

# The influence of perioperative oxygen concentration on postoperative lung function in moderately obese adults

Martin Zoremba, Frank Dette, Thorsten Hunecke, Stefan Braunecker and Hinnerk Wulf

**Background and objective** Obesity aggravates the negative effects of general anaesthesia and surgery on the respiratory system, resulting in decreased functional residual capacity and expiratory reserve volume, and increased atelectasis and ventilation/perfusion (Va/Q) mismatch. High-inspired oxygen concentrations also promote atelectasis. This study compares the effects of perioperative inspired low-oxygen and high-oxygen concentrations on postoperative lung function and pulse oximetry values in moderately obese patients (BMI 25–35).

**Methods** We prospectively studied 142 overweight patients, BMI 25–35, undergoing minor peripheral surgery; they were randomly allocated to receive either low-inspired or high-inspired oxygen concentrations during general anaesthesia. Premedication, general anaesthesia and respiratory patterns were standardized. Arterial oxygen saturation (pulse oximetry) was measured on air breathing. Inspiratory and expiratory lung functions were measured preoperatively (baseline) and at

10 min, 0.5, 2 and 24 h after extubation with the patient supine, in a 30° head-up position. The two groups were compared using repeated-measure analysis of variance and *t*-test analysis.

**Results** The low-inspired oxygen group had significantly better arterial saturation during the first 24 h ( $P < 0.01$ ). Mid-expiratory flow 25 values indicating small airway collapse were significantly better in the low-oxygen group at all measurements ( $P < 0.05$ ).

**Conclusion** We conclude that postoperative lung function and arterial saturation is better preserved by a low-oxygen strategy, although it is not clear whether this has clinical relevance for the prevention of postoperative pulmonary complications.

*Eur J Anaesthesiol* 2010;27:501–507

**Keywords:** atelectasis, obesity, respiratory function, spirometry, surgery

Received 17 December 2008 Revised 17 April 2009

Accepted 27 April 2009

## Introduction

Perioperative hypoxaemia is common. Approximately 50% of all patients undergoing general anaesthesia and surgery experience arterial oxygen desaturation of 85–90%,<sup>1,2</sup> and severe complications occur in up to 20% of these.<sup>3</sup> Intubation, muscle relaxation and mechanical ventilation cause a massive impairment of respiratory function, resulting in atelectasis and ventilation/perfusion mismatch. Atelectasis occurs within minutes of intubation and persists in 80% of cases during the first day after extubation.<sup>4</sup> The mechanism is thought to be the result of high-inspired oxygen fractions leading to oxygen reabsorption and alveolar collapse,<sup>5–7</sup> this effect being reinforced in obesity via compression atelectasis.<sup>8,9</sup> These changes result in a restrictive postoperative spirometric pattern and poor tissue oxygenation.<sup>10,11</sup>

Healthy patients may cope with a reduced vital capacity, but coughing and deep breathing are impaired in the obese. Nevertheless, intraoperative inspired oxygen concentrations are usually generous, allowing an emergency reserve in the case of airway difficulties.<sup>12</sup> Increased intraoperative oxygen fractions also favour wound healing and can reduce infection rates;<sup>13,14</sup> thus, the oxygen concentration issue remains controversial.<sup>15,16</sup> Atelectasis can be prevented at an inspired oxygen fraction of 0.8 during induction or before extubation, but it has never

been shown that the avoidance of high oxygen fractions has any benefits for postoperative lung function and oxygenation.

In the present study, we wanted to evaluate the effect of an intraoperative adapted low-oxygen strategy during general anaesthesia upon postoperative lung function and pulse oximetry saturation in overweight (moderately obese) adults.

## Methods

### Study population

The study was approved by the Ethics Committee of the University of Marburg, and informed written consent was obtained from each patient before inclusion. We prospectively included 142 moderately obese adults (BMI 25–35 according to the WHO criteria, ASA I–III) scheduled for minor peripheral surgery (Table 1). No surgery required abdominal insufflation (laparoscopy) or head-down tilt. The minimum surgery time was set to be at least 45 min up to 130 min. Patients were allocated on a random basis to receive either high-inspired or low-inspired oxygen concentration. We excluded patients with gastro-oesophageal reflux disease or hiatus hernia, physical examination of the airway suggesting the presence of difficult intubation, pregnancy, asthma requiring therapy, cardiac disease associated with dyspnoea more than New York Heart Association (NYHA) grade II or severe psychiatric disorders.

### General anaesthesia

During the evening before surgery, patients were premedicated with chlorazepate 20 mg oral. After 3 min of

From the Department of Anaesthesia and Intensive Care Medicine, University of Marburg, Marburg, Germany

Correspondence to M. Zoremba, Department of Anaesthesia and Intensive Care Medicine, University of Marburg, D-35033 Marburg, Germany  
Tel: +49 64215865980; fax: +49 64215866996;  
e-mail: zoremba@med.uni-marburg.de

**Table 1 Basic data for 142 patients undergoing elective minor peripheral surgery**

|   | High oxygen<br>(n = 71) | Low oxygen<br>(n = 71) |
|---|-------------------------|------------------------|
| Age (years)   | 51 ± 11                 | 50 ± 12                |
| BMI   | 31 ± 2.6                | 31 ± 2.4               |
| Surgery time (min)  | 82 ± 24                 | 85 ± 25                |
| Remifentanyl consumption (µg)                               | 1036 ± 270              | 1169 ± 191             |
| Propofol consumption (mg)                                   | 578.4 ± 106             | 585 ± 127              |
| BIS value during surgery                                    | 50 ± 6.1                | 51 ± 5.2               |
| BIS value at discontinuation<br>of anaesthesia              | 54 ± 4.1                | 52 ± 6.4               |
| Time to extubation (min)                                    | 6.2 ± 2.9               | 6.7 ± 2.7              |
| Fast track score >10 (min)                                  | 10.2 ± 4.0              | 9.7 ± 3.5              |
| Postoperative piritramide (mg)<br>consumption (within 24 h) | 10 ± 5.1                | 12 ± 4.2               |
| Knee arthroscopy  | 16                      | 14                     |
| Minor breast surgery  | 39                      | 41                     |
| TUR   | 10                      | 12                     |
| Hand surgery  | 6                       | 4                      |

Data are mean ± SD or numbers of patients. BIS, bispectral index; TUR, transurethral prostate resection.

breathing 100% oxygen (80% in the low-oxygen group) by face mask, anaesthesia was induced with fentanyl 2–3 µg kg<sup>-1</sup> and propofol 2 mg kg<sup>-1</sup>. A single dose of rocuronium (0.5 mg kg<sup>-1</sup> ideal body weight) was given to facilitate orotracheal intubation, and no further dose of any neuromuscular blocking agent was given at any time. Patients were manually ventilated with 100% oxygen (80% oxygen) via a face mask. After intubation, the lungs were mechanically ventilated with a tidal volume of 8 ml kg<sup>-1</sup> (ideal body mass, height –100 cm) and an inspiratory oxygen concentration of 80%, or 40% in the low-oxygen group. The rate was adjusted to maintain an end-tidal CO<sub>2</sub> pressure of approximately 4–4.7 kPa. A maximum peak pressure of 30 cmH<sub>2</sub>O was allowed. The inspiration to expiration ratio was 1:1.5 and a positive end-expiratory pressure (PEEP) of 10 cmH<sub>2</sub>O applied throughout in both groups. The cuff pressure was adjusted continuously to 30 cmH<sub>2</sub>O and standard monitoring was performed throughout (pulse oximetry, non-invasive blood pressure and electrocardiography). To achieve comparable anaesthetic depth levels, a self-adhesive bispectral index (BIS)-EEG electrode strip (BIS Quatro; Aspect Medical Systems, Freising, Germany) was positioned on the forehead as recommended by the manufacturer. General anaesthesia was maintained by continuous infusion of propofol 3–6 mg kg<sup>-1</sup> h<sup>-1</sup> (ideal body weight). Remifentanyl (0.1–0.2 µg kg<sup>-1</sup> min<sup>-1</sup>, ideal body weight) and propofol infusions were adjusted according to haemodynamics and to keep BIS values within 40–60. Fifteen minutes before extubation, dolasetron [25 mg intravenous (i.v.)] and dexamethasone (4 mg i.v.) were given. The effect of the neuromuscular blocking agents was monitored via train-of-four (TOF) ratio, ensuring a ratio of more than 0.90 before extubation.<sup>17</sup> When the patient was fully awake and breathing spontaneously, the trachea was extubated without suction in the head-up position with

a positive pressure of 10 cmH<sub>2</sub>O and an adjusted oxygen concentration of 100% (80% in the low-oxygen group). Patients were then transported to the postanesthesia care unit (PACU), breathing room air during transport. Pulse oximetry was used throughout. Patients were nursed in the head-up position in the PACU and maintained on supplemental oxygen (4 l min<sup>-1</sup> via face mask), which was stopped 5 min before spirometric and pulse oximetry measurements were taken.

Both groups received basic nonopioid analgesia with i.v. paracetamol 1 g and metamizol 1 g i.v. Intermittent piritramide i.v. was given whenever the visual analogue scale (VAS) was more than 4. Overall piritramide consumption within the first 24 h was recorded.

### Spirometry and pulse oximetry

Spirometry and pulse oximetry were standardized, and the investigator blinded, with each patient in a 30° head-up position<sup>18</sup> after breathing air without supplemental oxygen for 5 min. At the preanaesthetic visit, baseline (T0) spirometry and pulse oximetry were performed after thorough demonstration of the correct technique. For this purpose, we used the self-calibrating ‘Easy One CS Spirometer’ (GE healthcare, Munich, Germany). To produce reliable measurements, a minimum quality, degree ‘C’, had to be attained. Vital capacity, forced vital capacity (FVC), forced expiratory volume in 1 s (FEV1) mid-expiratory flow (MEF 25–75), peak expiratory flow (PEF), peak inspiratory flow (PIF) and the forced inspiratory vital capacity (FIVC) were measured and FEV1/FVC was calculated. At each assessment, spirometry was performed at least three times to be able to meet the criteria of the European Respiratory Society (ERS), and the best measurement was recorded.<sup>19</sup> On arrival in the recovery room, at about 5–10 min after extubation, we repeated spirometry (T1) as soon as the patient was alert and fully cooperative (fast track score >10);<sup>20</sup> pain and dyspnoea during coughing were assessed using the fast track score (>10) before and, if necessary, after analgesic therapy. All patients met these criteria within 20 min of extubation.

Spirometry and pulse oximetry assessments were repeated in the PACU at 0.5 (T2), 2 (T3) and 24 h (T4) after extubation. Prior to each measurement, all patients were free from pain during coughing and had a fast track score more than 10. Overall piritramide consumption was documented within the first 24 post-operative hours. Factors that interfered with breathing (e.g. pain, shivering) were eliminated or at least minimized to produce reliable measurements.

### Statistical analysis

A prospective power analysis performed with the PASS2002 software (Number Cruncher Statistical Systems, Kaysville, Utah, USA) revealed that 63 patients per group provided a more than 80% chance to detect an absolute improvement of 1% (e.g. 94% SaO<sub>2</sub> to 95%

**Table 2 Preoperative pulse oximetry and lung function values (baseline = 100%)**

|             | SpO <sub>2</sub> before premedication | SpO <sub>2</sub> after premedication | FVC        | FEV1       | PEF        | MEF 75     | MEF 50     | MEF 25     | FIVC       | PIF        |
|-------------|---------------------------------------|--------------------------------------|------------|------------|------------|------------|------------|------------|------------|------------|
| Low-oxygen  | 97.6 ± 1.1                            | 96.7 ± 1.3                           | 3.56 ± 1.1 | 2.72 ± 0.8 | 5.89 ± 2.3 | 5.12 ± 2.1 | 3.43 ± 1.4 | 1.26 ± 0.7 | 3.30 ± 1.5 | 3.04 ± 1.3 |
| High-oxygen | 97.4 ± 1.2                            | 96.8 ± 1.2                           | 3.62 ± 1   | 2.83 ± 0.7 | 6.13 ± 2.0 | 5.62 ± 2.2 | 3.56 ± 1.5 | 1.24 ± 0.6 | 3.55 ± 1.2 | 3.28 ± 1.4 |

FEV1, forced expiratory volume in 1 s; FIVC, forced inspiratory vital capacity; FVC, forced vital capacity; MEF, mid-expiratory flow; PEF, peak expiratory flow; PIF, peak inspiratory flow.

SaO<sub>2</sub>) with an expected standard deviation of 2 in both groups, using Student's *t*-test with a type-I error of 5%. For further characterization of the interaction between study groups, we performed a repeated-measure analysis of variance (ANOVA). To compare postoperative respiratory data and pulse oximetry between the two groups, we tested the null hypothesis (H<sub>0</sub>) that postoperative pulse oximetry values are comparable. The postoperative values for each time point were calculated as percentage of the individual preoperative values. H<sub>0</sub> was rejected at an adjusted *P* value of less than 0.034 due to multiple testing. Fisher's exact test was used to show significance between the complications in our study groups. To illustrate the impact of increased BMI, we plotted the various lung function variables against BMI. Overall, 142 patients were included with four values each. All values of the respective BIS, remifentanyl and propofol consumption were collected through an online documentary system (Medlinq Easy Software, Hamburg, Germany). Statistic analysis was carried out with StatView 4.57 for Windows (Abacus Software, SAS Institute, Heidelberg/Germany).

**Results**

We recruited 173 moderately obese patients (m/w). The mean duration of surgery was 84 (SD 25) min (45–130 min). All patients had been ventilated according to the respective target values. There were no episodes of severe desaturation (SpO<sub>2</sub> < 85%). Six patients declined to continue and measurements were unsatisfactory in a further 18 (10 in the low-oxygen and eight in the high-oxygen group). All unsatisfactory measurements were the result of missed fast track criteria (<10) within 20 min after surgery. Two patients in the high-oxygen group developed laryngospasm/bronchospasm and were excluded, as were four who had unexpected difficulties at intubation. Antagonism of muscle relaxation was not necessary in any patient. As a result, we present data for 142 patients, 71 in each group (Table 1).

**Pulse oximetry**

Baseline (preoperative) pulse oximetry values were within the normal range; there were no differences between groups before or after premedication (Table 2). In both, the lowest values were found directly after extubation in the PACU, after achieving a fast track criteria value of more than 10. The high-oxygen group showed a greater decrease in postoperative oxygenation than the low-oxygen group

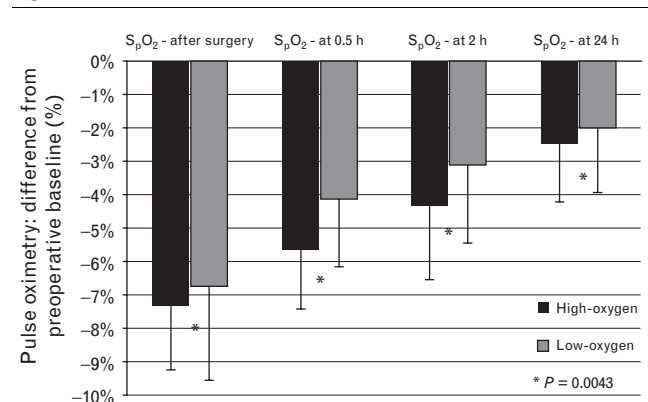
(Fig. 1, ANOVA *P* = 0.0043) and during the stay in the PACU (*t*-test: Table 3, *P* < 0.002), although there was no statistical difference at the first assessment in the PACU as well as 24 h after surgery (*t*-test, Table 3).

Pulse oximetry values decreased with increasing BMI at the first assessment in the PACU (Fig. 2a). The impact of BMI on pulse oximetry saturation was less in the low-oxygen group. Recovery profiles of pulse oximetry saturation at discharge from the PACU were better in the low-oxygen group (Fig. 2b). Overall mean pulse oximetry values differed within 1 percentage point.

**Spirometry measurements**

Preoperative inspired and expired spirometry values (baseline) were within the normal range (Table 2). Throughout the measurement period, the low-oxygen group tended to have better postoperative spirometry values than the high-oxygen group (Table 3). During the PACU stay, we observed only a moderate recovery of inspiratory and expiratory lung volumes, although the low-oxygen group improved more (Figs 3 and 4). MEF 25 values were better at all times in the low-oxygen group (*P* < 0.001), although there was no improvement in MEF 50 and PIF. Absolute values differed between the study groups within a range of 1–10% (Table 2). Even on the first day after surgery, lung function was reduced by up to 25% of baseline values.

**Fig. 1**



Postoperative pulse oximetry: difference from preoperative baseline. *P* value, interaction within the study groups [analysis of variance (ANOVA)]. Bars indicate SD.

**Table 3 Postoperative pulse oximetry and lung function values**

|                                | Low oxygen  | High oxygen | P (t-test) |
|--------------------------------|-------------|-------------|------------|
| SpO <sub>2</sub> after surgery | 93.3 ± 2.8  | 92.7 ± 1.9  | 0.298      |
| T 0.5 h                        | 95.9 ± 2.1  | 94.4 ± 2.2  | 0.012      |
| T 2 h                          | 96.9 ± 2.2  | 95.7 ± 2.1  | 0.002      |
| T 24 h                         | 98.0 ± 2.0  | 97.5 ± 1.7  | 0.105      |
| FVC after surgery              | 2.41 ± 0.36 | 2.29 ± 0.37 | 0.157      |
| T 0.5 h                        | 2.58 ± 0.41 | 2.46 ± 0.40 | 0.137      |
| T 2 h                          | 2.67 ± 0.44 | 2.59 ± 0.41 | 0.162      |
| T 24 h                         | 3.15 ± 0.32 | 2.78 ± 0.44 | <0.001     |
| FEV1 after surgery             | 1.64 ± 0.26 | 1.58 ± 0.31 | 0.261      |
| T 0.5 h                        | 1.71 ± 0.32 | 1.64 ± 0.32 | 0.086      |
| T 2 h                          | 2.04 ± 0.35 | 1.78 ± 0.34 | 0.001      |
| T 24 h                         | 2.34 ± 0.30 | 2.15 ± 0.33 | 0.021      |
| PEF after surgery              | 3.02 ± 0.67 | 2.81 ± 0.60 | 0.267      |
| T 0.5 h                        | 3.17 ± 0.72 | 3.05 ± 0.61 | 0.387      |
| T 2 h                          | 3.82 ± 0.71 | 3.21 ± 0.68 | 0.004      |
| T 24 h                         | 5.28 ± 1.06 | 4.75 ± 0.99 | 0.011      |
| MEF 75 after surgery           | 2.71 ± 0.57 | 2.62 ± 0.63 | 0.142      |
| T 0.5 h                        | 2.84 ± 0.65 | 2.75 ± 0.69 | 0.102      |
| T 2 h                          | 3.46 ± 0.82 | 2.98 ± 0.74 | 0.001      |
| T 24 h                         | 4.55 ± 0.94 | 4.18 ± 1.03 | 0.021      |
| MEF 50 after surgery           | 1.89 ± 0.38 | 1.88 ± 0.49 | 0.957      |
| T 0.5 h                        | 2.12 ± 0.41 | 2.06 ± 0.61 | 0.835      |
| T 2 h                          | 2.27 ± 0.46 | 2.21 ± 0.51 | 0.438      |
| T 24 h                         | 2.94 ± 0.56 | 2.85 ± 0.85 | 0.224      |
| MEF 25 after surgery           | 0.76 ± 0.15 | 0.63 ± 0.16 | 0.037      |
| T 0.5 h                        | 0.78 ± 0.17 | 0.65 ± 0.15 | 0.017      |
| T 2 h                          | 0.86 ± 0.22 | 0.69 ± 0.19 | 0.003      |
| T 24 h                         | 1.06 ± 0.21 | 0.95 ± 0.20 | 0.033      |
| FIVC after surgery             | 2.38 ± 0.62 | 1.78 ± 0.42 | <0.001     |
| T 0.5 h                        | 2.38 ± 0.71 | 2.06 ± 0.44 | 0.019      |
| T 2 h                          | 2.47 ± 0.69 | 2.17 ± 0.51 | 0.029      |
| T 24 h                         | 3.13 ± 0.84 | 2.76 ± 0.47 | <0.001     |
| PIF after surgery              | 1.55 ± 0.35 | 1.39 ± 0.32 | 0.197      |
| T 0.5 h                        | 1.72 ± 0.51 | 1.61 ± 0.31 | 0.057      |
| T 2 h                          | 1.81 ± 0.54 | 1.77 ± 0.49 | 0.295      |
| T 24 h                         | 2.42 ± 0.65 | 2.60 ± 0.59 | 0.713      |

P value = t-test analysis for each measurement point tested on a significance level of P < 0.05. FEV1, forced expiratory volume in 1 s; FIVC, forced inspiratory vital capacity; FVC, forced vital capacity; MEF, mid-expiratory flow.

**Spirometry measurement of small airway collapse (mid-expiratory flow 25)**

At the first PACU assessment, within 20 min of extubation, the low-oxygen group had better lung function, but there was no relationship between BMI and lung function in either group (Fig. 5a). At discharge from the PACU, 2 h after surgery, a linear decrease in lung function with BMI was evident in the high-oxygen group (Fig. 5b).

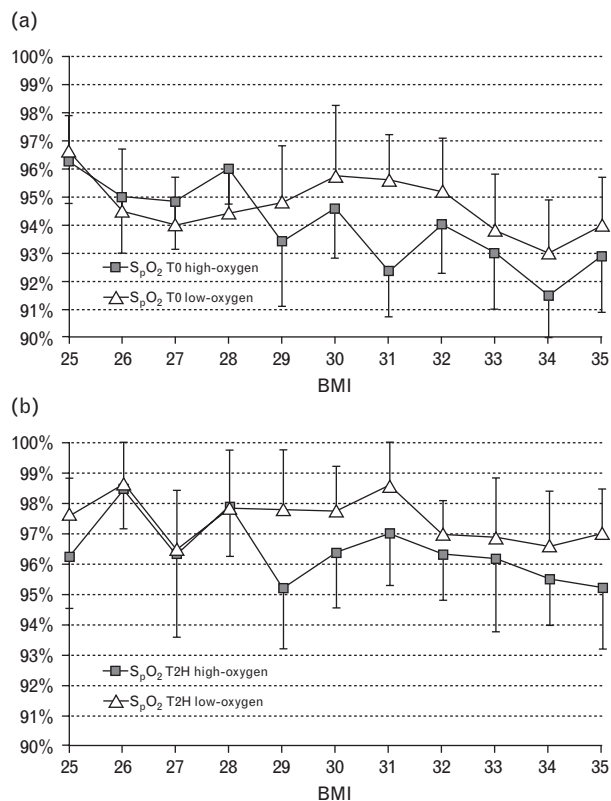
**Postoperative management**

No patient had untreatable postoperative pain. The maximum postoperative pain score on a VAS before analgesia was 6 in both groups. Opioid consumption for the first 24 h was comparable in the two groups (Table 2). At the respective measurement points, every patient included in this study had an acceptable awareness level and was free of pain, shivering and nausea, which might have interfered with spirometry.

**Discussion**

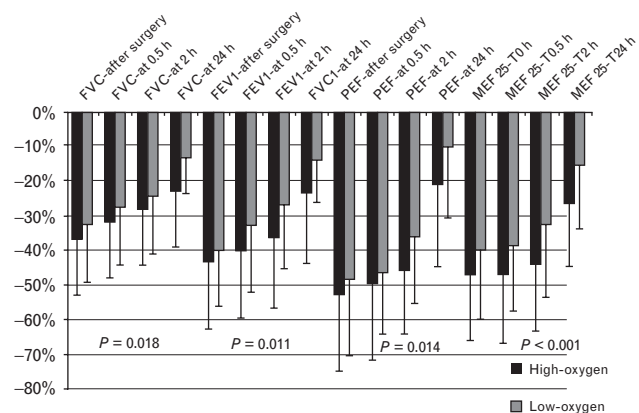
General anaesthesia causes a loss of functional residual capacity (FRC) due to atelectasis and increased shunt

**Fig. 2**



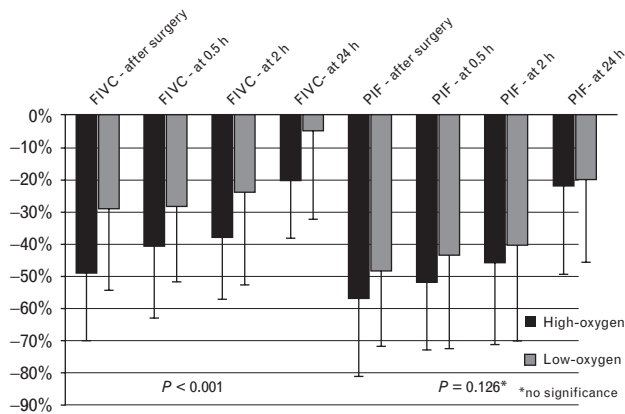
Pulse oximetry values at first assessment in the postanaesthesia care unit (within 20 min after extubation) related to BMI (a) and at discharge from postanaesthesia care unit (PACU) (b). Preoperative baseline = 100%.

**Fig. 3**



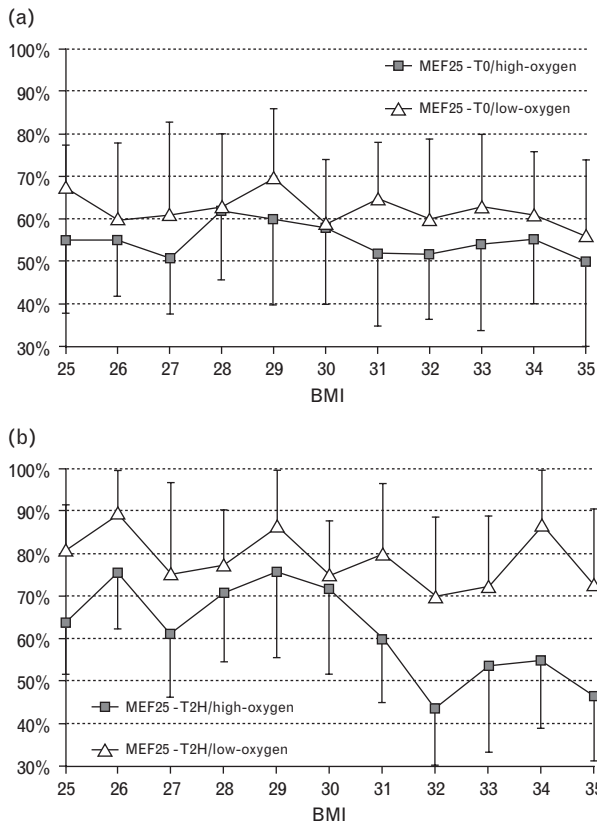
Expiratory lung function values: difference from preoperative baseline. Interaction within the study groups [analysis of variance (ANOVA)]. FEV1, forced expiratory volume in 1 s; FIVC, forced inspiratory vital capacity; FVC, forced vital capacity; MEF, mid-expiratory flow; PEF, peak expiratory flow; PIF, peak inspiratory flow.

Fig. 4



Postoperative inspiratory lung function values: difference from preoperative baseline. Interaction within the study groups [analysis of variance (ANOVA)]. FEV1, forced expiratory volume in 1 s; FIVC, forced inspiratory vital capacity; FVC, forced vital capacity; PEF, peak expiratory flow; PIF, peak inspiratory flow.

Fig. 5



Lung function: mid-expiratory flow 25 (percentage of preoperative baseline) in the postanesthesia care unit (within 20 min after extubation) related to BMI (a) and at discharge from postanesthesia care unit (PACU) (b). Preoperative baseline = 100%. MEF, mid-expiratory flow.

fraction, aggravated by obesity.<sup>21</sup> A reduction in both inspiratory and expiratory reserve volumes would affect vital capacity and may reduce the ability to cough effectively, predisposing to respiratory complications.<sup>22</sup> The poorest spirometry and pulse oximetry values were observed during the first assessment after extubation. Further measurements during PACU stay indicated only a slight recovery in lung volumes within the first 2 h. The reduction in spirometry volumes observed in our study may have been caused by impaired respiratory mechanics, obesity and atelectasis formation promoted by general anaesthesia in the supine position.<sup>23,24</sup> The decrease in vital capacity, FVC, FEV1, MEF 25–75 and PEF followed the same pattern, and the FEV1/FVC ratio did not change, suggesting a restrictive pattern in the immediate postoperative period, as previously described.<sup>25</sup> Residual neuromuscular block after extubation is unlikely to have contributed, as all patients were extubated after recovery of the TOF ratio to a value more than 0.9 and, in any case, this would not affect only one study population; further, functional recovery during the stay in the PACU followed a linear pattern.<sup>17,26,27</sup> Neither should the impairment in spirometric performance be blamed on a lack of cooperation, as all patients were alert and fully compliant within 20 min of extubation and pain had been minimized in the postoperative course. Again, lack of cooperation and insufficient pain management should affect the whole study population to a comparable degree.<sup>28</sup>

Our data suggest that a perioperative low-oxygen strategy during minor peripheral surgery is advantageous for postoperative oxygen saturation in moderately obese adults, although the absolute values differed within only a percentage point. We also found some evidence of greater mean lung volumes with the low-oxygen strategy; in particular, the MEF 25 values indicate a possible effect on small airway collapse. Lower perioperative oxygen concentrations during general anaesthesia appear to become more important as BMI increases; the high-oxygen group showed a linear decrease in postoperative lung function with increasing BMI, a relationship not seen in the low-oxygen group. However, neither study group showed any correlation between lung function and BMI immediately after extubation. Absolute lung function values differed within 10 percentage points between the study groups, a small effect which could nevertheless become important in morbidly obese patients or during major surgery.

Generous perioperative oxygen delivery is common, on the grounds of offering an adequate oxygen reserve in the event of airway difficulties, also possibly improving wound healing, and reducing perioperative tachycardia and the incidence of postoperative nausea and vomiting.<sup>13,14,29–31</sup> It is still unclear whether these effects are a function of supplemental postoperative oxygen administration or an intraoperative high oxygen supply. The

negative effects of oxygen cannot be denied<sup>32</sup> – atelectasis is a problem and may predispose to pulmonary complications, especially in the obese.<sup>33–35</sup> The positive effect of an adaptive low-oxygen strategy on postoperative lung function and saturation is clear; whether this has any clinical relevance is not clear. Edmark *et al.*<sup>15</sup> showed that an intraoperative  $f_{iO_2}$  of 0.8 almost completely prevented the occurrence of atelectasis. This concentration might constitute a suitable compromise between auxiliary oxygen supply and prevention of atelectasis.<sup>36</sup> Further studies with a larger study population are needed; as far as our findings go, we suggest that the decision regarding oxygen concentration be made on an individual basis; we cannot yet recommend unlimited use of a low-oxygen strategy.

### Limitations

No critical desaturation occurred in any patient, which suggests that both study populations had adequate oxygen reserves during anaesthesia. We selected patients with only moderate obesity, that is, BMI 25–35, scheduled for minor peripheral surgery, and without predictable intubation difficulties. We excluded patients with respiratory [e.g. chronic obstructive pulmonary disease (COPD) or asthma] or heart diseases (e.g. heart failure or cardiovascular disease) and avoided operations with abdominal insufflations and head-down tilt. Patients with gastroesophageal reflux disease or a hiatus hernia were excluded. We did not measure waist-to-hip ratios, or FRC and expiratory residual volume (ERV), which are particularly impaired when BMI increases. Thus, the interpretation of our MEF values must be handled cautiously as we see some inhomogeneity.

Our findings do not allow us to conclude that a low-oxygen strategy should become standard for these cases, nor can we draw conclusions about the impact of small airway collapse on respiratory complications. We did not perform any intraoperative recruitment manoeuvres to counteract atelectasis formation,<sup>37</sup> although PEEP was applied. The primary aim of our study, to examine the effects of a lower than usual inspired oxygen concentration during anaesthesia, showed that this is safe in the type of obese patients we selected. We were particularly interested in spirometric lung volumes during the postoperative period when the impact of surgical trauma and anaesthesia are likely to peak and trigger postoperative pulmonary morbidity; clearly, the low-oxygen strategy was successful here.

### References

- 1 Hedenstierna G. Alveolar collapse and closure of airways: regular effects of anaesthesia. *Clin Physiol Funct Imaging* 2003; **23**:123–129.
- 2 Rothen HU, Sporre B, Engberg G, *et al.* Airway closure, atelectasis and gas exchange during general anaesthesia. *Br J Anaesth* 1998; **81**:681–686.
- 3 Moller JT, Johannessen NW, Berg H, *et al.* Hypoxemia during anaesthesia – an observer study. *Br J Anaesth* 1991; **66**:437–444.

- 4 Lindberg P, Gunnarsson L, Tokics L, *et al.* Atelectasis and lung function in the postoperative period. *Acta Anaesthesiol Scand* 1992; **36**:546–553.
- 5 Rothen HU, Sporre B, Engberg G, *et al.* Prevention of atelectasis during general anaesthesia. *Lancet* 1995; **345**:1387–1391.
- 6 Rothen HU, Sporre B, Engberg G, *et al.* Atelectasis and pulmonary shunting during induction of general anaesthesia – can they be avoided? *Acta Anaesthesiol Scand* 1996; **40**:524–529.
- 7 Tokics L, Strandberg A, Brismar B, *et al.* Computerized-tomography of the chest and gas-exchange measurements during ketamine anesthesia. *Acta Anaesthesiol Scand* 1987; **31**:684–692.
- 8 Kabon B, Nagele A, Reddy D, *et al.* Obesity decreases perioperative tissue oxygenation. *Anesthesiology* 2004; **100**:274–280.
- 9 Fleischmann E, Kurz A, Niedermayr M, *et al.* Tissue oxygenation in obese and nonobese patients during laparoscopy. *Obes Surg* 2005; **15**:813–819.
- 10 Damia G, Mascheroni D, Croci M, Tarenzi L. Perioperative changes in functional residual capacity in morbidly obese patients. *Br J Anaesth* 1988; **60**:574–578.
- 11 Von Ungern-Sternberg BS, Regli A, Schneider MC, *et al.* Effect of obesity and site of surgery on perioperative lung volumes. *Br J Anaesth* 2004; **92**:202–207.
- 12 Benoit Z, Wicky S, Fischer JF, *et al.* The effect of increased FIO<sub>2</sub> before tracheal extubation on postoperative atelectasis. *Anesth Analg* 2002; **95**:1777–1781.
- 13 Greif R, Akca O, Horn EP, *et al.* Supplemental perioperative oxygen to reduce the incidence of surgical-wound infection. *N Engl J Med* 2000; **342**:161–167.
- 14 Belda FJ, Aguilera L, de la Asuncion JG, *et al.*, Spanish Reduccion de la Tasa de Infeccion Quirurgica Group. Supplemental perioperative oxygen and the risk of surgical wound infection – a randomized controlled trial. *JAMA* 2005; **294**:2035–2042.
- 15 Edmark L, Kostova-Aherdan K, Enlund M, Hedenstierna G. Optimal oxygen concentration during induction of general anaesthesia. *Anesthesiology* 2003; **98**:28–33.
- 16 Treschan TA, Zimmer C, Nass C, *et al.* Inspired oxygen fraction of 0.8 does not attenuate postoperative nausea and vomiting after strabismus surgery. *Anesthesiology* 2005; **103**:6–10.
- 17 Eikermann M, Groeben H, Hüsing J, Peters J. Accelerometry of adductor pollicis muscle predicts recovery of respiratory function from neuromuscular blockade. *Anesthesiology* 2003; **98**:1333–1337.
- 18 Gudmundson G, Cerveny M, Shasby DM. Spirometric values in obese individuals, effect on body position. *Am J Respir Crit Care Med* 1997; **155**:998–999.
- 19 Standardized lung function testing. Official statement of the European Respiratory Society. *Eur Respir J Suppl* 1993; **16**:1–100.
- 20 White PF, Song D. New criteria for fast-tracking after outpatient anaesthesia: a comparison with the modified Aldrete's scoring system. *Anesth Analg* 1999; **88**:1069–1072.
- 21 Eichenberger A, Proietti S, Wicky S, *et al.* Morbid obesity and postoperative pulmonary atelectasis: an underestimated problem. *Anesth Analg* 2002; **95**:1788–1792.
- 22 Thomas EJ, Goldman L, Mangione CM, *et al.* Body mass index as a correlate of postoperative complications and resource utilization. *Am J Med* 1997; **102**:277–283.
- 23 Neumann P, Rothen HU, Berglund JE, *et al.* Positive end-expiratory pressure prevents atelectasis during general anaesthesia even in the presence of a high inspired oxygen concentration. *Acta Anaesthesiol Scand* 1999; **43**:295–301.
- 24 Pelosi P, Ravagnan I, Giurati G, *et al.* Positive end-expiratory pressure improves respiratory function in obese but not in normal subjects during anaesthesia and paralysis. *Anesthesiology* 1999; **91**:1221–1231.
- 25 Ungern-Sternberg BS, Regli A, Reber A, Schneider MC. Comparison of perioperative spirometric data following spinal or general anaesthesia in normal-weight and overweight gynaecological patients. *Acta Anaesthesiol Scand* 2005; **49**:940–948.
- 26 Baillard C, Clec'h C, Catineau J, *et al.* Postoperative residual neuromuscular block: a survey of management. *Br J Anaesth* 2005; **95**:622–626.
- 27 Debaene B, Plaud B, Dilly MP, Donati F. Residual paralysis in the PACU after a single intubating dose of nondepolarizing muscle relaxant with an intermediate duration of action. *Anesthesiology* 2003; **98**:1042–1048.
- 28 Awad IT, Chung F. Factors affecting recovery and discharge following ambulatory surgery. *Can J Anaesth* 2007; **54**:243–244.

- 29 Goll V, Akca O, Greif R, *et al.* Odansetron is no more effective than supplemental intraoperative oxygen for prevention of postoperative nausea and vomiting. *Anesth Analg* 2001; **92**:112–117.
- 30 Stausholm K, Kehlet H, Rosenberg J. Oxygen therapy reduces postoperative tachycardia. *Anaesthesia* 1995; **50**:737–739.
- 31 Rosenberg-Adamsen S, Lie C, Bernhard A, *et al.* Effect of oxygen treatment on heart rate after abdominal surgery. *Anesthesiology* 1999; **90**:380–384.
- 32 Kabon B, Kurz A. Optimal perioperative oxygen administration. *Curr Opin Anaesthesiol* 2006; **19**:11–18.
- 33 Warner DO. Preventing postoperative pulmonary complications: the role of the anesthesiologist. *Anesthesiology* 2000; **92**:1467–1472.
- 34 Magnusson L, Zemgulis V, Wicky S, *et al.* Atelectasis is a major cause of hypoxemia and shunt after cardiopulmonary bypass: an experimental study. *Anesthesiology* 1997; **87**:1153–1163.
- 35 Griffin SM, Shaw IH, Dresner SM. Early complications after Ivor Lewis subtotal esophagectomy with two-field lymphadenectomy: risk factors and management. *J Am Coll Surg* 2002; **194**:285–297.
- 36 Akca O, Podolsky A, Eisenhuber E, *et al.* Comparable postoperative pulmonary atelectasis in patients given 30% or 80% oxygen during and 2 h after colon resection. *Anesthesiology* 1999; **91**:991–998.
- 37 Halter JM, Steinberg JM, Schiller HJ, *et al.* Positive end-expiratory pressure after a recruitment maneuver prevents both alveolar collapse and recruitment/derecruitment. *Am J Respir Crit Care Med* 2003; **167**:1620–1626.