Effect of Oxygen Treatment on Heart Rate after Abdominal Surgery

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Background: Cardiac complications are common during the postoperative period and may be associated with hypoxemia and tachycardia. Preliminary studies in high-risk patients after operation have shown a possible beneficial effect of oxygen therapy on arterial oxygen saturation and heart rate.

Methods: The authors studied the effect of oxygen therapy on arterial oxygen saturation and heart rate in 100 consecutive unselected patients randomly and double blindly allocated to receive air or oxygen therapy between the first and fourth day after major abdominal surgery.

Results: The median arterial oxygen saturation rate increased significantly from 96% to 99% ($P < 0.0001$) and the heart rate decreased significantly from 85 beats/min to 81 beats/min ($P < 0.0001$) during oxygen supplementation compared with air administered by a binasal catheter. The greatest decrease in heart rate occurred in patients with the lowest oxygen saturation or the highest heart rate values before oxygen supplementation. Overall, 73% of this unselected group of patients responded with decreased heart rate during supplemental oxygen therapy. No significant differences in changes in heart rate after oxygen supplementation were found between patients with or without an epidural catheter or between the postoperative day studied.

Conclusion: Postoperative oxygen therapy increased arterial oxygen saturation and decreased heart rate after uncomplicated abdominal surgery in a consecutive unselected group of patients who received routine postoperative care. (Key words: Hypoxemia; myocardial ischemia; oxygen therapy; postoperative complications; tachycardia.)

This article is accompanied by an Editorial View. Please see: Weiskopf RB: Simple, easy, safe, and inexpensive. But is it effective? ANESTHESIOLOGY 1999; 90:358–9.

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MAJOR surgery can be followed by complications such as myocardial infarction, wound infection, impaired wound healing, and ventilatory disturbances. This cannot be explained only by imperfections in surgical techniques, but rather may be caused by increased organ demands caused by the endocrine metabolic response to surgical trauma.[1] The most common complications are cardiac and account for more than one half of the deaths that occur after surgery.[2,3]

Postoperative myocardial ischemia is an important predictor of adverse cardiac outcome after noncardiac surgery,[3–5] and research has suggested that lengthy subendocardial ischemia rather than acute coronary occlusion is the predominant mechanism of infarction after major surgery.[4] Postoperative myocardial ischemia is often associated with tachycardia,[5–7] and episodic tachycardia and episodic hypoxemia may occur concomitantly after operation.[8–10] In addition, postoperative episodic hypoxemia may be related to the occurrence of myocardial ischemia.[10–12]

Myocardial ischemia may result from a reduction in oxygen supply and an increase in demand.[2] Thus, a simultaneous reduction in myocardial oxygen delivery and an increase in cardiac oxygen consumption as a result of the coexistence of arterial hypoxemia and tachycardia represent unfavorable postoperative conditions for the heart.[2] In a preliminary study in 12 patients after operation who had hypoxemia (oxygen saturation [SpO_2] ≤ 92%) and tachycardia (heart rate [HR] > 90 beats/min), oxygen therapy significantly increased SpO_2 and reduced HR.[13] It is not known, however, whether oxygen supplementation will increase arterial SpO_2 and decrease HR in all patients after operation. Therefore,

we evaluated the effect of oxygen therapy on arterial SpO_2 and HR in a large group of consecutive and unselected patients after major abdominal surgery.

Materials and Methods

Our local ethics committee approved the study, and the patients gave written informed consent. One hundred patients were recruited for the study. All patients were undergoing major abdominal operations and received routine perioperative care. Patients receiving pre- or postoperative oxygen therapy in the ward or pharmacologic treatment with β-blockers, calcium antagonists, or digoxin were not included. There were no restrictions for inclusion regarding SpO_2 or HR. The study was performed as one test session in the surgical ward during the day time between postoperative days 1 and 4, and only on weekdays. The study population consisted of 51 men and 49 women, with a median age of 60 yr (range, 19–97 yr), a height of 171 cm (range, 150–190 cm), and a weight of 55 kg (range, 40–110 kg). Forty-eight patients underwent colorectal procedures, 23 underwent gastroduodenal procedures, 10 underwent exploratory laparotomy, 9 underwent small bowel resection, 8 underwent operation for adhesions, and 2 underwent open cholecystectomies. Sixty-two patients received epidural anesthesia combined with enflurane, isoflurane, propofol, or midazolam and low-dose fentanyl. Postoperative analgesia consisted of an epidural regimen of 4 ml/h of a mixture of bupivacaine (2.5 mg/ml) and morphine (50 μg/ml), except in two patients, who received 2 ml/h of this mixture epidurally. The postoperative epidural analgesia was supplemented with 1 g paracetamol four times a day. Thirty-eight patients did not receive epidural anesthesia (acute surgery), and in these the main anesthetic agent was isoflurane (n = 25), midazolam and low-dose fentanyl (n = 6), enflurane (n = 5), or propofol (n = 2). In these patients, postoperative analgesia consisted of 1 g paracetamol four times a day and 5–10 mg morphine intramuscularly or 10–20 mg orally on demand.

The study had three parts that all used a binasal oxygen delivery catheter. In period 1 (control), the patients received 3 l/min air for 30 min; in period 2, they received 3 l/min 100% oxygen for 30 min; and in period 3, they received 3 l/min air for 30 min. Each monitoring period was preceded by a 15-min period in which the patients became accustomed to the inhalation by wearing the binasal oxygen catheter and receiving air or oxygen (similar to the next monitoring period). Periods 2 and 3 were reversed randomly. Oxygen saturation and HR were measured continuously with a pulse oximeter (Nellcor N-200; Nellcor Puritan Bennett, Pleasanton, CA) and an adhesive finger probe. The data were sampled at 1-s intervals and fed into a bedside computer with subsequent data printout and analysis. The patient and the observer performing the data analysis were blinded to the order of the inhalation regimen.

For statistical analyses, we used the Spearman correlation test, a linear regression analysis, the Wilcoxon signed rank test, the Mann–Whitney U test, and the Kruskal–Wallis test corrected for ties. $P < 0.05$ was considered significant. Group data are given as the median (range).

Results

The median duration of surgery was 130 min (range, 35–300 min). The duration of general anesthesia was 165 min (range, 55–370 min). In the first period (air), the median SpO_2 was 96% (range, 84–100%) and the HR was 84 beats/min (range, 56–160 beats/min). During oxygen supplementation, SpO_2 increased to 99% (range, 94–100%; $P < 0.0001$), and the HR decreased to 81 beats/min (range, 57–125 beats/min; $P < 0.0001$). In the second period with air, SpO_2 was 96% (range, 84–100%) and the HR was 85 beats/min (range, 60–144 beats/min; figs. 1A and B). There was no significant difference in HR ($P = 0.49$) or SpO_2 ($P = 0.45$) between the two periods of air treatment. Overall, 73 of 100 patients responded with decreased HRs with oxygen treatment.

Figures 2A and 2B show the change in HR during oxygen therapy, ΔHR, in relation to prestudy–control SpO_2 and HR. Comparing ΔHR for the defined subgroups of initial HRs, we found a significant reduction in HR with oxygen in the patients with initial HRs of 110 beats/min or more compared with patients with HRs of 70 beats/min or less ($P < 0.006$) and in patients with HRs between 71 and 109 ($P < 0.02$). Furthermore, when we applied the Kruskal–Wallis test, we found a significant overall intergroup difference between patients with HRs of 70 beats/min or less, between 71 and 109 beats/min, and 110 beats/min of more ($P = 0.02$). The linear regression analysis of initial HR *versus* ΔHR was significant (r = 0.30, $P = 0.002$), but the Spearman correlation test was not significant ($r_s = 0.17$, $P = 0.09$).
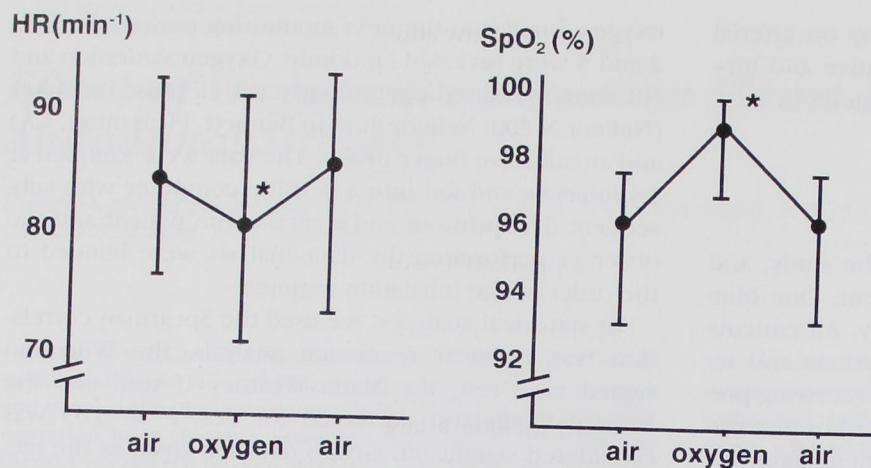
Patients with initial low SpO_2 values had a trend to-

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Fig. 1. (*A*) Heart rate and (*B*) arterial oxygen saturation (SpO_2) after oxygen supplementation or air by random order (medians and quartiles) *P < 0.0001 by the Wilcoxon test (n = 100).

ward a more pronounced reduction in HR with oxygen therapy, although this was not significant ($P = 0.06$ and $P = 0.12$; fig. 2A). Results of the linear regression analysis ($P = 0.18$) and the correlation test ($P = 0.37$) between initial SpO_2 and ΔHR were not significant.

Thirty-five patients were studied on postoperative day 1, 32 on postoperative day 2, 19 on postoperative day 3, and 14 on postoperative day 4. No significant differences in HR with air or oxygen ($P = 0.3$ and $P = 0.4$), changes in HR ($P = 0.5$), SpO_2 with air or oxygen ($P = 0.06$ and $P = 0.5$), or changes in SpO_2 ($P = 0.052$) were found between patients studied on the different postoperative days.

Patients receiving epidural analgesia had significantly lower HR values when receiving air (median 79 *versus* 90 beats/min, $P < 0.001$), and during supplemental oxygen administration (78 *versus* 88 beats/min, $P < 0.001$). Epidural analgesia, however, had no effect on ΔHR ($P > 0.2$) and was not significantly related to ΔHR (linear regression, $P = 0.90$; Spearman correlation, $P = 0.78$).

Discussion

This study shows a reduction in HR with oxygen therapy during the late postoperative period, and it was most pronounced in patients with high HR or low SpO_2 values. Thus, oxygen therapy may exert a positive effect on the cardiac oxygen delivery and consumption balance in unselected patients after operation. These findings are of clinical importance, because several studies have found a relation between postoperative myocardial ischemia and elevated HR.[5-7] Furthermore, episodic tachycardia and episodic hypoxemia may occur concomitantly in the late postoperative period.[8-10]

Myocardial ischemia may result from a reduction in oxygen supply and an increase in demand.[2] Late postoperative hypoxemia is commonly seen after major abdominal surgery,[14] with a minimum on the second and third postoperative nights.[15] Myocardial ischemia and infarction occur with a peak incidence during operation and on the third postoperative day.[5,16] Postoperative hypoxemia, leading to decreased oxygen supply to the body
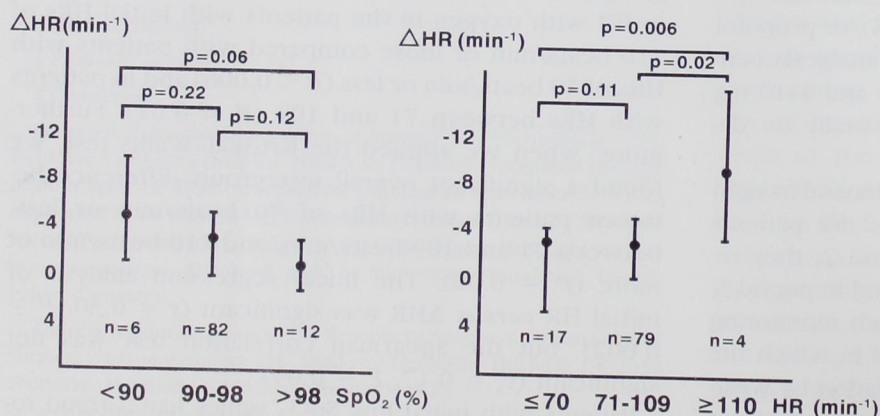

Fig. 2. Changes in heart rate (ΔHR) after oxygen supplementation for defined subgroups of arterial oxygen saturation (SpO_2) with air (*A*) and heart rate (HR) with air (*B*) (medians and quartiles). The Kruskal–Wallis test yielded $P = 0.12$ in *A* and $P = 0.02$ in *B*.

organs, was shown in previous studies to be temporarily associated with myocardial ischemia[10-12] and therefore may be a contributing factor in the development of postoperative myocardial infarction.[16] The findings of a study in which most postoperative myocardial infarctions were non–q-wave infarctions caused by long-duration subendocardial ischemia rather than coronary artery occlusion[4] further supports this hypothesis. The importance of postoperative tachycardia for myocardial ischemia has been described by Mangano *et al.*[5] and by other investigators,[6,7,17] and Weiskopf *et al.*[18] showed the association between increased HR and the probably increased myocardial oxygen consumption. The clinical relevance of our results is further supported by an interventional study in 300 patients receiving Mivazerol, a new α_2-adrenoceptor agonist, which reduced the incidence of postoperative myocardial ischemia in relation to a reduction in HR that was comparable to the reduction we found in the current study (5–10 beats/min).[17] Furthermore, a study of the effect of the perioperative use of atenolol in 200 high-risk patients undergoing noncardiac surgery showed a reduction in the mortality rate and the incidence of cardiovascular complications for as many as 2 yr after surgery.[19]

The mechanism of the reduced HR after oxygen supply is not fully understood. A reduction in HR after oxygen has been found in patients with chronic lung disease[20] and with liver cirrhosis[21] and in nonsurgical patients with chronic heart failure during a bicycle stress test.[22] Furthermore, in a study in healthy resting volunteers, a significant reduction in HR was observed during oxygen breathing, with simultaneously decreased cardiac index and increased peripheral vascular resistance and blood pressure.[23] In addition, in a recent study in conscious healthy patients and volunteers, a decreased blood oxygen content and reduced tissue oxygen delivery resulting from an isovolemic reduction of blood hemoglobin caused decreased systemic vascular resistance and increased HR, stroke volume, and cardiac index.[18] Because of these results, a possible sequence of events after the inhalation of oxygen, and thereby the increased blood oxygen content, may be constriction of the peripheral vascular bed with a resultant increase in arterial blood pressure and subsequent slowing of the HR because of the carotid sinus baroreceptor reflex.[23] Another mechanism triggering the reduction of HR with supplementary oxygen may be a reduction of sympathetic tone, because Becker and Kreuzer[24] showed that exposure to low oxygen tension stimulating 3,000 to 4,000 m of altitude increased epinephrine excretion but unchanged norepi-

nephrine in healthy adults. This may be supported by the findings of a decrease in the arterial concentration of epinephrine and a reduced HR after oxygen was supplied to patients with cirrhosis.[21] Thus, reduced sympathetic nervous activity may be a plausible explanation for the effect of oxygen supply on HR changes in patients after operation.

In the preliminary study in patients with concomitant hypoxemia ($SpO_2 \leq 92\%$) and tachycardia (HR > 90 beats/min), we found a significant reduction in HR (median 6 beats/min) after oxygen supply in each of the 12 patients studied.[13] In the current study, we deliberately chose to include a large group of unselected patients; that is, we also tested patients without hypoxemia and tachycardia between days 1 and 4 after operation, although we know that hypoxemia is worse on postoperative days 2 and 3.[15] We did this to potentially generalize the implications of our study depending on the results. We found that 73% of the patients responded with decreased HR after oxygen was supplied and that the most pronounced changes were seen in patients with preexisting tachycardia and hypoxemia, although the latter was not statistically significant (figs. 2A and 2B). When the current results are considered with those from our previous sample of patients who all had hypoxemia and tachycardia,[13] it is obvious that the HR-lowering response to oxygen treatment is most pronounced in patients with preexisting tachycardia. This seems to support the assumption that the described sympathetic reflex to postoperative oxygen supply would be most pronounced in high-risk patients.

Although the study was not designed for a further subanalysis of the results, we found significantly lower baseline HRs in patients who received epidural analgesia compared with patients receiving intramuscular morphine, probably because of reduced activity in the sympathetic nervous system. However, the HR response to oxygen supplementation was similar in patients with and without epidural analgesia. Furthermore, we found similar responses to oxygen administration on the different postoperative days studied, and no effect of age on the HR response to oxygen therapy.

As noted before, hypoxemia and tachycardia are potential risk factors for the development of postoperative myocardial ischemia. Furthermore, hypoxemia may be a contributing factor for the development of postoperative complications, such as cardiac arrhythmias, impaired wound healing, and mental confusion.[25] Our current results favor oxygen administration to patients after operation and add further weight to the growing body of

evidence of the benefits of postoperative oxygen therapy. It may be argued that an indication for postoperative oxygen therapy could be the presence of tachycardia regardless of arterial oxygen levels. However, until controlled studies have shown that oxygen treatment decreases postoperative morbidity and mortality rates, final recommendations for routine administration of postoperative oxygen must still be established.

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