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Tissue Oxygenation in Obese and Non-obese Patients During Laparoscopy

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Abstract

Background: Wound infection risk is inversely related to subcutaneous oxygenation, which is reduced in obese patients and may be reduced even more during laparoscopic procedures.

Methods: We evaluated subcutaneous tissue oxygenation (PsqO₂) in 20 patients with a body mass index (BMI) ≥ 40 kg·m⁻² (obese) and 15 patients with BMI < 30 kg·m⁻² (non-obese) undergoing laparoscopic surgery with standardised anaesthesia technique and fluid administration. Arterial oxygen tension was maintained near 150 mmHg. PsqO₂ was measured from a surrogate wound on the upper arm. Data were analyzed with unpaired two-tailed *t* or Wilcoxon rank-sum tests; *P* < 0.05 was statistically significant. Data are given as mean (SD).

Results: An FIO₂ of 51% (13%) was required in obese patients to reach an arterial oxygen tension of 150 mmHg; however, an FIO₂ of only 40% (7%) was required to reach the same oxygen tension in non-obese patients (*P*=0.007). PsqO₂ was significantly less in obese patients: 41 (10) vs. 57 (15) mmHg (*P*<0.001).

Conclusion: Obesity reduces the amount of inspired oxygen required to obtain a given arterial partial pressure and tissue oxygenation. Both factors probably contribute to high infection risk in obese patients.

Keywords

Anesthesia; Tissue oxygenation; Infection; Surgery; Wound infection; Obesity

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Obesity is a major risk factor for surgical site infection and contributes to a high morbidity and mortality in the obese population. In a recent study (1), perioperative tissue oxygen tension was found to be less in morbidly obese than in lean patients undergoing open abdominal surgery. As tissue oxygen tension is a major predictor for postoperative wound infections reduced oxygenation might contribute to the observed higher risk of wound infection rate in obese patients (2)

Over the past ten years laparoscopic surgery has replaced open procedures for many indications in the morbidly obese as well as the general population (3). Proven advantages of laparoscopic surgery are similar in lean and obese patients and include shorter duration of hospitalisation, decreased pain, reduced risk of postoperative infection, and fewer incisional hernias (4). Specifically, the incidence of postoperative wound infections is halved in patients undergoing laparoscopic instead of open surgery (5). However the incidence of wound infections remains distressingly high in the morbidly obese.

The effects of the pneumoperitoneum on subcutaneous tissue oxygenation remain unknown. Many studies have shown a marked increase in systemic vascular resistance and after load and a decrease in cardiac output (6). Both factors are likely to decrease peripheral tissue oxygen tension. Increased intra-abdominal pressure due to pneumoperitoneum additionally reduces microcirculatory flow (7). Furthermore the hemodynamic effects of the pneumoperitoneum are likely to be even more pronounced in the morbidly obese (8-10). As obesity augments the size of individual fat cells without increasing blood flow (11,12), these hemodynamic disturbances due to the pneumoperitoneum are likely to cause more hypoperfusion in the obese than in lean patients, and thus to especially reduce tissue oxygenation (13).

We therefore measured subcutaneous tissue oxygen tension in obese and lean patients during laparoscopic procedures.

Methods

With approval of the University of Vienna Institutional Review Board and written informed consent from the patients, we recruited 35 ASA physical status I - III patients between the ages of 18-60 years undergoing elective laparoscopic surgery. Two groups were enrolled based on their calculated body mass index (weight·height⁻²): BMI ≥ 40 kg·m⁻² (obese, N=20) or < 30 kg·m⁻² (non-obese, N=15).

All patients in the obese group had silicon adjustable gastric banding surgery; those in the non-obese group had fundoplication or cholecystectomy. Exclusion criteria included documented coronary or peripheral artery disease, insulin-dependent diabetes mellitus, history of recent smoking, and any symptoms of infection or sepsis. Patients with preoperative systolic arterial blood pressure > 170 mmHg or diastolic arterial blood pressure > 90 mmHg were also excluded.

Protocol

On the morning of surgery, patients were premedicated with oral midazolam (7.5 mg). For all operations, patients were placed in the 25° reverse Trendelenburg position. Rapid sequence anaesthetic induction was performed with rocuronium (0.6 mg·kg⁻¹), propofol (2-4 mg·kg⁻¹), and fentanyl (1-3 µg·kg⁻¹). Following induction of anaesthesia, a 20-g cannula was inserted into a radial artery. A silastic tonometer was inserted into the lateral right upper arm for measurement of subcutaneous tissue oxygenation and temperature.

Inspired oxygen fraction was adjusted in all patients to reach a target arterial partial pressure of 150 mmHg; this level was maintained throughout surgery. Patients' lungs were mechanically ventilated to maintain arterial carbon dioxide tension at approximately 40 mmHg. Positive end-

expiratory pressure was set to 5 mmHg, and peak ventilatory pressure was kept less than 30 mmHg. Subsequently, anaesthesia was maintained with sevoflurane (1.0-2.0%) in oxygen and air. Sevoflurane administration was adjusted to maintain mean arterial blood pressure within 20% of the preinduction value. A supplemental bolus dose of fentanyl (50 µg) was given when heart rate or arterial pressure exceeded 120% of the baseline value. No vasoactive drugs were given.

In all patients, optimal body weight in kg was calculated according to an average normal BMI of 22.5 kg·m⁻². Ringer's lactate solution of 10 mL·m⁻¹-optimal body weight was given before induction of anaesthesia in the pre-op room. Subsequently, patients were given a maintenance dose of 10 mL·m⁻¹ of estimated optimal body weight each hour. Supplemental Ringer's lactate solution was given as necessary to maintain urine output greater than 1 mL·m⁻¹ of estimated optimal body weight per hour and a mean arterial blood pressure within 20% of baseline value. Upper-body forced air warming was used to keep patients normothermic, while local warming of the measurement site was strictly avoided.

Measurements

Demographic data, ASA Physical Status, preoperative laboratory values, and type and duration of surgery were recorded. All routine anaesthetic, respiratory, and hemodynamic variables were also recorded, as was fluid management, including urine output. Inspired oxygen, end-tidal sevoflurane, and carbon dioxide concentrations were measured during anaesthesia. Oxygen saturation was evaluated with a pulse oximeter during anaesthesia. Core temperature was measured at the distal oesophagus. Arterial blood for gas analysis was obtained as necessary to maintain intraoperative arterial oxygen partial pressure near 150 mmHg. After induction of anaesthesia, a silastic tonometer was inserted into the lateral right arm to measure subcutaneous tissue oxygenation and temperature. Following a 30-min equilibration period after reaching target PaO₂ values, intraoperative PsqO₂ in the upper arm was recorded at 5-minute intervals during surgery. The tonometer consisted of 15 cm of silastic tubing filled with hypoxic saline; 10 cm of the tubing was tunnelled subcutaneously. A Clark-type oxygen sensor and thermistor (Licox, Gesellschaft für Medizinische SONDENSYSTEME, GmbH, Kiel, Germany) were inserted into the subcutaneous portion of the tonometer, as previously described (14). Temperature sensitivity of these sensors is 0.25% per °C; thermistors were incorporated into the probes, and temperature compensation was included in the tissue oxygen tension (PsqO₂) calculations.

In vitro accuracy of the oxygen sensors is ± 3 mmHg for the range from 0 to 100 mmHg, and ± 5% for 100 to 360 mmHg (in a water bath at 37°C). Oxygen sensor calibration remains stable (within 8% of baseline value for room air) *in vivo* for at least 8 hours. The electrodes were individually factory-calibrated, but calibration was confirmed by exposing the electrode to room air (ambient PO₂ of 154 mmHg); in all cases, measurements in air were within 10% of 154 mmHg. To exclude a significant drift of the oxygen sensor, probes were again exposed to room air after each investigation. None differed by more than 10% from baseline values.

Data Analysis

Routine anaesthetic measurements were recorded at 5-min intervals, the values were first averaged for each patient during the period; these values were subsequently averaged among the patients in each group. Tissue oxygenation and related values, which were recorded at 5-min intervals throughout surgery, were subsequently averaged among the patients in each group.

Potential confounding factors and outcomes of the study were analyzed with unpaired two-tailed *t*-tests or Wilcoxon rank-sum tests as appropriate; categorical data were analyzed with

chi square tests. Results are presented as means (SDs) unless otherwise indicated; $P < 0.05$ was considered statistically significant. Analysis was conducted with SPSS software (SPSS Inc., Chicago, IL, USA, Version 12.0.1)

Results

Age and height were similar in the two groups; per protocol, there were significant differences in weight and BMI (Table 1). There were significantly more women in the obese group than in the non-obese group. Duration of surgery and pneumoperitoneum was comparable in both groups (Table 2). All patients in the obese group underwent Silicon adjustable gastric banding. In the non-obese group, 10 patients had fundoplication surgery and 5 had cholecystectomy.

Anaesthetic management, fluid replacement, urine output, blood loss, and core temperature were similar in the groups. Neither group required blood, and haemoglobin concentrations were similar in each (Table 2). Hemodynamic values were also comparable.

To reach an arterial oxygen tension of ≈ 150 mmHg, an FIO_2 of 51 (13)% was required in obese patients whereas only 40 (7)% was necessary in the non-obese patients ($P = 0.007$; Table 3). Arterial carbon dioxide (PaCO_2) partial pressure was comparable in the two groups (Table 3)

Per protocol, intraoperative arterial oxygen partial pressures were virtually identical in the obese (155 (29) mmHg) and non-obese (158 (20) mmHg) patients. However, subcutaneous oxygen partial pressure (PsqO_2 ; Table 3) was significantly less in the obese patients: 41 (10) vs. 57 (15) mmHg (Fig. 1, $P = 0.001$)

Discussion

The incidence of surgical wound infections is directly related to tissue perfusion and oxygenation (14,15). Wound repair and resistance to infection both depend on tissue oxygen tension and can potentially be improved by increasing arterial tissue oxygen tension even of fully saturated blood (15-17). The primary defence against surgical pathogens is oxidative killing by neutrophils (18,19), which critically depends on tissue oxygen tension.

Obesity, defined as a BMI exceeding $30 \text{ kg}\cdot\text{m}^{-2}$, is a major determinant of perioperative tissue oxygenation. Wound and tissue hypoxia are common in obese patients in the perioperative period and most pronounced during surgery. Even with supplemental oxygen, tissue oxygen tension in obese patients is reduced to partial pressures that are associated with a substantial increase in infection risk (1). Local factors also contribute to wound healing disturbances; for example, wound tension resulting from increased abdominal pressure may increase tissue pressure and may reduce musculofascial microperfusion especially in obese patients (20). As might thus be expected, surgical-site infections are major sources of morbidity in morbidly obese patients, leading to prolonged hospitalisation and frequent rehospitalisation.

Laparoscopic abdominal surgery is relatively safe, even in morbidly obese patients (21,22) and is associated with less tissue injury than open surgery. It is therefore unsurprising that fewer normal-weight laparoscopic patients have infectious complications (11% vs. 23%) (5). However, laparoscopic procedures are considerably more complicated in obese patients.

Pneumoperitoneum and reversed Trendelenburg position might further augment tissue hypoxia especially in obese patients whose haemodynamic situation is often already compromised (23). Whether laparoscopy reduces infection risk in obese, as it does in lean, patients remains to be determined.

The essential comparison in our study was between obese and non-obese patients. We did not directly compare open and laparoscopic procedures within our protocol since almost all bariatric surgery is performed laparoscopically at the University of Vienna. Our previous work (1) used a slightly different study design and was performed in a different institution. Nevertheless anaesthetic management was standardised in both studies; furthermore, we strictly controlled confounding factors and the investigators were the same. It is thus reasonable to informally compare the results in our current and previous (1) studies. Results were similar, with tissue partial pressures differing by 15 mmHg in obese and non-obese patients. And again consistent with our previous observations, obese patients required $\approx 11\%$ more inspired oxygen than non-obese patients to produce a comparable arterial oxygen partial pressure (51% vs. 40%). Subcutaneous tissue oxygen tension is thus substantially reduced in obese patients, but increased intra-abdominal pressure and reversed Trendelenburg position did not impair peripheral tissue oxygenation.

We recorded subcutaneous oxygen partial pressure from a needle-induced surrogate wound in the arm. This is the classical method of evaluating perioperative tissue oxygen tension and has been used in numerous previous studies (1,15,24,25). The primary benefit of this location is convenient access and the fact that measurements can be easily conducted during surgery. However the essential tissue of interest is the area of surgical manipulation. In this context it has been shown that tissue oxygen values in the subcutaneous tissue of the arm are comparable to values close to the surgical wound in the postoperative period (26,27). However, it remains to be determined if this is the case during laparoscopic procedures where increased intra-abdominal pressure might reduce local tissue perfusion and oxygenation (7).

Another limitation is that we did not obtain baseline tissue oxygen values before insufflation of the abdomen. It seems possible that baseline values before surgery were altered during insufflation. However, we cannot confirm this assertion because our recording began after establishment of pneumoperitoneum. The primary reason was that CO₂ insufflation was performed immediately after incision, an interval that was too short to establish reliable baseline values. Arterial carbon dioxide partial pressure was slightly greater in the obese patients (43 vs. 41 mmHg). Hypercapnia increases cardiac output and improves tissue oxygenation by roughly 1 mmHg per mmHg increase in arterial PCO₂ (28,29). It is unlikely that just 2 mmHg of hypercapnia had any important effect; but to the extent it did, hypercapnia would have reduced the difference between obese and non-obese patients by improving oxygenation in the obese group.

Naturally, it was impossible to assign patients randomly to the two weight groups. A consequence is that there were more women in the obese non-obese group. Currently, there are no convincing data that gender *per se* is a confounding factor for tissue oxygenation and perfusion. Nevertheless some endocrinological factors cannot be totally excluded, for example, 17 β -estradiol is known to be a vasodilator and to increase cardiac output.

Lean patients had lower core temperatures than obese patients. It is a common clinical observation that obese patients become less hypothermic during surgery than thin ones (30). However a difference in core temperature of 0.4°, while being statistically significant, is clinically unimportant.

In summary, obese patients having laparoscopic surgery required a significantly greater FIO₂ to reach an arterial oxygen tension of about 150 mmHg than did non-obese laparoscopic patients; obese patients also had significantly lower subcutaneous oxygen tensions. Obesity thus reduced tissue oxygenation by an amount that is thought to be clinically important; values in both groups were similar to those reported previously in patients undergoing open abdominal surgery.

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References

1. Kabon B, Nagele A, Reddy D, Eagon C, Fleshman JW, Sessler DI, et al. Obesity decreases perioperative tissue oxygenation. *Anesthesiology* 2004;100:274–80. [PubMed: 14739800]
2. Choban PS, Heckler R, Burge JC, Flancbaum L. Increased incidence of nosocomial infections in obese surgical patients. *American Surgeon* 1995;61:1001–5. [PubMed: 7486411]
3. Casati A, Comotti L, Tommasino C, Leggieri C, Bignami E, Tarantino F, et al. Effects of pneumoperitoneum and reverse Trendelenburg position on cardiopulmonary function in morbidly obese patients receiving laparoscopic gastric banding. *European Journal of Anaesthesiology* 2000;17:300–5. [PubMed: 10926070]
4. Lujan JA, Frutos MD, Hernandez Q, Liron R, Cuenca JR, Valero G, et al. Laparoscopic versus open gastric bypass in the treatment of morbid obesity: a randomized prospective study. *Annals of Surgery* 2004;239:433–7. [PubMed: 15024302]
5. Braga M, Vignali A, Gianotti L, Zuliani W, Radaelli G, Gruarin P, et al. Laparoscopic versus open colorectal surgery: a randomized trial on short-term outcome. *Annals of Surgery* 2002;236:759–66. [PubMed: 12454514]
6. Harris SN, Ballantyne GH, Luther MA, Perrino AC Jr. Alterations of cardiovascular performance during laparoscopic colectomy: a combined hemodynamic and echocardiographic analysis. *Anesthesia & Analgesia* 1996;83:482–7. [PubMed: 8780267]
7. Schwarte LA, Scheeren TW, Lorenz C, De Bruyne F, Fournell A. Moderate increase in intraabdominal pressure attenuates gastric mucosal oxygen saturation in patients undergoing laparoscopy. *Anesthesiology* 2004;100:1081–7. [PubMed: 15114204]
8. Gelman S, Laws HL, Potzick J, Strong S, Smith L, Erdemir H. Thoracic epidural vs balanced anesthesia in morbid obesity: an intraoperative and postoperative hemodynamic study. *Anesthesia & Analgesia* 1980;59:902–8. [PubMed: 7192509]
9. Buskirk E, Taylor HL. Maximal oxygen intake and its relation to body composition, with special reference to chronic physical activity and obesity. *Journal of Applied Physiology* 1957;11:72–8. [PubMed: 13462921]
10. Nakatsuka M. Pulmonary vascular resistance and right ventricular function in morbid obesity in relation to gastric bypass surgery. *Journal of Clinical Anesthesia* 1996;8:205–9. [PubMed: 8703455]
11. Jansson PA, Larsson A, Smith U, Lonnroth P. Glycerol production in subcutaneous adipose tissue in lean and obese humans. *Journal of Clinical Investigation* 1992;89:1610–7. [PubMed: 1569199]
12. Cheymol G. Drug pharmacokinetics in the obese. *Fundamentals of Clinical Pharmacology* 1988;2:239–56.
13. Di Girolamo M, Skinner NS Jr, Hanley HG, Sachs RG. Relationship of adipose tissue blood flow to fat cell size and number. *American Journal of Physiology* 1971;220:932–7. [PubMed: 5551149]
14. Hopf HW, Viele M, Watson JJ, Feiner J, Weiskopf R, Hunt TK, et al. Subcutaneous perfusion and oxygen during acute severe isovolemic hemodilution in healthy volunteers. *Archives of Surgery* 2000;135:1443–9. [PubMed: 11115350]
15. Greif R, Akca O, Horn EP, Kurz A, Sessler DI. Supplemental perioperative oxygen to reduce the incidence of surgical-wound infection. Outcomes Research Group. *New England Journal of Medicine* 2000;342:161–7. [PubMed: 10639541]
16. Knighton DR, Halliday B, Hunt TK. Oxygen as an antibiotic. The effect of inspired oxygen on infection. *Archives of Surgery* 1984;119:199–204. [PubMed: 6365032]
17. Jonsson K, Hunt TK, Mathes SJ. Oxygen as an isolated variable influences resistance to infection. *Annals of Surgery* 1988;208:783–7. [PubMed: 3196100]
18. Babior BM. Oxygen-dependent microbial killing by phagocytes (first of two parts). *New England Journal of Medicine* 1978;298:659–68. [PubMed: 24176]

19. Babior BM. Oxygen-dependent microbial killing by phagocytes (second of two parts). *New England Journal of Medicine* 1978;298:721–5. [PubMed: 203852]
20. Sachdev U, Murphy K, Derzie A, Jaffer S, Bleiweiss IJ, Brower S. Predictors of nonsentinel lymph node metastasis in breast cancer patients. *American Journal of Surgery* 2002;183:213–7. [PubMed: 11943113]
21. Schauer PR, Ikramuddin S, Gourash W, Ramanathan R, Luketich J. Outcomes after laparoscopic Roux-en-Y gastric bypass for morbid obesity. *Annals of Surgery* 2000;232:515–29. [PubMed: 10998650]
22. Brolin RE. Laparoscopic verses open gastric bypass to treat morbid obesity. *Annals of Surgery* 2004;239:438–40. [PubMed: 15024303]
23. Sprung J, Whalley DG, Falcone T, Warner DO, Hubmayr RD, Hammel J. The impact of morbid obesity, pneumoperitoneum, and posture on respiratory system mechanics and oxygenation during laparoscopy. *Anesthesia & Analgesia* 2002;94:1345–50. [PubMed: 11973218]
24. HopfHWHuntTKWestJMBlomquistPGoodsonWH3rdJensenJAWound tissue oxygen tension predicts the risk of wound infection in surgical patients. *Archives of Surgery* 1997;132:997-1004 discussion 05 [PubMed: 9301613]
25. Akca O, Melischek M, Scheck T, Hellwagner K, Arkilic CF, Kurz A, et al. Postoperative pain and subcutaneous oxygen tension. *Lancet* 1999;354:41–2. [PubMed: 10406365]
26. Kabon B, Fleischmann E, Treschan T, Taguchi A, Kapral S, Kurz A. Thoracic epidural anesthesia increases tissue oxygenation during major abdominal surgery. *Anesthesia & Analgesia* 2003;97:1812–7. [PubMed: 14633566]
27. Chang N, Goodson WH 3rd, Gottrup F, Hunt TK. Direct measurement of wound and tissue oxygen tension in postoperative patients. *Annals of Surgery* 1983;197:470–8. [PubMed: 6830354]
28. Akca O, Liem E, Suleman MI, Doufas AG, Galandiuk S, Sessler DI. Effect of intra-operative end-tidal carbon dioxide partial pressure on tissue oxygenation. *Anaesthesia* 2003;58:536–42. [PubMed: 12846617]
29. Akca O, Doufas AG, Morioka N, Iscoe S, Fisher J, Sessler DI. Hypercapnia improves tissue oxygenation. *Anesthesiology* 2002;97:801–6. [PubMed: 12357143]
30. Kurz A, Sessler DI, Narzt E, Lenhardt R, Lackner F. Morphometric influences on intraoperative core temperature changes. *Anesthesia & Analgesia* 1995;80:562–7. [PubMed: 7864426]

Fig. 1. Subcutaneous oxygen partial pressure in the upper arm during surgery in 20 obese and 15 non-obese patients. The open circles represent the value in each patient. The squares show the group means and 95% confidence intervals; the means differed significantly ($P = 0.001$).

Table 1.

Demographics and Morphometric Characteristics

	BMI ≥ 40 kg·m ⁻²	BMI < 30 kg·m ⁻²	P
Number	20	15	---
Age (y)	40 (11)	43 (13)	0.482
Weight (kg)	136 (19)	72 (11)	<0.001
Height (cm)	171 (11)	173 (8)	0.425
BMI (kg·m ⁻²)	46 (7)	24 (3)	<0.001
Gender (M/F)	4 / 16	10/5	0.005
Preoperative Haemoglobin (mg·dl ⁻¹)	13.8 (0.9)	14.7 (1.1)	0.017
ASA (I/II/III)	1 / 16 / 3	11 / 4 / 0	<0.001

Results presented as means (SDs) or number of patients. All *P*-values are for unpaired, two-tailed t-tests, Wilcoxon rank-sum tests, or chi-square tests except for ASA Physical Status, which was analyzed with a Fisher exact test.

Table 2.

Intraoperative Management

	BMI ≥ 40 kg·m ⁻²	BMI < 30 kg·m ⁻²	P
Mean Arterial Pressure (mmHg)	91 (11)	88 (10)	0.376
Haemoglobin (mg·dL ⁻¹)	13.0 (1.1)	13.2 (1.7)	0.482
End-tidal Sevoflurane (%)	1.6 (0.4)	1.8 (0.3)	0.092
Fentanyl (mg)	0.63 (0.19)	0.53 (0.13)	0.098
Crystalloid (mL·h ⁻¹)	904 (355)	787 (257)	0.288
Urine Output (mL·h ⁻¹)	187 (127)	101 (57)	0.110
Core Temperature (°C)	36.4 (0.3)	36.0 (0.4)	0.001
Duration of Anaesthesia (h)	2.5 (1.1)	2.7 (0.9)	0.520
Duration of Surgery (h)	1.8 (0.9)	2.0 (0.8)	0.498
Duration of Pneumoperitoneum (h)	1.3 (0.8)	1.6 (0.8)	0.232
Inspired Oxygen (%)	51 (13)	40 (7)	0.017

Three non-obese patients and one obese patient were given comparable MAC-fractions of desflurane. Results presented as means (SDs). All *P*-values are for unpaired two-sided *t*-tests or Mann-Whitney rank-sum tests as appropriate.

Table 3.

Respiratory Parameters and Tissue Oxygenation

	BMI ≥ 40 kg·m ⁻²	BMI < 30 kg·m ⁻²	P
PaO ₂ (mmHg)	155 (29)	158 (20)	0.683
PaCO ₂ (mmHg)	43 (5)	41 (4)	0.140
PsqO ₂ (mmHg)	41 (10)	57 (15)	0.001
Tsq (°C)	32.1 (1.4)	33.3 (1.5)	0.016

Results presented as means (SDs). PsqO₂ = subcutaneous tissue oxygen tension; Tsq = subcutaneous tissue temperature