EFFECTS OF UPPER OR LOWER ABDOMINAL SURGERY ON DIAPHRAGMATIC FUNCTION

B. DUREUIL, J. P. CANTINEAU AND J. M. DESMONTS

Patients undergoing upper abdominal surgery develop a restrictive pattern of pulmonary dysfunction (Craig, 1981). Vital capacity (VC) is reduced to approximately 40–50% of its preoperative value, and remains decreased for at least 1 week (Craig, 1981). This reduction in VC is associated with a marked decrease in functional residual capacity, arterial hypoxaemia and, frequently, lower lobe atelectasis. Although the mechanisms producing these effects are still under investigation, diaphragmatic dysfunction has been demonstrated after upper abdominal surgery (Ford et al., 1983; Simmoneau et al., 1983) and has been suspected to be the main determinant of these alterations in function. In contrast, much lesser changes in VC, and fewer pulmonary complications, are observed after lower abdominal surgery (Craig, 1981). It may, therefore, be interesting to compare the changes in diaphragmatic function and VC between patients undergoing upper or lower abdominal surgery.

PATIENTS AND METHODS

Twenty-seven patients undergoing abdominal surgery were selected; all were free from cardio-respiratory disease. Informed consent was obtained from each patient. In 23 patients, diaphragmatic function and VC were determined before, and after, the surgical procedure. This group was subdivided into two subgroups according to the site of surgery. Group 1 consisted of 17 patients undergoing upper abdominal surgery involving the biliary tract or the stomach through a midline incision. Group 2 consisted of six patients undergoing prostatectomy or hysterectomy through a midline suprapubic incision. Characteristics of the patients are summarized in table I.

In 23 patients, VC was determined by spirometry, and the changes in the anterior–posterior dimensions of the ribcage (ΔRC) and abdomen (ΔAB) during quiet tidal breathing were measured with magnetometer coils, calibrated for linear distance (Mead et al., 1967) the day before surgery. The receiver coil for rib cage motion was placed anteriorly in the midline at the 4th or 5th intercostal space, the point of maximal observed motion. The receiver coil for abdominal motion was placed just above the umbilicus. Transmitter coils were placed at corresponding levels in the


SUMMARY

Changes in abdominal (ΔAB) and rib cage (ΔRC) movements, and in vital capacity, were compared between 23 patients undergoing upper or lower abdominal surgery at 1, 3 and 7 days after surgery. Diaphragmatic index was obtained by measuring the relative abdominal motion (ΔAB/ΔAB + ΔRC) using magnetometers. Electrical activity of abdominal muscles was assessed using needle electrodes after upper abdominal surgery in four additional patients. After upper abdominal surgery, the vital capacity and the diaphragmatic index were markedly reduced for 1 week. No abdominal muscle activity was observed at day 1. After lower abdominal surgery, the vital capacity returned to the normal range within 3 days of operation, without any diaphragmatic impairment. These findings substantiate the role of diaphragmatic dysfunction in postoperative reduction in vital capacity observed after upper abdominal surgery.
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Table 1. Details of patients (mean values ± SEM). UAS = Upper abdominal surgery; LAS = lower abdominal surgery; BMI = body mass index (weight (kg) divided by the square of height (m)). * Values before operation.

<table>
<thead>
<tr>
<th></th>
<th>Age (yr)</th>
<th>BMI (kg m⁻²)</th>
<th>Duration of surgery (min)</th>
<th>Measured VC/ theoretical VC (percent)</th>
<th>Diaphragmatic index f</th>
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<tbody>
<tr>
<td>Group 1 (UAS)</td>
<td>47 ± 6</td>
<td>24.0 ± 4.0</td>
<td>122 ± 22</td>
<td>0.95 ± 0.07</td>
<td>0.81 ± 0.10</td>
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<tr>
<td>(n = 17)</td>
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<tr>
<td>Group 2 (LAS)</td>
<td>46 ± 6</td>
<td>26.9 ± 3.5</td>
<td>120 ± 42</td>
<td>0.92 ± 0.09</td>
<td>0.83 ± 0.11</td>
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<tr>
<td>(n = 6)</td>
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<tr>
<td>Additional patients</td>
<td>46 ± 8</td>
<td>25.6 ± 3.0</td>
<td>130 ± 28</td>
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<td>(n = 4)</td>
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midline of the back. For small anteroposterior changes in abdomen and ribcage, as observed during quiet tidal breathing, the magnetometer signals were linear. At least 10 quiet breaths were recorded at each assessment. Relative abdominal motion (the ratio (ΔAB/ΔAB + ARC)) (Gilbert, Auchincloss and Peppi, 1981) was used as an index of the diaphragmatic contribution to the breathing process. A decrease in this index after surgery, from preoperative values, means that the contribution of the diaphragm to the breathing process is decreased (Gilbert, Auchincloss and Peppi, 1981). Measurements of VC and relative abdominal motion were carried out with the subjects in the supine position.

For the patients undergoing upper abdominal surgery, determinations of VC and of diaphragmatic index were repeated after surgery on days 1, 3 and 7. For the patients undergoing lower abdominal surgery, measurements were made on days 1 and 3. None of the patients had received opioids within the 6 h before measurements. In each group, data were compared using analysis of variance followed by paired comparison. The influence of the site of surgery was examined by an intergroup comparison using an analysis of variance in a factorial design. Values are given as mean ± SEM.

In the four additional patients, the electrical activity of the abdominal muscles was assessed 4 h and 24 h after the surgical procedure. All measurements were performed in the supine position. The subjects breathed through a mouthpiece attached to a pneumotachograph (Fleisch No. 3) connected to a pressure transducer (Valdyne DP15) for measurements of flow and for the determination of inspiratory and expiratory time. Concentric unipolar needle electrodes were used to record the electrical activity (EMG) of the external oblique muscle. In two subjects, the EMG of the rectus abdominus was studied also. EMG signals were processed using an electromyograph preamplifier (DISA 15G01), filtered below 50 Hz and above 2000 Hz. After the first set of measurements, the positions of the needle electrodes were verified carefully to ensure a similar position for the set of measurements performed 24 h after surgery. None of these patients had received opioids within the 6 h before the second measurement.

RESULTS

There was no significant difference between the groups with respect to age, body mass index or duration of surgical procedure (table I). Values of VC (expressed as percent of predicted value) and diaphragmatic index were similar.

The changes in VC, induced by the surgical procedure, were expressed as a percent of control value and are shown in figure 1. After lower abdominal surgery, VC was reduced at day 1 and had returned to its preoperative value at day 3. After upper abdominal surgery, VC was markedly reduced from day 1 to day 7 and the decrease in VC was more marked after upper abdominal surgery than after lower abdominal surgery at day 1 and day 3. A typical tracing of changes in AAB and ARC before and after upper abdominal surgery, in one patient, is shown in figure 2. Variations in anteroposterior abdominal diameter for patients undergoing upper abdominal surgery were markedly reduced on days 1, 3 and 7, whereas no significant change in ARC was noted (table II). This marked decrease in ΔAB after upper abdominal surgery was accompanied by a significant decrease in diaphragmatic index on days 1, 3 and 7 (fig. 3). In contrast, after lower
abdominal surgery, abdominal and thoracic motions were unchanged, as shown for one patient in figure 4. No change in diaphragmatic index was observed for these patients (fig. 3). Consequently, the postoperative decrease in diaphragmatic index was significantly greater after upper than after lower abdominal surgery (fig. 3). Expiratory activity of the external oblique muscle was observed 4 h after the surgical procedure in two patients, and is illustrated by a typical tracing (fig. 5). In these patients, abdominal muscle activity was markedly reduced, to almost zero, 24 h after

**TABLE II.** Mean values (±SEM) in anteroposterior changes of abdomen (ΔAB) and rib cage (ΔRC) in patients undergoing upper abdominal surgery. Significant difference from control: *P < 0.05; **P < 0.01

<table>
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<tr>
<th></th>
<th>Control</th>
<th>Day 1</th>
<th>Day 3</th>
<th>Day 7</th>
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<tbody>
<tr>
<td>ΔAB (mm)</td>
<td>6.03 ± 0.24</td>
<td>2.02 ± 0.10**</td>
<td>2.46 ± 10**</td>
<td>3.98 ± 0.35*</td>
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<tr>
<td>ΔRC (mm)</td>
<td>1.41 ± 0.09</td>
<td>1.23 ± 0.04</td>
<td>1.170 ± 0.04</td>
<td>1.29 ± 0.05</td>
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FLOW

EMG

1s

A

FIG. 5. Typical changes in air flow and in electrical activity (EMG) of external oblique muscle in one patient 4 h (A) and 24 h (B) after upper abdominal surgery.

FLOW

EMG

B

the surgical procedure (fig. 5). In the remaining two subjects, there was no expiration activity in the external oblique, or the rectus abdominis, muscle 4 h and 24 h after surgery.

DISCUSSION

Our results confirm the occurrence of a marked decrease in VC and impairment of diaphragmatic function after upper abdominal surgery. In contrast, lesser changes in VC were observed after lower abdominal surgery, and diaphragmatic function remained within normal limits.

In this study, diaphragmatic function was assessed by using an index previously described by Gilbert, Auchincloss and Peppi (1981). However, additional factors, not related to an impairment of diaphragm function, might have affected this index also: active contraction of the abdominal muscles during expiration; changes in the mechanical properties of the abdominal compartment; mechanical interaction between rib cage and diaphragm.

In normal subjects, in the supine position, no activity of the abdominal muscles has been reported during quiet tidal breathing (Campbell, 1952). However, our present data demonstrate that expiratory abdominal muscle contraction may occur in man during the first few hours following upper abdominal surgery—as previously observed in dogs 1 h after cholecystectomy (Dureuil et al., 1985). At least two mechanisms may be involved in this early abdominal muscle activity. First, the residual effects of anesthesia or the postoperative administration of opioids, or both, may play a role as Drummond, McCulloch and Brown (1984) have demonstrated that general anesthesia increases abdominal muscle activity in man. Second, the effects of abdominal surgery on reflex pathways may also be involved. Indeed, stimulation of abdominal splanchnic afferents produces an increase in expiratory output (Albano and Garnier, 1983). Occurrence of strong abdominal activity during expiration followed by relaxation at the beginning of the next inspiration, would have changed relative abdominal motion via an increase in ΔAAb even in the absence of changes in diaphragmatic function. This outward abdominal motion resulting from abdominal muscle relaxation would lead to an overestimate of the diaphragmatic contribution to the breathing process in the first few hours following surgery. However, no abdominal muscle activity could be detected during expiration 24 h after surgery using clinical (Simmoneau et al., 1983) or electromyographic assessment—as in the present study. These findings rule out a role of abdominal muscles in the genesis of the postoperative reduction in diaphragmatic index observed from day 1 to day 7.

Pneumoperitoneum, abdominal distension, or both, after operation may decrease abdominal compliance and so alter the mechanical properties of the abdominal compartment. These changes may reduce anteroposterior movement of the abdomen and thus affect the significance of the diaphragmatic index. However, no change in abdominal compliance was observed in dogs after cholecystectomy (Road et al., 1982). In addition, a decrease in abdominal wall compliance produces an increase in gastric pressure swings for the same diaphragmatic contraction. The fact that changes in gastric pressure, generated during inspiration, are reduced and even become negative after upper abdominal surgery (Ford et al., 1981; Simmoneau et al., 1983) suggests that marked diaphragmatic dysfunction is present, rather than an alteration in the mechanical properties of the abdominal compartment.

The last factor which could affect the use of the diaphragmatic index is the interaction between rib cage and diaphragm. Indeed, a decrease in this index could reflect increased ribcage activity as
well as decreased diaphragmatic activity. However, in our study, the marked decrease in ΔAB, associated with little changes in ΔRC, suggests that strong diaphragmatic dysfunction had occurred after upper abdominal surgery, without any major change in intercostal activity. We can conclude that the diaphragmatic index used in the present study can be considered a reliable index of diaphragmatic function when assessed before and at least 24 h after abdominal surgery.

Two main mechanisms may be responsible for the alteration of diaphragmatic function following upper abdominal surgery (Ford et al., 1983): an alteration of the contractile properties of the diaphragm as a consequence of the surgical trauma and a reflex inhibition of phrenic nerve output via parietal or abdominal receptors. The first mechanism may be eliminated as no change in diaphragmatic contractility has been observed after upper abdominal surgery (Dureuil et al., 1986). Thus, a decrease in phrenic nerve output, secondary to surgery, may be considered as the main cause of the alteration in diaphragmatic function. Previous animal studies had shown that ventilatory muscle activity may be modified reflexly by stimulation of intra-abdominal sympathetic afferent nerves (Albano and Garnier, 1983) and that inhibition of phrenic nerve output occurred during mechanical stimulation of the gall bladder in dogs (Ford et al., 1983). However, the nature of the receptors—and of the afferent pathways involved—remains unknown in man. Since diaphragmatic function is unchanged after lower abdominal surgery, the role of parietal or peritoneal receptors should not be of major importance. Although a role for nociceptors has been suggested, extradural analgesia with fentanyl failed to improve diaphragmatic function after upper abdominal surgery (Simmoneau et al., 1983). By contrast, thoracic extradural analgesia produced a marked improvement in diaphragmatic function associated with an increase in VC (Mankikian et al., 1985). This effect, when local anaesthetic is used, could be related to the blockage of sympathetic abdominal receptors, stimulated previously during the surgical procedure and responsible for the phrenic nerve inhibition (Albano and Garnier, 1983).

The reduction in lung volume observed after upper abdominal surgery may be related to diaphragmatic dysfunction after surgery, as it has been reported in patients with bilateral diaphragmatic paralysis (Newsom-Davis, 1979). Since VC is a measurement obtained from a voluntary manoeuvre in which diaphragmatic muscle is the major contributor (Bates, Macklem and Christie, 1971), any alteration in diaphragmatic muscle function affects the outcome of this manoeuvre. After upper abdominal surgery, diaphragmatic strength is reduced during maximal inspiratory manoeuvres and this reduction may account for the postoperative decrease in VC (Simmoneau et al., 1983). Nevertheless, VC does not depend only on ventilatory muscle activity, but also on the mechanical properties of the lungs. The decreases in lung compliance observed after upper abdominal surgery may be implicated as a cause of the decreased postoperative VC. However, the decrease in pulmonary compliance is moderate, within 10-15% of the preoperative value (Okinaka, 1966). Therefore, this decrease in lung compliance which is observed for at least 1 week after surgery cannot be regarded as the major determinant of the 50% decrease in VC after operation.

Finally, a decrease in diaphragmatic motion results in a diminished ventilation and expansion of the lower parts of the lungs (Loh, Hughes and Newsom-Davis, 1979). This alteration might be involved in the occurrence of small airways closure and atelectasis of the lung bases following upper abdominal surgery. In contrast, diaphragmatic function is not altered after lower abdominal surgery and therefore the ventilation of the lung bases is probably unchanged. The lower incidence of pulmonary complications after lower than after upper abdominal surgery (Ali et al., 1974) could be related to the absence of diaphragmatic impairment after the former. Since the occurrence of pulmonary complications is related to the reduction in lung volumes (Ali et al., 1974), it would be interesting to assess whether the therapeutic improvement of postoperative diaphragmatic function may reduce their incidence after upper abdominal surgery.

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REFERENCES


