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## Video Analysis of Prolonged Uncorrected Esophageal Intubation

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EVEN experienced anesthesia care providers occasionally intubate the esophagus. Many techniques and devices have been described to detect esophageal intubation.[1–9] We report here the analysis of videotaped events during an esophageal intubation that remained uncorrected for 6 min after emergency airway management in a trauma patient. Formal analysis of the events permitted uncovering the causes of failure to expeditiously correct the tracheal tube misplacement.

## Methods and Materials

### *Consent and Confidentiality*

The videotape of accidental esophageal intubation was obtained as part of a study that collected data from real patient management and examined decision-making under stress. The study was approved by the institutional review board, and the anesthesia care providers gave unrestricted consent to be videotaped.[10,11] They activated the video acquisition system and participated in all aspects of the video analysis. All videotapes obtained in the study were maintained according to institutional quality assurance guidelines.

### *Video Acquisition*

Video images and sound track were acquired by miniature cameras and microphones suspended from the ceiling of two patient admitting areas and two operating rooms of the authors' institution, as previously described.[10,11] Heart rate and noninvasive blood pressure (BP) signals were interfaced to a personal computer that included a video overlay board, so that these data were overlaid on the video image used for video analysis. The pulse oximeter and end-tidal carbon dioxide ($ET_{CO_2}$) signals were not interfaced because the Nellcor 1000 (displaying both oxygen saturation and $ET_{CO_2}$) was disconnected to service the equipment, and when it was returned, the personal computer interface was not reconnected. Pulse oximeter and $ET_{CO_2}$ data were obtained from verbal communication of the values when they appeared. Beat-by-beat pulse oximeter values were estimated by using the formula 160 Hz + 5 Hz/% × $O_2$ saturation = pitch of pulse oximeter audio signals in Hz.‖ To obtain beat-by-beat oxygen saturation, we used a square wave function generator (Wavetek model 20, San Diego, CA) connected to a speaker and adjusted the pitch until it matched that of the pulse oximeter heard on the audio channel of the videotape. The videotape was analyzed using the Observational Coding System of Tools (Triangle Research Collaborative, Triangle Research Park, NC), a commercial observational analysis software package.

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Key words: Communication. Esophageal intubation. Fixation errors. Systems failures. Video analysis.

*Videotape Review*

The videotaped patient management was reviewed separately with the two anesthesia care providers (ACP1 = supervisor, ACP2 = laryngoscopist). Each provided an audiorecorded commentary. Audible communications on the videotape were transcribed using the Observational Coding System of Tools. Two nonparticipant subject matter experts reviewed the videotape and provided audio-recorded commentaries. In addition, the subject matter experts completed an intubation analysis form developed to examine tasks performed in the intubation sequence.[12] ACP1 then repeatedly re-

**Table 1. The Usage, Sensitivity, and Specificity of the Tests, Examinations, or Observations Reported to Suggest Correct Placement of an Endotracheal Tube (ETT) in the Trachea as Applied by the Anesthesia Care Providers in Airway Management of This Prolonged Undetected Esophageal Intubation**

| NA | NP | ± | A | Before ventilation |
|---|---|---|---|---|
| | | − | 1 | Tube visualized passing through cords |
| | NP | | 2 | Detection of cuff distension in suprasternal notch during rapid cuff inflation[9,12,13] |
| | | + | 3 | Feeling movement with fingers placed on each side of trachea (*e.g.*, cricoid pressure) while moving ETT |
| | NP | | 4 | Rapid reinflation of an esophageal detector device attached to ETT[14,15] |
| | NP | | 5 | Pressing sharply on sternum produces air movement through ETT[1] |
| | NP | | 6 | Trachea tube introducer cannot be passed more than 28–30 cm into a tracheally placed ETT[16] |
| NA | | | 7 | Cough as tube enters trachea of sedated or awake patient |
| NA | | | 8 | Cessation of phonation or vocalization in sedated or awake patients |
| | NP | | 9 | Fiberoptic inspection identifies carina and tracheal cartilages |
| | | + | 10 | Lack of gastric contents on suction through ETT[1] |
| | NP | | 11 | Transtracheal illumination with a fiberoptic lightsource |
| | | | B | On ventilation |
| | | + | 1 | Normal feel and compliance of anesthesia bag during manual ventilation[1,20] |
| | | + | 2 | Condensation of water vapor fogging inside the tracheal tube on exhalation[1] |
| | | + | 3 | Breath sounds auscultated bilaterally over chest |
| | | − | 4 | No breath sounds heard over epigastrium[6] |
| | NP | | 5 | Breath sounds heard with a stethoscope in the sternal notch or esophagus[1] |
| | | − | 6 | Capnograph observed for 3–5 breaths after tracheal intubation showing normal and stable $CO_2$ values (Gold Standard for detection of ETT placement in trachea)[20] (in this case report $CO_2$ analyzer attached 4 min 39 s after esophageal intubation) |
| | | − | 7 | Measurement of exhaled volume nearly equal to tidal volume[1,7,9] |
| | | + | 8 | Absence of "guttural sounds," "bubbling sounds," or "death rattle" of air moving in esophagus[5]; on review of videotape ACP1 remarked on guttural sounds with resuscitator bag ventilation |
| | NP | | 9 | Neural network analysis of $CO_2$ volume and temperature wave forms from ETT[7] |
| NA | | | 10 | Observation of tidal volume changes in reservoir bag in spontaneously breathing patients[22] |
| | NP | | 11 | Video stethoscope[21] |
| | | + | 12 | Nondistension of epigastrium with continued ventilation[9] (although in this case report ETT in the esophagus was suctioned several times) |
| | NP | | 13 | Analysis of temperature of exhaled gas[7] |
| | | + | 14 | No escape of gas from the esophagus (esophagus suctioned; see above) |
| | NP | | 15 | Auscultation or measurements of gas flow through expiratory limb of circle system |
| | | − | 16 | Repeat direct laryngoscopy once tube in place shows tube passing through cords[9] (in this case report only occurred after $Sp_{O_2}$ and $CO_2$ signals suggested malposition of ETT) |
| | NP | | 17 | Mask ventilation around tube in trachea shows decreased $O_2$ saturation[6] |
| | | | C | Late findings |
| NA | | | 1 | Chest x-ray shows tube in trachea[9] |
| | NP | | 2 | Fiberoptic bronchoscopy |
| | | − | 3 | Normal $Sp_{O_2}$ maintained for > 10 min |
| | | − | 4 | Absence of cyanosis, and cardiac dysrhythmias for > 10 min |
| | | − | 5 | Persistence of appropriate normal vital signs for > 10 min |

Section A = tests to detect esophageal intubation, before the patient is ventilated; Section B = tests that generally depend on ventilation; Section C = late findings that would generally occur with an ETT tube correctly placed in the trachea. In the columns to the left are shown those tests that were used and gave positive (+) results indicating correct tracheal positioning of the ETT or negative (−) findings. Not applicable (NA) or not performed (NP) tests are also indicated.



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viewed parts of the videotape with one of the subject matter experts while audiorecording a discussion of some of the factors that have been reported in the literature as signs of correct placement of the endotracheal tube (ETT) in the trachea (table 1). The object of these reviews was to seek causes of the failure to correct the esophageal intubation expeditiously and identify the specificity and sensitivity of the tests used at the time to detect whether the ETT was correctly placed.[1–20] The video analyzers determined the frequency and duration of ACP1 and ACP2 viewing the vital signs and pulse oximeter/end-tidal carbon dioxide monitor to ascertain what physiologic signals the ACPs were searching for in the 6 min after esophageal intubation. The process required observation of when the ACPs looked at the monitors and was simplified by the positioning of the monitor displays. When the ACPs were in the intubating position at the patient's head, the vital signs monitor was positioned about 3 feet above and behind the ACP's right shoulder, and the pulse oximeter/$ET_{CO_2}$ monitor was placed about 2 feet behind their left shoulder at about eye level.

Twenty-two months after the event and about 18 months after most recently viewing the videotape, ACP1 was provided with the written anesthesia record (date, time, and patient's identifiers removed) and requested to complete an Australian Incident Monitoring Study report form after reading a description of the forms' use and purpose.[21] ACP1 also completed a questionnaire devised by us for our study that we called the postvideo recall questionnaire. The questionnaire asked for specific information about duration of preoxygenation, monitors in use, number of intubation attempts, time to successful intubation, values of patient vital signs, and identification of tasks completed in association with induction of anesthesia and tracheal intubation.

## Case Report

The patient was a pedestrian struck by a vehicle moving 60 miles/h. He sustained a closed-head injury (Glasgow coma scale 6 of 15), a right hemopneumothorax, and a left tibia/fibula fracture and pelvic fracture. He was unconscious and alcohol-intoxicated and required cardiopulmonary resuscitation at the scene. Videotaping began on admission, when vital signs were heart rate (HR) 80 beats/min, BP 110/80 mmHg, temperature 34.8°C. The lungs were ventilated with oxygen *via* a tightly fitting anesthesia face mask for 8 min, 50 s before the first laryngoscopy, during which time a neurologic examination was completed. Seven minutes, 50 s after admission, ACP1 administered 100 mg lidocaine and then induced anesthesia with 275 mg thiopental and administered 125 mg succinylcholine 8 min, 14 s after admission. Two attempts were made to intubate the trachea. Ten minutes after admission, esophageal intubation occurred and remained uncorrected for 6 min. The esophagus was extubated, and the third laryngoscopy, resulting in tracheal intubation, occurred 16 min, 7 s after patient admission. The patient left the admitting area for a computed tomography scan 12 min after the esophageal intubation was rectified and videotaping ended.

### *Events and Communications during Anesthetic Induction and Intubation*

Before induction of anesthesia, electrocardiogram (ECG), BP, and $ET_{CO_2}$, but not pulse oximeter hemoglobin oxygen saturation ($Sp_{O_2}$), were monitored and displayed (fig. 1). ACP1 applied cricoid pressure immediately after injection of succinylcholine. After the first direct laryngoscopy, ACP2 ventilated with a resuscitator bag, heard guttural sounds, and removed the ETT. On the second laryngoscopy, help was requested in manipulating the position of the larynx (ACP2 said, "This way, this way!"). ACP1 said, "Feels good," as the ETT passed beneath his fingers and he applied cricoid pressure.

The ETT cuff was sealed (fig. 1) and the resuscitator bag attached. A fourth-year medical student (MS IV), not undergoing training by the ACPs, listened to the chest during resuscitator bag compression and nodded yes in response to ACP2's question, "Did you hear sounds all right?" The MS IV then listened over the epigastrium, and after the ACPs had just completed a conversation about removing cricoid pressure, stated, "It's also going in here, too" (referring to his hearing of air entry into the stomach). This statement was not repeated and was apparently not heard by the ACPs or the nursing or surgical staff standing nearby. There was much concurrent noise and laughter from the next patient admitting area of nontask-related conversations among several people. This lasted from just before seal of the ETT (fig. 1) until 70 s later.

The patient's esophagus and stomach were manually ventilated with a resuscitator bag for 5 min, 10 s after esophageal intubation except for three interruptions totaling 50 s during which the ETT was suctioned and lavaged (fig. 1). At 6 min, 2 s after anesthetic induction, a pulse oximeter signal was obtained. During this time, neither ACP1 or ACP2 auscultated the chest or epigastrium. The frequency of looking at the vital signs (BP, electrocardiography, and temperature) monitor, pulse oximeter, and $ET_{CO_2}$ monitor are shown in figure 1. One minute, 47 s after esophageal intubation, ACP1 said, "Should you pull the tube out?" ACP2 responded, "No." For the next minute, there was no conversation, ACP2 suctioned the ETT, and a surgeon stated, "He's



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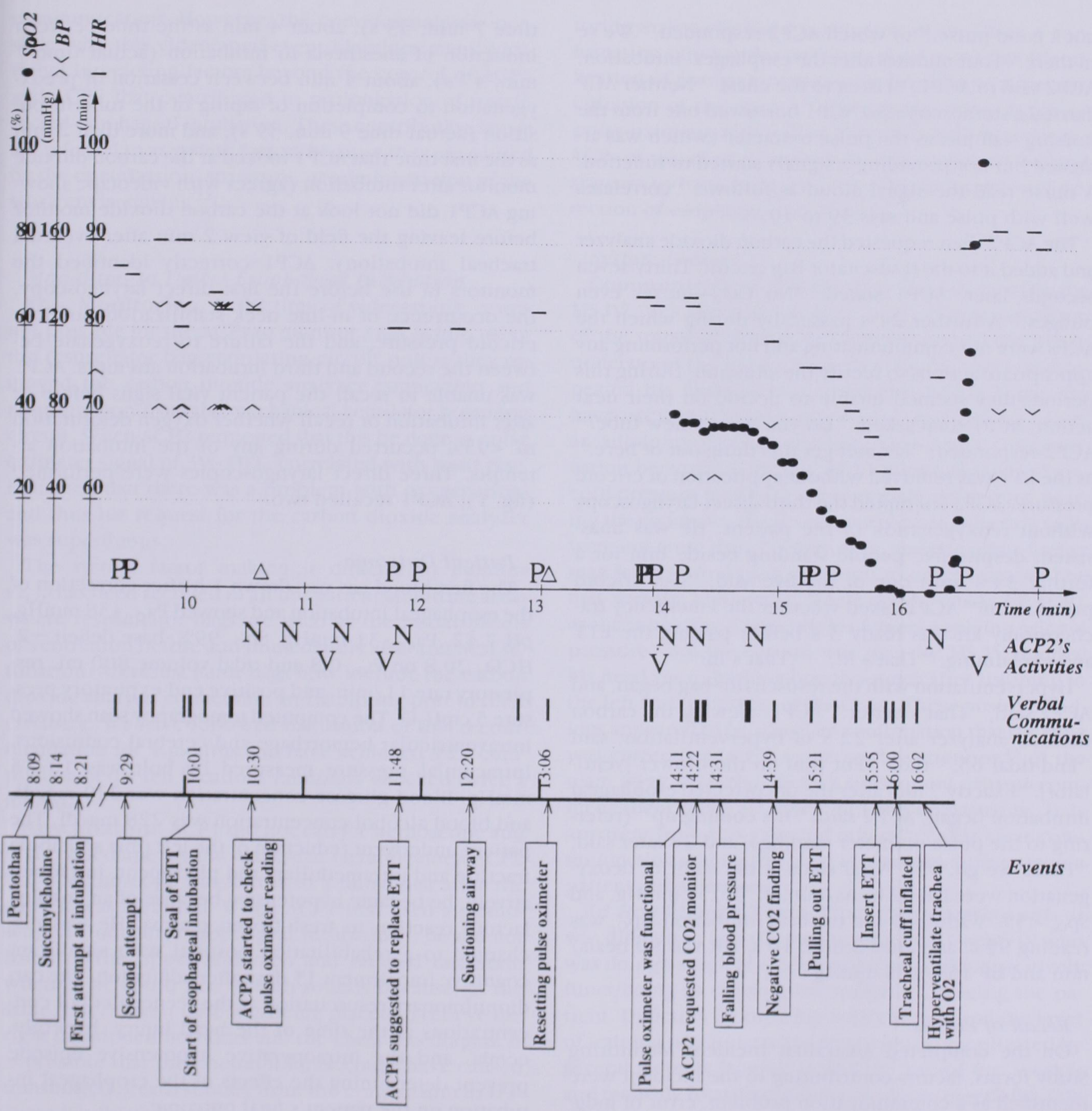


**Fig. 1.** An overview of events on a time scale (min:s) on *x*-axis and hemoglobin oxygen saturation ($Sp_{O_2}$%) noninvasive blood pressure (BP, in mmHg) and heart rate (HR, beats/min) on the *y*-axis. V = ACP2 checking BP and HR; N = ACP2 checking $Sp_{O_2}$ on pulse oximeter; P = cycling of BP monitor resulting in no display of BP measurement; ∨ = diastolic BP; - = HR; | = occurrence of verbal communications among the resuscitation team; △ = pulse oximeter switched on/off by the anesthesia care providers (ACP); ● = $Sp_{O_2}$; ∧ = systolic BP. The lower portion shows the attention pattern and occurrence of verbal communications between ACP and the four other members of the resuscitation team. A time-line (time 00:00 = patient admission) of major events is displayed along the bottom of the figure.



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got a good pulse," to which ACP2 responded, "We're in there." Four minutes after the esophageal intubation, ACP2 said to ACP1, "Listen to the chest." Neither ACP carried a stethoscope, so ACP1 borrowed one from the nursing staff just as the pulse oximeter (which was attached but not providing a signal) started to function. A nurse read the signal aloud as follows: "correlates well with pulse and says 39 to 40."

The ACP2 then requested the carbon dioxide analyzer and added it to the resuscitator bag circuit. Thirty-seven seconds later, ACP1 stated, "No $CO_2$—never even budges." A further 24 s passed by during which the ACPs were not communicating and not performing any appropriate actions to rectify the situation. During this period, they seemed unable to decide on their next action. ACP1 then asked, "Do you want a new tube?" ACP2 responded, "Let met get this thing out of here," as the ETT was removed without application of cricoid pressure. ACP2 attempted the third direct laryngoscopy without reoxygenation of the patient. He was unassisted, despite five people standing beside him for a further 34 s until one of the five said, "Get cricoid pressure on!" ACP2 asked whether the emergency tracheostomy kit was ready 3 s before passing the ETT and exclaiming, "That's it!. . .That's in!"

Hyperventilation with the resuscitator bag began, and ACP2 said, "That's better." ACP1, viewing the carbon dioxide analyzer after 22 s of hyperventilation, said "End-tidal 65," then "Put him on the blower [ventilator]." Exactly 7 min after the uncorrected esophageal intubation began, ACP2 said, "It's coming up" (referring to the pulse oximeter reading), and 2 s later said, "There we go, 99." Vital signs at the nadir of deoxygenation were HR 62 beats/min, BP 76/54 mmHg, and $Sp_{O_2}$ <5%. Within 39 s of tracheal intubation, $Sp_{O_2}$ was reading 99%, and after 2 min, 10 s, HR was 90 beats/min and BP 158/105 mmHg.

*Recall of Events*

On the completed Australian Incident Monitoring Study forms, factors contributing to the incident were identified as a communication problem, error of judgment, haste, and failure to use $ET_{CO_2}$. Factors minimizing the incident were listed as monitor detection and supervision. Suggested corrective strategies were improved supervision, quality assurance activity, and specific protocol development. ACP1 was unable to recall the time of day or month of the incident or the ASA status or outcome of the patient.

The completed postvideo recall questionnaire identified 3 min as the duration of preoxygenation (actual time 7 min, 53 s), about 4 min as the time between induction of anesthesia to intubation (actual time 7 min, 47 s), about 4 min between cessation of preoxygenation to completion of taping of the tube in position (actual time 9 min, 39 s), and more than 2 min as the first time that ACP1 looked at the carbon dioxide monitor after intubation (agrees with videotape showing ACP1 did not look at the carbon dioxide monitor before leaving the field of view 2 min after eventual tracheal intubation). ACP1 correctly identified the monitors in use before the first direct laryngoscopy, the occurrence of in-line neck stabilization, suction, cricoid pressure, and the failure to reoxygenate between the second and third intubation attempts. ACP1 was unable to recall the patient vital signs before or after intubation or recall whether oxygen desaturation to <95% occurred during any of the intubation attempts. Three direct laryngoscopies were performed (fig. 1); ACP1 recalled two.

*Patient Outcome*

The first blood gas was drawn 1 h after correction of the esophageal intubation and showed $Pa_{O_2}$ 438 mmHg, *p*H 7.42, $Pa_{CO_2}$ 31 mmHg, $Sp_{O_2}$ 99%, base deficit −2, $HCO_3$ 20.8 on $FI_{O_2}$ 0.8 and tidal volume 800 ml, respiratory rate 11/min, and positive end-expiratory pressure 5 $cmH_2O$. The computed tomography scan showed intraventricular hemorrhage and cerebral contusions. Intracranial pressure measured by bolt was 10–15 mmHg. Blood glucose concentration was 229 mg/dl, and blood alcohol concentration was 228 mg/dl. The patient underwent reduction of the left tibia and fibula fracture and intramedullary rod placement. Intraoperatively, he became hypotensive because of an anaphylactoid reaction to fresh-frozen plasma. He was discharged to a rehabilitation hospital with significant cognitive impairment 15 days after admission. The cardiopulmonary resuscitation at the scene, alcohol concentrations at the time of the head injury, hyperglycemia, and the intraoperative hypotensive episode prevent determining the effects of the esophageal intubation on the patient's final outcome.

## Discussion

Almost every experienced anesthesia care provider has intubated the esophagus at least once in their career. What makes this report of interest is that the time to recognition was prolonged, and the event was well documented. This report describes a failure of adequate clinical examination, patient monitoring, and team



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communication. However, the complex analysis possible with this videotaped event identifies many additional interacting factors beyond the control of ACP1 and ACP2 that contributed to prolongation of uncorrected esophageal intubation. These contributing issues are referred to as system factors because they are caused by the organization, structure, or administration of the work environment.[22]

### *Modalities to Detect Esophageal Intubation*

**$ET_{CO_2}$ Monitoring.** At the time of videotaping, it was not possible for the ACPs to monitor $ET_{CO_2}$ while using the resuscitator bag ventilating circuit unless they removed the carbon dioxide analyzer connection and sampling port from the mechanical ventilator breathing circuit. When ACP2 requested that this be done, a pulse oximeter signal of 39–40%, correlated with heart rate, indicated that there was a problem with oxygenation, and thus his request for the carbon dioxide analyzer was superfluous.

The system factor making it difficult to monitor $ET_{CO^2}$ has been rectified in all ten patient admitting areas where resuscitator bags are used as the initial means of ventilation before and immediately after tracheal intubation. All resuscitator bags now include the carbon dioxide analysis connection and sampling port in their circuitry. We have followed institution of this recommendation for 4 months and have achieved 92% compliance in the ten locations randomly checked twice a month.

**Auscultation.** ACP1 did not carry a stethoscope and in the videotape review stated that he rarely does. ACP2 had a stethoscope but lent it to a nurse just after the patient was admitted. When ACP1 first used a stethoscope (4 min after esophageal intubation), he did not listen to the upper abdomen and seemed uncertain whether he could hear breath sounds because, at the same time, a chest tube was being placed to relieve the right hemopneumothorax and the chest was draped. It is possible that the pneumothorax could have caused transmitted breath sounds from the epigastrium to resonate loudly in the chest, adding to the diagnostic confusion about lung air entry. Auscultating the epigastrium, in comparison with the chest, may have avoided this confusion.

**Observation of Monitors.** A cause for the failure to detect the esophageal intubation was the heavy dependence both ACPs placed on the monitors and the failure of the pulse oximeter to provide a signal. The advent of pulse oximetry and continuous $ET_{CO_2}$ monitoring makes clinical examination of the chest a confirmation of what the monitors display, so that identification of tracheal intubation is possible without auscultation of the chest.[7,20] This excess dependence on pulse oximetry rather than clinical examination by the ACPs or use of $ET_{CO_2}$ analysis is a training problem and appears to have been the major factor in delayed detection of esophageal intubation.

### *System Factors*

**Communication Failure.** Had the comment by the MS IV, "It's also going in here, too," after auscultation of the upper abdomen, been heard or had the MS IV understood the significance of what he heard and repeated his findings, the remaining events might not have occurred. Loud conversation and laughter from an adjoining patient admitting area and a communication between ACP1 and ACP2 about removal of cricoid pressure may have prevented the ACPs from hearing the comment. However, a surgeon and the two ACPs were not more than 2.5 feet away, and two other factors may have shifted their attention to other matters. The first was the comment, "Feels good," made by ACP1 as the tube passed beneath his fingers applying cricoid pressure, and the second was that the MS IV nodded his head yes to hearing breath sounds after listening to the left and right sides of the chest. These positive findings appeared to be adequate confirmation that the tube was correctly placed, so narrowing attention[23] of the team away from the MS IV's subsequent critical comment identifying air entry into the epigastrium. It is apparent from this case and others[10,24] that clear communication among the team is required during trauma patient resuscitation.

***Ad Hoc* Trauma Team.** From the patient records, it was difficult to find the training status of the MS IV who was doing a surgical subinternship and administratively functioning as the surgical resident admitting the patient. Difficulty in knowing both the role and the level of training of trauma team personnel is complicated by several systems factors, including the *ad hoc* weekly and monthly rotations of team members in training (MS IV, emergency medicine, surgical and anesthesia residents, certified registered nurse anesthetists, and nursing students, emergency medical technicians and trauma technicians); the random assembly of team members dependent on how many other patients, in addition to the one just admitted, require simultaneous management; the call schedules of anesthesia and surgical personnel rotate independently so the same team does not always work together; and the lack of iden-



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tification of the roles or status among the trauma team members. Team coordination and communication could be improved by team training, limiting trainee rotations, coordinating call schedules of anesthesia and surgical team members, and establishing a visual symbol for identification and status among all team members participating in patient resuscitation (*e.g.*, color-coded hats or gowns with name and status tag). Had the person auscultating the chest been identified as an MS IV, the ACPs might have been less willing to accept his findings on examination of the chest.

*Fixation Error*

DeKeyser and Woods[25] have described three main types of fixation errors, including the failure to revise a diagnosis or plan despite contradictory evidence and the persistent belief that no problem is occurring despite abundant evidence and the persistent failure to commit to the definitive treatment of a major problem. The analysis of underlying psychological factors of fixation errors has been previously reported. Several authors describe the possible occurrence of fixation error in anesthesiology[26,27] or in simulated anesthesia care.[28] This case report confirms that fixation error occurs in clinical anesthesiology. The response of ACP2 to the question, "Should you pull the tube out?" 2 min after esophageal intubation; ACP2's statement, "We're in there"; the frequent observation of the pulse oximeter; and the delay in responding to the low BP and oxygen saturation and the absence of $ET_{CO_2}$ suggest that the ACPs exhibited all three types of fixation error described by DeKeyser and Woods.[25]

The ACPs in this case gave credence to the weak indicators of ETT placement in the trachea ("Feels good," nods yes on listening to chest, "Pulse feels good," *i.e.*, stable vital signs, "We're in there") rather than the more reliable indicators of the low pulse oximeter readings and hypotension ("everything's OK" fixation). In reviewing this case, ACP1 stated, "People tend to believe the pulse oximeter when it displays normal values but discount it when it gives abnormal values." ACP2 sought yet more diagnostic information by inserting a carbon dioxide analyzer into the ventilating circuit instead of corroborating $Sp_{O_2}$ readings with clinical examination and vital signs data. With a falling BP, a slowing heart rate, and the statement "No $CO_2$," they remained unable for 30 s to definitively treat the problem by repeating the direct laryngoscopy, removing the esophageally placed ETT, and administering oxygen to the patient ("a persistent failure to commit to the definitive treatment" fixation, *i.e.*, the tube is in the correct place and it cannot be in the esophagus).

*Error Recovery*

Nearly 8 min of preoxygenation delayed detection of esophageal intubation because the patient remained adequately oxygenated. This effect of preoxygenation has been previously described[29] and analyzed. Good error recovery depends on the activation of intervention patterns in response to certain cues before control is lost. The ACPs in this case showed inappropriate error recovery as they did not respond expeditiously to the cues of decreasing HR, low BP, and $Sp_{O_2}$ values indicating that there was a possible airway problem. The team failed to apply cricoid pressure when the esophageal tube was removed. ACP2 also failed to reoxygenate the patient before the third direct laryngoscopy when it was clear the patient was hypoxemic. These failures to follow standard operating procedures or establish a "holding pattern" by stabilizing the patient's oxygenation (*e.g.*, by face mask ventilation and oxygenation) and reassess the situation are additional examples of delayed error recovery.

*Recall and Reporting*

Most retrospective reports of critical incidents depend on recall of the events by the participants at a later date, often months or years after the incident. Important information could not be identified by ACP1, including patient status on admission, whether $Sp_{O_2}$ <95% occurred, or the number of laryngoscopy attempts. Review of videotaped events avoids loss of these details. The Australian Incident Monitoring Study data collection forms completed by ACP1 did not identify lack of clinical examination as a contributory factor. Data collected by these forms may be improved by specific inclusion of a question about clinical examination. No report of this event was made to the Anesthesia Quality Assurance system. The only records of this incident were the words, "intubation #1, esophageal intubation" in the anesthesia record.

## Conclusions

Prolonged uncorrected esophageal intubation occurred because of three clinical management problems: (1) failure of ACP1 and ACP2 to confirm ETT placement in the trachea by either clinical examination or timely analysis of $ET_{CO_2}$, (2) excessive attention to the monitors, and (3) failure to revise airway management expeditiously despite evidence of clinical deterioration.



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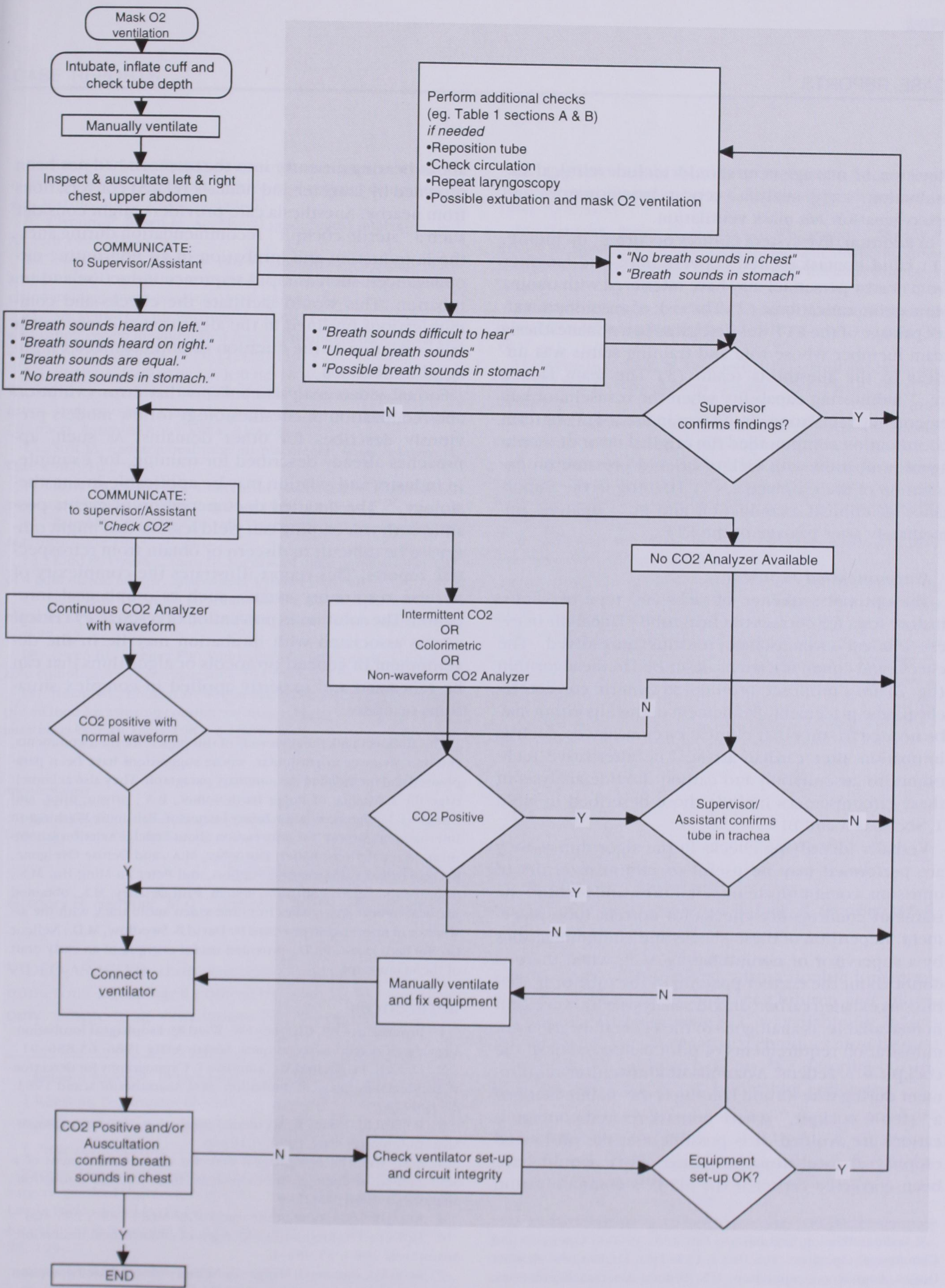


**Fig. 2. Proposed algorithm showing checks and communications to confirm placement of an endotracheal tube in the adult trachea. Typical path shown on left, unshaded.**

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Revision of management should include clinical examination, $ET_{CO_2}$ analysis, repeat laryngoscopy, and reoxygenation *via* mask ventilation.

In addition, five system failures occurred, including: (1) Loud nontask-related conversations and laughter from nearby personnel may have interfered with trauma team communications. (2) The task of auscultation after passage of the ETT was delegated to a nonanesthesia team member whose role and training status was unclear to the anesthesia team. (3) The team lacked $ET_{CO_2}$ monitoring capability when the resuscitator bag emergency ventilating circuit was in use. (4) Poor team coordination compounded the original error of esophageal intubation with lack of cricoid pressure on extubation of the esophagus. (5) Training in the importance of clinical examination and $ET_{CO_2}$ analysis immediately after passage of the ETT.

*Recommended Protocol*

The optimal sequence of tasks and type of confirmatory tests for correct tracheal tube placement in every clinical circumstance remains unresolved. The checks and communications described in the algorithm (fig. 2) are a proposed protocol to confirm correct tracheal tube placement. Refinement of this algorithm may be needed to suit other clinical circumstances, such as intubation after cardiac arrest. The alternative techniques to auscultation and carbon dioxide analysis in these circumstances include those described in table 1, sections A and B.

Verbally identifying checks in the algorithm as they are performed may be useful to minimize errors of omission, communicate uncertainties, and identify the status of confirmatory checks for correct tube placement. Repetition of these checks and communications by a supervisor or nonintubating ACP, when there is doubt about the correct position of the tube or if continuous exhaled carbon dioxide analysis with waveform in unavailable, is analogous to the Federal Aviation Administration requirements of pilot management in the cockpit.# A Federal Aviation Administration requirement during take off and landing is the maintenance of a "sterile cockpit," where nontask-related communications are avoided. It is possible that the prolonged esophageal intubation described above would have been corrected earlier if the MS IV's communication about hearing air entry into the stomach had not been drowned by laughter and nontask-related conversations from nearby. Anesthesia care providers might consider such a "sterile cockpit" recommendation during anesthesia induction and intubation in all nonroutine circumstances, such as rapid-sequence induction and intubation. This would facilitate the checks and communications outlined in the algorithm and may result in a reduction in the duration of unrecognized esophageal intubations.

Formal video analysis confirms that error evolution and rectification in anesthesiology follow models previously describes for other domains. As such, approaches already described for training, for example, in industry and aviation may be applicable in anesthesiology.[30] The detailed documentation of events possible with videotaping can yield lessons that might otherwise be difficult to discern or obtain from retrospective reports. This report illustrates the complexity of adverse respiratory events, such as esophageal intubation. The solution to prevention of respiratory critical events associated with intubation may lie in the development of general protocols or algorithms that can be rehearsed and expertly applied in complex situations or crises.

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# Single-lung Ventilation in Pediatric Patients

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VIDEO-ASSISTED thoracoscopic surgery (VATS) has numerous advantages compared with open thoracotomy. Single-lung ventilation (SLV), essential during VATS, usually is performed with a double-lumen endotracheal tube (ETT) in older children and adults. Because no double-lumen ETT is available for infants and small children, alternative techniques must be used to provide SLV in these patients. We describe our experience providing SLV to two young children.

## Case Reports

### *Case 1*

A 6-yr-old, 18-kg boy was scheduled to undergo right thoracoscopy for excision of pulmonary metastases from Stage D Wilms' tumor. He had previously undergone chemotherapy, radiation therapy, and a radical right nephrectomy. Medical history was otherwise unremarkable.

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