ABSTRACT

A retrospective study was undertaken to elucidate the changes of acid-base balance following general surgery. 2843 samples of arterial blood gas and pH determinations were obtained from 418 surgical patients before and after the operation. Before the operation, the incidence of acid-base disturbance was low, 79.5% of 190 determinations being normal in acid-base balance. During the postoperative period, metabolic alkalosis was the most common acid-base disturbance as has been observed in 39.5% of 2248 determinations, while respiratory alkalosis was less frequent, occurring in 13.3%. The incidences of other abnormalities were low before and after the operation except for a transient increase in metabolic acidosis on the day of operation. After the operation, metabolic alkalosis was found most frequently, occurring in 47.5% of 1305 determinations during the first to seventh postoperative days, whereas an increase in respiratory alkalosis was not clearly seen during this period. Metabolic alkalosis seemed to take a transient increase with the highest incidence being 60.1% on the fourth postoperative day. Further prospective controlled study is required to elucidate the incidence and the development of mechanism of postoperative metabolic alkalosis.

Key words: Acid-base balance, Metabolic alkalosis, Postoperative alkalosis

INTRODUCTION

The postoperative alterations in acid-base balance in general surgery have not been well documented. A metabolic acidosis associated with hypoxemia was recognized in patients underwent esophagectomy, and for the past twenty years, an increased incidence of postoperative alkalosis has been described in several reports. However, there is no communication dealing with a substantial number of general surgical patients to
assess the incidence and clinical courses of acid-base balance changes after the operation. A retrospective study was undertaken to elucidate the postoperative changes in acid-base balance following general surgery. The incidence and clinical courses of postoperative metabolic alkalosis were analyzed.

MATERIALS AND METHODS

418 surgical patients were included in the study. The patient's age ranged from 18 to 88, the average being 61 years old. There were 243 males and 175 females. The majority of operations were performed for gastrointestinal carcinomas (42.9%), gallstone (10.3%), hepatoma (8.4%) and breast cancer (8.1%). 2,843 samples of arterial blood were anaerobically obtained from the patients during the course of the treatment. There were 190 preoperative samples, 234 postoperative samples taken on the day of operation, 1,305 samples obtained during first to seventh postoperative days, 228 samples during eighth to fourteenth postoperative days and 481 samples after fourteenth postoperative day. pH and PCO₂ were determined using blood gas analyzer (Model 175, Corning Medical INC., Corning, New York, U.S.A.), while bicarbonate concentration and base excess were calculated from Sigaard-Anderson nomogram.7 Using significance band,8 the data were defined to one of seven major categories of acid-base balance.

RESULTS

Before the operation, 79.5% of the 190 determinations were normal in acid-base balance, while metabolic alkalosis was seen in 7.9% and respiratory alkalosis occurred in 6.9% (Table 1). On the other hand, metabolic alkalosis became the most common acid-base disturbance during the postoperative period, occurring in 39.5% of 2,248 determinations, while the incidence of normal acid-base balance reduced to 35.4%. Respiratory alkalosis also increased to 13.3% after the operation. The other abnormalities including metabolic acidosis and respiratory acidosis were extremely low before and after the operation.

The incidences of the each type of acid-base disturbance during the postoperative period are indicated in Table 2. On the day of operation, there was a transient increase in the incidence of metabolic acidosis up to 8.5%, while the incidences of the other acid-base abnormalities were essentially unchanged from the preoperative figure. During the first to seventh postoperative days, metabolic alkalosis was seen more frequently, as observed in 47.5% of 1,305 determinations. After the seventh postoperative day, metabolic alkalosis still remained to be the most common acid-base disturbance occurring in 35.1% of 228 determinations during the eighth to fourteenth postoperative days and 36.6% of 481 determinations after the fourteenth postoperative day, while respiratory alkalosis showed a gradual increase to 27.2% during the period.
Table 1

Distribution in acid-base categories in 2438 determinations before and after operation

<table>
<thead>
<tr>
<th>Acid-base Balance categories</th>
<th>Preoperative determinations</th>
<th>Postoperative determinations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metabolic alkalosis</td>
<td>7.9% (15)</td>
<td>39.5% (889)</td>
</tr>
<tr>
<td>Metabolic acidosis</td>
<td>2.1% (4)</td>
<td>3.7% (84)</td>
</tr>
<tr>
<td>Respiratory alkalosis</td>
<td>6.8% (13)</td>
<td>13.9% (298)</td>
</tr>
<tr>
<td>Respiratory acidosis</td>
<td>1.6% (3)</td>
<td>2.9% (66)</td>
</tr>
<tr>
<td>Combined alkalosis</td>
<td>1.6% (3)</td>
<td>4.4% (100)</td>
</tr>
<tr>
<td>Combined acidosis</td>
<td>0.5% (1)</td>
<td>0.7% (16)</td>
</tr>
<tr>
<td>Normal acid-base balance</td>
<td>79.5% (151)</td>
<td>35.4% (795)</td>
</tr>
<tr>
<td>Total</td>
<td>100.0% (190)</td>
<td>100.0% (2248)</td>
</tr>
</tbody>
</table>

( ) = number of determinations

Table 2

Changes of each acid-base disturbance during postoperative period

<table>
<thead>
<tr>
<th>Acid-base Balance</th>
<th>Pre</th>
<th>POD 0</th>
<th>POD 1–7</th>
<th>POD 8–14</th>
<th>POD 15–</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metabolic alkalosis</td>
<td>7.9%</td>
<td>5.6%</td>
<td>47.5%</td>
<td>35.1%</td>
<td>36.6%</td>
</tr>
<tr>
<td>Metabolic acidosis</td>
<td>2.1%</td>
<td>8.5%</td>
<td>2.3%</td>
<td>3.5%</td>
<td>5.4%</td>
</tr>
<tr>
<td>Respiratory alkalosis</td>
<td>6.8%</td>
<td>9.0%</td>
<td>8.0%</td>
<td>18.4%</td>
<td>27.2%</td>
</tr>
<tr>
<td>Respiratory acidosis</td>
<td>1.6%</td>
<td>2.1%</td>
<td>2.2%</td>
<td>2.2%</td>
<td>5.6%</td>
</tr>
<tr>
<td>Combined alkalosis</td>
<td>1.6%</td>
<td>3.4%</td>
<td>2.6%</td>
<td>8.3%</td>
<td>8.1%</td>
</tr>
<tr>
<td>Combined acidosis</td>
<td>0.5%</td>
<td>0.9%</td>
<td>0.5%</td>
<td>0.9%</td>
<td>1.0%</td>
</tr>
<tr>
<td>Normal acid-base balance</td>
<td>79.5%</td>
<td>70.5%</td>
<td>36.9%</td>
<td>31.6%</td>
<td>16.0%</td>
</tr>
</tbody>
</table>

The incidence of the six major acid-base disturbances during the postoperative days (0 through seven) was assessed on daily basis (Fig. 1). The incidence of metabolic alkalosis increased on the first postoperative day, reaching 58.1% on the third postoperative day and leveled off thereafter, the peak being 60.1% observed on the fourth postoperative day. The incidence of respiratory alkalosis did not show significant alteration in this period.

The daily changes of mean arterial pH, PCO₂, bicarbonate and base excess values before the operation and during the postoperative days (0 through seven) are shown in Figure 2. During the postoperative period, there was a gradual elevation of pH associated with an increase in bicarbonate concentration and base excess values. On the fifth postoperative day, mean pH elevated to 7.50, while bicarbonate concentration and base excess increased to 30.0 mEq/L and 6.3 mEq/L, respectively. On the contrary, PCO₂ was essentially unchanged through this period.
Fig. 1 Daily changes of each acid-base disturbance before and after operation.
Fig. 2 Changes of mean arterial pH, PCO₂, bicarbonate and base excess values before and after operation.
Table 3
Causes of metabolic alkalosis
(Seldin and Rector\textsuperscript{12})

1. Loss of acid from extracellular space
   A. Loss of acid into gastric juice: vomiting, gastric suction or fistula
   B. Loss of acid into urine: increased distal Na delivery in presence of hyperaldosteronism
   C. Loss of acid into cells: K deficiency
   D. Loss of acid into stools: congenital alkalosis with diarrhea

2. Excessive HCO\textsubscript{3}\textsuperscript{-} loads
   A. Absolute
      a. Oral or parenteral loads of NaHCO\textsubscript{3} or alkalinizing Na salts
      b. Metabolic conversion of endogenous acid anions (e.g. ketons, lactate) to HCO\textsubscript{3}\textsuperscript{-}
   B. Relative
      a. Alkaline loads in renal failure

3. Contraction of extracellular space
   A. Diuretic loss of NaCl without commensurate of NaHCO\textsubscript{3}

4. Post-hypercapneic state

DISCUSSION

Although postoperative alkalosis has been recognized to be a significant clinical problem in recent years, the details of metabolic alkalosis have still remained unknown in patients undergoing general surgery. In this study, it was found that metabolic alkalosis was the most common acid-base disturbance complicating general surgery, as has been observed in 39.5\% of 2,248 determinations during the postoperative period. Metabolic alkalosis was seen more frequently during the first to seventh postoperative days, occurring in 47.5\% of 1,305 determinations.

There have been several clinical reports dealing with postoperative acid-base disturbance.\textsuperscript{2-6} A high incidence of postoperative alkalosis has been similarly pointed out in these reports. Lyons and Moore\textsuperscript{2} found that 67 cases of 105 surgical patients who had one or more arterial blood gas determinations done, were alkalotic on at least one determination. In the study by Sato \textit{et al.},\textsuperscript{3} metabolic alkalosis was found in 37 samples of 59 arterial blood gas determinations obtained from 13 patients who were under serious condition after abdominal surgery. Hodgkin \textit{et al.}\textsuperscript{4} also reported that metabolic alkalosis was the most frequent disturbance occurring in 51.1\% of 7,433 determinations with abnormal acid-base values from 13,430 hospitalized patients. On the other hand, some authors\textsuperscript{5,6} described that respiratory alkalosis had a greater incidence than metabolic alkalosis after surgery. In our study, although the incidence of respiratory alkalosis showed a gradual increase following operation, it remained 13.3\% of the total deter-
Postoperative Metabolic Alkalosis

minations during the postoperative period. Besides, an increase in respiratory alkalosis was not clearly observed until the seventh postoperative day. Metabolic acidosis which had ever been regarded as a serious clinical problem after operation, was extremely rare before and after the operation, except for a transient increase to 8.5% on the day of operation.

With regards to the adverse effects of metabolic alkalosis, tissue oxygenation interference due to the shift of oxyhemoglobin dissociation curve to the left, muscular spasm and tetany resulted from overexcitability of the nervous system, cardiac arrhythmia and compensatory hypoventilation have been described in the literature. In a recent study by Wilson et al. in 177 critically ill surgical patients, a significant correlation was found between the mortality of the patients and the degree of alkalosis, while the mortality was highest in the cases with metabolic alkalosis, severe sepsis and respiratory failure.

Seldin and Rector classified the causes of metabolic alkalosis into four major categories as shown in Table 3. In general, metabolic alkalosis seems to have many causes that complicatedly interfere in one another. Although some authors have pointed out the loss of acid from nasogastric suction or gastointestinal fistula, an excessive bicarbonate load and transient hyperaldosteronism as the etiologic factors in the development of postoperative metabolic alkalosis, they also have described that the etiology of metabolic alkalosis in many surgical patients has been still difficult to clarify.

In this retrospective study, although it was confirmed that metabolic alkalosis was the most common acid-base disturbance after general surgery, the incidence might not represent the exact figure in surgical population. Obviously there is a possibility that the determinations were carried out more frequently and repeatedly in the patients having postoperative hypoxemia especially after the seventh postoperative day. Also the etiologic factors of metabolic alkalosis could not be assessed due to the nature of the retrospective study in which there were numbers of variable clinical factors influencing the acid-base balance. A further prospective controlled study is required in order to elucidate the exact incidence and the development of mechanism of metabolic alkalosis following general surgery.

REFERENCES

5. Wilson, R., Gibson, D., Percinel, A. et al.: Severe alkalosis in critically ill surgical