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Accidental oesophageal intubation

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Tracheal intubation to secure a patient's airway is a fundamental skill in anaesthetic practice. The routine nature of the procedure may lead to complacency about the possibility of mishap. Yet tracheal intubation, especially when associated with neuromuscular block, is a potential minefield for disaster [64]. Of 750 cases reported to the Medical Defence Union between 1970 and 1982, in which a patient died or suffered cerebral damage in relation to anaesthesia, 100 were caused by errors associated with tracheal intubation [63].

Accidentally placing a tracheal tube in the oesophagus happens to every experienced anaesthetist. It is not in itself harmful, provided that the tube is removed promptly and replaced in the trachea to establish the airway. It is undue delay in diagnosis and corrective action which leads to hypoxic damage and gives rise to claims for negligence arising from the complications of oesophageal intubation [10] (see table I).

How common is the problem?

Oesophageal intubation was recognized over 40 years ago as a major cause of anaesthetic mortality [20]. The problem has not diminished, as a recent analysis of closed medicolegal claims in the USA reveals [12] 94 of 1541 claims were the result of accidental oesophageal intubation, with the majority of cases resulting in death or major cerebral damage and settlement costs averaging more than $200000. In almost half of these oesophageal intubations, there was a notable diagnostic failure, whereby widely accepted clinical signs appeared to suggest correct placement of the tracheal tube, thereby delaying appropriate corrective action.

In the UK, analyses of reports of the Medical Defence Union [63] and Medical Protection Society [22] demonstrate that major morbidity and mortality from undetected oesophageal intubation are just as common. Successive Confidential Enquiries into Maternal Deaths have demonstrated oesophageal intubation as a major cause of mortality in obstetric anaesthesia [40]. Moreover, the problem does not appear to be diminishing with improvements in obstetric anaesthetic practice. A recent Confidential Enquiry revealed that, despite a marked reduction in overall anaesthetic-related deaths, three out of seven deaths were as a result of undetected oesophageal intubation [1].

Critical incident reporting, an indicator of the frequency of anaesthetic complications, shows that oesophageal intubation is common [27] and a significant cause of those incidents defined as producing "a substantive negative outcome" [16].

Why do anaesthetists fail to detect oesophageal intubation?

Experience alone does not prevent a failure to detect oesophageal intubation. It appears that staff anaesthetists are just as likely as trainees to fail to recognize oesophageal intubation [22, 27]. Furthermore, oesophageal misplacement occurs as frequently when intubation is apparently straightforward as during difficult intubation [27]. There are two quite distinct situations in which undetected oesophageal intubation occurs.

During straightforward intubation, confirmation of correct tube placement is made when it is seen to pass through the vocal cords into the larynx; and in the majority of routine intubations this is possible. However, undetected oesophageal intubation can occur even when the anaesthetist believes he has observed the tube pass into the larynx. This may happen because the anaesthetist is distracted at the crucial moment, or the tube may become displaced during fixation. Whatever the reason the apparently routine nature of the situation may lead to complacency, particularly when unreliable clinical observations of chest movement, ventilatory compliance and refilling of the breathing system reservoir bag reinforce the belief that all is well. The problem only becomes evident when the patient is noted to be hypoxic, either by the appearance of cyanosis or, more specifically, by detection with a pulse oximeter. The anaesthetist, still subconsciously convinced that the tube is correctly placed is likely to first explore other causes of hypoxia, such as endobronchial intubation, further delaying recognition of the true cause.

In contrast, when there is difficulty during tracheal intubation and the larynx is not properly visualized,

TABLE I. *Complications of accidental oesophageal intubation*

Hypoxia
Gas in stomach and intestine
Regurgitation

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KEY WORDS

Intubation, tracheal: complications. Complications: intubation, tracheal. Medicolegal.

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the anaesthetist is more alert to the possibility of oesophageal intubation. None the less, once unreliable clinical signs have conspired to mislead the anaesthetist into believing that the tube is in the trachea, he is often unwilling to consider the possibility of oesophageal intubation and looks elsewhere for the cause of the increasing hypoxia. Indeed, the very fact that intubation was difficult may make him reluctant to remove and replace the endotracheal tube.

Another complicating factor is the increasing practice of routinely preoxygenating patients before induction of anaesthesia. This delays the onset of hypoxia and separates the initiating event (i.e. oesophageal intubation) from the development of oxygen desaturation. This makes it more difficult to associate cause and effect; and for this reason Howells has argued against routine preoxygenation [29]. However, the benefits of preoxygenation are without question, and a more sensible approach is to improve methods for early detection of oesophageal intubation and not to rely on hypoxia as a means of detection.

In both these scenarios a high index of suspicion of the possibility of oesophageal intubation must be maintained especially in apparently straightforward situations. Anaesthetists also need to accept the limitations of clinical signs for detecting oesophageal intubation.

The problem of the tracheal tube which becomes displaced

The commonest cause of oesophageal intubation is misplacement during the act of intubation. However, the tracheal tube may become displaced at any time during the course of anaesthesia and this accounts for a significant minority of misadventures due to undetected oesophageal intubation [22, 34]. Positioning and movement of the patient can cause tracheal tube displacement. Radiological studies reveal that flexion and extension of the neck can cause the tube to move up and down within the trachea by as much as 5 cm resulting in inadvertent extubation [15] and the tube may subsequently slide into the oesophagus. Displacement can occur because of poor fixation which may go undetected, especially when visual assessment of tracheal tube position is obscured by the surgery. Thus, care in preventing this complication is essential, together with vigilance and the use of a reliable method of monitoring, so that tube displacement can be quickly detected. When cyanosis occurs, especially within a few minutes of intubation (say 10–20 min) or movement of the head, *suspect accidental extubation.*

Other situations in which tracheal intubation is performed

In addition to its frequent use to secure the airway during anaesthesia, tracheal intubation is performed in other localities, often by less experienced practitioners. Patients in the intensive care unit receive respiratory support for prolonged periods, and with a reduced conscious level, by means of a tracheal tube. During resuscitation, both in and out of hospital, a priority for basic life support is securing the airway by means of tracheal intubation. Because of the sometimes difficult environment and the frequent presence of inexperienced practitioners, the risk of incorrect placement is high. A simple reliable means of detecting correct placement and of detecting displacement would be invaluable.

Features of an ideal test for detecting oesophageal intubation

The ideal test for early detection of oesophageal intubation should be totally reliable, without giving false negative results which induce a false sense of security by indicating that the oesophageal intubation has not occurred. Of slightly less importance is that the test should not produce false positive results, as unnecessary removal of the tracheal tube is not without hazard in some situations, as for example after difficult intubation. The test should be simple and rapid to perform, and be entirely safe for the patient and the operator. Its simplicity should allow it to be utilized by inexperienced personnel, both in the operating theatre and at other sites in and out of hospital. It should therefore be practicable in difficult situations to detect displacement subsequent to successful tracheal placement at any time. Finally, it should not require complex equipment and be expensive. As yet, the perfect test does not exist.

The reliability of any method for detecting oesophageal intubation must depend upon extensive assessment. Any technique to discern oesophageal from tracheal intubation has limitations because of simulated conditions in normal patients and enthusiastic trained motivated investigators. Frequently, direct comparison is made by an observer with two tubes, one in the oesophagus and the other in the trachea, which is entirely artificial [67]. Everyday clinical practice is different and true evaluation of any technique must eventually require extensive studies in a variety of situations by practitioners of varying experience with all failures reported accurately. Only wide field experience can ensure that any technique is reliable.

METHODS FOR DETECTING CORRECT TRACHEAL TUBE PLACEMENT

These can be simply divided into clinical and technical tests.

CLINICAL SIGNS (TABLE II)

Direct visualization

The observation of the tracheal tube passing through the vocal cords into the larynx *should* be the standard for ensuring correct tracheal tube place-

TABLE II. *Clinical tests for confirming successful tracheal intubation*

(1) Visualization of tube passing through the cords
(2) Auscultation over trachea, apices, bases and epigastrium
(3) Observation of chest movements
(4) Palpation of tracheal tube movement within trachea
(5) Reservoir bag compliance and lack of progressive abdominal distension
(6) Lack of cyanosis
(7) Presence of water vapour condensing in breathing system during expiration

ment. However, visualization of the larynx is not always possible for anatomical reasons. Furthermore, many experienced anaesthetists can recall a situation in which the tracheal tube entered the larynx, yet subsequently it was found that the oesophagus had been intubated. Whether this is the result of distraction during intubation, mistaken identification of the larynx, or displacement during fixation, is uncertain. Direct visualization of the vocal cords, therefore, cannot be considered totally reliable, and is the cause of false security by possibly deceiving a practitioner into believing that the oesophageal intubation could not be the cause of the resultant hypoxia.

When a problem with tracheal tube placement is suspected, particularly when the practitioner is a trainee under supervision, the repeat laryngoscopy, providing the larynx can be properly visualized, is essential and should confirm the tracheal tube's correct position. A useful technique when the larynx cannot be visualized, is to press the tracheal tube backwards towards the hard palate. This manoeuvre will often bring the larynx into view providing the tube is in the trachea [21].

Visualization of chest movement

Symmetrical bilateral outward expansion of the chest wall is frequently relied upon as a sign. However, chest wall movement can be difficult to assess in the obese patient, in the presence of large breasts, or where the patient has a rigid chest wall or lung disease. Moreover, in a cadaver study, chest wall movement simulating lung ventilation has been shown to occur when the oesophagus alone is ventilated [51]. That observation may be because of intermittent distension of the oesophagus with a closed cardio-oesophageal sphincter which lifts the mediastinum and expands the chest wall. Distension of the stomach by gas leaking through the cardio-oesophageal sphincter can also cause intermittent epigastric distension mimicking diaphragmatic descent and expansion of the lower chest. Both these mechanisms can occur simultaneously. Hence, chest wall movement is an unreliable sign and anecdotal case reports support this view [17, 30, 48, 51].

Breath sounds

The presence of breath sounds over the chest has been considered a reliable confirmatory clinical sign of correct tracheal tube placement. Often, clinicians auscultate each axilla and lung base. However, numerous cases have been described where these signs have been misleading [17, 30, 48, 49, 51, 57, 62] and during a prospective study of 40 patients in which the oesophagus was intentionally intubated, a blind observer auscultating the chest was misled in six patients [2]. The quality of breath sounds varies between patients and between sites on the chest wall and is further influenced by the rate and volume of ventilation. Air passing through the oesophagus can produce oesophageal wall vibration which can be transmitted through the lung to sound similar to harsh breath sounds [30]. Without true breath sounds for comparison, oesophageal sounds can be mistaken for lung ventilation.

Additional auscultation over the epigastrium to detect the bubbling sound of gastric ventilation has been proposed [49], and is reported to increase the sensitivity of chest auscultation [2]. Although this procedure is not in routine use, failure of this sign to detect oesophageal intubation has not been reported [36]. On the other hand, in some thin individuals transmitted true breath sounds can be heard over the epigastrium and could confuse the clinician into believing that they are the result of gastric ventilation, initiating inappropriate extubation [9]. Auscultation over the trachea which transmits typical inspiratory and expiratory breath sounds, may be an additional precaution, but has not been evaluated.

Gastric distension

If there is oesophageal intubation, gas insufflated into the stomach cannot escape through the cardio-oesophageal sphincter so that the stomach and upper intestine progressively dilate which may alert the clinician to the possibility of tube misplacement [61]. However, this sign can be difficult to discern from normal abdominal movements, particularly in the obese patient. The stomach will dilate less if there is reflux of gas back into the oesophagus. Gastric dilatation might also be attributed to gas introduced during mask ventilation before tracheal intubation. Overall this sign is very unreliable [51].

Reservoir bag compliance and refill

Much reliance is placed upon the characteristic "feel" of the reservoir bag when ventilating the patient after tracheal tube placement. This sign relies upon the characteristic compliance of the lung and refill of the bag during expiration. However, lung compliance varies widely between patients and within the same patient with time, which means that "feel" can be deceptive. Apparently normal refill of the reservoir bag of insufflated gas from the stomach and oesophagus can also occur [30, 48, 51] especially when fresh gas continues to flow into the breathing system [6].

The refill of the reservoir bag during expiration in spontaneous respiration has also been shown to be an unreliable sign [57]. Robinson demonstrated tidal volumes in excess of 50 ml, sufficient to produce adequate movement of the reservoir bag, from a tube placed in the oesophagus of an anaesthetized patient attempting to breathe spontaneously when a tube in the trachea was obstructed [53]. He suggests that the high intrathoracic pressure generated during obstructed breathing is transmitted to the oesophagus, producing flow of gas into and out of the oesophagus, mimicking respiratory excursions of the reservoir bag.

Cuff manoeuvres, neck and arytenoid palpation

The sound of gas escaping during inflation, when the tracheal cuff is deflated, is said to produce a characteristically different sound when the tube is in the oesophagus from one placed in the trachea. Owing to the less rigid oesophageal wall, the sound is a lower pitched "guttural" note or is flatus-like compared with the higher pitched sound from a tube placed in the trachea. Furthermore, the less rigid structure of the oesophagus makes it more difficult to achieve an effective seal so that air escapes more readily when high pressures are generated during ventilation. This is less likely to occur if the cuff within the oesophagus is at the level of the cricoid ring [51].

Palpation of the tracheal tube cuff within the palpable portion of the trachea aided by in and out movement of the tube or inflation and deflation sequences of the cuff [13] have been used to verify correct tube placement. A small controlled study using blinded observers to differentiate between tracheal and oesophageal intubation, demonstrated that palpation of the cuff was not reliable [23].

Roy has suggested that during the supervision of a trainee performing tracheal intubation, the supervisor palpates the trachea in the sternal notch or applies cricoid pressure [54]. If the tube enters the trachea the palpating fingers will appreciate vibrations likened to those produced by an old washboard, as the tip rubs against the tracheal rings. The reliability of this sign has not been verified [54].

Another palpation technique relies upon a gloved hand being placed into the mouth after intubation and the palpating hand identifying the intra-arytenoid grovė and its relation to the tube. In a study of 200 patients the test correctly verified tracheal placement in 97% of cases [14]. In addition to not being totally reliable, a thorough familiarity with the technique is required [28], and the sign is limited by anatomical abnormalities such as poor mouth opening.

Condensation of water vapour

The presence of water vapour in expired gas can be detected as condensation in the lumen of clear plastic tracheal tubes and breathing systems. Water vapour is more likely to be present in expired gas coming from a tube correctly placed in the trachea than one misplaced in the oesophagus. However, condensation is not always evident in expired gas and can also be present in gas emanating from the stomach. This sign has, not surprisingly, been found to be extremely unreliable [2, 23], and is of limited value even as a supplementary sign.

Sternal compression

Sharp compression of the sternum while listening over the open end of the tracheal tube for air expelled from the lungs is occasionally used as a means of differentiating tracheal from oesophageal intubation. This test is unreliable [51] as it is difficult to distinguish expired air passing up the tube from that passing alongside the tube when the tube is in the oesophagus. Furthermore, air in the oesophagus, introduced during manual ventilation before intubation, can be squeezed through an oesophageal tube during sternal compression.

Presence of gastric contents in the tube

The presence of gastric contents in the tube can lead to the diagnosis of oesophageal intubation [9]. This is unreliable as there can be no distinction from previously aspirated stomach contents or even from excessive lung secretions.

Cyanosis and pulse oximetry

The appearance of cyanosis is a relatively late manifestation of oesophageal intubation and is not in itself diagnostic, merely an indicator of mishap. Owing to the sigmoid shape of the haemoglobin oxygen dissociation curve, desaturation will proceed rapidly when it is sufficient for cyanosis to be detected. Prompt diagnosis with remediable action then needs to be taken if cardiac arrest and irreversible cerebral hypoxia are to be avoided. Moreover, cyanosis is difficult to detect in certain patients such as those with dark skin or anaemia.

The increasing availability of pulse oximetry makes early detection of desaturation possible. During undetected oesophageal intubation and ventilation in a relaxed patient, lung ventilation can still occur by intermittent gastric and oesophageal distension compressing the lungs and producing gas flow through an open larynx [37]. In such circumstances, particularly when preoxygenation has been carried out before intubation, oxygen desaturation and cyanosis occur late and will not be associated with a misplaced tube during intubation; thus appropriate action will be delayed.

Pulse oximetry should be considered as an important backup monitor in detecting oesophageal intubation [27]. Even the use of more sophisticated high resolution pulse oximeters, which can rapidly alert to small falls in oxygen saturation, will not detect oesophageal intubation as rapidly as capnography, especially when patients have been preoxygenated [25].

In summary, when in doubt check the larynx. Change the tracheal tube if there is still doubt.

TECHNICAL TESTS (TABLE III)

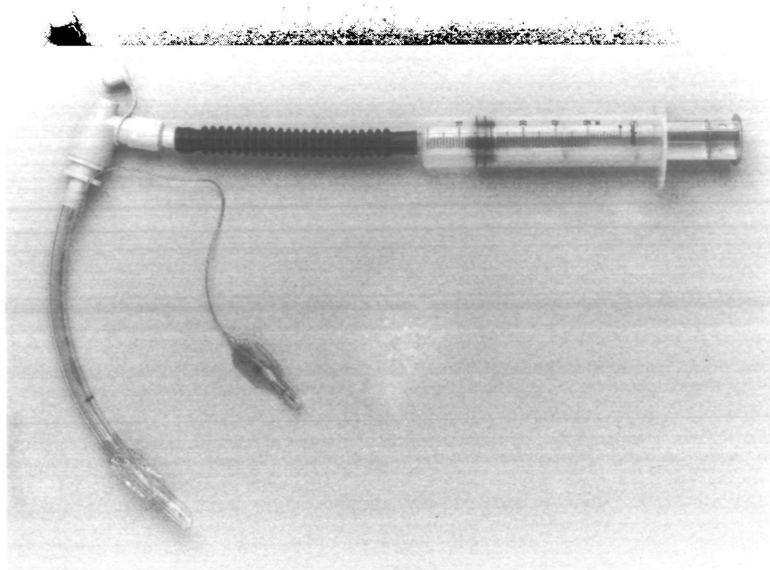
The inconsistency of clinical signs at detecting oesophageal intubation has led to the examination and use of a variety of tests; some simple using readily available equipment, and others involving more complex apparatus.

Chest radiography

Chest radiography is sometimes used in the intensive care unit to verify correct position of the tracheal tube. It is time consuming, expensive and involves some delay before the film is available to be viewed. The confirmation of the tube shadow within that of the tracheal column on an anterior–posterior projection is unreliable [8], though a 25 degree right oblique view improves accurate identification of tracheal tube position [55]. The main value of chest radiography is to verify position of the distal end of the tube and detect endobronchial intubation.

TABLE III. *Technical tests for detecting accidental oesophageal intubation*

(1) Expired carbon dioxide
(2) Negative pressure test
(3) Oxygen saturation
(4) Fibreoptic light wand
(5) Fibreoptic inspection



Ultrasound imaging has been suggested as an alternative to radiographical confirmation of tracheal tube position [52]. This technique requires the use of a foam cuff or the substitution of saline for air in the cuff to improve imaging of the tube.

Video stethoscope

This device consists of two small microphones placed on each side of the chest with their output displayed on an oscilloscope in an X-Y format. The patterns obtained are reported to allow easy distinction between tracheal and oesophageal ventilation [31]. The technique appears cumbersome and there are no reports of its reliability during extended use.

Fibreoptic confirmation

Visualization of the carina and tracheal rings through a fibreoptic bronchoscope or intubating laryngoscope reliably confirms tracheal placement [69]. The technique is only practical when the instrument has been used for intubation as it is expensive, fragile and not easily cleaned between cases.

Transtracheal illumination

The light wand, a fibreoptic light source, can be passed through the tracheal tube and the intensity of transillumination used to differentiate tracheal from oesophageal intubation [56]. The test requires dimming of overhead lights and relies upon the experience of the operator. Maximum transillumination is visible just below the cricoid. Obesity and swelling of the neck make the technique difficult.

Eschmann introducer and similar devices

The use of a flexible intubating stilette, such as an Eschmann introducer, can help confirm correct tube placement; the tip of the stilette rubs over the tracheal ring and this is felt by the intubator [35]. In addition, if the introducer is pushed down until resistance is encountered when it abuts against the carina at about 28–32 cm in an adult, it is in the trachea, but if the tube is in the oesophagus no such resistance is encountered [9]. Kalpokas [33] suggests the use of a nasogastric catheter of a bore sufficient to pass easily down the tracheal tube. The lubricated catheter is threaded down the tube after intubation until resistance is met, then gently withdrawn as suction is applied to the catheter. The absence of an abrupt halt to the catheter advancement, and resistance during withdrawal (owing to oesophageal wall collapse) are indicative of oesophageal intubation in the small number of patients studied. More extensive experience with this technique has not been reported.

Negative pressure tests

The use of negative pressure devices to detect oesophageal intubation are a recent innovation and rely upon the differences in rigidity of the tracheal and oesophageal walls. When a negative pressure is applied to a tube within the oesophagus, the soft walls collapse down around the tube and aspiration of gas is prevented. In contrast, the support of the tracheal rings prevents the wall collapsing around a tracheal tube and gas is freely aspirated.

Wee utilized this principle in a detection device consisting of a catheter mount connected to a 60-ml syringe (fig. 1) [66]. The catheter mount is attached to the tracheal tube after intubation and free aspiration of gas by the syringe confirms correct tracheal placement. If the tube is within the oesophagus, there is resistance to aspiration. The device can be used additionally to inject air into the tube while listening over the epigastrium to detect gurgling in the stomach [66]. Under simulated conditions the device successfully detected oesophageal intubation [2, 47, 66, 72]. However, false positive tests occurred when there was failure to freely aspirate air from a tube placed in the trachea because of mucus obstructing the lumen [19, 66].

Modifications of this device, by attaching an Ellick's evacuator bulb [44] or the bulb of a disposable catheter-tip bulb syringe [38] to a tracheal tube connector, allows single-handed use (fig. 2)

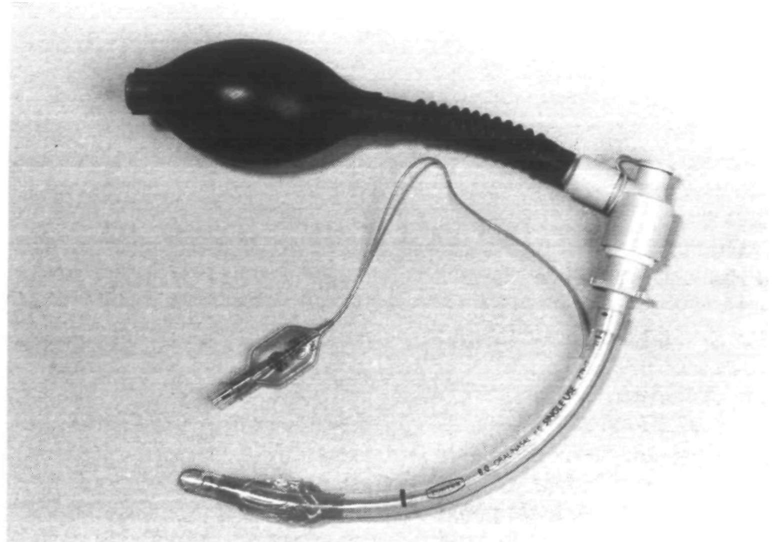


FIG. 2. Nunn's modification of negative pressure oesophageal detector.

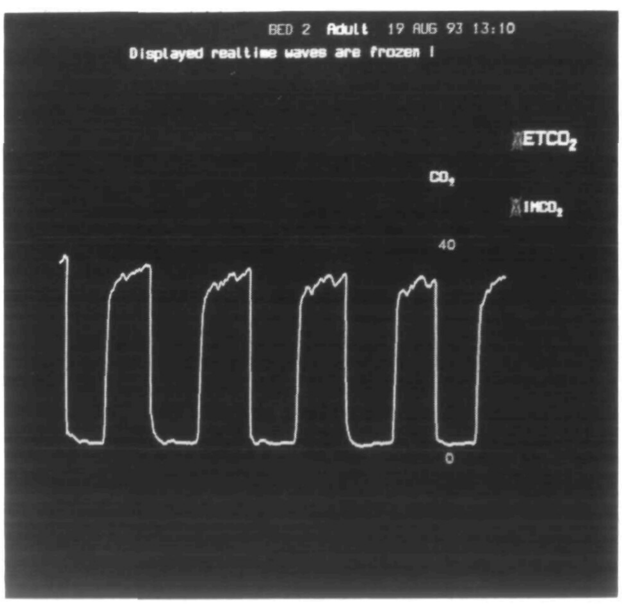


FIG. 3. Normal capnograph.

[44]. After intubation the device is connected and the bulb is first emptied, which often elicits a characteristic flatus-like noise if the tube is within the oesophagus. On release, rapid refill of the bulb confirms tracheal placement, while absent or delayed refill indicates oesophageal intubation. Under simulated conditions this technique has been shown to distinguish effectively between oesophageal and tracheal intubation [5, 70], but differentiation is not always precise and some experience is required [70]. It has also been used successfully with uncuffed tubes in children [41, 68].

Both of these devices are cheap, simple and convenient to use. They are inclined to give false positive results as a consequence either of endobronchial intubation, or of tracheal mucosa obstructing the end of the tube [67], particularly if the bevel is facing backwards and abuts against the unsupported posterior tracheal wall [11], though the presence of a Murphy's eye may prevent this [67]. To overcome these problems it has been suggested that if resistance to aspiration is encountered, the tube is retracted 0.5 to 1 cm and rotated through 90 degrees before repeating the test [11, 67]. False positive tests can also occur in asthmatics [4], in patients with upper airway obstruction or tracheomalacia [3], and it is not a suitable technique for small infants [26]. Earlier ventilation of the patient, either by means of a mask or by the tube after intubation, does not appear to interfere with the effectiveness of the tests [67].

Despite the simplicity and convenience of these tests, they are not yet widely used so that their reliability at detecting the unexpected oesophageal intubation cannot be determined.

Detection of carbon dioxide

Provided pulmonary perfusion is adequate, alveolar gas contains carbon dioxide in a concentration in the order of 5 % (fig. 3), while gas emanating from the oesophagus and stomach is usually free of carbon dioxide. Since the early 1980s, capnometry has been used as a reliable test to distinguish tracheal from oesophageal intubation [7, 32, 43]. The technique has been widely adopted in North America and the ASA have recently modified their standards for basic intraoperative monitoring to include the identification of carbon dioxide in the expired gas to verify correct tracheal tube placement.

Ideally, quantitative devices which can display the concentration of carbon dioxide as a waveform should be used. This can be achieved by relatively expensive infra-red analysers, but the usefulness of such equipment for also detecting ventilatory problems, circuit disconnections, tube obstruction and malignant hyperpyrexia [71], make it an invaluable monitor. In addition, continuous capnography will detect the tracheal tube which becomes displaced into the oesophagus during the course of the anaesthetic.

False positive tests of oesophageal tube placement are well recognized. These are often related to

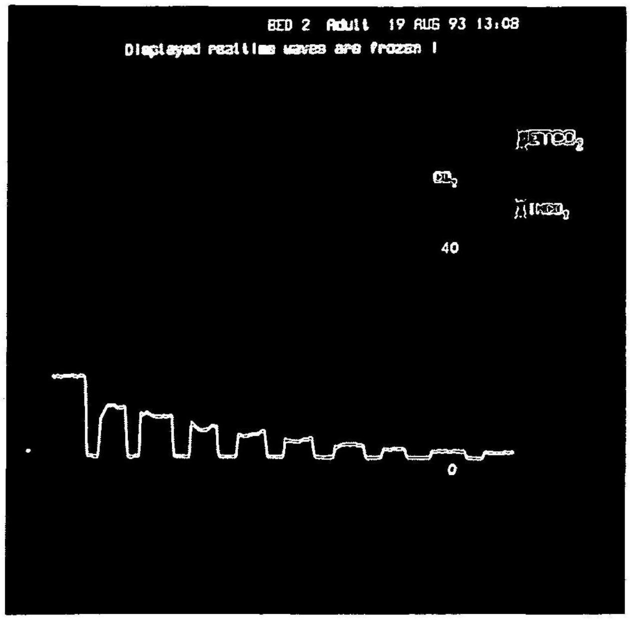


FIG. 4. Simulated capnograph after oesophageal intubation and washout of carbon dioxide from the stomach.

technical problems such as mechanical failure and interference with gas sampling. Others, such as kinked and obstructed tubes, large gas leak around the tube and severe upper airway obstruction, require remedial action in themselves and should not be considered as true monitor failures.

False negative tests too have been reported, when significant concentrations of carbon dioxide, greater than 3% and simulating normal expiratory capnography, have been detected in gas returning from the stomach [37, 59]. There are several mechanisms which can account for this. During mask ventilation, before intubation, expired alveolar gas can be introduced into the stomach. Ingestion of carbonated drinks before intubation, the aptly named "cola complication", is another source of carbon dioxide [73]. Theoretically, though not actually reported, ingestion of antacids can release carbon dioxide in the stomach [60]. In all these circumstances, initial expired breaths from a tube placed in the oesophagus contain carbon dioxide mimicking normal capnography but conveniently this rapidly diminishes towards zero over a few breaths as the carbon dioxide is washed out (fig. 4). Thus, easy distinction is possible, provided capnography is observed over the initial six breaths [37], though longer observation over 1 min has been advocated [60].

Capnography may be readily available in the operating theatre but is inconvenient in other localities where tracheal intubation is performed. Portable, non-quantitative infra-red devices are available, such as the Minicap III carbon dioxide detector [65]. This device has been shown to be effective in distinguishing between tracheal and oesophageal intubation under simulated conditions [39], but is very sensitive and reacts to concentrations greater than 0.3%. This means that potentially it will continue to react to the presence of traces of carbon dioxide in the stomach long after oesophageal intubation [50], so delaying recognition.

A much simpler portable device is the Fenum carbon dioxide detector (fig. 5). This is a disposable plastic attachment which fits onto the catheter mount and contains a pH sensitive chemical indicator which changes colour on exposure to carbon dioxide [45, 58]. The colour changes from purple to yellow rapidly so allowing a breath by breath response. The detector can be left in place for several hours before the chemical becomes exhausted and loses its responsiveness, thus providing continuous ventilatory monitoring. It has proved an effective detector of oesophageal intubation under study conditions [18, 24, 46], though, as with the negative pressure devices, true evaluation of reliability can only follow extensive use in a variety of clinical settings. Its portability makes it potentially convenient during cardiopulmonary resuscitation (CPR) but the carbon dioxide excretion is greatly diminished in such situations. This reduces the sensitivity of a colorimetric detector at distinguishing between oesophageal and tracheal tube placement [19, 42].

CONCLUSION (TABLES IV, V, VI)

Tracheal intubation is required frequently in medical practice; accidental oesophageal intubation is uncommon, and undetected oesophageal intubation a rarity so that even experienced clinicians may never have encountered this emergency. This could lead to complacency; but the outcome is potentially so devastating that awareness of the possibility of oesophageal intubation at each instance of tracheal intubation is crucial to patient safety.

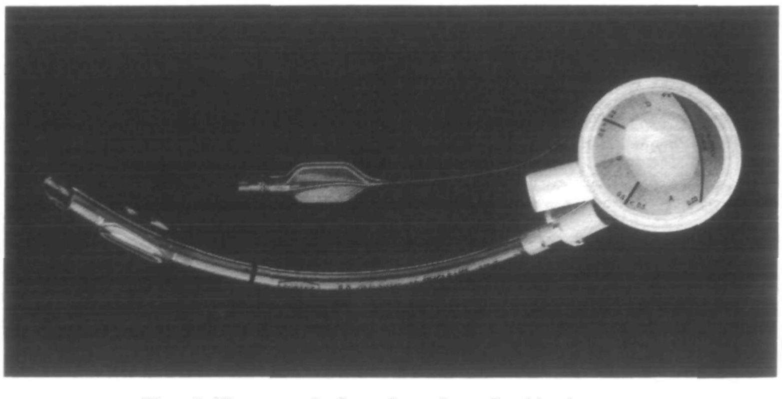


FIG. 5. Fenum colorimetric carbon dioxide detector.

TABLE IV. *Suspected oesophageal intubation—clinical indications for extubation*

(1) Poor or no chest movements
(2) Cyanosis developing within 10 min of preoxygenation
(3) Failure to oxygenate
(4) Suspicion about tube length
(5) Tachycardia and hypertension
(6) Increasing abdominal distension
(7) Failure to palpate tracheal tube movement within the trachea
(8) Lack of condensation in expired gas

TABLE V. *Various actions for suspected oesophageal intubation*

(1) Replace tracheal tube if laryngoscopy does not provide good view of the larynx
(2) Place guide (bougie) through tracheal tube if intubation was difficult, and extubate. This permits re-intubation if suspicion is unfounded
(3) Extubate and either
  (a) ventilate through a mask
  (b) place a laryngeal mask
  (c) place an oesophageal obturator
  (d) resort to failed intubation drill

TABLE VI. *Minimum check after placement of tracheal tube*

Auscultate over trachea, apices, axillae and epigastrium
and either
confirm carbon dioxide concentration > 4 %
or
perform negative pressure test

Clinical signs of correct tracheal tube placement are usually relied upon especially when no difficulties have been encountered. Yet, clinical signs are fallible and an overestimation of their reliability contributes to a failure to detect oesophageal intubation. The most reliable clinical signs are the visualization of the tube passing into the larynx followed by auscultation at both lung bases and over the epigastrium and trachea. These clinical observations should be backed up where possible by reliable technical tests.

Of the technical tests, capnography is the most reliable when properly applied and supported by clinical signs. Capnography is increasingly available in the operating theatres of developed countries but its use immediately after straightforward intubation is not routine. When available, capnography should always be utilized during induction of anaesthesia when tracheal intubation is planned. In the UK, where induction is usually performed in a separate anaesthetic room, the capnograph may be housed on a mobile trolley to avoid expensive duplication of monitors.

Capnography is not possible in every situation where tracheal intubation is performed. In difficult locations the colorimetric carbon dioxide detectors appear promising but they are expensive, experience is limited as yet and their sensitivity during CPR has to be ascertained. Negative pressure devices are cheap and simple and appear reliable providing the clinician has been trained to use them and to correctly elicit clinical signs. It has been suggested as an interesting possibility that it may be more reliable to combine a colorimetric detector with a negative pressure device [70].

When there is doubt as to whether the tube is in the oesophagus or in the trachea, the standard advice is to remove the tube: "When in doubt—take it out". This is sound advice. However, unnecessary extubation is not without hazard in some situations, and an alternative initial manoeuvre when the cause of desaturation is unclear, is to disconnect the tracheal tube and apply a mask over the mouth to ventilate both the tube and around the tube [30]. An improvement in saturation suggests that the tracheal tube is the cause of the problem and should be removed.

The perfect means of detecting accidental oesophageal intubation does not exist. A full awareness of the problem, together with a comprehensive knowledge of the limitations of clinical signs and tests by all personnel undertaking tracheal intubation, and speedy action are essential.

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