ORIGINAL RESEARCH

Evaluation of a Semi-Quantitative CO_2 Monitor with Pulse Oximetry for Prehospital Endotracheal Tube Placement and Management

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Abbreviations:
ALS = Advanced Life Support
CO_2 = carbon dioxide
$EtCO_2$ = end-tidal carbon dioxide

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Abstract

Objective: To evaluate three prototype versions of semi-quantitative end-tidal CO_2 monitors with different alarm features during prehospital or interfacility use.

Methods: Subjects were 43 adult, non-pregnant patients requiring intubation, or who already were intubated and required transport. Teams at one AirEvac and seven Advanced Life Support (ALS) paramedic stations were trained in the use of the monitors. Team members at each station evaluated each model for eight days. Participants completed questionnaires following each use.

Results: The monitors performed properly in all cases, but in one case, vomit in the airway adapter tube prevented obtaining a readout. The monitors aided management in 40 of 43 cases (93%); in one, the monitor reading was reported as variable (between 20 and 30 mmHg) although the teams knew the monitors were semi-quantitative; in another, the monitor was not required, but performed properly; and the third was the one in which vomit in the tube prevented a reading. In 26 of 43 cases (60.4%), the monitor was used to confirm endotracheal tube placement (there were no instances of incorrect placement). In all cases, the devices were used to monitor respiration and oxygen saturation. Alarms were audible in the environment, but only preferred in the AirEvac situation. The "breath beep" feature was useful, particularly in patients in whom chest movements during respiration were difficult to observe.

Conclusions: "Breath beeps" were clearly audible and were a useful feature in all prehospital and transport environments, while audible alarms were desired only in the AirEvac situation. Semi-quantitative CO_2 detection is valuable in the ALS/AirEvac environment, even for teams with high intubation success rates.

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Introduction

Specifically designed monitoring equipment for the prehospital and transport environments is vitally important if the equipment is to be used effectively. The adverse conditions in these environments are well-known and include poor lighting, high noise levels, awkward positioning, and highly variable environmental conditions.[1] The design of equipment for this environment is critical to its effectiveness, and must address such factors as weight, size, ease of use, visibility of readouts, audibility of alarms, cost-effectiveness, and packaging.[2–4]

Paramedics often perform intubations in extremely adverse conditions, and ensuring that tube placement is correct often is difficult. Esophageal intubation can occur in up to 10% of

Question	Responses	Mean of Scores
Rate performance of the device compared to your expectations	24	4.8
Rate the device's ease of use	24	4.8
How useful was the device in helping to confirm endotracheal tube placement?	16	4.3
How would you rate the CO_2 bar graph for ease of reading and interpretation?	20	4.2
How adequate was the soft case for carrying the device and its accessories?	24	4.0
How would you rate the CO_2 sensor and airway adapter's ease of assembly and use	19	4.0
How useful did you find the "breath beeps"?	19	3.7
Rate the length of the CO_2 sensor cable.	19	3.7
How difficult did you find changing the batteries in the device?	14	3.7

Table 1—Questionnaire results with scoring on a Likert scale in which 1 is lowest and 5 was highest

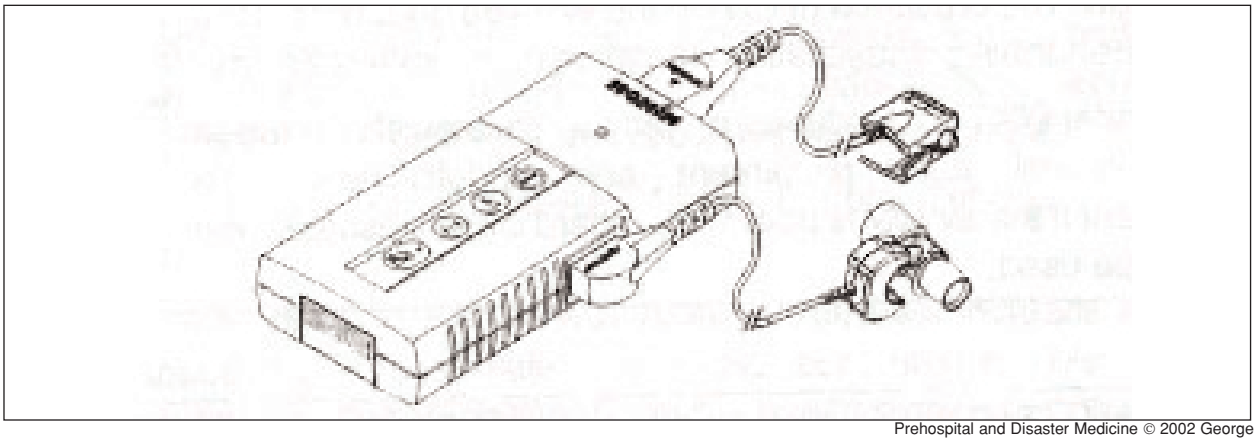

Figure 1—The Nonin 9840 pulse oximeter

cases, even among experienced physicians in a hospital environment, and esophageal intubation can remain undetected with clinical assessment in 1 to 5% of cases.[5,6] As stated by White and Slovis, "unrecognized esophageal intubation is a catastrophic, iatrogenic complication that effectively nullifies any chance for resuscitation—even a 1% failure rate simply is unacceptable."[6] A variety of technologies has been employed to help confirm correct endotracheal tube placement, all using one of three methods: 1) detection of CO_2, 2) transmission of light from the tip of the stylette; or 3) reflection of sound.[2] Detection of CO_2 has been shown to be 100% sensitive to esophageal intubation.[5] Equipment that uses transmission of light has been shown to decrease intubation time significantly, and to increase intubation success in difficult situations,[7] but the usefulness of these tools is limited to the confirmation of correct placement, whereas, it also is important to monitor ventilation following intubation. Particularly in patients with head injuries, it is important to avoid secondary insults from inadequate oxygenation and hypo/hypercardia that may cause further neurologic damage.[8] Detection of CO_2 combines the ability to confirm endotracheal tube placement with the ability to monitor the effectiveness of ventilation and safeguard cerebral perfusion during transport.

The Nonin 9840 series instruments combine end-tidal CO_2 detection with a pulse oximeter in a compact, handheld, portable unit (Figure 1). The monitors use infrared light absorption to detect CO_2 concentration in an airway adapter tube attached to the endotracheal tube. The fully-patent airway adapter tube was designed to address the problems of other commercially available, mainstream end-tidal CO_2 monitors that have narrow-gauge adapters that may restrict air flow and hence, result in increased respiratory effort. It is a sterile, single-patient use item. The accuracy of the monitor has been verified in hospital-based tests.

This study evaluated the usefulness of a semi-quantitative end-tidal CO_2 ($EtCO_2$) monitor to help verify endotracheal tube placement and ventilation of intubated patients in the prehospital and interfacility transport environments. The secondary objective was to determine which of three alarm configurations of the Nonin 9840 series of monitors was preferred by AirEvac and Advanced Life Support paramedics: 1) 9843 (audible "breath beep"); 2) 9845 (absence of breath ("apnea") alarms and "breath beep"); or 3) the model 9847 (pulse oximetry alarm, $EtCO_2$ alarm, apnea alarm, and "breath beeps"). Finally, the following characteristics were evaluated: 1)design elements of monitor, 2) visibility of the LED bar graph readout, 3) ease of interpretation of the bar graph readout; 4) the suitability of cases; and 5) ease of connecting adapters.

Methods

This was a prospective evaluation study by paramedics in the prehospital and interfacility emergency transport environments. The study was approved by the institution's Human Ethics Review Board (Certificate #C98-0221). Subjects were patients ≥19 years of age and >10 kg who required emergency intubation or who already were intubated and required emergency transport. Patients who were pregnant were excluded. Patients could be excluded at the discretion of the paramedics, if, based on their assessment, the addition of evaluation of the devices might compromise their ability to safely provide all currently-required clinical care and procedures. The monitor information was not used to affect care decisions without confirmation by other means.

The monitors were evaluated by paramedic teams at one AirEvac and seven Advanced Life Support (ALS) stations. Paramedics received training in the use of each three of the models during regular work hours at their stations between calls. The three models then were distributed randomly among the stations and left for two shift rotations (8 days). The monitors then were retrieved and a different model provided. After each use, paramedics completed an evaluation questionnaire.

Results

Forty-three patients were enrolled in the study. In 26 of the 43 cases (60.5%), the monitors were used to confirm initial endotracheal tube placement, and then were used to monitor ventilation. In the remaining 17 cases (39.5%), the devices were used to monitor ventilation in patients who already were intubated, where confirmation of endotracheal tube placement had been done by other means. In all cases, the monitor was assessed to have performed properly. In one case, readings were not obtained after vomit blocked the tube. In 40 of 43 cases (93%), paramedics providing care reported that the monitors aided their management. In three patients, no benefit was deemed to have accrued: in one case, the monitor reading was reported as variable (between 20 and 30 mmHg), although the teams were instructed that the monitors were semi-quantitative; in another, information from the monitor was deemed to provide no benefit, but it performed properly; and the third case was the one in which vomit in the tube prevented a reading being obtained. In the 26 patients intubated, there were no instances of esophageal intubation.

All alarms were audible in all prehospital environments (Table 1). The choice of alarm options was unanimous among the ALS teams: the audible "breath beeps" were deemed desirable, but other alarms were perceived as "distracting" and "unnecessary". In the AirEvac environment, teams found the pulse oximeter and CO_2 alarms desirable and selected the Model 9847 as their first choice.

Subjective reports on design were that the (152 cm; 60 inch) cables could be lengthened somewhat to allow more latitude in placing the monitor in a visible but out-of-the-way position; and that the case could be improved to allow the probes to remain connected without being bent at an acute angle or needing to have the zipper partially open around the cables.

Discussion

This study found that the monitors functioned properly in all cases, and that audible alarms are desired in the AirEvac environment, but not by ALS teams. The paramedics at the stations studied, have a successful intubation rate of 99%, and expected to find the monitors "interesting" but not "useful". After using the monitors, all of the participants felt they potentially were valuable as a tool in the ALS and AirEvac environment. The Model 9843 (breath beeps only) was preferred by ground-based crews with short-duration transports of unstable patients who required very close monitoring, while the Model 9847 (pulse oximetry and CO_2 alarms with "breath beeps") was preferred by AirEvac crews with longer duration (>20 minutes) transports of stabilized patients where a lower level of vigilance is appropriate and/or monitoring ventilation may be more difficult. Paramedics using the Model 9840 series recommended that the cables be lengthened from 152 cm. One paramedic also recommended a "fool-proof" modification to the airway sensor/adapter assembly to ensure that errors in connection could not be made, even when assembly is performed by an inexperienced person in the dark.

End-tidal CO_2 monitors, whether quantitative or semi-quantitative, have proven to be of clinical benefit and cost-effective in the emergency department and operating room environments.[9-11] However, meeting the design requirements of the prehospital and interfacility transport environments is essential if monitors are to be used in these environments.[1,3,4]

The Nonin 9840 series of pulse oximeters/CO_2 detectors was designed to meet the stringent environmental requirements of the prehospital and interfacility emergency transport situations. It is small (15cm x 8cm x 2cm), lightweight (weight with batteries = 310 g), and has been tested at environmental extremes (0 to 50°C). The alarms and "breath beeps" are audible even in the AirEvac environment where ambient noise levels may reach 120 dB.[12] The battery life is 20 hours with 6 AA batteries. The bright orange carrying case reduces loss in the field. Other good design features include the bright displays, ruggedness, and durability of the unit.

Conclusion

The Nonin 9840 series hand-held pulse oximeter/CO_2 detectors with semi-quantitative $EtCO_2$ bar graph readout are useful adjuncts for confirming endotracheal tube placement and for monitoring intubated patients in the prehospital and transport environments. The audible "breath beeps" on the Model 9845 are desirable in the pre-hospital/ground ambulance situation, while the more extensive alarm system on the Model 9847 is desirable in the transport or AirEvac situation.

References

1. Ragosta K, Kanter RK: Airway management. In *Pediatric Transport Medicine*, McCloskey K, Orr R (eds), Mosby: St Louis, 1995.
2. Cardoso MM, Banner MJ, Melker RJ, Bjoraker DG: Portable devices used to detect endotracheal intubation during emergency situations: review. *Crit Care Med* 1998;26(5):957–964.
3. Hawkins J, Noah Z: Equipment. In: *Pediatric Transport Medicine.* McCloskey K, Orr R (eds), Mosby:St Louis, 1995.
4. American Academy of Pediatrics ACP Guidelines for Air and Ground Transport of Neonatal and Pediatric Patients. Elk Grave Village, Il: Americam Academy of Pediatrics 1999.
5. White SJ, Slovis CM: Inadvertent esophageal intubation in the field: Reliance on a fool's "gold standard". *Acad Emerg Med* 1997;4(2):89–90.
6. White SJ, Slovis CM: Response to comments. *Acad Emerg Med* 1997;4(9):929–991
7. Macnab AJ, MacPhail I, Macnab MK, Noble R, O'Flaherty D: A comparison of intubation success for paediatric transport team paramedics using lighted vs regular tracheal tube stylets. *Paediatric Anaesthesia* 1998;8:215–220.
8. Davey A, Macnab AJ, Green G: Changes in pCO_2 during air medical transport of children with closed head injuries. *Air Med J* 2001;20(4):27–30.
9. MacLeod BA, Heller MB, Gerard J, Yealy DM, Menegazzi JJ: Verification of endotracheal tube placement with colorimetric end-tidal CO_2 detection. *Ann Emerg Med* 1991;20(3):267–270.
10. Sanders AB: Capnography in emergency medicine. *Ann Emerg Med* 1989;18(12):1287–1290.
11. Roizen MF, Schreider B, Austin W, Carter C, Polk S: Pulse oximetry, capnometry, and blood gas measurements: Reducing cost and improving the quality of care with technology. *J Clin Monit* 1193;9(4):237–240.
12. Macnab AJ, Chen Y, Gagnon FA, Bora B, Laszlo C: Vibration and noise in pediatric emergency transport vehicles: A potential cause of morbidity? *Aviat Space Environ Med* 1995;66:212–219.