Current Utilization of Continuous End-Tidal Carbon Dioxide Monitoring in Pediatric Emergency Departments

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Objective: End-tidal carbon dioxide ($ETCO_2$) monitoring has numerous clinical applications in the emergency setting. This study was designed to explore the current availability and utilization patterns for continuous $ETCO_2$ monitoring in pediatric emergency departments.

Methods: A Web-based survey was distributed to directors of all accredited pediatric emergency medicine fellowship programs in the United States and Canada.

Results: Eighty-one percent of directors completed this survey. Eighty-eight percent had access to $ETCO_2$ monitoring for intubated patients and 53% for nonintubated patients. Seventy-nine percent of respondents used $ETCO_2$ monitoring "always" or "often" for endotracheal tube confirmation. Only 20% of respondents used $ETCO_2$ monitoring "always" or "often" for moderate sedation, 16% for trauma, and 6% for acid-base disturbances. One hundred percent of respondents who used $ETCO_2$ monitoring felt that it was easy to use. The most common reason for not using $ETCO_2$ monitoring was lack of equipment (65%).

Conclusions: $ETCO_2$ monitoring is widely available, yet underutilized, for spontaneously breathing patients in pediatric emergency departments.

Key Words: end-tidal carbon dioxide, monitoring

Capnography is the measurement of the exhaled carbon dioxide (CO_2) during inspiration and expiration. A capnogram is the wave form representing the concentration of CO_2 over time. Capnometry is the numeric value of maximum exhaled CO_2 in the respiratory cycle, also known as the end-tidal carbon dioxide ($ETCO_2$). $ETCO_2$ represents the alveolar concentration of carbon dioxide and has been shown to closely approximate arterial CO_2 concentrations.[1] Recent advances have made it possible to easily measure exhaled CO_2 in intubated patients, through an inline attachment to the endotracheal tube, as well as in patients that are spontaneously breathing through a nasal cannula. Smaller portable devices make it convenient to observe exhaled CO_2 levels at the bedside in a noninvasive manner, which is well tolerated by children.

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Capnography and $ETCO_2$ are objective markers of ventilatory status. In addition, this monitoring tool offers a noninvasive method of measuring acid-base status and cardiac output. Current uses in emergency departments include confirmation of endotracheal intubation, monitoring the ventilatory status of intubated patients, and monitoring nonintubated patients undergoing moderate sedation.[2] Recent studies have also used it to measure metabolic disturbances.[3,4]

It has been shown, however, that continuous $ETCO_2$ monitoring is underutilized by physicians in pediatric and adult intensive care units abroad and physicians in adult emergency departments and emergency medical service personnel in the United States.[5–8] This is the first study to investigate how $ETCO_2$ monitoring is being used by pediatric emergency medicine (PEM) physicians. Our objective was to determine the current availability and utilization of continuous $ETCO_2$ monitoring in pediatric emergency departments (PED).

METHODS

Between June and July 2006, a Web-based survey was distributed to the directors of all accredited PEM fellowship programs in the United States and Canada. Respondents were queried about the type of facility in which they practiced, the availability of continuous $ETCO_2$ monitoring for intubated and nonintubated patients, the perceived strengths and weaknesses of the device, and interest in learning more about $ETCO_2$ monitoring and its applications. A 4-point Likert scale was used to assess current utilization of continuous $ETCO_2$ monitoring for various clinical applications, rated as "always," "often," "sometimes," and "never."

The survey was distributed up to 3 times to ensure maximum participation. Data were analyzed with SPSS 14.0 (SPSS Inc, Chicago, IL). Descriptive analyses and chi-square analysis were performed. This study was approved by the Yale University Human Investigation Committee.

RESULTS

Forty-three (74%) of 58 PEM fellowship directors completed the survey. Seventy-four percent stated that their primary institution was a stand-alone children's hospital, and 23% of respondents had a separate PED in a general hospital. One respondent described their facility as a separate PED adjacent to an adult emergency department. Thirty-eight respondents (88%) had access to continuous $ETCO_2$ monitoring for intubated patients and 23 respondents (53%) for nonintubated patients. Two respondents were unsure if monitoring was available for nonintubated patients. Five

TABLE 1. Current Utilization of Continuous $ETCO_2$ Monitoring in Clinical Situations (N = 38)

Clinical Situation	Always	Often	Sometimes	Never
Endotracheal tube confirmation	69%	10%	10%	10%
Moderate sedation	14%	6%	19%	61%
Trauma	8%	8%	38%	46%
Acid-base disturbances (eg, diabetic ketoacidosis, gastroenteritis)	3%	3%	22%	72%
Cardiopulmonary resuscitation	54%	8%	19%	19%

respondents did not have access to $ETCO_2$ monitoring for either intubated or nonintubated patients.

If continuous $ETCO_2$ monitoring was available, fellowship directors were asked about its current utilization in several clinical situations; these results are listed in Table 1. There was a significant difference in the frequency of utilization of $ETCO_2$ monitoring for endotracheal tube confirmation and cardiopulmonary resuscitation between respondents from stand-alone children's hospital and PEDs within general hospitals ($P = 0.001$).

Of the institutions that currently use continuous $ETCO_2$ monitoring, 34 (100%) felt that it is easy to use, 33 (97%) felt that the results are accurate, and 31 (91%) felt that the results are easy to interpret. Furthermore, 25 respondents (74%) felt knowledgeable regarding current $ETCO_2$ literature and 19 (59%) felt that the equipment for continuous $ETCO_2$ monitoring was inexpensive.

Of the 18 respondents who did not routinely use continuous $ETCO_2$ monitoring in the PED, their primary reason was lack of equipment (65%). Other reasons included lack of familiarity (33%), lack of perceived need (22%), perception of poor evidence for use in the medical literature (22%), perceived inaccurate measurements (11%), expense (11%), and difficulty with use (6%).

Thirty-one respondents (78%) were interested in learning more about continuous $ETCO_2$ monitoring and its applications. The majority (45%) would prefer receiving literature, whereas 35% desired online information, 33% would attend a workshop, and 33% would view an on-site demonstration.

DISCUSSION

This study demonstrated that continuous $ETCO_2$ monitoring is available in most PEDs for both intubated and nonintubated patients. Similarly, most PEM fellowship directors have positive opinions regarding the technical aspects of this device. Despite these views, however, $ETCO_2$ monitoring is not being used in many common medical and traumatic situations that occur in the PED.

$ETCO_2$ has been studied in a variety of clinical settings. Several studies have demonstrated the superiority of capnometry and capnography over auscultation in the detection of esophageal intubations in patients who were emergently intubated.[9,10] As a continuous monitor of ventilatory status and a marker of cardiac output, this device is useful in several emergency department situations in addition to confirmation of endotracheal intubations. These conditions where noninvasive monitoring of $ETCO_2$ may be beneficial include moderate sedation, status epilepticus, sepsis, trauma, and cardiopulmonary resuscitation.[11–14]

The most frequently studied application of capnography for nonintubated patients is in the area of sedation and analgesia. It has been proposed that $ETCO_2$ monitoring can improve patient safety. It is a valuable marker of hypoventilation and apnea. Research has demonstrated that $ETCO_2$ can detect trends toward respiratory depression with much greater sensitivity than either pulse oximetry or clinical observations, which are the current standards of care.[15,16] Furthermore, $ETCO_2$ monitoring has shown objective differences in the degree of hypercapnia based on the type of medications used for sedation. Children who receive propofol or a combination of midazolam and an opiate for procedural sedation have been shown to have higher $ETCO_2$ levels than those with other medications including ketamine, ketamine with midazolam, or midazolam alone.[12,16,17]

Exhaled CO_2 can be a marker of metabolic disturbances. Therefore, it is also helpful in managing conditions such as diabetic ketoacidosis and dehydration.[3,4] Fearon and Steele[3] demonstrated a linear relationship between $ETCO_2$ measurements and serum bicarbonate levels in children with diabetes. $ETCO_2$ was shown to correlate with the severity of metabolic acidosis and thus acted as a predictor of diabetic ketoacidosis in comparison to hyperglycemia. Similarly, Nagler et al demonstrated a linear correlation between $ETCO_2$ measurements and serum bicarbonate levels in children with dehydration from gastroenteritis. Children with lower $ETCO_2$ levels were more likely to be severely dehydrated and require treatment with intravenous fluids than those who received oral rehydration and were assessed as being less dehydrated. In addition, children who had unscheduled return visits had lower $ETCO_2$ levels than those who did not seek further medical evaluation.[4]

This study is limited by its design and sample size. There are a small number of accredited PEM fellowship programs across the United States and Canada. Similarly, we are relying on the experiences of one physician within each institution to represent the group as a whole. On the other hand, PEM fellowship programs are usually based in academic settings. It is likely that these represent the forefront of utilization of new technologies. One may argue that the availability and knowledge of this technology would be greater than that of physicians in other nonacademic and community hospitals.

Although continuous $ETCO_2$ monitoring is widely used in PEDs for intubated patients, our survey results indicated that there was far less utilization of this technology for children who are spontaneously breathing, despite a fair body of evidence supporting its use. Further development and dissemination of training curriculum, such as workshops at future fellows' conferences, may expand the utilization of this noninvasive diagnostic modality for the benefit of patients in the PED.

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