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Disposable Colorimetric Carbon Dioxide Detector Use as an Indicator of a Patent Airway During Noninvasive Mask Ventilation

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ABSTRACT

Colorimetric carbon dioxide detectors are useful indicators of proper endotracheal tube placement. We have found that they also are helpful during bag and mask ventilation as an indicator of a patent airway. In this report, we describe our experience with these devices for use during preintubation airway stabilization as observed during videotaped performances from a prospective, randomized trial of intubation premedication.

ESTABLISHING A PATENT airway is the first step in stabilizing any patient who requires resuscitation. This skill may be challenging for neonates, whose small size makes precise positioning critical. Bag and mask ventilation is an intervention that is performed in up to 10% of delivery room resuscitations in newborn infants.¹ Recommended evidence of effective assisted ventilation is the observation of adequate chest rise.² However, chest rise can be difficult to identify by inexperienced personnel, may be confused with abdominal rise from stomach inflation, and is associated with increased ventilating pressures.^{3,4}

Carbon dioxide (CO₂) detectors have been used to confirm tracheal intubation and have been shown to decrease the time required to recognize a malpositioned endotracheal tube.⁵⁻⁷ Colorimetric CO₂ detectors use an indicator that changes color cyclically with each breath as CO₂ is exhaled onto the indicator. We have observed that when a colorimetric CO₂ detector is placed between the resuscitation device (anesthesia bag or T-piece resuscitator) and the mask, the resuscitation team is able to recognize easily a patent versus obstructed airway during bag and mask ventilation. We now routinely use the CO₂ detector during bag and mask ventilation and describe our experience with this technique as observed in a videotaped trial of premedication for intubation.

METHODS

Videotapes from 1 site of a 2-center randomized, controlled trial of premedication for intubation were reviewed retrospectively to evaluate function of a disposable CO₂ detector (PediCap; Nellcor Puritan Bennett,

Pleasanton, CA) that is used during infant stabilization before intubation. The main trial was a prospective, randomized trial that compared the use of atropine, fentanyl, and mivacurium with the use of atropine and fentanyl alone as premedication for intubation.⁸ The main trial was approved by the University of California, San Diego, Human Subjects Committee, and parental consent was obtained for enrollment in the trial and video recording of the procedure to allow accurate measurements of the duration of the interventions. Vital signs were monitored continuously throughout the trial, and data from a dedicated pulse oximeter were digitally recorded. Each procedure was videotaped with a digital video camera mounted on a portable cart with a video display. At the beginning of each procedure, the cart was positioned near the patient with the head of the patient and the hands of the intubator visible on the screen. The video recording and analog pulse oximeter data were synchronously encoded into a data file for later analysis. The data files were reviewed with simultaneous playback of the recording and analog display of the oximeter values. Each procedure was reviewed and examined for episodes of absence of color change of the PediCap during bag-mask ventilation or mask continuous positive

Key Words: CO₂ detector, bag and mask ventilation, airway obstruction

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airway pressure application. The individual episodes were examined to determine the pulse rate and oxygen saturation while the CO₂ detector was displaying lack of cyclical color change and after reestablishment of cyclical color change. The elapsed time from when the cyclical color change was lost until reestablishment of cyclical color change was measured. When the infant had an oxygen saturation of <85% during the episode, it was considered an event that was associated with desaturation and the time from establishment of cyclical color change to improvement in oxygen saturation was measured. The maneuvers that were performed before reestablishment of cyclical color change were recorded.

RESULTS

Patients were recruited for the initial study from February 2004 to February 2005. A total of 24 patients were enrolled at the University of California, San Diego, site. The main study results will be reported separately. The intubation of 1 enrolled infant was not videotaped because of technical problems with the video camera. The 23 included infants had a median gestational age of 29 weeks (range: 25–42 weeks) and a median birth weight of 1295 g (range: 640–4990 g). The indication for intubation most commonly was respiratory distress ($n = 17$), followed by apnea ($n = 3$), preoperative ($n = 2$), and self-extubation ($n = 1$). The videotaped intubation procedures were reviewed for evidence of lack of cyclical color change in the CO₂ detector during bag and mask ventilation or mask continuous positive airway pressure provision throughout the procedure. A total of 21 occurrences of clear lack of cyclical color change in the PediCap were identified during stabilization before intubation in 6 infants. Occurrences of lack of cyclical color change, indicating airway obstruction, occurred most frequently on application of the mask with initial application, after suctioning, or after an intubation attempt. The median duration of each event was 15 seconds (range: 8–77 seconds). Six of the episodes were associated with an oxygen desaturation (oxygen saturation <85%). In each instance, the oxygen desaturation began before the mask was applied to the infant's face, and after mask application and ventilation, there was no observed cyclical color change of the CO₂ detector. Three events occurred after intubation attempts: 1 occurred after suctioning, and 2 occurred on initial application of the mask for apnea. The median time from establishing cyclical color change in the PediCap to improvement in the saturation was 9.5 seconds (range: 4–13 seconds). The maneuver that was used most frequently to achieve recovery of cyclical color change was an adjustment in the head/jaw position ($n = 20$). Other maneuvers included changes in mask position ($n = 5$; see Video 1, which is published as supporting information at www.pediatrics.org/content/full/118/1/e202); removal of other

equipment from the face, such as a nasal cannula or nasogastric tube ($n = 3$); and changing the operator ($n = 2$). During 7 events, >1 maneuver was attempted to improve color change.

DISCUSSION

During positive pressure ventilation, the standard method of confirming airway patency is the observation of chest rise. The visualization of chest rise may be difficult in some circumstances because of operator positioning, presence of other equipment or people, and infant size. The observation skills that are required for appreciating adequate chest rise may take some experience to develop. In small infants, chest rise, at appropriate tidal volumes, may be a subtle finding and may be confused with abdominal rise. It is possible that the use of pressures that produce visible chest rise may be excessive for immature lungs. In addition, it is difficult to observe chest wall movement in the delivery room with the use of plastic wrap for the extremely low birth weight infant.

We find that by using the colorimetric CO₂ detector with a face mask and positive pressure device, we easily can determine airway patency versus obstruction on a nearly breath-to-breath basis. The PediCap provides a color signal that is in the direct line of vision of the operator and is simple to observe. When a lack of cyclical color change occurs, the operator is alerted that the airway is obstructed and that adjustments must be made. Similarly, if the CO₂ detector is cyclically changing color indicating the presence of a patent airway and the infant is not responding to ventilation, then the operator can consider adjusting the ventilation in other ways. The presence of this easily visible monitor during bag and mask ventilation may be able to prevent clinical deterioration that would occur if airway obstruction were not readily appreciated and were left unresolved and may simplify troubleshooting during difficult bag and mask ventilation.

All of the oxygen desaturation episodes that we recorded were associated with other events such as intubation attempts. Hypoxia is a sign of many different pathologic conditions and in our patients was most likely related to a combination of possible airway obstruction, underlying lung disease, and intermittent removal of external ventilatory support during the procedure such as occurs with an intubation attempt or suctioning. The recognition of an obstructed airway was facilitated by the lack of color change, and led to maneuvers to correct the obstruction. It is clear from our observations that each time a patent airway was established during episodes of hypoxia, as indicated by the return of cyclical color change of the CO₂ detector, the oxygen saturation of the infant improved shortly thereafter. As was seen with our series of patients, this may be most beneficial at

the initiation of bag and mask ventilation when the mask is placed on the face and proper airway positioning is critical to establishing a patent airway.

The occurrence of airway obstruction was not associated with oxygen desaturation most of the time, indicating that the obstruction was relieved before the onset of hypoxia. The addition of the CO₂ detector to the respiratory circuit adds a small amount of dead space to the circuit. The internal volume of the device as reported by the manufacturer is 3 cm³. Our experience has been that the device is sensitive enough to detect CO₂ that is exhaled from infants of all weights despite the indication for its use in infants who weigh from 1 to 15 kg.⁹

Although we have not evaluated this technique in a randomized, controlled manner, we believe it to be a simple method that can be very helpful. The use of a CO₂ detector during bag-mask ventilation adds a level of monitoring to a potentially unstable patient. It is not intended to replace other forms of evaluation of patient well-being and effectiveness of ventilation. At the present time, most operators feel confident that they are using the bag and mask effectively if they create a target pressure within the mask, and the assessment of adequate chest movement is not evaluated easily. Indeed, the inflation of the stomach can be interpreted as chest movement. The usual response to lack of adequate chest movement is to use larger pressures. We believe that in many circumstances, knowledge that one is dealing with an airway obstruction allows different interventions, such as mask reposition, use of an airway, or airway suctioning. We are continuing to evaluate the utility of a

CO₂ detector during bag and mask ventilation and encourage others to evaluate this technique as well.

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