# End-Tidal Carbon Dioxide Measurements as a Prognostic Indicator of Outcome in Cardiac Arrest

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• ***Purpose*** ***To evaluate the use of end-tidal carbon dioxide values in predicting survival in cardiopulmonary arrest.***

• ***Background*** ***The decision about when to terminate resuscitative efforts for patients with cardiopulmonary arrest is often subjective. End-tidal carbon dioxide values have been suggested as potential objective criteria for making this decision.***

• ***Methods*** ***This study was a cooperative effort of the St Louis chapter of the American Association of Critical-Care Nurses and its members and involved 6 hospitals and an air evacuation service. All adult patients who had a cardiopulmonary arrest were eligible for the study. Once a patient with cardiac arrest was intubated, end-tidal carbon dioxide and cardiac rhythms were measured and recorded every 5 minutes for 20 minutes or until resuscitation efforts were terminated. Patients' survival at the time of the arrest, survival 24 hours after the arrest, and discharge status were followed up.***

• ***Results*** ***A total of 127 patients were enrolled in the study. All but 1 patient with end-tidal carbon dioxide values less than 10 mm Hg died before discharge. End-tidal carbon dioxide values greater than 10 mm Hg were associated with various degrees of survival. Overall survival to discharge was less than 14%, regardless of the end-tidal carbon dioxide value.***

• ***Conclusion*** ***Measurements of end-tidal carbon dioxide can be used to accurately predict nonsurvival of patients with cardiopulmonary arrest. End-tidal carbon dioxide levels should be monitored during cardiopulmonary arrest and should be considered a useful prognostic value for determining the outcome of resuscitative efforts. (American Journal of Critical Care. 2001;10:391-398)***

Assessment of survival during cardiopulmonary resuscitation (CPR) is an inexact science. Guidelines for clinicians for stopping a resuscitation attempt are inconsistent, primarily because of the inability to predict survival of patients who have cardiopulmonary arrest. The American Heart Association, in its Advanced Cardiac Life Support guidelines,[1] suggests that clinicians consider factors such as underlying heart rhythm to determine when to stop resuscitation efforts. However, the guidelines are not definitive. Stopping a resuscitation effort is largely based on the judgment of the physician managing the resuscitation effort.

In one study[2] of 710 patients, electrocardiographic rhythm, resuscitation delay time, patients' ages, use of defibrillation and intubation, and delay

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to defibrillation were important factors in predicting survival until discharge. In another study[3] of 2404 patients, poor outcomes were associated with certain dysrhythmias.

The reported rate of survival in cardiopulmonary arrests varies. For example, in studies by Ebell and colleagues,[4,5] the mean rate of survival to discharge from the hospital after attempted CPR ranged from 5.3% to 12.8%. Despite poor outcomes in resuscitation, not all resuscitative efforts are futile. Some conditions, such as ventricular dysrhythmias due to heart disease, are more likely than others, such as ventricular dysrhythmias due to sepsis, to respond to resuscitative efforts.[6,7] However, in general, resuscitative efforts are associated with low rates of survival to discharge.

## Use of Capnography to Predict Survival in a Cardiopulmonary Arrest

In order to avoid some of the problems associated with resuscitation, a clear end point that indicates the patient will not survive is needed. One end point with growing research support is end-tidal carbon dioxide ($PETCO_2$) values derived via capnography. Capnography is the measurement of exhaled carbon dioxide. A capnogram is the recording of the exhaled carbon dioxide waveform. The point on the capnogram that occurs just before inspiration is called the $PETCO_2$ value.

In 1985, 2 articles[8,9] reported a correlation between $PETCO_2$ values and blood flow. Weil[8] was one of the first to recognize that $PETCO_2$ correlated with blood flow to the lungs. In a study in minipigs, he confirmed a high linear correlation between $PETCO_2$ and cardiac output. In addition, he found an increase in mixed venous carbon dioxide tension. He hypothesized that the concurrent decrease in $PETCO_2$ reflected a critical reduction in cardiac output, which reduced alveolar blood flow to the extent that carbon dioxide clearance by the lung did not keep pace with systemic production of carbon dioxide. Sanders et al[9] reported that capnography could be used to predict outcome after cardiopulmonary arrest in dogs. Survivors of resuscitation had higher $PETCO_2$ values than did nonsurvivors.

Animal studies[10,11] were used to determine that $PETCO_2$ values were higher in survivors of cardiopulmonary arrest than in nonsurvivors. Using a swine model, several researchers[12,13] also found that controlled minute ventilation was an important potential variable in predicting the level of $PETCO_2$. Shibutani et al[14] were among the first to report the results of a controlled study in humans (anesthetized patients). These investigators[14] found a direct correlation between $PETCO_2$ values and changes in cardiac output.

Perhaps the most definitive of the efforts to date was a study by Levine et al.[15] In their investigation, reported in 1997, mortality was 100% in patients who had out-of-hospital cardiac arrest and had $PETCO_2$ values of less than 10 mm Hg after 20 minutes of resuscitation. However, Levine et al investigated only those cases of cardiopulmonary arrest that were not due to primary ventricular tachycardia or fibrillation. They also reported earlier work regarding the potential cost of the resuscitative efforts if capnography had been used as an indicator. The cost to the hospital was about \$100 000 to \$150 000 for 169 patients who could not be resuscitated in the emergency department. The cost of 16 patients who were resuscitated in the emergency department and admitted to the hospital but who died before discharge was \$181 000. By extrapolation, the authors concluded that using $PETCO_2$ values to decide which CPR attempts should be terminated before transport to the hospital would save the United States more than \$1 billion annually.

These studies suggest that capnography might be an important aid in evaluating the success of resuscitative efforts and in making a decision about terminating CPR. Still lacking is an analysis of cardiopulmonary arrests from all causes in hospitalized patients; in our study, we attempted to address this paucity. Our research question was as follows: Can $PETCO_2$ values be used to predict survival from all causes of cardiopulmonary arrest?

## Methods

Six hospitals and a helicopter evacuation service in St Louis were involved in collecting data on patients experiencing cardiopulmonary arrest. The study was reviewed by each institution's human subjects committee and was granted exempt status.

A core team of nurses and respiratory therapists from each hospital formed the coordinating committee for the study. A nurse from this committee was responsible for educating the nurses, respiratory therapists, and members of the code team on the use of capnography and on data collection. The in-service training included proper setup of capnography equipment (eg, calibration, placement in the ventilatory circuit) and interpretation of capnographic waveforms.

### Equipment

Capnography equipment was standardized at the participating hospitals by using either sidestream hand-held units (manufactured by Mallinckrodt Medical Inc, St Louis, Mo) or mainstream sampling systems (manufactured by Hewlett Packard/Agilent, Andover, Mass). The sidestream units require a yearly calibration, which was done before the study began, and the study was completed before the next required calibration period. The mainstream capnography units required calibration with each new patient and were used solely with patients who had continuous capnographic monitoring before the cardiopulmonary arrest. In these circumstances, the capnography sensor was kept in line with the existing endotracheal tube. The mainstream units were calibrated per the manufacturer's recommendation at the time of the patient's admission.

### Sample

All patients who had cardiopulmonary arrest at the participating sites during the period of June 1998 to June 1999 were eligible for the study. Subjects were obtained via convenience sampling. The total number of patients who experienced cardiopulmonary arrest at each site was not determined for several reasons. Many arrests called via the institution pager systems were not full cardiopulmonary arrests; therefore, tracking of all arrests that occurred when data collectors were not present was difficult. In addition, the intensive care units did not page for arrest situations at many sites. If a data collector was present at a cardiopulmonary arrest that was not announced over the paging system, data were collected; however, many arrests were missed. Only adults 18 years or older were included in the sample.

### Data Collection and Analysis

Advanced Cardiac Life Support protocol was followed during all cardiopulmonary arrests. The use of capnography did not affect the resuscitation effort or the use of Advanced Cardiac Life Support guidelines. A data collector measured $PETCO_2$ and recorded the values on a separate data collection sheet; therefore, members of the code team were not aware of the $PETCO_2$ values during the resuscitation effort.

Immediately upon responding to a cardiopulmonary arrest (absence of pulse and respiration) from any cause and after tracheal intubation was established, the responding nurse or respiratory therapist attached a carbon dioxide sensor (for mainstream devices) or an aspirating line (for sidestream devices) to the endotracheal tube. $PETCO_2$ and cardiac rhythm were measured and recorded by the data collector after tracheal intubation or at the time of cardiopulmonary arrest in patients who had an endotracheal tube in place at the time of cardiopulmonary arrest and then every 5 minutes for 20 minutes or until the resuscitation effort was terminated or the patient had a spontaneous pulse for 10 minutes. The 20-minute data collection period was based on the study by Levine et al[15] as the conclusive end point for $PETCO_2$ values that could be used to predict survival after a cardiopulmonary arrest. The same end point was used for data collection on patients from the air evacuation system.

Data were collected on whether the arrest was witnessed by another person, the estimated time of arrest, the time the resuscitative effort began, and the time tracheal intubation was established. In order to evaluate the potential economic impact of using capnography, data on whether patients survived the arrest and patients' discharge status from the hospital were obtained.

Statistical analysis included $\chi^2$ tests of data on survivors and nonsurvivors. In addition, a decision tree was used to detect trends in the use of $PETCO_2$ values in cardiopulmonary arrest.

## Results

A total of 127 patients were enrolled in the study. Data were only partially complete for 10 patients. Overall, 43% (55/127) survived the cardiopulmonary arrest, and 13.7% (16/117) survived to discharge from the hospital. Of those who survived to discharge, 6.8% (8/117) went home, and 6.8% were discharged to extended-care facilities. About 32% (40/127) survived 24 hours after the arrest, but of these patients, 15 died before discharge from the hospital. Patients who survived the arrest but died before discharge stayed an additional mean of 19.9 days in the hospital (Table 1).

**Table 1** Characteristics of the sample

| Variable | No. of patients* | % |
|---|---|---|
| Cardiopulmonary arrest witnessed | | |
| Yes | 85 | 68.5 |
| No | 39 | 31.5 |
| Survived cardiac arrest | | |
| Yes | 55 | 43 |
| No | 72 | 57 |
| Survived 24 hours | | |
| Yes | 40 | 31.5 |
| No | 87 | 68.5 |
| Discharge status | | |
| Home | 8 | 6.8 |
| Extended-care facility/ rehabilitation | 8 | 6.8 |
| Died | 101 | 86.3 |
| **Mean length of stay (days) of patients who survived >24 hours** | **No. of patients** | **Days** |
| Patients who died before discharge | 15 | 19.9 |
| Patients who survived to discharge | 16 | 22.2 |

*Total numbers of patients in each category vary because only partial data were available for 10 patients.

**Table 2** Initial cardiac rhythm at time of first measurement of end-tidal carbon dioxide

| Initial rhythm | No. of patients | % | Mean time to intubation, min | Mean duration of resuscitative efforts, min |
|---|---|---|---|---|
| All rhythms | 120 | 100 | 12.3* | 43.2† |
| Lethal | 91 | 76 | 11.5 | 49.1 |
| Ventricular | 12 | 10 | 16.4 | 28.6 |
| Atrial | 17 | 14 | 13.8 | 22.9 |

*$P = .74$, indicating that the mean time to intubation did not differ significantly among patients with different initial cardiac rhythms.
†$P = .02$, indicating that the mean duration of resuscitative efforts differed significantly among patients with different initial rhythms.

At the time of tracheal intubation and the first $P_{ETCO_2}$ measurement, 91 (76%) of 120 patients had lethal cardiac rhythms (ventricular fibrillation, asystole, or pulseless electrical activity), 12 (10%) had ventricular tachycardia, and 17 (14%) had supraventricular rhythm (Table 2). The patients with a supraventricular rhythm at the time of intubation and the first $P_{ETCO_2}$ measurement had experienced cardiopulmonary arrest, but by the time of intubation, they had return of pulse with a supraventricular rhythm. In these patients, $P_{ETCO_2}$ values were measured for 10 minutes after return of spontaneous circulation. $P_{ETCO_2}$ was significantly lower in patients with lethal rhythms than in those with the other dysrhythmias at all times measured (Table 3). In patients with lethal rhythms, $P_{ETCO_2}$ decreased progressively as the duration of the resuscitative effort increased. Differences in survival between witnessed and unwitnessed cardiopulmonary arrests were not significant ($P$>.05).

$P_{ETCO_2}$ values were significantly higher in patients who were successfully resuscitated than in patients who died (Table 4). Although a $P_{ETCO_2}$ in excess of 20 mm Hg did not guarantee survival, it was associated with improved chances of surviving the cardiopulmonary arrest.

Regardless of the factors associated with the cardiopulmonary arrest, such as precipitating cardiac rhythm, whether the arrest was witnessed or unwitnessed, time to intubation, and duration of the resuscitative effort, the initial $P_{ETCO_2}$ measurements correlated with survival to discharge. Patients with an initial $P_{ETCO_2}$ of less than 10 mm Hg had an immediate resuscitation survival rate of 17% (8/47). The survival to discharge rate was 2% (1/45). The survival to discharge rate for this group was consistent (2%-4%) at every time (5, 10, 15, and 20 minutes; Table 4).

Overall, 87% of patients with $P_{ETCO_2}$ greater than 20 mm Hg survived the resuscitation. About 33% of these patients survived to discharge from the hospital. This survival rate was significantly higher ($P$<.001) than that of patients with $P_{ETCO_2}$ of less than 10 mm Hg. Only one patient had a $P_{ETCO_2}$ of less than 10 mm Hg at any time and survived the resuscitative effort. This one patient received extraordinary resuscitative efforts and can be viewed as an exception (the patient had an open thoracotomy performed, never regained consciousness, and died in an extended-care facility 9 weeks after the cardiopulmonary arrest). If this patient is eliminated from the database, no patient with a $P_{ETCO_2}$ of less than 10 mm Hg survived to discharge, regardless of when the $P_{ETCO_2}$ was measured.

**Table 3** Mean end-tidal carbon dioxide values during cardiopulmonary resuscitation

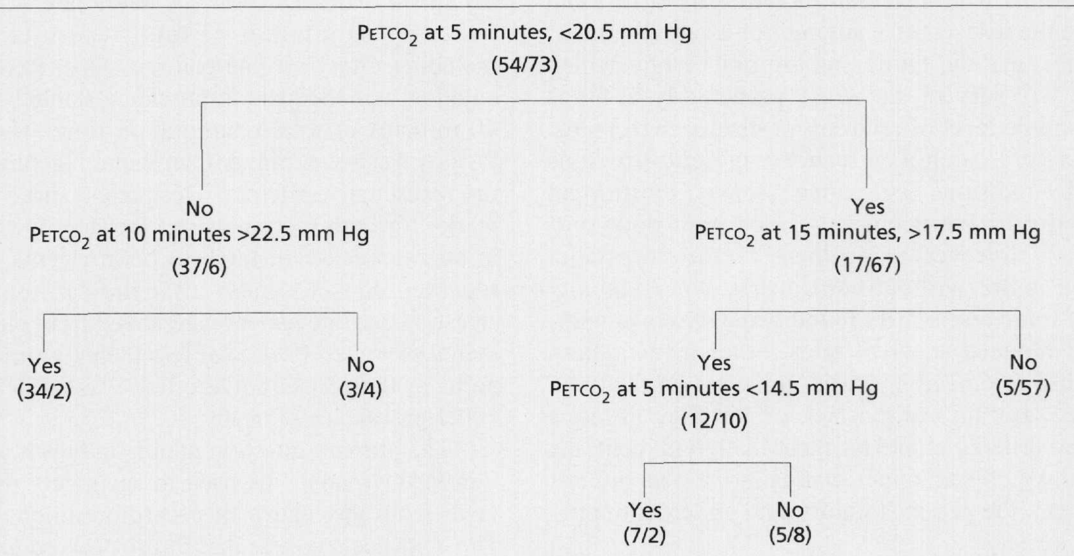
| Time, min | Mean end-tidal carbon dioxide (mm Hg) for various cardiac rhythms | | | | *P* |
|---|---|---|---|---|---|
| | All | Lethal | Ventricular | Atrial | |
| 0 (baseline) | 16.4 | 12.74 | 20.00 | 33.24 | <.001 |
| 5 | 18.7 | 15.57 | 24.92 | 34.54 | .03 |
| 10 | 15.5 | 13.19 | 22.43 | 29.00 | <.001 |
| 15 | 13.3 | 11.93 | 13.75 | 29.40 | .005 |
| 20 | 12.6 | 10.77 | 21.00 | 29.75 | .02 |

**Table 4** Survival at different end-tidal carbon dioxide values after start of cardiopulmonary resuscitation

| | | No. of patients who | | |
|---|---|---|---|---|
| Time, min | End-tidal carbon dioxide, mm Hg | Survived code, yes/no | Survived 24 hours, yes/no | Survived to discharge, yes/no |
| 0 (baseline) | <10 | 8/39 | 6/41 | 1/44 |
| | 10-20 | 14/24 | 7/31 | 2/32 |
| | >20 | 30/8 | 25/13 | 12/22 |
| 5 | <10 | 4/34 | 2/36 | 1/36 |
| | 10-20 | 10/28 | 5/33 | 1/36 |
| | >20 | 33/6 | 27/12 | 11/22 |
| 10 | <10 | 2/36 | 2/36 | 1/37 |
| | 10-20 | 7/18 | 4/21 | 0/23 |
| | >20 | 29/9 | 22/16 | 11/24 |
| 15 | <10 | 1/30 | 1/30 | 1/30 |
| | 10-20 | 8/17 | 5/20 | 1/22 |
| | >20 | 12/5 | 10/7 | 4/11 |
| 20 | <10 | 1/27 | 1/27 | 1/27 |
| | 10-20 | 1/12 | 1/12 | 0/13 |
| | >20 | 12/1 | 10/3 | 4/8 |
| Final | <10 | 1/47 | 1/47 | 1/47 |
| | 10-20 | 7/20 | 3/24 | 0/25 |
| | >20 | 45/7 | 35/17 | 15/30 |

For differences between patients who survived to discharge and patients who did not, *P* for 15 min = .02, *P* for 20 min = .006. For all other times and variables, *P*<.001.

To further analyze the data, we created a classification tree (see Figure) to determine $P_{ETCO_2}$ values that might better correlate with survival and nonsurvival. The tree provides additional support for the usefulness of $P_{ETCO_2}$ values in predicting outcome. With the tree, the patients were automatically split, via a decision-analysis program, into subgroups such that within a subgroup, patients are more similar in terms of their outcomes.[16] Initially, at the top of the tree, the population of patients consists of 54




Classification tree of survivors versus nonsurvivors. Numbers in parentheses are No. of survivors/No. of nonsurvivors.

survivors and 73 nonsurvivors. With a series of splits, the tree indicates 2 subgroups that have clinical significance. By using the tree, we found that one subgroup of patients with relatively high $P_{ETCO_2}$ values (>20 mm Hg at 5 and 10 minutes) had a 94.4% survival rate (34 survivors, 2 nonsurvivors). We also found that a subgroup with relatively low $P_{ETCO_2}$ (<17.5 mm Hg at 15 minutes) had a 91.9% nonsurvival rate (57 nonsurvivors, 5 survivors). The classification tree is based on the premise that patients with higher $P_{ETCO_2}$ values are more likely to survive than are patients with low $P_{ETCO_2}$ values. The remaining groups had small numbers of patients and most likely are not suitable for predicting survival.

## Discussion

The results of using $P_{ETCO_2}$ values to predict nonsurvival during cardiopulmonary arrest must be interpreted in light of overall survival after the arrest. Clearly, most patients who have cardiopulmonary arrest do not survive. This lack of survival is true both for patients who have in-hospital cardiopulmonary arrest and for those who have out-of-hospital arrest. In prehospital settings, for those patients in whom circulation has not returned before they arrive at the hospital, survival rates until the time of discharge from the hospital of 1% to 2% have been reported.[17-20] However, even in the prehospital setting, patients with some conditions (eg, rapid defibrillation of ventricular fibrillation) respond better than others do.[21] Because of the uncertainty of knowing which patients might survive, clinicians perform CPR on most persons who have cardiopulmonary arrest and continue the resuscitative attempt for a variable time.

Unfortunately, clinicians are not certain which patients will survive the arrest, particularly in terms of a desirable level of recovery or discharge to home. Some factors, such as advanced age and previous medical conditions (eg, cancer, sepsis, multiorgan dysfunction) have been associated with poor outcomes.[22,23] However, using these factors to predict outcome is not without controversy. For example, whereas some researchers found that age was an indicator of reduced survival rates, other investigators found that advanced age was not a major factor in outcome.[24] Because of the lack of accuracy in terms of current criteria, clinicians most likely will continue resuscitative efforts longer than is in the best interest of a patient, the patient's family, and, in terms of economics, society.

Studies to date consistently indicate that $P_{ETCO_2}$ correlates with blood flow, cardiac output, and outcome of resuscitation. The effectiveness of capnography as a reflection of blood flow is illustrated by the results of researchers who noted that capnographic findings indicated the effectiveness of resuscitative efforts. As early as 1978, Kalenda[25] reported that capnographic findings correlated with resuscitation quality. Kalenda discovered that capnograms indicate the effectiveness of chest compressions during closed-chest compressions. Other researchers[26,27] found that capnographic findings indicate the effectiveness of chest compressions because the findings reflect blood flow (cardiac output).

The exact $P_{ETCO_2}$ value that most likely is predictive of nonsurvival is approximately 10 mm Hg.[15] Callaham and Barton[28] found that patients who were successfully resuscitated had a $P_{ETCO_2}$ of greater than 19 torr during CPR, whereas patients who died had a $P_{ETCO_2}$ of about 5 torr.

Capnography during CPR is more useful in predicting nonsurvival than in predicting survival. Levine et al[15] found that a $P_{ETCO_2}$ of 10 mm Hg at 20 minutes into the resuscitative effort was 100% sensitive and 100% specific for predicting nonsurvival.

Our results are similar to those of Levine et al. With one exception, $P_{ETCO_2}$ values of less than 10 mm Hg were predictive of nonsurvival from the time of the initial measurement of $P_{ETCO_2}$ during resuscitation. The one survivor who had a $P_{ETCO_2}$ of less than 10 mm Hg throughout the resuscitative attempt was a postoperative patient who had a cardiopulmonary arrest after an esophagectomy. After 20 minutes of resuscitation, he had a $P_{ETCO_2}$ of less than 5 mm Hg. The surgeon elected not to terminate the resuscitation at that point and instead performed an open thoracotomy in the patient's room. A heart rate was reestablished at 30 minutes of total resuscitation time, including direct cardiac compressions. Return of circulation was adequate to provide a stable heart rate at 40 minutes of total resuscitation time. The patient's $P_{ETCO_2}$ was never higher than 9 mm Hg during the entire resuscitative attempt. This patient survived 9 more weeks (in both the intensive care/step-down unit and in an extended-care facility) before dying. He never regained consciousness after the cardiopulmonary arrest. If this one patient is removed from our analysis, then a sustained $P_{ETCO_2}$ of less than 10 mm Hg at any point in the resuscitative effort was associated with 100% prevalence of death.

The primary question in our study was as follows: Can $P_{ETCO_2}$ values be used to accurately predict survival from any cause of a cardiopulmonary arrest? The evidence suggests that $P_{ETCO_2}$ can be used to predict nonsurvival in cardiopulmonary arrest. Our results are an important addition to those of Levine et al.[15] In their study, the sample of patients consisted solely of patients with cardiopulmonary arrest associated with cardiac rhythms other than ventricular fibrillation and tachycardia, because of the supposedly higher resuscitation rate in patients with these last 2 dysrhythmias. Our sample included patients with cardiopulmonary arrest due to all causes, and the dominant initial cardiac rhythm was ventricular fibrillation or tachycardia.

However, the precipitating dysrhythmia is not as important as how the dysrhythmia is affected by treatment. In patients who have a good chance of survival, regardless of the cause of the arrest, the $P_{ETCO_2}$ increases in response to the therapeutic efforts. If the $P_{ETCO_2}$ value does not increase and remains at less than 10 mm Hg, survival to discharge is highly unlikely. The results of our classification tree analysis provide additional support for the usefulness of using $P_{ETCO_2}$ values to predict the outcome of cardiopulmonary arrest. The significance of using $P_{ETCO_2}$ values to determine the futility of continued resuscitative efforts is enhanced by data from our study and by data from the study of Levine et al.

**Potential Issues in Using Capnography to Predict Outcome**

Use of capnography during cardiopulmonary arrest has a potential limitation when alveolar ventilation is considered. The $P_{CO_2}$ can be altered by ventilation. If ventilation has not been controlled, a low $P_{ETCO_2}$ could be partially the result of excessive ventilation. Asplin and White[29] addressed this limitation by providing a fixed-minute ventilation during resuscitation. They found that $P_{ETCO_2}$ values highly correlated with return of spontaneous circulation even after minute ventilation was controlled for. Using an animal model in which ventilation was controlled, Isserles and Breen[13] found that changes in $P_{ETCO_2}$ were directly related to changes in blood flow. In our investigation, on the basis of these 2 studies,[13,29] ventilation was performed by a variety of clinicians and was not controlled.

Another possible limitation is the use of sodium bicarbonate during resuscitative efforts. The use of bicarbonate could result in increases in $P_{ETCO_2}$ by elevating the amount of carbon dioxide. This concern was addressed by Dohi et al,[30] who noted that bicarbonate did not affect the elimination of carbon dioxide from a prognostic perspective. They recommended monitoring $P_{ETCO_2}$ for at least 5 minutes after administration of bicarbonate.

A third possible limitation is the potential for epinephrine to decrease $P_{ETCO_2}$ values. In animal models, for unclear reasons, $P_{ETCO_2}$ values decrease after the administration of epinephrine. Recently, Cantineau et al[31] suggested that using $P_{ETCO_2}$ to predict outcome might be limited by the use of epinephrine, although the $P_{ETCO_2}$ did not change consistently in their study. Callaham et al[32] addressed this issue in a study that indicated administration of epinephrine produced only small, insignificant changes in $P_{ETCO_2}$. They concluded that using $P_{ETCO_2}$ as a basis for predicting the outcome of resuscitation was not affected by the administration of epinephrine.

**Potential Economic Impact of Using $P_{ETCO_2}$ Values as a Basis for Terminating Resuscitative Efforts**

We found that patients who survived cardiopulmonary arrest but died before discharge from the hospital survived a mean of 20 days. The cost of care for these patients, who remained in the intensive care unit for most of the time before death, was conservatively estimated as more than $20 000 per patient (assuming a mean cost per day of about $1000). In our sample, 15 patients survived the arrest but died before discharge. For a mean survival time of 20 days and a mean estimated cost of $20 000, the amount spent on care for these 15 patients was about $300 000. The cost to the United States for care of patients who survive for 20 days after resuscitation most likely is greater than $1 billion a year.[33]

**Limitations of the Study**

Our study is limited in predicting which patients will survive a cardiopulmonary arrest because of the small numbers of patients who survived the resuscitative efforts and survived to discharge from the hospital (18 of 127 patients). Moreover, the total sample size of 127 was only part of the number of patients who had cardiopulmonary arrest. Possibly, a selection bias associated with convenience sampling influenced the interpretation of the results. Our study did not include any patients with hypothermia or drug overdose.

## Summary

$P_{ETCO_2}$ values can be used to accurately predict survival in adults who have cardiopulmonary arrest. Like the results of other studies, our findings indicate that patients with $P_{ETCO_2}$ of less than 10 mm Hg 20 minutes into the resuscitative effort do not survive. We also found that a $P_{ETCO_2}$ of less than 10 mm Hg at any point in the resuscitative effort could be used to accurately predict mortality. Although some conditions and dysrhythmias that precipitate a cardiopulmonary arrest are associated with improved survival, these situations have many exceptions. A more objective management of resuscitation would be to base decisions to terminate efforts on an indicator of blood flow, that is, $P_{ETCO_2}$. The use of $P_{ETCO_2}$ values may have important clinical, ethical, and economic effects in the setting of CPR.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