Anesthesiology
80:42–48, 1994

J. B. Lippincott Company, Philadelphia

Efficacy of the Self-inflating Bulb in Detecting Esophageal Intubation

Does the Presence of a Nasogastric Tube or Cuff Deflation Make a Difference?

M. Ramez Salem, M.D., Yaser Wafai, M.D.,† Ninos J. Joseph, B.S.,‡ Anis Baraka, M.D., F.R.C.Anaesth. (Hon.),§ Edward A. Czinn, M.D.†*

Background: The principle underlying the use of the self-inflating bulb in differentiating esophageal from tracheal intubation is that the trachea is held open by rigid cartilaginous rings, whereas the esophagus collapses when a negative pressure is applied to its lumen. This investigation was designed to test the efficacy of the bulb in detecting esophageal intubation in the presence of a nasogastric tube and after tracheal tube cuff deflation.

Methods: In anesthetized patients, the trachea and esophagus were intubated with identical tubes. The efficacy of the bulb was tested after a nasogastric tube was placed (group 1, n = 70) and after cuff deflation (group 2, n = 60) by a second anesthesiologist.

Results: In patients with nasogastric tubes (group 1), the anesthesiologists reported no reinflation of the compressed bulbs connected to tubes placed in the esophagus and immediate reinflation when connected to tracheally placed tubes in every case. In group 2, the determination of tube placement was correct in every case after cuff deflation. Mean (± SEM) negative pressures generated when compressed bulbs were connected to esophageally placed tubes were 57.8 ± 0.48 mmHg (group 1) and 55.3 ± 0.52 mmHg (group 2) and remained unchanged after the introduction of nasogastric tubes or after cuff deflation.

Conclusions: These results confirm that a nasogastric tube or cuff deflation does not interfere with the reliability of the self-inflating bulb in detecting esophageal intubation and thus does not contribute to false positive results. Confirmation of tracheal tube placement by this simple method makes it ideal for use with other recognized methods both in and outside the operating rooms and enables physicians and emergency personnel to proceed with other resuscitative measures. (Key words: Equipment: nasogastric tube; self-inflating bulb; tubes, tracheal. Intubation: esophageal; tracheal.)

THE use of the self-inflating bulb in differentiating esophageal from tracheal intubation is based on the principle of the "esophageal detector" devised by Wee.[1] The principle underlying the use of the device is that the trachea is held open by rigid cartilaginous rings, whereas the esophagus readily collapses when a negative pressure is applied to its lumen. Thus, when a 60-ml syringe is attached to a tube correctly placed in the trachea, withdrawal of the plunger of the syringe will aspirate gas from the patient's lungs without any resistance.[1,2] If the tube is placed in the nonrigid esophagus, however, withdrawal of the plunger will create a negative pressure, occluding the esophageal lumen around the tube, and resistance will be felt when the plunger is pulled back.

Nunn[3] modified the technique by replacing the syringe with a self-inflating bulb (Ellick's evacuator). This modification simplified the technique while maintaining its reliability.[4] The device is connected to the tracheal tube and the bulb compressed. Compression is silent and refilling is instantaneous if the tube is in the trachea. In contrast, if the tube is in the esophagus, compression of the bulb is accompanied by a characteristic flatuslike noise, and the bulb remains collapsed on release of pressure.[4] This technique has been simplified further by the squeezing of the bulb before, rather than after, connection to the tracheal tube con-

* Chairman, Department of Anesthesiology, Illinois Masonic Medical Center; Clinical Professor of Anesthesiology, University of Illinois, College of Medicine, Chicago, Illinois.

† Attending Anesthesiologist, Illinois Masonic Medical Center; Clinical Assistant Professor of Anesthesiology, University of Illinois, College of Medicine, Chicago, Illinois.

‡ Research Associate, Department of Anesthesiology, Illinois Masonic Medical Center.

§ Professor and Chairman, Department of Anesthesiology, American University of Beirut.

Received from the Illinois Masonic Medical Center, Chicago, Illinois, and the American University Hospital, Beirut, Lebanon. Accepted for publication August 30, 1993. Presented in part at the annual meeting of the American Society of Anesthesiologists, New Orleans, Louisiana, October 1992.

nector.[5] Using the latter technique in a recent study, Zaleski *et al.*[6] found that in 500 instances of tracheal intubation, bulb reinflation and the capnogram always agreed, whereas the compressed bulb did not reinflate in all 181 instances of esophageal intubation. The sensitivity, specificity, and predictive value in their study was 100%, thus confirming earlier studies.[4,7]

Despite the efficacy of the esophageal detector device and the self-inflating bulb in differentiating esophageal from tracheal intubation, false negative results (when the tube is in trachea, but gas cannot be aspirated by the syringe or the bulb does not reinflate) have been reported.[8–10] It also is conceivable that false positive results (when the tube is in the esophagus, but the bulb reinflates) may occur in the following situations: gastric insufflation after bag-and-mask ventilation before intubation; in the presence of a nasogastric tube; and when the tracheal tube cuff is deflated. The current investigation was designed specifically to test the efficacy of the self-inflating bulb in differentiating esophageal from tracheal intubation (1) when a nasogastric tube is present and (2) when the tracheal tube cuff is deflated.

Materials and Methods

With institutional review board approval, 130 consenting ASA physical status 1 patients between the ages of 16 and 58 yr who were scheduled to undergo elective surgical procedures requiring tracheal intubation were included in the study. They gave no history suggestive of drug allergy, and none had clinical evidence of cardiovascular, respiratory, or gastroesophageal disease. All anesthesiologists involved in the care of these patients cooperated in this prospective study. A number of self-inflating bulbs (capacity 75 ml, Premium Plastic, Chicago, IL) fitted with standard 15-mm adapters were prepared beforehand (fig. 1). The devices were checked for airtightness before use by connecting the compressed bulb to a clamped tracheal tube; the absence of reinflation was an indication of airtightness.

After a peripheral intravenous catheter was inserted, fentanyl 50–100 μg and midazolam 1–2 mg were given. Routine monitoring was used and included pulse oximetry. After oxygenation of the patient's lungs, D-tubocurarine 3–4 mg was given. After 2–3 min, anesthesia was induced with a thiopental–succinylcholine sequence. The trachea was intubated with either a 7.0- or a 7.5-mm (ID) disposable (Mallinckrodt Anesthe-

Fig. 1. The self-inflating bulb fitted with a standard 15-mm adapter.

siology, St. Louis, MO) Murphy-eye tracheal tube under direct-vision rigid laryngoscopy and the cuff inflated until no leak was detected at 25 cmH_2O. Before initiation of controlled ventilation, the compressed self-inflating bulb was attached to the tracheal tube connector, and the speed of reinflation was noted. The bulb then was disconnected, and the tracheal tube was attached to the anesthesia circuit. Controlled ventilation was commenced as the exhaled CO_2 waveform was monitored by mass spectrometry. Complete muscular relaxation was maintained by intermittent doses of vecuronium or atracurium. The esophagus then was intubated under direct vision using a lubricated tube identical to that placed in the trachea but positioned to emerge from the opposite side of the mouth. The position of the tubes was randomized by the intubating anesthesiologist. The compressed bulb was attached to the tube connector, and the speed of reinflation was noted.

The patients were divided into two groups. Group 1 consisted of 70 patients (21 males and 49 females) in whom the insertion of a nasogastric tube was considered desirable for the surgical procedure. In these patients, an 18-French Salem Sump nasogastric tube was introduced from the nose to the stomach, and its position was verified by aspiration of gastric contents. The cuff of the esophageally placed tube then was inflated with 10 ml air. The anesthesia circuit was temporarily disconnected from the tracheal tube. The efficacy of the bulb in differentiating esophageal from tracheal intubation after the introduction of nasogastric tubes was tested by a second, independent anesthesiologist who connected the compressed bulb to each of the tubes and graded the speed of reinflation as instantaneous (< 2 s), delayed (> 2 s), or absent. The tests were repeated if necessary to determine the location of each tube. The second anesthesiologist had no knowledge of the location of either tube at the time of testing. The intubating anesthesiologist then reconnected the anesthesia circuit to the tracheal tube, and the tube was secured in position by tape. The stomach was aspirated, and both the nasogastric tube as well as the esophageally placed tube were removed. In 15 patients, the negative pressures generated in the esophagus by the compressed bulbs were measured before and after the introduction of a nasogastric tube *via* an air-filled pressure transducer (model T4812DT-R, Viggo-Spectromed, Oxnard, CA) interposed between the bulb and the tube. The system was zeroed to atmospheric pressure and calibrated to −100 mmHg against a pressure manometer.

Group 2 consisted of 60 patients (20 males and 40 females) in whom nasogastric tubes were not required. In these patients, the cuffs of the esophageally placed tubes were inflated with 10 ml air. The anesthesia circuit was temporarily disconnected from the tracheal tube by the intubating anesthesiologist. The efficacy of the bulb in identifying the location of each tube was tested as it was for group 1 by a second anesthesiologist, who had no knowledge of the location of either tube. The intubating anesthesiologist then connected the anesthesia circuit to the tracheally placed tube, and controlled ventilation was continued. After 5 min, the tests were repeated after the cuffs of both tubes were completely deflated. Observations were made under each of the following conditions: (1) inflated tracheal tube cuff, (2) deflated tracheal tube cuff, (3) inflated esophageal tube cuff, and (4) deflated esophageal tube cuff. The intubating anesthesiologist then reconnected the anesthesia circuit to the tracheal tube, which was securely taped, and the esophageally placed tube was removed. In 31 patients, the negative pressures generated by the compressed bulbs connected to esophageally placed tubes were measured as previously described before and after cuff deflation.

Student's *t* test was used to identify statistically significant differences ($P < 0.05$) when comparing mean negative pressures before and after (1) insertion of nasogastric tubes in group 1 and (2) before and after cuff deflation in group 2. Based on the total number of intubations (tracheal and esophageal) in both groups 1 and 2, the 95% confidence interval (binomial proportion based on a binomial distribution) for bulb reliability was calculated.

Results

Group 1

The intubating anesthesiologist noted in all patients that the compressed bulbs instantaneously reinflated when connected to tracheally placed tubes but that they showed no reinflation when connected to esophageally placed tubes. After the introduction of nasogastric tubes, the second anesthesiologist reported no reinflation of the bulbs connected to tubes placed in the esophagus and immediate reinflation when connected to tubes placed in the trachea in all patients (fig. 2). The second anesthesiologist's identification of the tube in the trachea and the tube in the esophagus was correct in every case. Tracheal intubation was confirmed by mass spectrometry, which showed the classical rectangular CO_2 waveform. The mean (± SEM) negative pressure produced by the compressed bulb when connected to esophageally placed tubes was 57 ± 0.5 mmHg and after introduction of nasogastric tubes was 58 ± 0.7 mmHg ($P > 0.05$). A typical tracing of the pressures generated by the compressed bulb before and after the introduction of a nasogastric tube is shown in figure 3. The pulse oximeter reading was ≥ 98% in all patients during the study period.

Group 2

In all patients, the intubating and second anesthesiologists noted instantaneous reinflation of the bulb when it was connected to tubes placed in the trachea and absence of reinflation when connected to tubes placed in the esophagus. After cuff deflation, the second anesthesiologist's determination of the location of each tube was correct in every case. The compressed bulb remained collapsed when connected to esophageally placed tubes after cuff deflation. The mean (± SEM) negative pressure produced by the compressed bulb when connected to esophageally placed tubes was 56 ± 0.5 mmHg when the cuffs were inflated and 57 ± 0.4 mmHg after cuff deflation (fig. 4) ($P > 0.05$). The pulse oximeter reading was ≥ 98% in all patients during the study period.

Predictive Values

In a total of 260 tracheal and esophageal intubations in groups 1 and 2, there was zero incidence of false

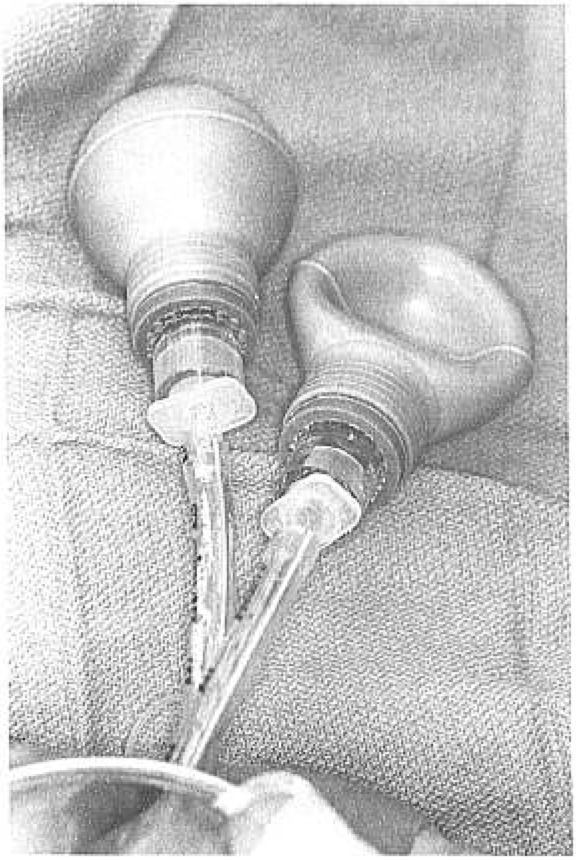

Fig. 2. In a demonstration, collapsed self-inflating bulbs were connected simultaneously to tracheally and esophageally placed tubes in the presence of a nasogastric tube. The bulb connected to the tube in the trachea instantaneously reinflated, while that connected to the tube in the esophagus remained collapsed.

negative or false positive results, which reflects sensitivity, selectivity, and positive predictive values of 100%. The calculated lower limit of the 95% confidence interval was 0.986.

Discussion

The current report confirms previous findings that the self-inflating bulb[4–7] can rapidly and reliably differentiate between tracheal and esophageal intubation. Furthermore, it demonstrates that neither the presence of a nasogastric tube nor the absence of cuff inflation interferes with the effectiveness of the bulb in detecting esophageal intubation. The negative pressures generated by the compressed bulbs when connected to esophageally placed tubes were essentially unchanged by the presence of a nasogastric tube or cuff deflation. The compressed bulb created a sustained negative pressure sufficient to result in collapse of the esophageal wall and occlusion of its lumen around the esophageally placed tube whether or not its cuff was inflated and whether or not a nasogastric tube was present.

The finding that nasogastric tubes did not interfere with the reliability of the self-inflating bulb in detecting esophageal intubation should not be surprising. Although it has been theorized that the presence of a nasogastric tube may interfere with obliteration of the upper esophageal lumen during cricoid compression, investigations have demonstrated that cricoid compression in infants[11] and adults[12] is effective in sealing the esophagus around a nasogastric tube against an intraesophageal pressure of up to 100 cmH_2O. Thus, either external pressure on the esophagus or negative pressure within the esophageal lumen is effective in producing occlusion of the esophageal lumen.

Theoretical conditions leading to false positive results (reinflation of the compressed bulb when connected to esophageally placed tubes) include bag-and-mask ventilation, resulting in gastric insufflation before intubation; the presence of a nasogastric tube; cuff deflation; and the presence of an esophageal pathologic condition, such as a tear, fibrosis, or diverticulum. Recently it has been demonstrated that modest insufflation of the stomach as a result of esophageal ventilation does not interfere with the effectiveness of the bulb in differentiating esophageal from tracheal intubation.[13] Although the reliability of the bulb in the presence of an esophageal pathologic condition has not yet been tested, based on the findings of the current study it seems safe to conclude that neither cuff deflation nor the presence of a nasogastric tube alters the efficacy of the bulb in detecting esophageal intubation. These findings may have important clinical implications when intubation is performed in settings outside the operating room, such as the emergency room, hospital floors, or the trauma scene. Frequently, patients requiring tracheal intubation in these settings may have had bag-and-mask ventilation with gastric insufflation before attempts at tracheal intubation, and some may have a nasogastric tube in place.

Using the syringe method of esophageal detection, O'Leary *et al.*[2] emphasized the importance of cuff deflation during plunger withdrawal of a 50-ml syringe. They noted that cuff deflation allows entrainment of air from the upper airway passages when the tube is in

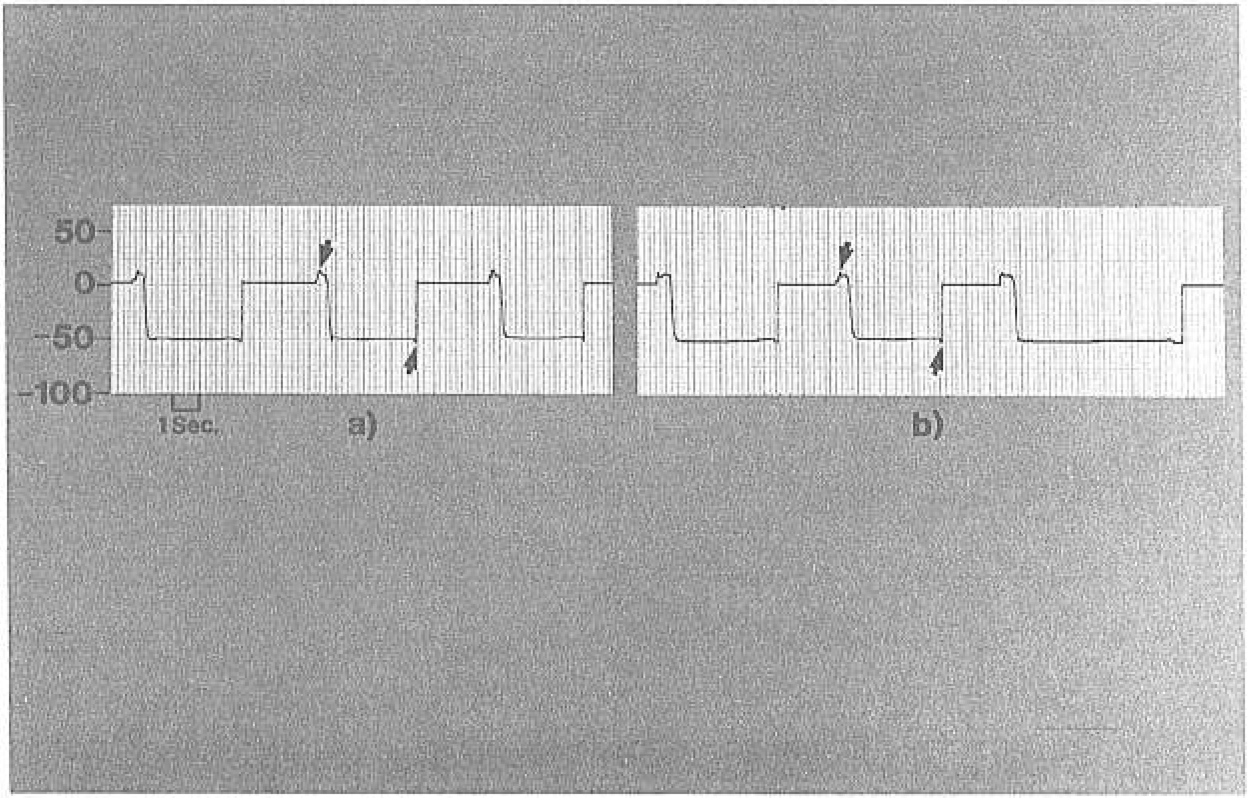

Fig. 3. A typical tracing of the pressures generated in the esophagus by the compressed bulb (*A*) before insertion of a nasogastric tube and (*B*) after the insertion of a nasogastric tube. The arrows above and below the tracing denote attachment and removal of the self-inflating bulb.

the trachea, thus permitting easy aspiration and prevention of tracheal collapse and hypoxemia. Although their recommendation seems reasonable, the current study, which was limited to healthy patients, did not show any difference in reinflation of the bulbs when tracheal tube cuffs were deflated. Because the test using the self-inflating bulb requires less than 4 s, hypoxemia as evidenced by pulse oximetry was not noted. Furthermore, cuff deflation may not be desirable in patients at risk of aspiration, unless cricoid pressure is maintained.

Identification of CO_2 in the exhaled gas has emerged as the standard for verification of proper tracheal tube placement.‖ Two methods currently are available: CO_2 waveform[14–16] (capnography) and colorimetric detection of CO_2.[17–19] Although the CO_2 waveform typically distinguishes tracheal from esophageal intubation, false negative results[20,21] (with the tube in the trachea: waveform absent) and false positive results[22–26] (with the tube in the esophagus or pharynx: waveform present) have been reported.

Like capnography, the self-inflating bulb may fail to confirm proper tracheal tube placement in patients who have severe upper or lower airway obstruction and whenever the tracheal tube is obstructed.[8] The bulb also may fail to confirm tracheal tube placement in infants, in whom the tracheal wall is not held rigidly by cartilage as it is in adults.[9] We have noticed that the device may fail to reinflate or may reinflate slowly when connected to a properly placed tracheal tube in morbidly obese patients[27] and in other patients who have marked reduction in expiratory reserve volume, such as those with pulmonary edema or acute respiratory distress syndrome. In the current study, delayed reinflation was not observed in any patient, whereas Zaleski *et al.*[6] reported slow reinflation of the bulb (5–30 s)

‖ Standards for basic intraoperative monitoring, Directory of Medicine. Park Ridge, American Society of Anesthesiologists, 1991, p 670.

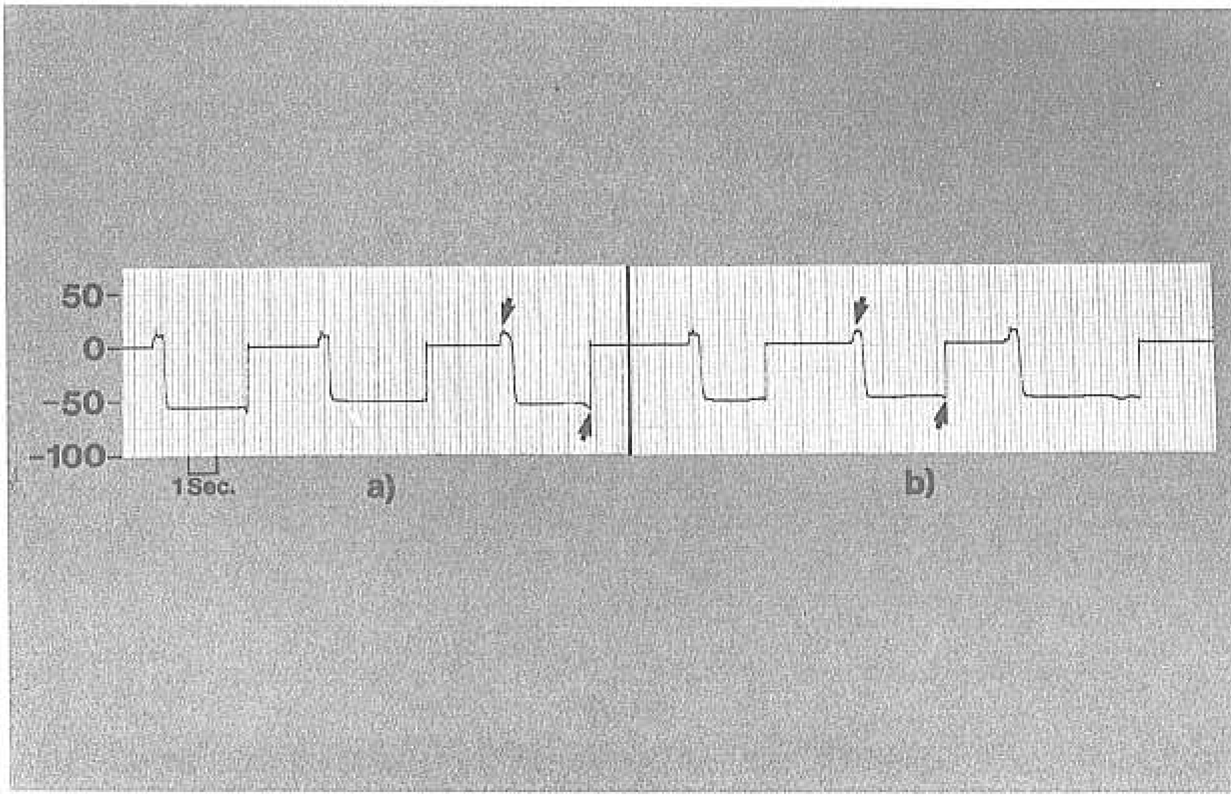

Fig. 4. A typical tracing of the pressures generated in the esophagus by the compressed bulb (*A*) with an inflated cuff and (*B*) after cuff deflation. The arrows above and below the tracing denote attachment and removal of the self-inflating bulb.

in 6% of tracheally intubated patients. This difference may be attributed to the absence of respiratory disease in the patients selected in our study and possibly to the inclusion of patients with markedly reduced expiratory reserve volume in the study by Zaleski *et al.*[6] Thus, the self-inflating bulb occasionally may show false negative results, but in contrast to capnography or colorimetric detection of CO_2, false positive results are probably nonexistent.

Unlike capnography[28] or colorimetric detection,[18,19] the self-inflating bulb functions equally well in patients with cardiac arrest and in those with an intact circulation. The bulb can be used in the operating room in conjunction with capnography as well as outside the operating room, in situations where tracheal intubation may be performed as an emergency measure. Verification of proper tracheal tube placement by this simple, quick method enables physicians and emergency personnel to proceed with other resuscitative measures.

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