Obesity Increases Perioperative Tissue Oxygenation

Barbara Kabon, M.D.,* Angelika Nagele, R.N.,† Dayakar Reddy, M.D.,† Chris Eagon, M.D.,‡ James W. Fleshman, M.D.,§ Daniel I. Sessler, M.D.,∥ Andrea Kurz, M.D.¶

Background: Obesity is an important risk factor for surgical site infections. The incidence of surgical wound infections is directly related to tissue perfusion and oxygenation. Fat tissue mass expands with a concomitant increase in blood flow per cell, which might result in a relative hypoperfusion with decreased tissue oxygenation. Consequently, the authors tested the hypothesis that perioperative tissue oxygen tensions were reduced in obese surgical patients. Furthermore, they compared the effect of supplemental oxygen administration on tissue oxygenation in obese and nonobese patients.

Methods: Forty-six patients undergoing major abdominal surgery were assigned to one of two groups according to their body mass index: body mass index less than 30 kg/m² (nonobese) or 30 kg/m² or greater (obese). Intraoperative oxygen administration was adjusted to arterial oxygen tensions of approximately 150 mmHg and approximately 300 mmHg in random order. Anesthesia technique and perioperative fluid management were standardized. Subcutaneous tissue oxygen tension was measured with a polarographic electrode positioned within a subcutaneous fat tissue compartment: the left upper arm during surgery, in the recovery room, and on the first postoperative day. Postoperative tissue oxygen was also measured adjacent to the wound. Data were compared with unpaired two-tailed t tests and Wilcoxon rank sum test; P < 0.05 was considered statistically significant.

Results: Intraoperative subcutaneous tissue oxygen tension was significantly less in the obese patients at baseline (36 vs. 57 mmHg; P = 0.002) and with supplemental oxygen administration (47 vs. 76 mmHg; P = 0.014). Immediate postoperative tissue oxygen tension was also significantly less in subcutaneous tissue of the upper arm (43 vs. 54 mmHg; P = 0.011) as well as near the incision (42 vs. 62 mmHg; P = 0.012) in obese patients. In contrast, tissue oxygen tension was comparable in each group on the first postoperative morning.

Conclusion: Wound and tissue hypoxia were common in obese patients in the perioperative period and most pronounced during surgery. Even with supplemental oxygen tissue oxygen tension in obese patients was reduced to levels that are associated with a substantial increase in infection risk.

Oxidative killing by neutrophils is the primary defense against surgical pathogens, and the risk of infection is thus inversely related to tissue oxygen partial pressure. Tissue oxygenation is especially important in the hours immediately after bacterial contamination when infections are established; this time is known as the decisive period. Factors that reduce tissue oxygenation thus augment infection risk. For example, hypothermia and smoking—each of which reduces subcutaneous tissue oxygen tension (PsqO₂)—increase the incidence of infection. Obesity is also a major risk factor for surgical site infection and contributes to high morbidity and mortality in the obese population.

Cardiac output, circulating blood volume, and resting oxygen consumption are all increased in obese persons; however, total blood flow is subnormal in relation to body weight. Obesity augments the size of individual fat cells without increasing blood flow. Fat tissue is therefore relatively hypoperfused and likely to be poorly oxygenated. Even supplemental oxygen fails to increase tissue oxygenation in hypoperfused tissues.

Therefore, we tested the hypothesis that subcutaneous tissue oxygenation is inadequate in obese surgical patients and only minimally improved by administration of supplemental oxygen.

Materials and Methods

With approval from the Institutional Review Board at Washington University in St. Louis and written informed consent, we studied 46 patients aged 18–60 yr undergoing elective major abdominal surgery involving a midline abdominal incision. Exclusion criteria included documented coronary or peripheral artery disease, insulin-dependent diabetes mellitus, recent history of smoking, and any symptoms of infection or sepsis. We also excluded patients with preoperative systolic arterial blood pressure greater than 170 mmHg or diastolic arterial blood pressure greater than 90 mmHg.

Protocol

On the basis of their calculated body mass index (BMI; weight/height²), patients were assigned in advance to two groups: BMI less than 30 kg/m² (nonobese) or 30 kg/m² or greater (obese). Every patient was evaluated at two
different intraoperative arterial oxygen partial pressure (PaO₂) values: approximately 150 mmHg and approximately 300 mmHg. The treatment order was randomly assigned, based on computer-generated codes that were maintained in sequentially numbered opaque envelopes. The inspiratory oxygen fraction was adjusted in all patients to reach target partial pressures, which were maintained for 1 h.

General anesthesia was induced with sodium thiopental (3–5 mg/kg) and fentanyl (1–3 µg/kg). Vecuronium (0.1 mg/kg) or succinylcholine (0.8–1 mg/kg) was given to facilitate tracheal intubation. Ventilation was mechanically controlled to maintain arterial carbon dioxide partial pressure (PaCO₂) at approximately 40 mmHg. Positive end-expiratory pressure was maintained at 5 mmH₂O, and peak ventilatory pressure was kept less than 30 mmH₂O. Subsequently, anesthesia was maintained with sevoflurane (1–2%) 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 (100 µg) was given when heart rate or arterial pressure increased more than 20% of the baseline value. No vasoactive drugs were given.

After induction of anesthesia, a 20-gauge cannula was inserted into a radial artery. In all patients, normal body weight in kilograms was calculated according to an average normal BMI of 22.5 kg/m². A fluid bolus of 10 ml/kg normal body weight was given before induction of anesthesia. Subsequently, patients were given a maintenance dose of 10 ml/kg estimated normal body weight each hour. In addition, blood loss was replaced with crystalloid at a 4:1 ratio or colloid at a 2:1 ratio; supplemental fluid was given as necessary to maintain urine output greater than 1 ml/kg estimated normal body weight per hour. Allogenic blood was administered as necessary to maintain a hematocrit greater than 26%. Lower-body forced-air warming was used to keep patients normothermic.

At the end of surgery, wounds were dressed with standard surgical bandages that did not apply direct pressure to the wound. Anesthesia was discontinued, and the patients’ tracheas were extubated. Oxygen was delivered via a facemask at a rate sufficient to maintain a PaO₂ of approximately 120 mmHg.

Postoperative pain was treated with intravenous morphine via a patient-controlled analgesia system. Supplemental morphine was given as necessary by nurses who were not involved in the study and were not informed of the study purpose. In the PACU, crystalloid was administered at a rate of 3.5 ml/kg estimated normal body weight per hour. Additional fluid was given as necessary to maintain a urine output of at least 1 ml/kg estimated normal body weight per hour and a mean arterial blood pressure within 20% of the baseline value. Fluid management, supplemental oxygen administration, and analgesia on the ward were managed by the surgical team.

**Measurements**

Demographic data, American Society of Anesthesiologists physical status, preoperative laboratory values, and type and duration of surgery were recorded. All routine anesthetic, respiratory, and hemodynamic variables were also recorded. Detailed records of fluid management, including urine output, were kept. Inspired oxygen, end-tidal sevoflurane, and carbon dioxide concentrations were measured during anesthesia. Oxygen saturation was measured with pulse oximeters during anesthesia and postoperative measurement periods. Intraoperative core temperature was measured in the distal esophagus (Mon-a-therm; Tyco-Mallinckrodt Anesthesiology Products, St. Louis, MO). Postoperative core temperatures were measured with tympanic membrane probes (Mon-a-therm).

Arterial pressure was monitored continuously from the arterial catheter during surgery and in the PACU; it was measured noninvasively on the first postoperative morning. Because the primary determinants of tissue oxygen availability are arterial oxygen tension, cardiac output, and local perfusion, cardiac output was measured noninvasively using the partial rebreathing Fick method (NICO; Novametrix Medical System Inc., Wallingford, CT). Arterial blood gases were obtained intraoperatively and in the PACU as necessary to maintain the target arterial oxygen pressure.

After induction of anesthesia, a silastic tonometer was inserted into the lateral left upper arm for measurement of subcutaneous tissue oxygenation and temperature. At the end of surgery, a second tonometer was inserted 2–3 cm lateral and parallel to the surgical incision. Each tonometer consisted of 15 cm of tubing filled with hypoxic saline; 10 cm of the tubing was tunneled subcutaneously. A Clark-type oxygen sensor and thermistor (Licox; Gesellschaft für Medizinische Sondensysteme, GmBH, Kiel, Germany) were inserted into the subcutaneous portion of both tonometers as previously described.²⁰

The *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). Temperature sensitivity is 0.25%/°C; thermistors are incorporated into the probes, and temperature compensation is included in the PsqO₂ calculations. Oxygen sensor calibration remains stable (within 8% of the baseline value for room air) *in vivo* for at least 8 h. The electrodes are individually factory calibrated, but calibration was confirmed by exposing the electrode to room air (ambient partial pressure of oxygen [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.

Subcutaneous oxygen tension was recorded in 10-min intervals during a 30-min measurement period following a 30-min equilibration period after reaching target PaO\textsubscript{2} values. Intraoperative PsO\textsubscript{2} was recorded from the upper arm at arterial oxygen partial pressures of 150 and 300 mmHg. Postoperative PsO\textsubscript{2} was recorded from the upper arm and adjacent to the surgical incision. Again, an equilibration period of 30 min was allowed before measurements were performed for 30 more minutes. On the first postoperative morning, baseline values were obtained from each site, with the patient breathing room air or sufficient supplemental oxygen to maintain an arterial saturation of at least 96%. Subsequently, measurements were repeated during oxygen challenge, which consisted of oxygen given at a rate of 10 l/min into a nonrebreathing facemask that provided an inspired oxygen fraction near 50%.

Data Analysis

Routine anesthetic measurements were recorded at 10-min intervals. The values were first averaged within each patient over each treatment condition (e.g., measurement period); these values were subsequently averaged among the patients in each group. Routine postoperative values were evaluated similarly. Tissue oxygenation and related values were recorded at 10-min intervals during each measurement period. Measurements were first averaged within each patient over the relevant period; these values were subsequently averaged among the patients receiving each treatment.

Potential confounding factors and outcomes of the study were analyzed with unpaired, two-sided t tests when the data were normally distributed. These results are presented as mean ± SD. Data that were not normally distributed were compared using the Wilcoxon rank sum test. These results are reported as median (25th percentile, 75th percentile). For paired comparisons, either a two-sided, paired t test or a Wilcoxon signed-rank test was used. Once again, the test used depended on the distribution of the data values. P < 0.05 was considered statistically significant.

Results

Age and height were similar in the two weight groups; there were significant differences in weight (70 ± 14 vs. 144 ± 45 kg), BMI (24 ± 4 vs. 51 ± 15 kg/m\textsuperscript{2}), and American Society of Anesthesiologists physical status classification. There were also more women in the obese group than in the nonobese group. The duration of surgery was significantly longer for the obese patients (table 1). Nearly all of the obese patients had gastric bypass surgery; among the 23 others, 17 patients underwent colorectal surgery, and 6 had gastrectomies.

### Table 1. Demographics and Morphometric Characteristics

<table>
<thead>
<tr>
<th></th>
<th>BMI ≥30 kg/m\textsuperscript{2}</th>
<th>BMI &lt;30 kg/m\textsuperscript{2}</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>23</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Age, yr</td>
<td>44 ± 9</td>
<td>44 ± 13</td>
<td>0.619</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>144 ± 45</td>
<td>70 ± 14</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Height, cm</td>
<td>166 ± 10</td>
<td>170 ± 10</td>
<td>0.253</td>
</tr>
<tr>
<td>BMI, kg/m\textsuperscript{2}</td>
<td>51 ± 15</td>
<td>24 ± 4</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>3/20</td>
<td>12/11</td>
<td>0.005</td>
</tr>
<tr>
<td>Preoperative hemoglobin, mg/dl</td>
<td>13.2 ± 1.4</td>
<td>12.7 ± 1.4</td>
<td>0.207</td>
</tr>
<tr>
<td>ASA status (I/II/III)</td>
<td>0/8/15</td>
<td>2/20/1</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Duration of anesthesia, min</td>
<td>245 (215, 300)</td>
<td>180 (155, 210)</td>
<td>0.017</td>
</tr>
<tr>
<td>Duration of surgery, min</td>
<td>195 (172, 260)</td>
<td>130 (115, 177)</td>
<td>0.004</td>
</tr>
</tbody>
</table>

Data are presented as mean ± SD, median (25th percentile, 75th percentile), or as counts for the categorical outcomes. Means were compared with unpaired, two-sided t test, medians were compared with Wilcoxon rank sum test, and counts were compared with chi-square test or Fisher exact test.

ASA = American Society of Anesthesiologists; BMI = body mass index.

### Table 2. Intraoperative Management

<table>
<thead>
<tr>
<th></th>
<th>BMI ≥30 kg/m\textsuperscript{2}</th>
<th>BMI &lt;30 kg/m\textsuperscript{2}</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core temperature, °C</td>
<td>36.1 ± 0.5</td>
<td>35.9 ± 0.5</td>
<td>0.125</td>
</tr>
<tr>
<td>End-tidal sevoflurane, %</td>
<td>1.7 ± 0.5</td>
<td>1.6 ± 0.5</td>
<td>0.487</td>
</tr>
<tr>
<td>Fentanyl, mg</td>
<td>0.25 (0.25, 0.50)</td>
<td>0.25 (0.25, 0.50)</td>
<td>0.879</td>
</tr>
<tr>
<td>Blood loss, ml</td>
<td>300 (200, 500)</td>
<td>300 (150, 300)</td>
<td>0.531</td>
</tr>
<tr>
<td>Crystalloid, ml/h</td>
<td>919 ± 235</td>
<td>874 ± 327</td>
<td>0.589</td>
</tr>
<tr>
<td>Colloid, ml/h</td>
<td>0 (0, 86)</td>
<td>0 (0, 143)</td>
<td>0.661</td>
</tr>
<tr>
<td>Urine output, ml/h</td>
<td>115 (91, 192)</td>
<td>115 (71, 234)</td>
<td>0.974</td>
</tr>
<tr>
<td>Hemoglobin, mg/dl</td>
<td>11.6 (10.5, 12.1)</td>
<td>11.2 (10.5, 11.6)</td>
<td>0.523</td>
</tr>
</tbody>
</table>

Data are presented as mean ± SD or median (25th percentile, 75th percentile). Means were compared with unpaired, two-sided t test, and medians were compared with Wilcoxon rank sum test.

BMI = body mass index.
PACU

Two obese patients could not be studied in the postoperative period because they required postoperative mechanical ventilation. Therefore, we evaluated 21 obese and 23 nonobese patients in the PACU. Mean arterial blood pressure, core temperature, fluid management, urinary output, and visual analog scale pain scores were comparable in the groups (table 4).

Subcutaneous oxygen tension in the arm (43 vs. 54 mmHg; \( P < 0.01 \)) and adjacent to the wound (42 vs. 62 mmHg; \( P = 0.01 \)) was significantly less in obese than in the nonobese patients. However, within each weight group, tissue oxygen tensions measured at the arm and wound were virtually identical (table 5).

First Postoperative Day

In two nonobese patients, measurements could not be performed because the patients withdrew from the study. Therefore, we evaluated 21 obese and 21 nonobese patients on the first postoperative morning. Mean arterial blood pressure and pain were similar in the two groups; however, urine output was significantly less and core temperature was greater in the obese patients (table 6).

Subcutaneous oxygen tensions in the arm as well as adjacent to the wound were similar in the obese and nonobese patients at baseline and during oxygen challenge. Supplemental oxygen significantly increased tissue oxygenation, by 14.4 (2.5, 26.9) mmHg in the obese patients and by 21.4 (14.4, 29.8) mmHg in the nonobese patients \(( P = 0.21)\). Within each weight group, \( P_{\text{SO}_2} \)
Discussion

Administration of 50% inspired oxygen to the obese patients, a typical concentration, produced a \( P_{\text{A}}O_2 \) of 150 mmHg and an oxygen saturation of 99%. Intraoperative and immediate postoperative subcutaneous tissue oxygenation was nonetheless critically low (approximately 40 mmHg), a value associated with a high risk of infection. In contrast, tissue oxygenation in the nonobese patients was roughly 20 mmHg greater, a value that is considerably less likely to be associated with infection. Therefore, it is apparent that subcutaneous tissue is often hypoxic in obese patients undergoing routine anesthetic management. Although we did not evaluate the incidence of infection in this relatively small study, the link between subcutaneous oxygenation and wound infection risk is well established. Inadequate subcutaneous oxygenation is likely to account for the observed increased number of postoperative infections in obese patients.

An inspired oxygen concentration of 95% was required to increase \( P_{\text{A}}O_2 \) to 300 mmHg in the obese patients. However, this 150-mmHg increase in arterial partial pressure improved subcutaneous oxygenation only 10 mmHg—to a value that remained marginal. Medical oxygen is possibly the least expensive drug, and supplemental intraoperative oxygen is easy to provide. Prolonged administration of oxygen at concentrations near 100% causes pulmonary toxicity. However, short-term exposure in the perioperative period is nontoxic and may even improve pulmonary resistance to infection. Perioperative concentrations of oxygen restricted to 80% do not provoke atelectasis or other pulmonary dysfunction. Therefore, available data suggest that it would be prudent to provide obese patients with an inspired oxygen concentration of at least 80% because the risk and cost are small, and doing so somewhat improves tissue oxygenation.

Supplemental oxygen administration is one of many factors influencing \( PsqO_2 \). For example, it is well established that hypothermia, surgical and postoperative pain, and smoking all reduce tissue oxygen tension. In contrast, administration of supplemental fluid, hypercapnia, and epidural anesthesia increase subcutaneous tissue oxygenation. Intraoperative tissue oxygenation was suboptimal in our obese patients, at a \( P_{\text{A}}O_2 \) of 150 mmHg, and remained marginal even with an inspired oxygen concentration of 95%. Therefore, it is likely that combining supplemental oxygen with other treatments that have a potential of improving tissue oxygenation may prove beneficial in obese patients.

Interestingly, arm and wound tissue oxygen tensions were comparable in obese and nonobese patients on the first postoperative day. Furthermore, supplemental oxygen administration was considerably more effective postoperatively in the obese patients than intraoperatively (approximately 20 vs. 10 mmHg)—although delivery of oxygen (\( via \) a facemask) was surely less effective. A potential explanation for this different response is that the obese patients had significantly higher core temperatures. Hyperthermia causes peripheral vasodilation, hyperemia, and increased tissue perfusion. Furthermore, it is likely that obese patients are fairly hypercapnic in the postoperative period; mild hypercapnia is known to improve tissue oxygenation.

Intraoperatively, we recorded \( PsqO_2 \) from a needle-induced surrogate wound in the arm. This is the classic method of evaluating perioperative tissue oxygenation and has been used in numerous previous studies. The primary benefit of this location is convenient access and the fact that measurements can be conducted during surgery. However, the tissue of interest is actually the

Table 5. PACU Tissue Oxygenation

<table>
<thead>
<tr>
<th></th>
<th>BMI ≥30 kg/m²</th>
<th>BMI &lt;30 kg/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm</td>
<td>Wound</td>
<td>Arm</td>
</tr>
<tr>
<td>( PsqO_2 ), mmHg</td>
<td>43 (37, 54)†</td>
<td>42 (36, 60)†</td>
</tr>
<tr>
<td>( Tsq ), °C</td>
<td>32.9 (32.2, 33.5)†</td>
<td>34.9 (33.9, 35.9)*</td>
</tr>
</tbody>
</table>

Data are presented as median (25th percentile, 75th percentile).

* \( P < 0.05 \) compared with the arm (Wilcoxon signed-rank test).
† \( P < 0.05 \) compared with the nonobese patients (Wilcoxon rank sum test).

BMI = body mass index; \( PsqO_2 \) = subcutaneous oxygen tension; \( Tsq \) = subcutaneous temperature.
The observed tissue oxygen values in our study were virtually identical to previous studies, even in the nonobese group.6 This may be explained by the fact that our patients were randomly assigned to two oxygen treatments. Consequently, in 50% of all patients, the high oxygen tension recorded before surgery was initiated at a point during anesthetic or fluid management. Therefore, fluid administration was strictly controlled by protocol, using estimated normal body weight as the basis for management. However, there is no consensus on what constitutes optimal or even comparable fluid management in obese patients.52 It is therefore possible that this conservative regime made our obese patients relatively hypovolemic. Nonetheless, hemodynamic parameters, such as mean arterial blood pressure and cardiac index, were similar in both groups, as was urine output. These data suggest that our perioperative fluid administration was adequate even in the obese patients.

Surgery lasted significantly longer in the obese than in the nonobese patients. However, intraoperative tissue oxygen was recorded at similar times, usually during the first 2 h of surgery in each weight group. Therefore, it seems unlikely that observed intraoperative differences between the obese and nonobese patients were artifacts of anesthetic or fluid management. There is evidence that duration of surgery is a confounding factor in regard to postoperative tissue oxygen tension2; we cannot exclude that duration of surgery affected our Psco₂ values in the postoperative period. However, all patients underwent major abdominal procedures with similar surgical stress responses and pathophysiologic alterations.31 It seems likely that preoperative tissue oxygenation differed substantially in the obese and nonobese pa-

Table 6. Postoperative Management on the First Postoperative Morning

<table>
<thead>
<tr>
<th></th>
<th>BMI ≥30 kg/m²</th>
<th>BMI &lt;30 kg/m²</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAP, mmHg</td>
<td>84 ± 11</td>
<td>87 ± 17</td>
<td>0.418</td>
</tr>
<tr>
<td>Core temperature, °C</td>
<td>37.5 ± 0.8</td>
<td>36.8 ± 0.8</td>
<td>0.017</td>
</tr>
<tr>
<td>Fluid intake/24 h, ml</td>
<td>1,700 (1,480, 1,918)</td>
<td>2,100 (1,560, 2,744)</td>
<td>0.091</td>
</tr>
<tr>
<td>Urine output/24 h, ml</td>
<td>900 (550, 1,500)</td>
<td>1,405 (1,238, 2,215)</td>
<td>0.028</td>
</tr>
<tr>
<td>Pain, VAS score</td>
<td>47 (30, 75)</td>
<td>45 (10, 50)</td>
<td>0.524</td>
</tr>
</tbody>
</table>

Data are presented as mean ± SD or median (25th percentile, 75th percentile). Means were compared with unpaired, two-sided t test, and medians were compared with Wilcoxon rank sum test. VAS is a 100-mm visual analog scale with 0 mm as no pain and 100 mm as the worst imaginable pain.

BMI = body mass index; MAP = mean arterial pressure.

Table 7. Tissue Oxygenation on the First Postoperative Morning

<table>
<thead>
<tr>
<th></th>
<th>Arm</th>
<th>Wound</th>
<th>BMI ≥30 kg/m²</th>
<th>Wound</th>
<th>BMI ≥30 kg/m²</th>
<th>Wound</th>
<th>BMI &lt;30 kg/m²</th>
<th>Wound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline SaO₂, %</td>
<td>96 (96, 97)</td>
<td>97 (96, 98)</td>
<td>48 (39, 58)</td>
<td>51 (42, 57)</td>
<td>52 (45, 58)</td>
<td>52 (45, 62)</td>
<td>34.6 (33.6, 35.5)</td>
<td>36.3 (35.5, 36.8)*</td>
</tr>
<tr>
<td>PsqO₂, mmHg</td>
<td>34.7 (33.5, 36.0)</td>
<td>36.4 (36.0, 37.1)*</td>
<td>34.7 (33.5, 36.0)</td>
<td>36.4 (36.0, 37.1)*</td>
<td>34.4 (33.7, 35.2)</td>
<td>36.3 (35.5, 36.8)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tsq, °C</td>
<td>69 (43, 84)†</td>
<td>75 (56, 85)†</td>
<td>35.0 (34.4, 36.3)</td>
<td>36.4 (36.1, 37.1)*</td>
<td>34.4 (33.7, 35.2)</td>
<td>36.3 (35.5, 36.8)*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data are presented as median (25th percentile, 75th percentile).

* P < 0.05 compared to arm. † P < 0.05 compared to baseline values (Wilcoxon rank sum test). Tissue oxygenation did not differ significantly in the obese and nonobese patients.

BMI = body mass index; PsqO₂ = subcutaneous oxygen tension; SaO₂ = arterial oxygen saturation; Tsq = subcutaneous temperature.
tients. However, we cannot confirm this assertion because our recording began after induction of general anesthesia. The primary reason we delayed data collection was that unanesthetized patients find probe insertion uncomfortable. Furthermore, measurements during baseline conditions in uninjured tissues before initiation of surgical trauma and bacterial contamination are of less clinical impact. Therefore, we considered only intraoperative and postoperative measurements to be of major importance.

In summary, our data indicate that obesity, defined as a BMI of 30 kg/m² or greater, is a major determinant of perioperative tissue oxygenation. In obese surgical patients, subcutaneous tissue hypoxia was common. Even with supplemental oxygen administration, tissue oxygen tension was reduced to a level that is associated with a substantial increase in infection risk. Tissue oxygenation recorded from a surrogate wound in the arm was similar to that recorded from a probe inserted adjacent to the surgical incision, suggesting that the technically simpler arm measurements can be substituted for more challenging wound recordings.

References


Anesthesiology, V 100, No 2, Feb 2004