16 h after surgery. This severe episodic hypoxaemia differs from the mild arterial hypoxaemia that occurs after all types of surgery [2].

The purpose of this study was to evaluate the occurrence of this phenomenon in the late postoperative period, when the patient has returned to the surgical ward.

PATIENTS

After local Ethics Committee approval, we studied 20 otherwise healthy patients (14 men and six women; median age 66 yr (range 16–79 yr), weight 71 (50–94) kg) undergoing elective major abdominal surgery. Exclusion criteria included neurological and respiratory disease, including excessive daytime sleepiness. Oxygen treatment was not given during the first 48 h after surgery other than in the recovery room, with the exception of one patient who received oxygen treatment without any apparent indication on the second night after operation. This patient was not included in the analysis.

Seven patients underwent gastric resection, six colonic resection, two jejunoojunostomy and four cholecystectomy. Measurements were performed at night 2 days before operation and on the first two nights after operation from 23:00 to 07:30. Monitoring was performed at night because, during sleep, behavioural ventilatory stimulation is minimized or abolished, and breathing is dependent on activity in the autonomic control system [3]. Oxygen saturation was measured with an Ohmeda 3700 pulse oximeter [4] using a finger probe. Heart rate was measured with a monitor (Quadriscop 8034, S&W Medico Teknik A/S, Copenhagen) and displayed continuously on a penwriter.

Premedication comprised diazepam 5–10 mg; anaesthesia was induced and maintained using a combination of drugs which included thiopentone, midazolam, fentanyl, suxamethonium, pan-

SUMMARY

In 20 patients undergoing elective major abdominal surgery, heart rate and arterial oxygen saturation were monitored continuously during the night 2 days before operation and during the first and second nights after operation (23:00 to 07:30). Mean heart rate increased by 16 beat min⁻¹ (P < 0.0006) and mean oxygen saturation decreased by 3.2% (P < 0.0002) after operation. Four patients had 21, 27, 120 and 372 episodes of sudden desaturation to a value less than 80% on the second night after operation. The patient with 372 episodes of sudden desaturation had severe cardiac arrhythmias on the morning of the third day after operation. In another patient the episodes of desaturation correlated with increases in heart rate. There was no correlation between administration of opioids and heart rate and saturation disturbances. The mechanism and clinical relevance of episodic desaturation in the late postoperative period remain unknown, but may be important in the pathogenesis of postoperative cardiac, cerebral and wound dysfunction.
curonium and nitrous oxide in oxygen. Two patients received small concentrations of halothane or enflurane in addition. Administration of opioids was monitored carefully for the first 48 h after surgery.

Data were analysed using Wilcoxon's signed rank test and Spearman's rank correlation test. Level of significance was chosen at $P < 0.05$.

**RESULTS**

Before operation, four patients had an episode of sudden arterial desaturation ($S_{aO_2}$) to values less than 80%. After operation, three patients had one, three and eight episodes on the first night, and on the second night after operation eight patients had one, two, two, 21, 27, 120 and 372 episodes, respectively ($P < 0.04$ compared with preoperative values). The majority of the episodes lasted for less than 1 min. Some episodes lasted 3–5 min. Two patients with 120 and 372 episodes of sudden arterial desaturation to values less than 80% spent, respectively, 49% and 78% of the second night after operation with an $S_{aO_2}$ less than 80%.

The median decrease in $S_{aO_2}$ (fig. 1) was 2.3% on the first night after operation ($P < 0.0007$), and 3.2% on the second night ($P < 0.0002$) compared with preoperative values.

The median increase in heart rate (fig. 1) was 12 beat min$^{-1}$ on the first night after operation ($P < 0.0003$) and 16 beat min$^{-1}$ on the second night ($P < 0.0006$) compared with preoperative values.

The preoperative minimum $S_{aO_2}$ (fig. 2) was 86% (median; range 75–94). The postoperative values were 85% (76–90) on the first night after operation (ns) and 80% (41–90) on the second night ($P < 0.005$ compared with preoperative value).

In one patient there was a good correlation between sudden arterial desaturation and increase in heart rate during the entire second night after operation during oxygen therapy (60% oxygen 15 litre min$^{-1}$ by Hudson Mask) (fig. 3). Another patient exhibited cardiac arrhythmias with ventricular extrasystoles and periods with bigemini on the third morning after operation, a few hours after the study had terminated. This patient had a total of 372 episodes of severe desaturation and a mean $S_{aO_2}$ on the second night after operation of 79%. Oxygen treatment (3 litre min$^{-1}$ by nasal catheter) was given and a normal cardiac rhythm was restored. The patient with 21 episodes of severe desaturation on the second night after

![Fig. 1. Changes in mean arterial oxygen saturation ($S_{aO_2}$) and mean heart rate in 19 patients undergoing laparotomy.](image)

![Fig. 2. Changes in minimum $S_{aO_2}$ in 19 patients undergoing laparotomy.](image)
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FIG. 3. Concomitant changes in $S_{A\text{O}_2}$ and heart rate (HR) in a patient on the second night after gastric surgery.

operation had on this night a mean $S_{A\text{O}_2}$ of 82 %. He had no history of ischaemic heart disease, but the following day at 11:00 he developed dyspnoea and chest pain. He was transferred to the cardiology department, where an ECG showed signs of acute myocardial infarction. He died 1 h later, and the postmortem examination showed pulmonary emboli, but cardiac examination was inconclusive.

The patients received fentanyl 0.6 (0.2–0.9) mg during operation and morphine 20 (6–75) mg or opioid equivalent on the first day after operation, 25 (5–232) mg on the second day after operation (median 52 (11–307) mg on the two days together). Sedatives and peripherally acting analgesics were not used. There was no correlation between the amount of opioid and degree of hypoxaemia or the number of sudden desaturations or between the time of administration of opioid and appearance of disturbances in heart rate and $S_{A\text{O}_2}$.

There was no correlation between age, site of operation, and degree of hypoxaemia or number of sudden desaturations (ns). A weak correlation was found between duration of surgery and decrease in saturation from preoperative values to those on the second night after operation ($r_s = 0.51$, $P < 0.04$), and between increase in heart rate and change in $S_{A\text{O}_2}$ from preoperative to second postoperative night ($r_s = 0.54$, $P < 0.03$).

DISCUSSION

All types of major surgery, and especially upper abdominal surgery [5], are followed by moderate hypoxaemia for up to 2 weeks [2], caused by a reduction in functional residual capacity (FRC) caused partly by pain [6], neurogenic reflexes impairing diaphragmatic function [7] and the supine position [8]. Hypoxaemia is greatest after the first day after operation [2, 5], coinciding with the maximal decrease in FRC, that occurs approximately 16 h after surgery [2, 9].

In addition to constant postoperative hypoxaemia, Catley and colleagues [1] described a new phenomenon, episodic arterial desaturation to values of $S_{A\text{O}_2}$ less than 80 %, in the first 16 h after operation. These episodes occurred only in patients who received systemic opioids for pain relief, whereas patients who received regional anaesthesia did not show episodic desaturation to values less than 80 % [1]. Desaturation was observed only during sleep, and mostly in the first 8 h after surgery. The pathogenesis of sudden desaturation in the early postoperative period would include residual effects of inhalation anaesthesia [10], postoperative pain [11] or prolonged curarization [12].

This study has demonstrated periods of severe episodic desaturation in the late postoperative period (days 1–3 after operation). The clinical relevance of this is unknown, but in some patients these events may provoke cardiovascular disturbances. This may explain the unexpected death of a patient making an apparently uncomplicated recovery from surgery. The patient in our study who died on the third day after operation may have suffered from either myocardial infarction or pulmonary embolism. It is notable that the patient in our study who had 372 episodes of desaturation the second night after operation exhibited cardiac arrhythmias on the morning of the third day, and oxygen therapy restored normal cardiac rhythm. In another patient there was a correlation between sudden desaturation and tachycardia, but this patient had no symptoms of cardiac or pulmonary disturbances. There was a weak correlation between increase in heart rate and decrease in $S_{A\text{O}_2}$ in 19 patients. It is possible, therefore, that sudden severe desaturation combined with a persistently low $S_{A\text{O}_2}$ may contribute to development of postoperative cardiac [13, 14] and cerebral [15] dysfunction.

One study has shown that administration of 28 % oxygen by face mask [16] reduced the number of episodes of early postoperative arterial desaturation to zero, but did not have any effect on breathing abnormalities in the first 12-h period after operation. Future studies should evaluate
the efficacy of different types of oxygen therapy necessary to maintain a normal \( \text{Sa}_o \) following major abdominal surgery.

The pathogenesis of late episodic severe postoperative nocturnal desaturation is not known. A preliminary investigation demonstrated episodic desaturation on the second and third nights after upper abdominal surgery in obese patients [17], occurring especially during rapid eye movement (REM) sleep. Sleep causes respiratory depression in normal healthy adults and this effect is more pronounced during REM than non-REM sleep [18]. Knill and colleagues did not observe REM sleep on the first night after upper abdominal surgery [17], as noted also following herniotomy [19]. Kavey and Altshuler observed that when there was marked decrease in REM sleep and types III and IV sleep on the first night, normal sleep patterns were re-established after two or three nights [19]. Re-establishment of REM sleep on the second night after operation might therefore contribute to respiratory disturbance and episodic desaturation in the late postoperative period [17]. Respiratory disturbances may include obstructive apnoea, as demonstrated in the sleep apnoea syndrome in non-surgical patients [20] and in the early postoperative recovery period [1].

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REFERENCES