Postoperative Arterial Blood Gas Measurement in Obese Patients:

Effect of Position on Gas Exchange

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The effect of position change on blood gas exchange was studied in 22 markedly obese, otherwise healthy, women both preoperatively and postoperatively. There was a statistically significant decrease in arterial oxygen tension and a simultaneous reduction both in the arterial carbon dioxide tension and the base excess with the assumption of the supine versus the semirecumbent position on postoperative days one and two. However, no positional difference was demonstrable in any variable by the third postoperative day. This study indicates that in obese patients during the first 48 hours after abdominal surgery, assumption and maintenance of the semirecumbent posture is a valuable therapeutic adjunct to improve arterial oxygenation.

THE OVERALL INCIDENCE of postoperative pulmonary complications, and hence hypoxemia, is affected by age, sex, duration of the operation, body habitus, preexisting pulmonary disease, and cigarette smoking.[8] Obese subjects undergoing abdominal surgery are recognized as being a particularly high risk group in terms of postoperative pulmonary complications.[3] Recently we demonstrated that markedly obese subjects, after jejunoileal small bowel bypass, manifest significant hypoxemia during the first four postoperative days.[14] We have also shown that with vertical incisions the hypoxemia was more marked than with transverse incisions.[15] Postoperatively, patients are usually placed in the supine position. Such a position, however, may further increase the severity of the hypoxemia because of the reduction in lung volume secondary to the pressure of the intra-abdominal contents on the diaphragm.

The purpose of the present study was to evaluate, in a group of postoperative obese females, whether a change from the supine to the semirecumbent position would alter blood gas exchange.

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Method

Twenty-two morbidly obese non-smoking female patients, without clinical evidence of cardiopulmonary disease, were studied preoperatively and on postoperative days one through three. Informed consent was obtained from each unsedated patient preoperatively. The operative incisions (vertical midline) and surgical procedures (jejuoileal bypass, liver biopsy, and appendectomy) were identical for all patients. The mean duration of anesthesia was 186 ± 23 minutes.

Samples of arterial blood were obtained with the patient in bed, breathing room air for 15 to 20 minutes. Each patient served as her own control. Sampling was performed anaerobically from the radial artery by direct puncture after infiltration of the skin with 0.5% lidocaine or from an indwelling intra-arterial cannula. Arterial blood was collected into iced plastic syringes containing heparin and analyzed for P_{O_2}, P_{CO_2}, and pH, within 30 min of sampling, by the same technician in our research laboratory. Appropriate corrections were made for changes produced by time and temperature.[6]

Each arterial sample was taken at least 4 hours after any narcotic medication or respiratory therapy treatment: the specimens were obtained each morning between 8 and 10 AM.

The fractional oxygen saturation of hemoglobin $\left(\frac{HbO_2}{Hb + HbO_2}\right)$ was calculated according to the method of Thomas[12] using measured arterial pH, P_{CO_2}, P_{O_2}, and

TABLE 1. *Physical Characteristics of 22 Obese Adult Female Subjects*

Case #	Age (Yrs.)	Height (cm)	Body Weight (kg)	Deviation from ideal weight (%)*	Weight (kg)/ Height (cm) ratio
1	27	162	154.0	192	0.95
2	27	173	156.0	153	0.90
3	37	150	116.4	146	0.78
4	33	175	128.6	103	0.73
5	31	168	125.5	116	0.75
6	24	168	155.5	168	0.93
7	38	165	141.8	154	0.86
8	36	163	128.6	137	0.79
9	38	165	190.0	240	1.15
10	39	159	150.0	188	0.94
11	34	175	142.0	124	0.81
12	30	178	178.0	173	1.00
13	52	163	118.0	117	0.73
14	27	160	104.0	97	0.65
15	47	163	160.0	195	0.98
16	31	176	125.0	97	0.71
17	25	178	154.1	136	0.87
18	29	170	131.4	120	0.77
19	42	165	125.0	124	0.76
20	26	171	119.0	99	0.70
21	42	170	128.0	114	0.75
22	29	164	104.0	86	0.63
Mean	33.8	167.3	138	140	0.82
S.D.	7.5	7.0	22.3	39.5	0.13

*Deviation from ideal weight = $\frac{\text{actual weight (kg)} - \text{ideal weight (kg)}}{\text{ideal weight (kg)}\dagger} \times 100$

†Ideal weight = determined from the standard Metropolitan Life Insurance Co. weight/height table[10] using the mid-range value of the medium frame group at each height.

hematocrit. Collected data were analyzed with an analysis of variance to ascertain differences within and between the two positions studied. Subsequently, a student's paired t-test was employed to evaluate the significance of the differences between the two groups (semirecumbent versus supine).

Results

Table 1 characterizes this patient sample as young (mean age 33.8 years) and markedly obese (mean of 140% in excess of ideal weight).

Patients were studied to ascertain the effect of a positional change on arterial blood gases. There was no statistically significant difference in any blood gas measurement in the semirecumbent versus the supine position ($P > 0.05$) preoperatively (Tables 2 and 3). However, semirecumbent arterial oxygen tension (Pa_{O_2}) was reduced (mean 76.4 ± 1.6 torr) when compared to nonobese patients matched for age; assumption of the supine position slightly improved mean (Pa_{O_2}) (78.4 ± 2.4 torr), although statistically this was not significant.

There was a statistically significant increase in arterial oxygen tension, carbon dioxide tension and base excess with the assumption of the semirecumbent position on postoperative days one and two (Tables 2 and 3, Fig. 1).

At the levels of arterial oxygenation encountered postoperatively in some of these obese patients, the slope of the hemoglobin-oxygen dissociation curve can change radically. On the more vertical portion of this curve ($Pa_{O_2} < 55$ to 60 torr), a small reduction in Pa_{O_2} will cause a marked decrease in the percent saturation of hemoglobin. Consequently, in addition to measurement of Pa_{O_2}, we compared the changes in per cent saturation of hemoglobin. These results comparing the two positions are presented in Table 2. As would be predicted from the Pa_{O_2} values, there is a statistically significant reduction in hemoglobin saturation in the supine versus the semirecumbent position on postoperative days one and two, but not on day three.

Comparing oxygenation variables (Pa_{O_2} and per cent saturation of hemoglobin) between postoperative days one and two, there was no statistical difference identifiable. However, the lowest values for both Pa_{O_2} and per cent saturation of hemoglobin were noted on postoperative day two. The most profound reduction in arterial oxygenation was observed in the supine position on postoperative day two (Table 2).

The results in Table 3 demonstrate that there is a statistically significant increase in Pa_{CO_2} and base excess following the assumption of the semirecumbent postion on postoperative days one and two. However, the increase in these two variables is not clinically relevant.

TABLE 2. *Positional Differences in Arterial Oxygenation (Semirecumbent to Supine). Values Represent Mean of 22 Obese Adult Female Patients Breathing Room Air.*

Oxygenation Variable	Semirecumbent Mean ± S.E.	Semirecumbent Range	Supine Mean ± S.E.	Supine Range	Mean Difference (supine-semirecumbent)	Significance (P value)
Preop						
Pa_{O_2} (mm Hg)	76.4 ± 1.6	63 – 93	78.4 ± 2.4	58 – 96	2.0	N.S.*
% O_2 Saturation of Hb	95.5 ± 0.7	92.6 – 97.1	95.6 ± 0.8	89.9 – 97.8	0.1	N.S.
Postop Day 1						
Pa_{O_2} (mm Hg)	64.2 ± 2.1	48 – 88	58.6 ± 1.8	41 – 72	−5.6	<0.001
$\%O_2$ Saturation of Hb	92.2 ± 0.7	79.0 – 96.7	90.1 ± 0.9	76.0 – 94.5	−2.1	<0.001
Postop Day 2						
Pa_{O_2} (mm Hg)	60.4 ± 2.1	43 – 78	54.5 ± 1.8	38 – 66	−5.9	<0.001
$\%O_2$ Saturation of Hb	91.1 ± 0.9	77.2 – 95.8	88.5 ± 1.1	73.7 – 93.9	−2.6	<0.001
Postop Day 3						
Pa_{O_2} (mm Hg)	61.4 ± 2.7	46 – 82	61.5 ± 2.3	46 – 80	0.1	N.S.
$\%O_2$ Saturation of Hb	91.4 ± 0.9	78.0 – 96.5	91.7 ± 0.8	78.0 – 95.8	0.3	N.S.

*N.S. = not statistically significant using Student's *t*-test.

An attempt was made to correlate the mean difference (supine-semirecembent) in Pa_{O_2} with age, weight/height ratio, and per cent deviation from ideal weight on postoperative days one and two. No significant correlation was found.

Discussion

Presently there are no data available relating the effect of changes in body position on arterial oxygen tension in postoperative patients, either non-obese or obese. Tucker[13] has reported the effect of change from the seated to the recumbent position on the lung volumes of obese subjects; there were significant decreases in all lung subdivisions, except the residual volume. The expiratory reserve volume, in particular, became quite small in the recumbent position.

LeBlanc et al[7] were the first to suggest the phenomenon of airway closure as a factor which might influence gas exchange with the change in posture. They pointed out that while "closing volume" (lung volume at which airway closure started to occur) does not change substantially with posture, there is a decrease in the functional residual capacity (FRC) in the supine position, thus increasing the chance of the "closing volume" falling within the breathing range. If this occurred, ventilation to affected regions would be impaired, thereby lowering the regional ventilation to perfusion (V/Q) ratios. This un-

TABLE 3. *Positional Differences in Arterial Acid-base Variables (Semirecumbent to Supine) in 22 Obese Adult Female Patients Breathing Room Air.*

Acid-base Variables	Semirecumbent Mean ± S.E.	Semirecumbent Range	Supine Mean ± S.E.	Supine Range	Mean Difference (supine-semirecumbent)	Significance (P value)
Preop						
$PaCO_2$ (mm Hg)	37.2 ± 0.4	34 – 41	36.7 ± 0.7	29 – 42	−0.5	N.S.*
Base excess (mEq/L)	1.8 ± 0.5	−3 to 8	1.6 ± 0.5	−3 to 7.5	−0.2	N.S.
Postop Day 1						
$PaCO_2$ (mm Hg)	39.1 ± 0.8	29 – 46	37.4 ± 0.7	29 – 45	−1.7	<0.01
Base excess (mEq/L)	1.0 ± 0.6	7 to −2.7	0.1 ± 0.6	4.9 to −4.8	−0.9	<0.01
Postop Day 2						
$PaCO_2$ (mm Hg)	40.0 ± 0.9	34 – 47	38.9 ± 0.9	30 – 46	−1.1	<0.01
Base excess (mEq/L)	2.9 ± 0.7	8.1 to −1.6	2.1 ± 0.7	7.5 to −5.2	−0.8	<0.01
Postop Day 3						
$PaCO_2$ (mm Hg)	40.5 ± 1.0	33 – 45	40.4 ± 1.1	31 – 46	−0.1	N.S.
Base excess (mEq/L)	3.9 ± 0.9	10.5 to, −2.3	3.7 ± 0.9	11.2 to −2.5	−0.2	N.S.

*N.S. = Not statistically significant using Student's *t*-test

evenness of ventilation would tend to promote arterial hypoxemia. LeBlanc's study indicated that the age at which "closing volume" started to occur within the tidal range in non-obese subjects was about 65 years in the upright position and 44 years in the supine position. However, an extrapolation of these data to our markedly obese patients is not possible.

Alexander et al.[1] measured postoperative lung function to identify the mechanism of the observed hypoxemia. He demonstrated that all lung volumes were reduced following abdominal operations and the reductions were most severe after upper abdominal procedures. In his patients, there was a mean reduction of 28% in the FRC on postoperative day one. He also suggested that after surgery, the lung volume at which airways close [closing volume (CV)] might remain relatively unchanged while FRC decreased. Thus, there would be an increased likelihood of maldistribution of the tidal volume, mismatching of ventilation with perfusion, and thereby hypoxemia. Subsequently, Alexander et al.[2] were able to show a significant correlation between the (FRC-CV) relationship and arterial oxygenation.

Craig et al.[4] collected the only available data relating the effect of a change in posture on gas exchange. In 22 normal subjects the change in arterial oxygenation with change in position from seated to supine, as well as changes in the relationship of breathing level (FRC + tidal volume) to closing volume were evaluated. They postulated that alterations of gas exchange from the seated to the supine position would result from the interaction of three factors: 1) the increased cardiac output in the supine position,[9] with its effect on the mixed venous oxygen content;[11] 2) the increased uniformity of perfusion distributions and of regional ventilation/perfusion (V/Q) relationships in the supine lung;[5] amd 3) the increased involvement of the lung volume by "airway closure" in the supine position[7] tending to retard dependent zone ventilation and to lower dependent zone V/Q relationships. Arterial oxygenation would be improved by the first two factors, but impaired by the third. Craig found that the FRC decreased in the supine position, whereas "closing volume" was unchanged. The arterial oxygenation changes correlated directly with the degree of impingement of CV on the breathing level. However, when subjects were grouped specifically according to weight, age, or smoking history, no effect of posture on gas exchange was demonstrable.

In contrast to Craig's study in non-operated subjects, our resluts demonstrate that in markedly obese women, position has a significant effect on the Pa_{O_2} for 48 hours postoperatively. A likely pathophysiologic explanation for our findings is that in obese patients the additive effect of a reduced lung volume preoperatively, an abdominal vertical incision with its attendent pain and splinting,

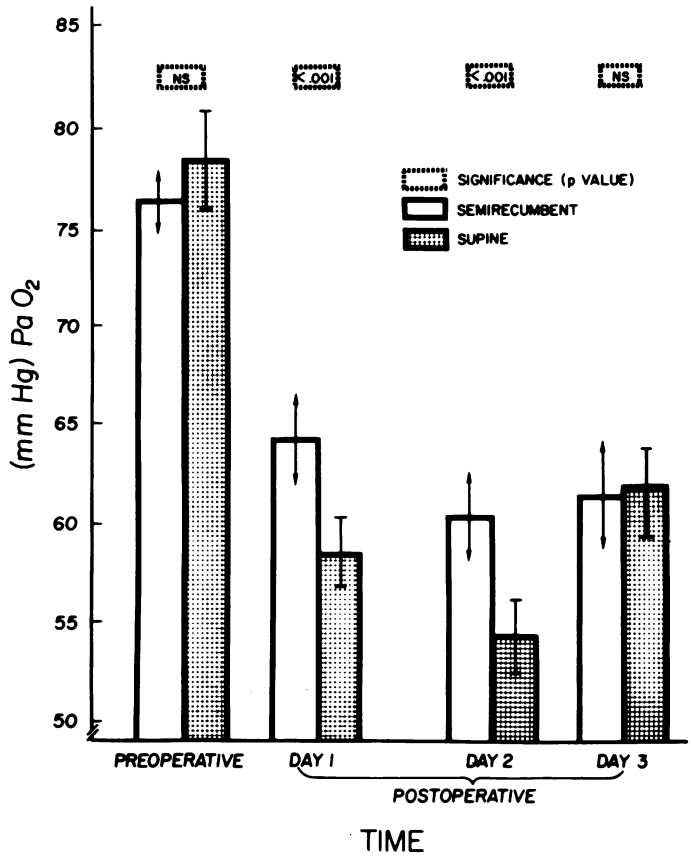

FIG. 1. Arterial oxygen tension (mean ± S.E.) in 22 obese female subjects in the semirecumbent compared to the supine position preoperatively and on each of postoperative days one through three. Preoperatively and on postoperative day three, no positional effect on Pa_{O_2} was demonstrable. On postoperative days one and two, however, a change to the supine position resulted in a statistically significant decrease ($P<0.001$) in Pa_{O_2}. Significance is considered as between the two positions not preoperative versus postoperative Pa_{O_2} values. NS = not statistically significant. All values were obtained with the patient breathing room air at rest.

and the assumption of supine posture cause the increased involvement of the lung volume by "airway closure" during the first 48 hours after operation. As FRC returns toward preoperative levels by postoperative day three, the overall effect of position change on arterial oxygenation is no longer demonstrable.

In conclusion, the present study indicates that, in obese subjects, the assumption of the semirecumbent versus the supine posture during the early postoperative period is a valuable therapeutic tool to improve gas exchange. The clinical implications for those concerned with postoperative and other forms of intensive care are apparent. It should be noted that our data concerning arterial oxygenation were collected in a group of young, non-smoking, obese, but otherwise healthy women with no evidence of cardiorespiratory disease. In obese patients with cardiorespiratory disease positional change is likely to have an even more marked effect on oxygenation. It is often routine to place all individuals (obese or

non-obese) with any degree of cardiovascular instability in a head down position. The advisability of this maneuver should be seriously questioned in obese subjects, unless adequate care is given to control the airway (intubation), assist ventilation, and supplement the inspired air with oxygen.

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