DOI: 10.1093/bja/aeh046

BJA

Effect of obesity and site of surgery on perioperative lung volumes

B. S. von Ungern-Sternberg*, A. Regli, M. C. Schneider, F. Kunz and A. Reber

Department of Anaesthesia, University of Basel/Kantonsspital, CH-4031 Basel, Switzerland

**Corresponding author. E-mail: bvonungern@uhbs.ch*

Background. Although obese patients are thought to be susceptible to postoperative pulmonary complications, there are only limited data on the relationship between obesity and lung volumes after surgery. We studied how surgery and obesity affect lung volumes measured by spirometry.

Methods. We prospectively studied 161 patients having either breast surgery (Group A, *n*=80) or lower abdominal laparotomy (Group B, *n*=81). Premedication and general anaesthesia were standardized. Spirometry was measured with the patient supine, in a 30° head-up position. We measured vital capacity (VC), forced vital capacity, peak expiratory flow and forced expiratory volume in 1 s at preoperative assessment (baseline), after premedication (before induction of anaesthesia) and 10–20 min, 1 h and 3 h after extubation.

Results. Baseline spirometric values were all within the normal range. All perioperative values decreased significantly with increasing body mass index (BMI). The greatest reduction of mean VC (expressed as percentage of baseline values) occurred after extubation, and was more marked after laparotomy than after breast surgery (23 (SD 14)% *vs* 20 (14)%). Considering patients according to BMI (<25, 25–30, >30), VC decreased after surgery by 12 (7)%, 24 (8)% and 40 (10)%, respectively. VC recovered more rapidly in Group A.

Conclusion. Postoperative reduction in spirometric volumes was related to BMI. Obesity had more effect on VC than the site of surgery.

Br J Anaesth 2004; **92**: 202–7

Keywords: anaesthesia; complications, obesity; lung, respiratory function; monitoring, spirometry; pharmacokinetics, body mass index

Accepted for publication: August 20, 2003

About one third of the population of industrial countries are at least 20% overweight and the prevalence of obesity is increasing.[1] Obese patients have reduced respiratory function[2] and are considered to be more likely to develop postoperative pulmonary complications.[3 4] General anaesthesia and surgery reduce lung volumes and this effect may be greater in the obese.[2 5 6]

Clinically, obese patients appear to have worse respiratory function after surgery but only limited data show that obesity causes reduced lung volumes after surgery.[3 7] In normal subjects the site of surgery affects respiratory function: impairment is greater after abdominal surgery than after non-abdominal surgery.[6 8] Since there are no studies assessing the influence of body mass index (BMI) and the site of surgery on perioperative lung volumes, we carried out the present study.

We considered that patients with a normal BMI (<25) would be less affected compared with obese patients (BMI>30) who would be more affected. We performed perioperative spirometry in non-obese and obese patients undergoing lower abdominal surgery or breast surgery.

Material and methods

Study population

The study was approved by the Ethics Committee of the University of Basel, Switzerland. Informed written consent was obtained from each patient before inclusion. We studied 161 women (ASA physical status I–II) scheduled for either breast surgery (Group A, *n*=80) or lower abdominal laparotomy with a transverse incision (Group B, *n*=81).

We excluded patients who were pregnant, those who had bronchial asthma requiring regular therapy, cardiac disease associated with dyspnoea >NYHA II, or severe psychiatric disorders. The expected duration of surgery was 90–150 min.

Anaesthesia

Premedication consisted of oral midazolam 7.5 mg, 30–60 min before surgery. General anaesthesia was standardized and induced with propofol 2 mg kg^{-1} and fentanyl 2 μg kg^{-1} i.v. Tracheal intubation was facilitated by atracurium 0.5 mg kg^{-1} i.v. A laryngeal mask was not used. Anaesthesia was maintained with nitrous oxide 66% in oxygen and propofol by infusion using the Bristol formula (10 mg kg^{-1} h^{-1} for the first 10 min of general anaesthesia, 8 mg kg^{-1} h^{-1} for another 10 min and thereafter 6 mg kg^{-1} h^{-1} or adjusted to individual needs).[9] Ventilation was controlled using an ADU ventilator (Datex Ohmeda, S/5 ADU Helsinki, Finland) with a circle system. Repeated doses of fentanyl were given during surgery as necessary based on clinical signs (heart rate, arterial pressure, pupil size and sweating) but not within 30–60 min of the estimated end of the operation. To have the patient fully alert and compliant for spirometry, we substituted sevoflurane for propofol 30–60 min before the estimated end of surgery as this was considered, on the basis of clinical observations, to give more rapid recovery. Increments of atracurium 5 mg i.v. were given to maintain muscle relaxation, which was monitored by train-of-four (TOF) stimulation. Neostigmine 2.5 mg and glycopyrrolate 0.5 mg were given i.v. as needed to antagonize neuromuscular block. Before extubation, four equal twitches in the TOF without tetanic fade (50 Hz over 5 s) were required, as well as recovery of consciousness (eye opening on demand), protective airway reflexes and adequate spontaneous ventilation.

For postoperative pain relief, we gave methadone 2 mg i.v. to achieve a pain score of ⩽20 mm while coughing, assessed on the 100 mm visual analogue scale (VAS; where 0 mm represented no pain or no dyspnoea and l00 mm was worst possible pain or dyspnoea). The total dose of methadone given to each patient was neither limited nor weight adjusted. Basic analgesia consisted of paracetamol 1000 mg rectally or orally every 6 h starting directly after the operation. We did not administer any local anaesthetic into the wound.

Spirometry

Before the operation we measured the weight and height of each patient to obtain the exact BMI. A vitalograph (Vitalograph 2120, Vitalograph, Hamburg, Germany) was used for spirometric measurements. Measurements were made with the patient in a 30° head-up position.[10] After a thorough demonstration of the correct use during the preanaesthetic visit, spirometry was measured and taken as baseline (T_0). When the patient arrived in the operating theatre (30–60 min after premedication), spirometry was repeated before induction of anaesthesia (T_1). After extubation, as soon as the patient was alert and fully cooperative, pain and dyspnoea were assessed using the VAS before and, if necessary, after analgesic (methadone) was given. As soon as a VAS pain score ⩽20 mm was achieved (all patients within 20 min of extubation), spirometry was performed for the third time (T_2). We use the VAS routinely to score pain and dyspnoea in our clinical practice in the postanaesthetic care unit. Spirometric measurements were repeated in the postanaesthetic care unit 1 h (T_3) and 3 h (T_4) after extubation. Methadone dosage was recorded at each assessment.

We measured vital capacity (VC), forced vital capacity (FVC), forced expiratory volume in 1 s (FEV_1) and peak expiratory flow (PEF) and calculated the FEV_1/FVC ratio. At each measurement time, two spirometry manoeuvres were done, one for VC and the other for FVC, PEF and FEV_1; each was done at least three times to meet the European Respiratory Society (ERS) criteria for reproducibility[11] and the best measurement was recorded. For VC, the patient was asked to inhale fully and then exhale slowly but completely. For FVC, PEF and FEV_1, the patient was asked to expire as forcefully as possible.

Statistical analysis

To allow comparison between the patients and the two groups, the values were calculated as percentage change from the value measured at baseline (preoperative assessment). We used repeated-measures analysis of variance (ANOVA) to compare data within groups. We used a Wilcoxon rank sum test to compare measurements between the groups. A Bonverroni test was used for *post hoc* comparisons. The Spearman rank correlation test was used to assess the relationship between spirometric measurements and BMI. $P<0.05$ was considered significant. For statistical calculations, we used StatView for windows (SAS Institute Inc., Cary NC, USA, Version 5.0.1).

Results

We recruited 187 women. In eight, the planned surgery was altered, 13 patients declined to continue, and measurements were unsatisfactory in five. We therefore present data for 161 patients (Table 1). The patients with unsatisfactory spirometric measurements did not differ in age or weight from those with acceptable measurements, and they did not have extreme values of BMI. The distribution of non-smokers between the groups was similar with 59 (74%) in Group A and 60 (74%) in Group B. The smokers (2–15 pack-years) were evenly distributed over the BMI range, with a minor tendency towards smaller BMI. Antagonism of muscle relaxation was necessary in only three patients in

Table 1 Details of patients. Data are median (range) for age, or median (interquartile range)

Breast surgery (*n*=80)		**Laparotomy (*n*=81)**	
Lumpectomy	56	Hysterectomy	72
Mastectomy (without pectoralis muscle)	24	Hysterectomy + salpingo-oophorectomy	9
Age (yr)	55 (18–90)		48 (23–90)
Height (cm)	173 (8)		172 (9)
Weight (kg)	75 (27)		73 (27)
BMI	25 (8)		25 (7)

Table 2 Absolute and relative values of vital capacity (VC), forced vital capacity (FVC), forced expiratory flow rate in 1 s (FEV_1) and peak expiratory flow (PEF) for patients undergoing breast surgery (Group A) and laparotomy (Group B). Data are mean (SD). T_0, baseline (preoperative) value; *significant difference between groups (ANOVA)

	VC		**FVC**		**FEV_1**		**PEF**	
Group	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**
Baseline (T_0)	2.8 (0.6)	3.2 (0.6)*	2.8 (0.5)	3.1 (0.6)*	2.4 (0.5)	2.7 (0.5)*	345 (62.9)	374 (53.1)*
Premedication (T_1)	2.7 (0.6)	3.0 (0.6)*	2.6 (0.5)	2.9 (0.6)*	2.2 (0.5)	2.5 (0.5)*	325 (61.8)	352 (51.7)*
% decrease from T_0	5 (6)	5 (5)	6 (6)	5 (5)	6 (5)	6 (5)	6 (7)	6 (5)
After surgery (T_2)	2.3 (0.6)	2.5 (0.7)*	2.2 (0.6)	2.4 (0.7)*	1.9 (0.6)	2.0 (0.6)	273 (69.7)	279 (58.5)
% decrease from T_0	20 (14)	23 (14)*	21 (14)	23 (14)*	22 (14)	24 (14)*	21 (13)	26 (12)*
1 hr (T_3)	2.4 (0.6)	2.6 (0.7)*	2.3 (0.6)	2.5 (0.7)*	2.0 (0.5)	2.1 (0.6)	289 (66.5)	284.3 (57.0)
% decrease from T_0	15 (10)	20 (13)*	16 (10)	20 (13)*	16 (11)	21 (13)*	17 (11)	24 (12)*
3 h (T_4)	2.6 (0.6)	2.7 (0.7)	2.5 (0.6)	2.6 (0.6)	2.1(0.5)	2.2 (0.6)	306 (65.8)	296 (59.4)*
% decrease from T_0	10 (9)	16 (13)*	11 (10)*	17 (13)*	11 (9)	17 (13)*	12 (10)	21 (13)

each group. All patients met the extubation criteria completely. The duration of surgery was 120 (SD 18) min and the maximum 150 min.

Vital capacity

The baseline VC values were all within the normal range (Table 2). After premedication, the values decreased by 5 (5)% in both groups (Table 2, Fig. 1). The decrease was greater in those with a greater BMI, although the effect in normal-weight patients was minimal (Table 3). In both groups, the greatest decrease was directly after extubation (Group A: 20 (14)%; Group B: 23 (14)%; Table 2). Laparotomy caused a significantly greater decrease in VC and recovery was slower than after breast surgery (10 (9)% *vs* 16 (13)% in Groups A and B, respectively, 3 h after surgery; Table 2, Fig. 2). At each postoperative measurement time there was a significant negative correlation between BMI and VC (Table 3 and Fig. 2).

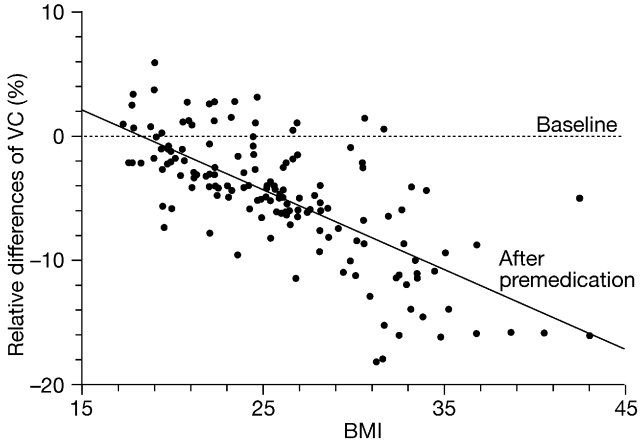

Fig 1 Percentage change in vital capacity (VC) in all 161 patients in relation to BMI after premedication (r=–0.703, P<0.001).

Other spirometric values

The baseline values for all other variables (FVC, FEV_1 and PEF) were within the normal ranges. During the perioperative period they changed in parallel with VC (Table 2). The FEV_1/FVC ratio did not change in either group throughout the study period.

Pain scores and pain relief

There were no differences in pain score between the two groups when spirometry was performed. In both groups, a maximum VAS for pain value of 20 mm was recorded and a comparable dose of methadone was administered directly after extubation (0.78 (1.3) mg in Group A and 0.96 (1.2) mg in Group B). However, at 1 and 3 h after extubation, the doses of methadone given to the patients after laparotomy were significantly greater than those given after breast surgery: 4.2 (2.2) mg *vs* 2.7 (1.9) mg and 4.4 (2.6) mg *vs* 2.8 (2.1) mg, respectively (P<0.001). The total amounts of methadone given during the first 3 h after surgery were 9.6 (3.3) mg *vs* 6.3 (3.5) mg for groups A and B, respectively (P<0.001). None of the patients complained of dyspnoea.

Discussion

Baseline spirometric values in non-obese and obese patients

The excess body fat in obese patients affects chest wall mechanics. The compliance of the respiratory system is less (mass loading)[5 12] and lung volumes such as FRC and VC are reduced. Although VC increases in parallel with the BMI within the normal weight range, VC decreases progressively in more obese patients.[12–15] The effect of obesity on other spirometric measurements is less clear.

Our initial spirometric measurements were in line with these observations: they were within the normal ranges for non-obese and for obese patients. There were no signs of airway obstruction as FEV_1 and the FEV_1/FVC ratio were not, or only minimally, influenced by obesity.[16] The values obtained in the group scheduled for breast surgery were lower than in the group scheduled for laparotomy, which could be explained by their greater age, as VC decreases with age.[17] To compare the groups, we used percentage change from baseline.

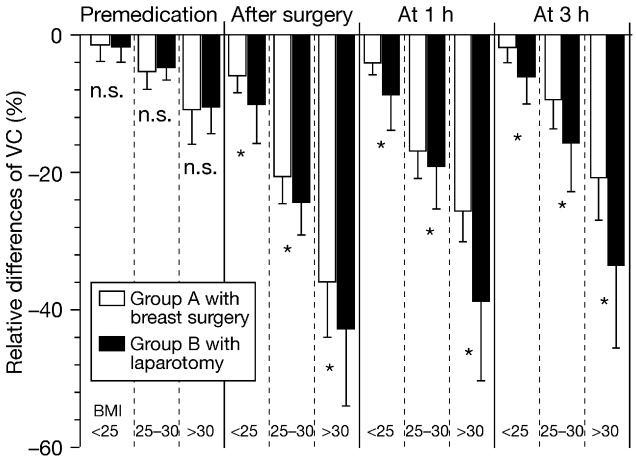

Fig 2 Differences (%) in vital capacity (VC) between the groups according to BMI. Group A *vs* Group B: **P*<0.05; n.s.=not significant

Effect of premedication

Premedication reduced VC, with no significant difference between the groups scheduled for breast surgery or laparotomy. We found, unexpectedly, that this reduction in VC was related to BMI. Normal-weight patients showed a minimal effect compared with obese patients (BMI >30; 10% decrease, Table 3). There was, however, a comparatively wide range of individual responses to premedication (Fig. 2).

Premedication may affect the activity of the respiratory muscles. VC is a good index of respiratory muscle strength in patients with neuromuscular disorders.[18 19] Benzodiazepines have a spinally mediated muscle relaxant effect that can affect the respiratory muscles,[20] so premedication could affect respiration. Obese patients might be more affected by these agents because they have a greater work of breathing.[12] Another explanation could be that sedation by midazolam interfered with the performance of spirometry, although completely reproducible tracings at all measurements were obtained for all patients. This effect should have affected both obese and non-obese patients equally.

The finding that VC was markedly reduced in obese patients after premedication with benzodiazepines might imply that these patients should receive supplemental oxygen before the operation.

Anaesthesia and immediate postoperative respiratory function

In our study, the smallest spirometric values were found immediately after extubation. The decrease in VC, FVC, FEV_1 and PEF followed the same trends (Table 2), and the FEV_1/FVC ratio did not change. This suggests a restrictive pattern of respiratory compromise in the postoperative period, which has been described previously.[6 21–23]

The postoperative impairment of respiratory function was probably not caused by insufficient cooperation, since all patients were alert and fully compliant within 10–20 min of extubation and produced normal spirometric tracings that completely met the ERS criteria.[11] Adequate patient cooperation was achieved by strictly following a

Table 3 Absolute values and changes of vital capacity (VC) for patients undergoing breast surgery (Group A) or laparotomy (Group B) according to BMI. Data are mean (SD). T_0, baseline (preoperative) value. All differences between BMI <25 and >30 were statistically signifcant (ANOVA)

	Group A			**Group B**			**A + B**		
BMI	**<25**	**25–30**	**>30**	**<25**	**25–30**	**>30**	**<25**	**25–30**	**>30**
n	**37**	**22**	**21**	**42**	**24**	**15**	**161**	**161**	**161**
Baseline (T_0)	2.9 (0.5)	2.9 (0.7)	2.7 (0.5)	3.2 (0.6)	3.2 (0.5)	3.0 (0.6)	3.1 (0.5)	3.0 (0.6)	2.8 (0.6)
Premedication (T_1)	2.9 (0.5)	2.7 (0.7)	2.4 (0.6)	3.1 (0.5)	3.0 (0.5)	2.8 (0.6)	3.0 (0.5)	2.9 (0.6)	2.5 (0.6)
% decrease from T_0	2 (4)	6 (3)	11 (5)	2 (2)	5 (2)	9 (5)	2 (3)	5 (3)	10 (5)
After surgery (T_2)	2.7 (0.5)	2.3 (0.6)	1.6 (0.5)	2.8 (0.6)	2.3 (0.5)	1.8 (0.5)	2.7 (0.5)	2.3 (0.5)	1.7 (0.5)
% decrease from T_0	10 (5)	21 (4)	39 (10)	13 (8)	27 (10)	43 (11)	12 (7)	24 (8)	40 (10)
1 h (T_3)	2.7 (0.4)	2.4 (0.6)	1.9 (0.5)	2.9 (0.6)	2.5 (0.5)	1.9 (0.6)	2.8 (0.5)	2.4 (0.5)	1.9 (0.5)
% decrease from T_0	7 (4)	17 (4)	28 (7)	11 (7)	23 (8)	38 (12)	9 (6)	20 (7)	32 (11)
3 h (T_4)	2.8 (0.4)	2.6 (0.7)	2.1 (0.5)	3.0 (0.6)	2.6 (0.5)	2.0 (0.6)	2.9 (0.5)	2.6 (0.6)	2.0 (0.5)
% decrease from T_0	4 (3)	9 (4)	23 (8)	8 (7)	19 (9)	33 (12)	6 (6)	15 (9)	27 (11)

standardized anaesthetic regimen based on short-acting anaesthetic agents, a prerequisite for collecting representative data.

The reduced spirometric volumes in our study may have been caused by impaired respiratory mechanics as well as atelectasis formation promoted by general anaesthesia in the supine position.[24–27] A reduction in VC could be caused by a reduction in both inspiratory and expiratory reserve volumes.[23 28] A reduced inspiratory capacity could reduce the ability to cough effectively and may predispose to respiratory complications.[3 6 23]

BMI and immediate postoperative respiratory function

Data on the impairment of postoperative respiratory function in obese patients were previously sparse. There are two small studies[3 7] but no controlled clinical trials and none relate the changes of postoperative lung volumes to obesity. We found a strong negative correlation between lung volumes and BMI: the smallest values of VC occurred in grossly obese patients (BMI>30) 20 min after extubation compared with non-obese patients (BMI<25) (reduction in VC 41% *vs* 11%, Table 3). The greatest decline in postoperative lung volumes occurred in patients with BMI>40 (Groups A and B, 51 (5)%). Three h after extubation, patients of normal weight had only a small residual reduction in lung volumes or had made a complete recovery whereas obese patients still had significantly smaller lung volumes (reduction in VC 6% *vs* 28%) irrespective of the site of surgery.

As the expiratory reserve volume is reduced in obese patients, obesity is associated with a decrease in FRC and VC[2 12 16] and thus an enhanced response to general anaesthesia compared with normal-weight patients.[5] Obesity predisposes to the formation of atelectasis *per se* and even more so after induction of general anaesthesia,[29] which could significantly reduce postoperative lung volumes. Our findings support previous small studies investigating the effects of BMI on lung volumes;[3 6 7 24–27] most of them, however, did not start their measurements before the first postoperative day.

Site of surgery, postoperative pain and respiratory function

In studies of non-obese patients, the magnitude of the reduction in VC, tidal volume and FRC is related to the site of surgery. Ali and colleagues[6] reported that abdominal surgery resulted in a greater reduction of VC than superficial surgery (42% *vs* 29%) 4 h after the operation, and Diament and Palmer[8] observed a larger reduction of FVC after lower abdominal surgery than after non-abdominal surgery (25% *vs* 8%) on the first day after surgery. In our study, the reduction in VC was more pronounced after laparotomy than after breast surgery but not as marked as in other studies, although in those studies there was a longer time between surgery and spirometry.[6 7 23 30] In those studies, the decrease in lung volume was thought to be related to pain and abdominal muscle spasm. The greater impairment of postoperative respiratory function in these studies might be that shorter acting anaesthetic agents and pain relief given according to VAS scores were not used in these earlier studies.[31] It is crucial for a patient to be as free from pain as possible during spirometry and to be as close to the preoperative baseline conditions, in order to avoid factors that affect test performance. Nevertheless, in our study, even though VAS scores <20 mm were achieved while coughing in obese and non-obese patients, differences in nociception (visceral compared with somatic pain) might still have caused some differences in lung volumes. The greater sedation from larger doses of methadone required for analgesia after laparotomy might have interfered with spirometry, despite meeting the ERS criteria. Even assuming such an effect, this should have affected obese and normal-weight patients equally, as when midazolam was used as premedication. Other body changes caused by surgery, anaesthesia and postoperative analgesia may also have meant that laparotomy had a greater effect on respiratory function.[32]

Duration of observation of the perioperative respiratory function

In contrast to most other studies of the later postoperative period,[6–8 28 33] we focused on the immediate postoperative period when lung volumes could be most severely affected. We limited the observation period to 3 h, corresponding to the time patients stay in our postanaesthetic care unit. The patients were mobilized in the unit immediately before discharge to the ward where further mobilization was encouraged, as this improves postoperative lung function.[34] No patients developed pulmonary complications during the first 24 h.

We did not assess the effect of the duration of surgery on postoperative respiratory function. Respiratory function could possibly be more affected after longer surgical procedures.

We conclude that premedication with midazolam caused a moderate reduction of lung volumes, more in the obese. Postoperative respiratory function was significantly more impaired in obese patients. Respiratory impairment after laparotomy persisted well into the recovery period and was more pronounced than after breast surgery. In non-obese patients, impairment of lung function after surgery was minor and independent of the site of operation. Obesity impaired lung volumes more than the effect of surgery.

Acknowledgements

The authors are indebted to the recovery room nurses for their great help. The authors also thank J. Etlinger for editorial assistance. This study was

supported by the Department of Anaesthesia, University of Basel/ Kantonsspital, Basel, Switzerland.

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