End-tidal carbon dioxide monitoring in the detection of anesthesia-related critical incidents

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A prospective study was undertaken in an effort to determine the usefulness of the end-tidal carbon dioxide monitor in detecting anesthesia-related critical incidents. The critical incident technique was employed in the evaluation of 2,334 anesthetics. Anesthesia providers completed a critical incident questionnaire following each anesthetic. All questionnaires were analyzed for the occurrence of a critical incident. The anesthesia provider was interviewed and the patient record reviewed in all cases of reported critical incidents to determine (1) the frequency of specific anesthesia-related critical incidents, and (2) the usefulness of the end-tidal carbon dioxide monitor in detecting such events. The critical incident technique revealed 79 such incidents. Monitoring of end-tidal carbon dioxide was found to be useful in confirming the occurrence of already suspected critical incidents 58% of the time. The end-tidal carbon dioxide monitor was also found to be the initial detector of 27% of the reported anesthesia-related critical incidents. Monitoring of end-tidal carbon dioxide proved to be beneficial in detecting and confirming critical incidents during anesthetic management.

Key words: Anesthesia mishaps, capnograph, end-tidal carbon dioxide monitor.

Introduction

The occurrence of an anesthesia mishap is a fear shared by those who administer or receive an anesthetic. According to Keenan, anesthesia mishaps are the cause of persistently high malpractice insurance for anesthesia providers.1

In 1986, St. Paul Fire & Marine Insurance Company, a large, nationwide malpractice insurer, published a list of the 10 most common claims recorded against anesthesiologists. It covered claims recorded in 1985, including the dollar reserves set aside for each claim. Three of the top four claims were subsets of anesthesia disasters. These subsets included adverse reactions, catastrophe, and cardiac arrest. The total cost for these three categories was $11,935,558, which accounted for 80% of all costs on the list. It was clear that anesthesia disasters are very expensive and the cause of anesthesia providers' malpractice problems.1

Harrison looked at the incidence of death attributable to anesthesia during a 10-year period.2 The survey was conducted in a 1,300-bed teaching hospital in South Africa. Anesthesia mortality was defined as a death occurring during or within 24 hours of anesthesia or the failure of a patient, conscious before, to regain consciousness after anesthesia.

Pertinent information was obtained from the anesthesia record and from an interview with the anesthetist involved with each death. This information was reviewed in relation to three questions:
1. Was the anesthetic responsible for the death?
2. What was the precise anesthetic cause?
3. Was there a clinical lesson to be learned from the data collected?

The causes were found to be either failure of respiratory homeostasis or circulatory homeostasis. There was considerable overlap between these causes. Deaths from anesthesia were found to be multiple, compound interactions with many variables.

Harrison initially identified 531 anesthesia-related deaths (number (N) = 177,928). This was calculated as 2.2 deaths per 1,000 anesthetics. In further studying the data, Harrison found that 10% of these were assessed as being attributed to anesthesia. Consequently, the anesthesia death rate was reduced to 0.22 deaths per 1,000 anesthetics. Four clinical situations were found to be responsible for two-thirds of the anesthesia-related deaths. These were:

2. Respiratory inadequacy following myoneural blockade.
3. Inadequate postoperative care.

The remaining deaths did not constitute a homogeneous group.

The most frequent causes of anesthesia deaths are drug overdose, aspiration, circulatory instability, and failure to ventilate. These causes compare favorably to the findings of Cooper and associates, in that approximately 80% of anesthesia mishaps are human errors and, therefore, preventable. It is also noted that only 4% of anesthesia mishaps with substantive negative outcomes involve equipment failure. This confirms the earlier finding that human error is the dominant issue in anesthesia disasters. In an attempt to reduce human error, specific monitoring devices may be invaluable to the anesthesia provider in administering a safer anesthetic.

The end-tidal carbon dioxide monitor is quickly becoming a standard in anesthesia. This device monitors the efficiency of ventilation by detecting the amount of carbon dioxide present in the anesthetized patient's exhaled gas. Since carbon dioxide is a normal constituent of exhaled gas, its ratio to other gases is known.

The capnograph displays a digital value of carbon dioxide concentration along with a respiratory waveform. It provides information regarding both the integrity and function of the patient's cardio-pulmonary system and the system for delivery of life-supporting gases. Malfunctions in either can be detected by noting changes in the capnograph during an anesthetic.

The majority of common anesthesia mishaps can be detected by changes in the end-tidal carbon dioxide waveform. There is either no waveform present or there is loss of a previous waveform when esophageal intubations and breathing system disconnects occur. Respiratory acidemia or alkalemia resulting from altered carbon dioxide states can also be detected with the end-tidal carbon dioxide monitor. Hypoventilation or hyperventilation caused by a drug overdose is detectable in a spontaneously breathing patient using a capnograph.

Murray and Modell investigated how rapidly events such as esophageal intubations, accidental tracheal extubations, ventilator disconnections, and endotracheal tube obstructions were detected by changes in exhaled carbon dioxide concentrations. Intubated mongrel dogs were used for their study (N = 12). Once a baseline carbon dioxide tracing was obtained, the responses to disconnections, kinks, and endotracheal tube misplacements were observed. Monitoring of the end-tidal carbon dioxide concentration resulted in immediate detection when total loss of ventilation occurred. Whenever there was partial extubation, or any situation causing partial loss of carbon dioxide concentration, a recognizable erratic pattern was seen. This pattern was not detectable when carbon dioxide was monitored only in numerical form (capnometer).

Cote performed a prospective study involving the same concepts as Murray and Modell. However, Cote studied children in the clinical setting and did not alter the routine anesthetic management. The findings in both studies were very similar. Incidents such as endotracheal tube disconnects, misplacements, and kinks were found.

Cote's study differed from that of Murray and Modell because Cote used both intubated and nonintubated subjects. Hypocarbia was common in intubated patients, and hypercarbia was common in nonintubated patients. This study supported Murray and Modell's findings concerning capnography versus capnometry. A greater number of incidents were detected when the carbon dioxide waveform was displayed. Also, incidents detected by the expired carbon dioxide concentration could not always be diagnosed with a stethoscope or through visual observations.

Since end-tidal carbon dioxide monitoring can detect many of the most frequent causes of anesthesia mishaps, it may be beneficial in alerting the anesthesia provider to the early occurrence of a

* A 1980 British study that looked at 486,000 anesthetics revealed a rate of one anesthetic death in 185,056 patients. (Lunn JN, Devlin HB. Lessons from the confidential inquiry into perioperative deaths in three NHS regions. Lancet. 1987;2:1384-1386.)
critical event. The capnogram may also assist the anesthesia provider in detecting mishaps that enable him or her to make prompt correction and, therefore, help decrease the 80% incidence of human error in anesthesia mishaps.

The critical incident technique has been used for years in making behavioral observations for solving problems. A critical incident has been defined as any observable activity sufficiently complete in itself to permit inferences and predictions to be made about the act. The literature has given supporting evidence for the reliability and validity of the critical incident technique in evaluating activities.

A study of anesthesia mishaps using the critical incident technique was performed by Cooper. This study employed a retrospective examination of the characteristics of both human error and equipment failure in anesthesia practice. The objective was to identify patterns of incidents that occurred frequently. Once such incidents were identified, a more thorough investigation of their cause could be made.

The methodology included collection of information about preventable mishaps from staff and resident anesthesiologists at a large metropolitan teaching hospital. The information was collected randomly by interviewing department members. All the interviews were conducted by the same interviewer in the same neutral location, using a technique that had been refined to minimize bias. Selected practitioners were asked to describe preventable incidents they had observed or participated in which involved either a human or equipment error.

The incidents recorded ranged in seriousness from laryngoscope malfunctions with no known sequelae affecting the patient to breathing circuit disconnections resulting in death. Human error was involved in 82% of the preventable incidents reported and equipment failure in 14%. The remaining 16 incidents could not be placed definitively into any specific category. This study also found that accounts of overt equipment failure were few (50 incidents) and rarely resulted in sequelae that lasted beyond correction of the immediate problem. Only six of the interviews concerned incidents that involved functional failure of a machine.

Several patterns of incidents that occurred frequently were noted. It was found that 82% of the mishaps were the result of preventable occurrences. This percentage left a large area for prospective investigation into correctable interventions. The study might have elicited more detailed incidents if it had defined the period from which they were recalled. Practitioners were asked to recall any event from the past. A more structured recall method could have been utilized in which the participants were interviewed shortly after documented mishaps.

McKay and Noble applied the critical incident technique to anesthesia when they evaluated the reliability of the pulse oximeter in detecting anesthesia mishaps. This monitoring device was found to be both reliable and beneficial to the practice of anesthesia. Their methodology is followed in this study to determine the usefulness of the capnograph in detecting critical anesthesia incidents.

**Methods and materials**

- **Research design.** A prospective research design was used. This involved monitoring end-tidal carbon dioxide levels during anesthesia administration and a postoperative review of those cases in which critical incidents occurred. Questionnaires were distributed to all anesthesia providers so they were aware of the research process prior to administration of the anesthetic. Patient charts and interviews with anesthesia care providers were used as sources of information for the documentation of positive findings. Information was gathered from surgical anesthetics, excluding obstetric and outpatient anesthesia settings. Anyone who provided anesthesia care in those settings was eligible for inclusion in the study.

- **Population.** All anesthetics administered in the operating rooms of a major mid-Atlantic university teaching hospital during a 4-month period were reviewed. These included the following techniques: (1) general, (2) regional, and (3) monitored standby anesthesia. Patient demographics were not used as inclusion criteria. From the total number of anesthetics administered during the designated time period, only those that possessed predetermined characteristics were studied as critical incidents. The inclusion criteria for the study included:
  1. An unexpected physiological event occurring at a time when the patient was under the care of an anesthesia provider.
  2. The event led to, or could have led to, an adverse outcome.
  3. The event was not caused by expected physiological changes resulting from changing levels of anesthesia.

- **Instrumentation.** Two types of end-tidal carbon dioxide monitors were used. The type available was determined by the location of the anesthetic. Both sidestream and mainstream monitors were used and were capable of displaying a numerical figure along with a waveform pattern. Sidestream monitors aspirated a sample from the breathing circuit and analyzed it within the capnograph, while mainstream monitors utilized sensors which
analyzed the exhaled gas directly at the point of exhalation.

- Questionnaire. A questionnaire adapted from the critical incident study by McKay and Noble was used. To familiarize anesthesia personnel with the research project, both the questionnaire and details of the study were introduced at a group meeting 1 week prior to initiating data collection. Information from the questionnaire pinpointed those anesthetics where a critical incident had occurred.

The questionnaire involved six questions:
1. Was the end-tidal carbon dioxide monitor used?
2. Did any problems occur with the anesthetic?
3. If problems occurred, what were they?
4. Did the end-tidal carbon dioxide monitor help warn of the problem?
5. Was the end-tidal carbon dioxide monitor the first indicator of the unexpected problem?
6. Did a false alarm occur?

A second data collection sheet was completed when the first questionnaire produced a positive response. This sheet contained information concerning the specific critical event and further data about the patient involved.

- Protocol. The questionnaire was distributed by the operating rooms' main control center to all anesthesia providers at the beginning of the anesthetic. The questionnaire was included in each packet of anesthesia records.

All the completed and returned questionnaires were reviewed. Within 48 hours, those that indicated a critical incident were identified and separated from the others. Once these questionnaires were identified, the follow-up procedure was carried out. This included a personal or telephone interview with the anesthesia provider within 48 hours of the administration of the anesthetic. The anesthesia record was also reviewed, although this process did not have a time restriction placed upon it. When an unexpected physiologic change was detected that was severe enough to require intervention by the anesthesia provider, a critical incident was recorded. Documentation of the type of anesthetic and phase of anesthetic as well as pertinent demographic data concerning the patient were noted.

Once the data collection was complete, the critical incidents were classified as to type of anesthetic; phase of anesthetic (induction, maintenance, or emergence); subjects' gender, age, smoking history, ASA physical class, incidence of obesity; and type of critical incident. The data were then examined. Types of critical incidents that were most frequently identified were noted, and comparisons were made of specific patient characteristics in relation to the types of critical incidents which were detected most often.

- Data analysis. Once the reported critical incidents were grouped into categories of similar characteristics, the data was analyzed using the chi-square, nonparametric test for significance. For further statistical analysis, the population represented by the returned questionnaires was weighted against the parent population. Chi-square analysis was again used to examine the possible relationship of the critical incidents to type of surgery, ASA risk, and patient age. An alpha level of .05 was designated as the level of significance for this study.

Results
- Descriptive analysis. The total number of anesthetics administered during the 4-month study period was 4,058. There were 2,334 critical incident forms returned, resulting in a return rate of 56% (N = 2,334); however, forms were not correctly completed in 159 of the cases. Most incorrectly completed forms had a patient's name attached and the first question completed, but the rest of the form was not completed. These were eliminated from the study, resulting in a correctly completed return rate of 54% (N = 2,175). The returned forms recorded that the capnograph was utilized during 1,583 of the anesthetics administered, which corresponds to a capnograph application rate of 73% (N = 1,583).

Questionnaires were returned and marked with a positive response for a critical incident 82 times. Seven positively marked forms were disqualified from the study after further discussion with the anesthesia provider and a review of the chart. The disqualifications were caused by incidents that did not fit one or more of the prestated inclusion requirements for the study. One form had three incidents recorded, and two other forms each had two incidents marked. Therefore, analysis was based on 79 critical incidents. This produced a critical incident rate of 3.6% (N = 2,175). Of the correctly completed forms, there were a total of 31 false alarms, for a rate of 1.4%.

A total of 25 different categories of critical incidents were reported. Esophageal intubations were reported most frequently (N = 12). The four other categories for which the greatest number of incidents were reported were breathing system disconnects, hypoxia, bronchospasm, and difficult intubations. Eight breathing system disconnects and 10 difficult intubations were recorded. The other most frequently reported critical incidents were hypoxia and bronchospasm, with a total of five incidents each.

The 20 remaining groups had an incident occurrence range of between one and four. For statisti-
cal analysis the groups were combined according to similar characteristics. The following categories were formed:

1. Altered ventilation (N = 9).
2. Hypotension with or without blood loss (N = 7).
3. Hypercarbia other than altered ventilation (N = 5).
4. Arrhythmias (N = 5).
5. Miscellaneous others (N = 8).

 Bronchospasms were combined with laryngospasms into a category called airway obstruction (N = 8). Incorrectly placed endotracheal tubes, but not those placed in the esophagus, were combined with esophageal intubations in a category called esophageal/misplaced intubations (N = 14). This resulted in 10 categories for data analysis, which were reviewed in the order of most frequent occurrence.

Of the 14 esophageal/misplaced intubations, 12 were detected by the capnograph. The two remaining esophageal intubations were not detected by the capnograph; however, one occurred while the capnograph was not in use. The capnograph was selected on five occasions as being the first indication of a problem. Auscultation of breath sounds and chest movement were the two indicators most frequently recorded on the nine remaining incidents.

The category of difficult intubations (N = 10) showed the capnograph being used as a diagnostic tool rather than as an indicator of a critical incident. Nine questionnaires indicated that the capnograph was helpful during difficult intubations. One listed the capnograph as the first indicator of correct endotracheal tube placement. Auscultation of breath sounds was listed as the first indicator of correct endotracheal tube placement in the other nine difficult intubations. However, all forms listed the capnograph as a diagnostic tool to confirm correct tube placement when placement of the endotracheal tube was uncertain.

The category of altered ventilation was formed by combining hypoventilation (N = 3), hyperventilation (N = 4), and difficult mask fit in cases where the anesthesia provider was unable to adequately ventilate (N = 2). This category had a total of nine incidents. The capnograph was marked as the first monitor to make the detection seven times. The two remaining incidents had the capnograph listed as not being helpful in the detection.

Breathing circuit disconnects occurred eight times, and the questionnaire reported the capnograph as a helpful monitor in aiding detection. Of the eight incidents, three recorded the capnograph as the first monitor to detect the disconnect. The ventilator disconnect alarm and loss of resistance in the reservoir bag were listed as the first indicators of a disconnect in those cases where the capnograph was not recorded.

There were eight occurrences of airway obstruction. The obstruction was caused either by a laryngospasm or a bronchospasm. One incident recorded the capnograph as aiding in detection; however, it was not the first indication of the occurrence. In the seven remaining instances, it was felt that the capnograph did not assist in detection. In one case, the capnograph had been turned off prior to the occurrence of the incident. Increased airway pressures and the inability to deliver the previously obtained tidal volume were listed as the leading indicators of airway obstruction.

Hypotension, with or without significant blood loss, occurred seven times. The capnograph was recorded as useful, but not the first indicator, for only one case. Other than blood pressure recordings, visual inspection of blood loss and tachycardia were the two most commonly listed indicators of hypotension.

Hypoxia was reported five times. The capnograph was not marked as a helpful monitor in any of the incidents reported. The pulse oximeter was recorded as the leading monitor in detecting hypoxia.

Arrhythmias accounted for five of the reported critical incidents. None of the reported arrhythmias resulted in asystole. Only one case had hypotension associated with the arrhythmia. The capnograph did not assist in diagnosing the presence of these arrhythmias.

Hypercarbia, caused by factors other than inadequate ventilation, occurred five times. It involved two cases of metabolic acidosis, two incidents of mucous plugs in the endotracheal tube, and one case of hypercarbia following a tourniquet release. The capnograph was listed as helpful in detecting hypercarbia four times and as the first monitor to detect its presence three out of the four times. In one case of metabolic acidosis, it was reported that the monitoring of end-tidal carbon dioxide was not beneficial.

There were eight incidents that occurred only once and were unrelated to any of the previously listed categories. Therefore, they were included in a group of miscellaneous others. The capnograph was recorded as helpful in the detection of four of these incidents and as the first indicator in three cases, including a depletion of soda lime efficiency, a kinked endotracheal tube, and a failure to turn the ventilator switch to automode ventilation. The four remaining incidents were not detected by the capnograph.

- **Statistical analysis.** The 10 categories of critical incidents were examined. First, the effectiveness of
the end-tidal carbon dioxide monitor in detecting critical incidents was examined by the chi-square test of independence. A significant chi-square was obtained when the capnograph was analyzed both as a useful monitor $X^2(9, N = 79) = 43.22, P = .001$ and as the first monitor to detect a critical incident $X^2(9, N = 79) = 26.15, P = .002$ (Tables I and II). More than one-fifth of the designated categories were sparse (frequency less than 5).

### Table I

<table>
<thead>
<tr>
<th>Group</th>
<th>Detection</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Helpful</td>
<td>Not helpful</td>
<td>Total</td>
</tr>
<tr>
<td>Esophageal intubations</td>
<td>12</td>
<td>2</td>
<td>14*</td>
</tr>
<tr>
<td>Difficult intubations</td>
<td>9</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Altered ventilation</td>
<td>7</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>Disconnects</td>
<td>8</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Airway obstruction</td>
<td>1</td>
<td>7</td>
<td>8*</td>
</tr>
<tr>
<td>Others</td>
<td>4</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Hypotension</td>
<td>1</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Hypercarbia</td>
<td>4</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Arrhythmias</td>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Hypoxia</td>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>46</strong></td>
<td><strong>33</strong></td>
<td><strong>79</strong></td>
</tr>
</tbody>
</table>

$P = .001$.  
*Note: More than one-fifth of the designated categories are sparse (frequency less than 5).  
*One occurred when capnograph was not in use.

### Table II

<table>
<thead>
<tr>
<th>Group</th>
<th>Detection</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>First</td>
<td>Not first</td>
<td>Total</td>
</tr>
<tr>
<td>Esophageal intubations</td>
<td>5</td>
<td>9</td>
<td>14*</td>
</tr>
<tr>
<td>Difficult intubations</td>
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<td>10</td>
</tr>
<tr>
<td>Altered ventilation</td>
<td>7</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>Disconnects</td>
<td>3</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Airway obstruction</td>
<td>0</td>
<td>8</td>
<td>8*</td>
</tr>
<tr>
<td>Others</td>
<td>3</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Hypotension</td>
<td>0</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Hypercarbia</td>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Arrhythmias</td>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Hypoxia</td>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>22</strong></td>
<td><strong>57</strong></td>
<td><strong>79</strong></td>
</tr>
</tbody>
</table>

$P = .002$.  
*Note: More than one-fifth of the designated categories are sparse (frequency less than 5).  
*One occurred when capnograph was not in use.

Next, the possible relationships between critical incidents, types of surgery, ASA risks, and patient age were examined. However, not all of these factors were equally represented in the parent population. For example, the number of surgical cases by surgical service varied from thoracic (7.4%) to orthopedic (20.39%). To compensate for this variance, the data were adjusted to match the parent population profile. The most frequent surgery type was given a weight of 1.0, and the other types were given proportionately higher weights. The cell frequencies were then adjusted to reflect what they might be if all types of surgery were equally represented in the parent population. All designated categories were rounded off to the nearest whole number.

The adjusted contingency table for critical incidents in relation to type of surgery shows there would be a total of 130 critical incidents, if each of the other seven surgical services had the same number of cases as orthopedics. A significant chi-square was obtained when the types of surgical cases were weighted against the number of orthopedic cases $X^2(63, N = 130) = 172.74, P = .001$ (Table III).

A similar weighting procedure was used to equalize the age groups. The ">40" group had the largest percentage of patients and was assigned a weight of 1.0; the other groups were given higher weights. The revised contingency table showed 121 critical incidents. The chi-square was significant when the other age groups were equalized with the >40 group $X^2(18, N = 121) = 46.3, P = .001$ (Table IV).

A weighted contingency table of anesthesia risks was also prepared. ASA classes I and II were assigned a value of 1.0; ASA classes III, IV, and V were assigned a higher value. This contingency table produced 87 critical incidents, and a significant chi-square was obtained $X^2(9, N = 87) = 17.19, P = .046$ (Table V).

### Discussion

The purpose of this study was to evaluate the capnograph in relation to its usefulness in detecting and alerting anesthesia providers to potential anesthesia mishaps. The capnograph's helpfulness in confirming already suspected anesthesia-related critical incidents proved both statistically and clinically significant. While statistical analysis did not support the capnograph as the initial detector of critical incidents, clinically, monitoring of end-tidal carbon dioxide proved to be useful. The capnograph initially detected 27% of the reported critical incidents. This is clinically significant, considering the possibility of an adverse patient outcome each time a critical incident goes undetected.

Information from the capnograph also proved to be beneficial in decision making during anesthe-
### Table III
Critical incidents in relation to surgery type

<table>
<thead>
<tr>
<th>Group</th>
<th>Thoracic</th>
<th>Genito-urinary</th>
<th>Vascular</th>
<th>Neurological</th>
<th>Orthopedic</th>
<th>Gynecological</th>
<th>General and throat</th>
<th>Total</th>
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</thead>
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<tr>
<td>Weight*</td>
<td>2.8</td>
<td>2.5</td>
<td>1.4</td>
<td>1.6</td>
<td>1.0</td>
<td>1.2</td>
<td>1.2</td>
<td>2.5</td>
</tr>
<tr>
<td>Esophageal intubations</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>3</td>
<td>0</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Difficult intubations</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>3</td>
<td>0</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Altered ventilation</td>
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<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
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<td>5</td>
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</tr>
<tr>
<td>Disconnects</td>
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<td>0</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>5</td>
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<tr>
<td>Airway obstruction</td>
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<td>0</td>
<td>2</td>
<td>3</td>
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<tr>
<td>Others</td>
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<td>Hypotension</td>
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<td>0</td>
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<td>2</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
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<td>4</td>
<td>8</td>
<td>22</td>
<td>18</td>
<td>15</td>
<td>130</td>
</tr>
</tbody>
</table>

P < .001.

Note: More than one-fifth of the designated categories are sparse (frequency less than 5).

* Weight is based on proportion of total cases in which critical incidents occurred (number = 2,462).

### Summary

The critical incident technique was used to effectively collect a large amount of data from a diversified patient population over a relatively short period of time. It was found that monitoring endotracheal tube placement in difficult intubations, guidance of ventilation parameters, and diagnosis of insufficient ventilation. Once the critical incidents were detected, it was noted that the frequency was greater among older patients; patients in ASA classifications I and II; and those undergoing orthopedic, gynecological, ear, nose and throat, and general surgery.

The critical incident technique was used to effectively collect a large amount of data from a diversified patient population over a relatively short period of time. It was found that monitoring

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of end-tidal carbon dioxide is beneficial in anesthesia management. It can lead to the detection of suspected critical incidents and, therefore, decrease the incidence of anesthesia mishaps. The capnograph can also be utilized as a valuable monitor in directing airway and ventilatory management.

REFERENCES


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