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Title: Development and Enhancement of a Model of Performance and Decision Making Under Stress in a Real Life Setting

Institution: University of Maryland at Baltimore and
Maryland Institute for Emergency Medical Systems

Current staff with percent effort of each on project:

| | |
|---|---|
| Colin F. Mackenzie | 22% |
| William Bernhard | 5% |
| Kevin Gerold | 5% |
| Brian McAlary | 5% |
| Kenneth Dauphinee | 5% |
| Michael Parr | 5% |
| Andy Trohanis | 5% |
| Jim Brown | 5% |
| Peter Hu | 5% |
| Paul Delaney | 5% |
| Denise Ovelgone | 50% |
| Robert Durocher | 50% |

Sub-contract Man-Made Systems Corp.

| | |
|---|---|
| Richard Horst | 15% |
| David Mahaffey | 20% |

Undergraduate Research Assistants (URA's)

| | |
|---|---|
| Linda Hawkes | 40 hrs/week |
| Terry Smith | 40 hrs/week |
| Dennis Wood | 40 hrs/week |

Navy 7th Quarterly Report

Between November 1, 1992 and January 31, 1993 we have

1) Continued the analysis of the 52 cases collected to date, 2) Refined our communication analysis, 3) Trained three undergraduate research assistants (URA's) in data analysis, and trouble shooting of the data acquisition system, 4) Collected information on anesthesiologist performance using a synthetic work environment (SYNWORK), three times during daytime (7am - 7pm) and nighttime (7pm - 7am) hours. Developed a more rigorous version (SYNFAST) of this synthetic work environment which may be more able to detect subtle degradation in physician performance than SYNWORK, 5) Met with Shock Trauma anesthesiologists in a renewed effort at data acquisition specifically of emergency tracheal intubation (usually in the admitting area) and elective (non-emergency) tracheal intubation (usually in the operating room), 6) Written up one paper describing 2 unusual emergency tracheal intubations and have 2 papers in preparation (video data acquisition and video data analysis), 7) Had 2 abstracts accepted for presentation at a meeting titled "Human Performance and Anesthesia Technology" and had three invitations to present our material a) ONR stress conference in April, b) International Trauma Anesthesia Conference in May, c) Real-World Decision Making organized by McGill University in June.

1) Data Analyses: Subjective Ratings of Stress/Workload

Our initial analyses, mentioned in the last quarterly progress report, focused on the subjective ratings of stress/workload that we are obtaining from both the anesthesiologist participants who were taped during a given case and other anesthesiologists who are subject matter experts but who were not directly involved in the case. These subjective ratings data are still being summarized and accumulated across a sufficient number of cases to make conclusions worthwhile. In general, the ratings seem to reflect predicted differences in the stressors of interest. The ratings reflect higher stress during cases involving more severe injuries, and within cases, higher stress prior to and during patient intubation than after intubation. We are considering some minor modifications to our procedures for collecting subjective ratings in order to better distinguish ratings of stressors (i.e., the potential for creating stress) from that of perceived stress.

2) Communication Analyses

We have also begun to quantify the frequency, content, and patterning of verbal communications among the trauma team during selected cases. Preliminary results have indicated that there were systematic differences in verbal communications during periods entailing different levels of stress. Comparisons are being made between cases involving high and low injury severity and between various segments of particular cases, i.e., pre-, post- and during the induction/intubation of the patient. Verbalizations were categorized into ten types -- communicating with the patient, undirected comments "to oneself," asking a task-relevant question or for assistance, providing an answer to such a query, providing task relevant information unsolicited, communicating a strategy, giving directions, other task relevant comments, and non-task relevant comments. Counts of the number of each of these types of verbalizations were tallied for two minute periods before, during, and for ten minutes after induction/intubation. Preliminary results from six cases suggested that during periods when the

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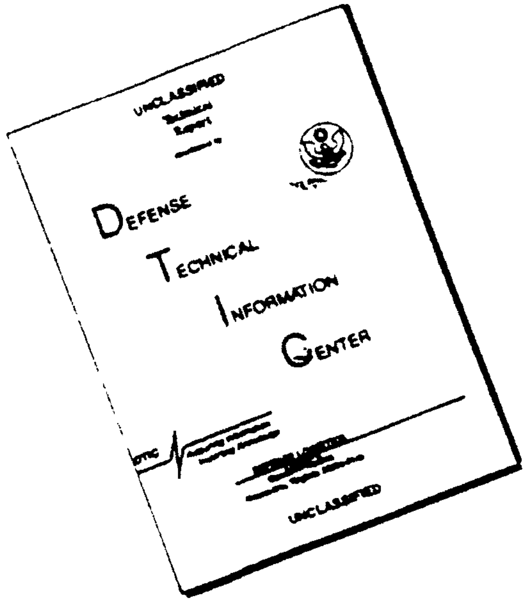


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team functioned under higher stress, verbalizations tended to increase, often occurring simultaneously, and their content became more focused on task-relevant comments, particularly requests for assistance and information. Surprisingly, strategic decisions were not often communicated explicitly. We are continuing to add to this data set as relevant new cases become available. We have received very useful publications from Judith Orasanu at NASA - Ames regarding stress, team decision making, crew communication and coordination which we believe will be very helpful in making comparisons with our data which involves group decision-making.

3) Personnel

Three new undergraduate research assistants were hired and trained on data acquisition and analysis procedures. These URAs will work directly in Shocktrauma, often during weekend and evening hours when the most interesting cases tend to occur. Their duties include ensuring that all video taping and data acquisition computer equipment is functional, supplies are replenished in a timely manner, encouraging/reminding trauma teams to video tape their cases, reviewing tapes with subject matter experts, and assisting with video data analysis, data entry, and data-base management. We hope that the presence of these individuals in the Shocktrauma environment will allow us to successfully video tape more cases, shorten the turn-around time between taping and review of the tape with the participants, and lessen the anxieties that some trauma team staff members have about the project.

Two VCRs failed early in the quarter and were unavailable for use during much of this period. These machines have been repaired and are back on-line. However one other machine broke so we are still not able to video tape in one of our 4 locations. One microphone power supply is currently in need of repair. We have experimented to some extent with alternative microphone positions and with mixing the outputs of two microphones in order to create better coverage of verbal communications among the trauma team, particularly in the operating rooms. Our efforts to maximize the intelligibility of recorded verbal communications continue.

4) Anesthesiologists Performance

We have used a synthetic work environment (SYNWORK) to test performance of anesthesiologist during their workday and worknight. An abstract of this work will be presented at a meeting in February titled Human Performance and Anesthesia Technology and this abstract is attached to this report as Enclosure #1. We will be exploring the abilities of SYNWORK further using a revised version (SYNFAST) which we believe may be able to detect more fine grained degradation in physician performance. We will also be testing the original SYNWORK with know depressors of performance to calibrate the decrements in performance on SYNWORK.

5) Cooperation among Shocktrauma Staff

Lack of cooperation and enthusiasm for the project among a subset of the Shocktrauma staff continues to be a problem. The intentional disabling of equipment has, at times, prevented effective data acquisition from teams willing to participate. We hope that the presence of the

URAs in Shocktrauma on a daily basis will ameliorate these problems, and we are increasing our public relationships efforts to win over staff members who may misunderstand the intent of the project. It appears that during the past 2 weeks the URA's have been helpful in facilitating data collection and in making audio tapes of the anesthesiologists participating in the video tape.

We have also focused our efforts on one particular aspect of trauma patient resuscitation - namely airway management. Airway management is the A of the ABC of cardiac arrest management, it is the first and most critical area of resuscitation without which everything else done to the patient is meaningless. It is a highly stressful maneuver and many unusual and unpredictable events occur during airway management, tracheal intubation, connection of the ventilator and checking of the system, the monitors and the patient. Induction of anesthesia and production of muscle paralysis sufficient to insert a cuffed tracheal tube is potentially extremely hazardous in a patient with impaired conciousness and a full stomach.

6) Papers being Drafted

Attached is a paper titled "Videoanalysis of two-emergency tracheal intubations identifies errors and inappropriate decision-making" (Enclosure #2). This is the second draft. After presentation of the abstract of this paper (See Enclosure #3) at the Human Performance and Anesthesia Technology conference, comments made at that conference in relation to the abstract presentation will be incorporated into the final version of the paper to be submitted to Anesthesiology for possible publication.

The video analysis described in the draft paper and Enclosure #3 revealed subtle instances of inappropriate decision-making during intubation of patients. These cases can be related to various decision-making models in the literature and demonstrate the value of our video analysis approach.

A second paper will be a report of our video data acquisition methodology. This will cover the on-site data acquisition of video and physiological data in Shocktrauma, the automated storage of these data via campus data networks, and the processing of the physiological data into a form that can be accessed relationally along with observational data.

A third paper will be a report of our video data analysis methodology. This will cover the various types of data that we are collecting, the means of processing them into a common data-base format, and coding procedures for observational data.

7) The two abstracts (Enclose #1 and #3) have been accepted for presentation. We have also received an invitation to present our material at a) An ONR Grantee Meeting and Tri-Science Review of Basic Research in Stress and Performance on April 5-7th, organized by Dr. Terry Allard of the Congnitive Science Program, b) International Trauma Anesthesia and Critical Care Society (ITACCS) meeting May 20-23rd. Dr. Mackenzie will chair a session and present material documenting video tapes of trauma patient management in the field and during transport (J Donchin MD Israeal Defence Force) during transport from heliport to resuscitation area (F. Forrest MD Shock Trauma (MIEMSS) Baltimore) and in the resuscitation and operating rooms at MIEMSS (C.F. Mackenzie, MD). The objective is to demonstrate real-life management with all it's warts and blemishes! We have video tapes both of management being performed correctly and incorrectly. Dr. Horst (Co-investogator) will also present communication analyses

at this meeting and David Gaba MD (consultant) will identify the effects of fatigue and experience on performance and e) Dr. Horst has been invited by Dr. Vimla Patel to present at a symposium titled "Real World Problem Solving and Decision-Making" June 18-21. The symposium is organized by McGill University. The abstract of his presentation is attached (Enclosure #4).

Logistics and Personnel

Three undergraduate assistants were trained and are now working with this project. Funding is according to a revised budget request lodged with and approved by ONR.

An ASSERT augumentation award application was made to enable Denise Ovelgone and Linda Hawkes to continue work on this project.





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# PERFORMANCE OF TRAUMA ANESTHESIOLOGISTS ASSESSED BY A SYNTHETIC WORK ENVIRONMENT

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Summary. We investigated the effect of fatigue on performance in five trauma anesthesiologists using a multitasking synthetic work environment model (Synwork). We found no significant change in performance of Synwork in three assessments during a twelve-hour shift or when comparing day and night shifts. We conclude that day or night shiftwork and a twelve-hour long shift does not result in a decrement in performance of four simultaneous tasks that are similar to those carried out during anesthesia.

Introduction: Clinical anesthesia can involve prolonged periods of routine monitoring interspersed with intense and critical activity. With the increased use of complex equipment to monitor patient vital signs and function of anesthetic machines, the anesthesiologist has to recognize, interpret and respond to a wide variety of visual and auditory stimuli. Prolonged periods with minimal sleep or rest may be detrimental to patient care if performance is adversely affected.

Synwork was used to assess the ability of anesthesiologists to carry out four simultaneous tasks over a five-minute period. The tasks tested are similar to those performed in clinical anesthesia and include monitoring of visual and auditory signals, setting alarms, mental arithmetic and short-term memory storage and retrieval. We used Synwork to determine whether there was a decrement in performance of these tasks over a twelve-hour period and compared night with day shifts.

Methods: Each anesthesiologist achieved asymptotic performance on Synwork during ten practice sessions (Figure 1). Synwork was then performed at the start, middle (seven to eight hours after start) and end of a twelve-hour shift, both during the day (7am to 7pm) and at night (7pm to 7am). Testing was performed randomly over a three-week on-call period for up to three day and night shifts per subject with a minimum of twelve hours rest between each shift. Results were compared by paired *t*-tests ($p < 0.05$ was significant).

Results: There were no difference between total scores on Synwork at the start, middle or end of a twelve-hour day or night shift (Figure 2). There was also no difference when comparing nighttime and daytime scores. In addition, we examined the four individual components of Synwork (memory, maths, visual, auditory) and found no difference between nighttime and daytime performance of the four components or in performance of these four tasks within the twelve-hour shift.

Discussion: Synwork has been used to assess performance of combat pilots and the effects of sleep deprivation[1]. The similarity of the multitasking software to the tasks of anesthesiologists make it a potentially useful assessment of clinical performance. During twelve-hour shiftwork, we were unable to detect any decrements in performance of Synwork either in total scores or in any of the individual components.

1) Elsmore, T.F. A Synthetic Work Environment for PC-Compatible Microcomputers. Proc. 1991 Med. Def. Biosc. Rev. pp. 351-354. Aug 1991.

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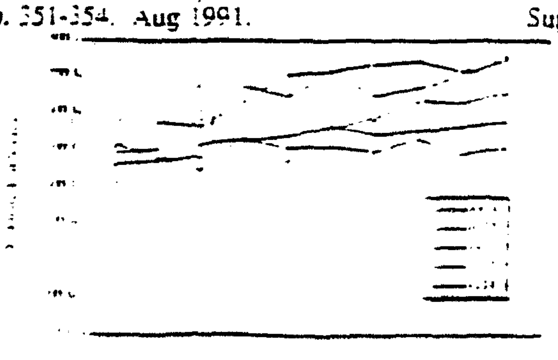

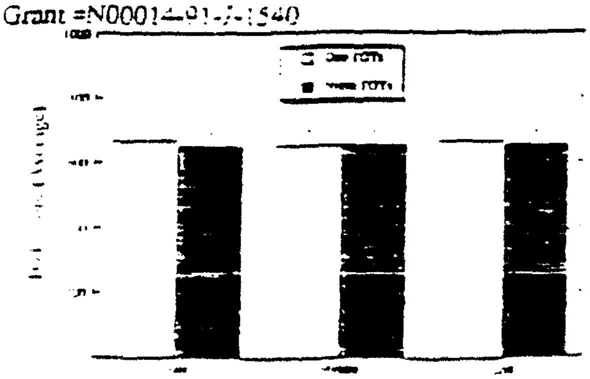

Figure 2. Mean and standard errors of Total [illegible]

ENCLOSURE #2

# Video analysis of two emergency tracheal intubations identifies errors and inappropriate decision-making.

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The opinions expressed in this paper are the authors' and do not reflect the opinion or policy of the U.S. Navy.

Abbreviated Title: Video analysis of emergency intubations

## Introduction

We studied videotapes of two emergency tracheal intubations of trauma patients in which a combination of unusual circumstances, diagnostic errors, judgement errors, monitoring failures and inappropriate decision-making occurred. However, no patient injury resulted. This report therefore includes a prospective examination of the three categories of human error described by Cooper et al.[1] Video analysis of the anesthesia team during these intubations was used to document what occurred, examine team communications and establish what may have caused these errors and how these errors could be avoided in the future. As a result of the management of these two patients we also reviewed whether there were any changes required in the algorithms and protocols used for emergency management of the trauma patients' airway.

Methods and Materials

Video images and sound track were acquired respectively by miniature cameras and microphones suspended from the ceiling of two admitting areas at the Maryland Institute for Emergency Medical Services Systems (MIEMSS). The field of view included the anesthesiology team, anesthesia equipment, drug cart, monitors and intravenous (IV) fluids. The audio channel captured communications among the entire trauma team consisting of anesthesiologist(s), nurse anesthetist(s) (CRNA), surgeons, emergency medicine physicians (EMP), nurses, and technicians. Physiological monitors of vital signs were interfaced at each location to a personal computer (PC) which included a video overlay board so that physiological data [heart rate (HR); arterial blood pressure (BP) or venous blood pressures; end-tidal $CO_2$ ($ETCO_2$); arterial $O_2$ saturation ($SaO_2$); and temperature] were updated every 5 seconds and overlaid onto the video image that was simultaneously being recorded by the video camera. The digital display of each component of the physiological data only appeared on the videotape when that component of the monitoring system was in use. Video acquisition occurred when a videotape was inserted into a video cassette recorder(VCR) located in each admitting area. Videotape insertion into the VCR activated the video, audio, and physiological data acquisition and data overlay by means of RS232 interfaces between the VCR and PC and physiological monitors. In addition videotape insertion initialized the videotape and overlaid an image of the date and real time, then elapsed time from videotape insertion, produced by a time code generator board in the PC.

Videotapes were analyzed using Observational Coding System Tools (OCS Tools, Research Triangle, NC), a commercial video analysis software package. Additionally the anesthesiologists involved in each of these two cases reviewed the videotape shortly after it was made and recorded audio comments about the events, communications, and stressors occurring on and off the cameras' field of view. These comments and those of at least one other trauma anesthesiologist who was not directly involved in patient care were transcribed using OCS Tools. The computer files obtained from the comments were then merged with the trauma team communications obtained from the audio channel of the videotape to provide a complete transcription and commentary. Synchronization of the data was ensured by having the same time code stamped on the video image, the communications and commentary in OCS Tools software, and the physiological data. The study was approved by the Institutional Review Board (IRB) and consent obtained from the anesthesiologist(s) and CRNA's who were videotaped. Approval was obtained from the IRB to waive consent from the patients as we agreed to remove identifiers and camouflage patient identity on the video tapes.

Results

The first patient (patient one) had a history of a cardiac arrest in the field. There was confusion in the initial reports as to whether the patient had sustained a head injury or whether he was under the influence of drugs or had suffered an epileptiform seizure. Later it was learned that the patient was assaulted, had a cardiac arrest, was initially resuscitated at the scene and was also found in possession of drug paraphernalia. On admission, by ambulance, he was unconscious and ventilated with a resuscitator bag through an esophageal obturator airway (EOA), which resulted in chest movements. He was met by an anesthesiologist who took 2 min to transport him upstairs to the admitting area. The major events that took place during admission and resuscitation of patient one are shown in Table 1.

In the admitting area both the attending anesthesiologist and an EMP listened to the patient's chest but neither made comment on the adequacy of ventilation. The elapsed time in Table 1 shows that 2 minutes later ventilation was delegated to an EMP undergoing tracheal intubation training. Pentothal and succinylcholine were given IV. The EMP had some difficulty visualizing the cords but stated that "the EOA is in the trachea." The attending anesthesiologist who was standing alongside the patient told the EMP to "ventilate again and take it (the EOA) out and change to an ET tube." Cricoid pressure was applied, the EOA removed and the trachea was intubated with a conventional cuffed endotracheal (ET) tube by the EMP with some difficulty. The patient was then manually ventilated with a resuscitator bag and breath sounds were checked by stethoscope. Right sided endobronchial intubation was detected and the tracheal tube was withdrawn a few cms. The mechanical ventilator was connected but the setting had accidentally been switched from mandatory ventilation to pressure support. Because of residual succinylcholine paralysis, the patient was not ventilated. This problem was recognized and then corrected approximately 1 min later after tracing the fault. The remaining resuscitation and management proceeded uneventfully. The patient awoke on day two and was discharged on day four after admission. Arterial blood gases taken on admission while the patient was ventilated with the EOA showed $PaO_2$ 456 mm Hg, pH 6.53, $PaCO_2$ 94 mm Hg on 100% $O_2$. These results show good oxygenation with hypoventilation and indicate that the EOA was correctly positioned in the esophagus. Elevated $PaCO_2$ and acidosis is reported to occur frequently when the EOA is used after cardiac arrest.[2,3] Even though the patient had a blood pressure of 98/60, $ETCO_2$ monitoring was not employed nor was the pulse oximeter connected before the EOA removal and conventional tracheal tube intubation.

On admission patient two was severely obtunded[4] (Glasgow Coma Scale 9/15), obese (about 100 Kg), had tightly clenched jaws, an unrecordable blood pressure due to hemorrhage from an abdominal gun shot wound (GSW) and no IV access because he was an IV drug abuser. The major events that occurred during admission and resuscitation before proceeding to the operating room (OR) are shown in Table 2. The elapsed time in Table 2 identifies that initially the patient was ventilated by face mask. After 1 minute the trauma team leader ordered intubation. Because there was no IV access at this time the anesthesiologist gave 130 mg succinylcholine intramuscularly (IM) into the tongue. Within 17 sec the CRNA began blind nasotracheal intubation which caused gagging and then precipitated repeated vomiting. The patient became combative. Four mins and 25 sec after admission, IV access was obtained.

Succinylcholine 100 mg was given IV and cricoid pressure applied. Because of hemorrhagic shock, the IV succinylcholine took 2 minutes to circulate and produce relaxation adequate for intubation. Resuscitation continued with blood and other fluids. $ETCO_2$ monitoring began 5 mins after intubation with temperature monitoring occurring shortly thereafter. Because of the patient's obesity and hemorrhagic shock, BP was not obtained until an arterial catheter was placed by cut-down 15 mins after admission. Bleeding continued despite external compression and vital signs remained unstable even though 2 units of blood and 3L of crystalloid fluids were given within 16 mins of admission. The patient died in the operating room 3 hrs after admission from exsanguination, after receiving 52 units of blood . 46L of crystalloid, 20 units of fresh frozen plasma and 10 units of platelets. There was an associated coagulopathy secondary to massive transfusion for vascular injuries to the left iliac artery and iliac vein caused by the GSW.

## Discussion

The video tapes objectively document two airway management incidents prospectively. This report therefore does not suffer from factual uncertainty present in many other retrospective reports of emergency airway management that discuss not what actually happened but what "must have happened."[5] We document that human error is a contributor to preventable anesthetic mishaps[1,6-12] and that the anesthesiologist supervising multiple simultaneous tasks does have impaired vigilance for detecting other incidents, for instance, the cause of failure to ventilate. Tracheal intubation, detection and correction of endobronchial intubation, supervision of the EMP, and direction of the anesthesiology fellow to manage a second admission that occurred during airway manipulation, distracted the attending anesthesiologist managing patient one from detecting why the mechanical ventilator was not ventilating the patient. No monitors of ventilation, such as $ETCO_2$, or oxygenation (although it is doubtful $SaO_2$ would have fallen sufficiently in the time to trigger an alarm) were employed during resuscitator-bag ventilation and the auditory apnea alarm on the ventilator was disabled. It was only when the anesthesiologist looked at and listened to the patient's chest that he realized there was an absence of ventilation and then he detected the incorrect ventilator setting. The mechanical ventilator used (Siemens 900C) is a complex machine with multiple switches and dials making it time consuming to trace faulty control settings. Technical errors or slips[10] such as accidentally changing the ventilator setting are reported to occur as a result of stress and there is frequently amnesia for the event so[11,12] that retrospective reports are unlikely to detect such incidents.

In this prospective study, endobronchial intubation was more rapidly detected in the two-person real-life anesthesia team than in a simulated single-person anesthesia environment[13] (50 sec in real life v 102 $\pm$ 142 sec in the simulation) and was more rapidly corrected (84 sec in real life v 553 $\pm$ SD 358 sec in the simulation). This could be due to the high state of vigilance and expectancy of complications that surrounds emergency intubation. Whether endobronchial intubation always occurred in conjunction with tracheal intubation, when it may be more rapidly detected and corrected, is not identified in the simulation.[13] In the high workload situation in which endobronchial intubation occurred in patient one, having two people managing the patient rather than the one in the simulation should expedite correction and possibly also detection of the endobronchial intubation.

Gaba and Cooper have identified erroneous decision-making as more important than the slip or technical error [1,10] (turning the ventilator dial to the wrong position) because judgmental errors may trigger a cascade of problems eventually leading to an accident that involves actual harm to the patient.[10] Fortunately, in the first patient we describe, the cascade only went from a problem to a critical incident because the trachea was successfully intubated without aspiration. Endobronchial intubation and lack of ventilation were both successfully detected and corrected before any adverse patient consequences occurred. In patient two, although vomiting with an unprotected airway and clenched jaws was a critical incident, the tracheal tube which was advanced into the esophagus both caused the vomiting and prevented pulmonary aspiration. The tracheal tube stimulated the larynx and vomiting as it was advanced into the esophagus, but also the esophageally placed tube can be seen on the video tape repeatedly diverting the projectile vomitus out of the nasopharynx so preventing aspiration. The warning gagging noises that can be heard on the audio channel should have been heeded and the CRNA told to remove the nasotracheal tube before vomiting occurred. We think the situation in patient two fits the definition of a 'near miss' described by Wiley.[14]

## Cause and Prevention

### *Stress*

What caused these occurrences and what can be done to prevent their re-occurrence? Removal of the EOA, before protection of the airway in an unconscious patient is an error and places the patient at risk for aspiration because regurgitation of stomach contents frequently occurs,[17] although cricoid pressure may have reduced this likelihood. Although errors are a normal part of human cognitive function[5], fortunately they do not always result in an adverse outcome.[1,10,11] We believe patient one illustrates the effects of stress on the cognitive-functioning and decision-making of the anesthesiologist and the diagnostic and psychomotor skills of the EMP. Illogical and irrational thought processes and omissions of action are reported to occur when the decision maker is under stress. Time, noise and communication stressors may be important causes of accidents and inadequate monitoring and examination.[12] It is irrational for the EMP to have diagnosed that the EOA was in the trachea and for the attending anesthesiologist to have believed this diagnosis, since the patient had survived transportation from the field with the EOA inflated in place and the EMP had himself listened to the chest and seen the supervising anesthesiologist listen to the chest during EOA ventilation. When told that the EOA was in the trachea, the anesthesiologists' retort was to suggest ventilating again through the EOA. This response was inappropriate because ventilation and oxygenation adequate for survival would not occur if the EOA was inflated in the trachea. However the supervising anesthesiologist thought "there was a ventilating tube in the EOA" [an esophageal-gastric tube airway[3] (EGTA)] making ventilation possible, as he had detected ventilation on auscultation.

*Inadequate monitoring and examination*

Whether the chest inflation observed was due to air entry into the lungs or gastric inflation could have been established by monitoring $ETCO_2$ or $SaO_2$ or by direct laryngoscopy by a more experienced laryngoscopist than the EMP. None of these monitors or examinations were used. Equally lung inflation could be established by listening to the chest, and although this was done, the supervising anesthesiologist did not communicate his findings from chest auscultation to the EMP. The supervising anesthesiologist was anxious about the adequacy of the EMP's skill and should have personally checked the EOA placement and could have used the available $ETCO_2$ and $SaO_2$ monitors to confirm the adequacy of ventilation before deciding to remove the EOA. As noted in analysis of pilot errors in the cockpit, problems encountered are often due to the crews inability to use resources which are readily available.[16]

*Training of non-anesthesiologist to intubate*

The EMP further added to the stress of the supervising anesthesiologist by intubating the trachea with some difficulty (3 attempts), and advancing the tube too far into the right mainstem bronchus. Correction of the endobronchial intubation was achieved rapidly and bilateral lung ventilation was confirmed. However, the EMP and the anesthesiologist did not immediately diagnose the cause of the lack of air entry when the ventilator was connected and so did not recognize the ventilation failure caused by an inappropriate ventilator setting combined with neuromuscular blockade. The EMP had successfully achieved six other emergency tracheal intubations, but under stress during this airway management his psychomotor skills were impaired resulting in a failure to easily intubate and to over-insertion of the tracheal tube. It was perhaps a mistake of the supervising anesthesiologist to allow the EMP to perform this intubation since the anesthesiologist himself was not completely familiar with the EOA. From the analysis of the management of patient one it is clear that the attending, fellows, and probably CRNA staff need training in alternate airway management devices including EOA,[2] ETGA,[3] the Combitube[15] and laryngeal mask.[25] Unfortunately, there are no training devices that entirely substitute for real emergency tracheal intubation and so it is common practice to train people using the "hands on" approach.

*Inadequate anesthetic technique*

In patient two, the video tape demonstrated that IM succinylcholine is not efficacious in hemorrhagic shock, because the patient can be seen moving for 3 min after the injection although the IM dose given of 1.3 mg/Kg was much lower than the 3-4 mg/Kg recommended.[18] Even IV succinylcholine took 2 min to produce neuromuscular blockade. If IM succinylcholine is given, even to non-shocked patients, it is clear that more than 17 seconds must elapse (Table 1) before attempted tracheal intubation. When gagging occurs during blind nasotracheal intubation, it is evidence of incomplete muscle relaxation and the tracheal tube should be withdrawn to prevent further stimulation and vomiting. Both the premature intubation attempts, and the persistence with nasotracheal tube advancement despite gagging, suggest the CRNA was also anxious about this intubation. Vomiting was particularly hazardous because there was no airway access due to clenched-tight jaws. The obvious alternative management to either IM succinylcholine or blind nasal intubation was to ignore the team leader's request for immediate tracheal intubation and to continue mask ventilation. This approach, while contrary to the role of the team leader as the coordinator and decision-maker, could have readily been rationalized if $ETCO_2$ had been monitored and if the wave form and digital readout displayed were normal. Similarly a normal $SaO_2$ would prompt continuation of mask ventilation until IV access was obtained and succinylcholine could be given by the more predictable IV route. The decision to intubate was correct, but the timing of implementation was erroneous. If IV access could not be obtained and values of $ETCO_2$ and $SaO_2$ were deteriorating during mask ventilation then the recommended decision is for the anesthesiologist to either use jet ventilation through the cricoid membrane with a 14G cannula or to request the surgical team to perform a cricothyroidotomy.[19]

However, in reality, it is unlikely that $ETCO_2$ monitoring would have been useful in the combative patient two, because of low pulmonary blood flow and difficulty in maintaining a mask-fit sufficient to allow adequate monitoring of the low exhaled $CO_2$. Reduced peripheral blood flow and patient movements would also reduce the likelihood of adequate monitoring of $O_2$ saturation by pulse oximetry. In addition, cricothyroidotomy in a combative emergency room patient with penetrating trauma, 13.6% of whom are known, in Baltimore, to test positive for human immunodeficiency virus,[20] is hazardous both for the patient and emergency room personnel. It is therefore our recommendation in a situation where values of $ETCO_2$ and $SaO_2$

are deteriorating and IV access is imminent, that mask-ventilation should persist until IV access is obtained, instead of proceeding to cricothyroidotomy. In the interim, mask ventilation may be improved by restraining the patient and employing a second assistant to squeeze the resuscitator bag while the anesthesiologist maintains the airway and mask fit with both hands. Only if this maneuver fails to stop the deterioration in values of $ETCO_2$ and $SaO_2$ should cricothyroidotomy be performed.

*Poor Ergonomics*

As a result of videotaping these two patients we also established that neither anesthesiologist had recall of the $ETCO_2$ when tracheal intubation was achieved and the ventilator was connected and functioned. The $CO_2$ monitor (Nellcor 1000) sampling site was at the Y-piece of the ventilator tubing and in patient one, $ETCO_2$ was grossly abnormal. Despite this abnormality, because of the placement of the monitor (which displays both $SaO_2$ and $ETCO_2$) on a shelf behind the anesthesiologist in the admitting area, the abnormality was not recognized and the alarm is scarcely audible in the video tape above the background noise of the resuscitation team. Further ergonomic discoveries were that the Nellcor 1000 takes 2 mins to warm up, and cannot be tested (by breathing into the circuit) before a patient admission without an alarm sounding continuously after testing is completed. Similarily the Siemens 900C cannot be left in the switched-on ready state delivering a tidal volume without a continuous auditory alarm. Both of these ergonomic factors together with the complexity of the Siemens 900C control panel, the necessity to disable the apnea alarm and the position of the Nellcor 1000 behind and remote from the anesthesiologist, make implementation of ventilation and monitoring of $ETCO_2$ and $SaO_2$ during initial resuscitation more difficult. The Nellcor 1000 has now been relocated in the admitting area at an eye-level position above the Siemens 900C and both the Nellcor 1000 and Siemens 900C can be tested to ensure correct operation and then switched off to prevent the continuous auditory alarms. The Nellcor 1000 does not alarm provided it is switched on without testing.

*Communication failure*

During management of both patients there was a failure of communication between the supervising anesthesiologist and the EMP (patient one) and CRNA (patient two). In patient one there was a lack of communication that air entry was acceptable during EOA ventilation and the anesthesiologist did not convey his uncertainty about the type of airway to the EMP. In patient two there was a failure of the anesthesiologist to tell the CRNA to wait longer after succinylcholine administration before attempting nasotracheal intubation and to desist from advancing the tube when gagging sounds occurred. Both the anesthesiologist and CRNA failed to communicate to the team leader that ventilation was adequate by face mask. Such omission of communications are seen particularly in time-stress situations,[11,12] as occur during emergency tracheal intubation.

*Real compared to simulated environment*

It is of interest that neither of these two scenarios that were videotaped during emergency tracheal intubation appear in either the American Society of Anesthesiologist's Management of the difficult airway algorithm,[19] or in the Anesthesia Crisis Resource Management (ACRM) training in a comprehensive anesthesia simulation environment[21,22] or in the Gainesville Anesthesia Simulations[23] or in a Flight simulator for General Anesthesia Training.[24] The ACRM course, although including IV failure, does not identify inability to start an IV as a critical incident.[22] The real anesthesia environment has many advantages for the study of critical incidents over simulation. A comparison between the real and simulated anesthesia environment (Table 3) identifies the absence of adverse patient outcome, lack of medicolegal risk and limited training requirements as the major advantages of simulation. However, the real environment has more variability, uncertainty, management options, stress, complexity, and potentially adverse consequences than simulation. Video taping of the real environment enables management of critical incidents and current anesthesia practices to be repeatedly and intimately analysed.

Video analysis of these two emergency intubations suggests measures to prevent reoccurrence of errors and inadequate decision-making including: 1) Skills training[26]-e.g. correct IM dose of succinylcholine; withdrawal of tracheal tube with gagging; conventional tracheal tube insertion before removal of EOA; monitoring of $ETCO_2$ and $SaO_2$, 2) Crew training[26,27,28] e.g. improve communications among trauma team; better evaluation of trainee performance; prior contingency planning to cope with the unexpected; better task management, and 3) Stress reduction[28,29,30] e.g. education, rehearsal and application. These 3 measures to prevent reoccurrence should be discussed in an educational setting, ideally practiced in a simulated environment then implemented in real-life. We believe it is by systematic study of such real critical incidents that the mechanisms involved in their genesis will be understood and from these analyses preventative measures or particular approaches to training may be devised.

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Table 1: Major events and elapsed time (mm:sec) since admission during resuscitation of patient one*

| | |
|---|---|
| 00:00 | Patient arrives in admitting area receiving $O_2$ by resuscitator bag attached to EOA. |
| 00:03 | "He's got a pulse" |
| 00:48 | IV working in right arm, IV fluids hanging |
| 01:00 | Anesthesiologist listens to both sides of chest |
| 1:26 | "Blood pressure 98/60" |
| 2:16 | Tracheal tube in hands of EMP |
| 3:01 | Pentothal 50 mg, succinyl choline 100 mg given IV |
| 3:10 | Anterior half of cervical collar off; cricoid pressure applied |
| 3:20 | EMP takes over ventilation through EOA from anesthesia fellow |
| 3:27 | EMP disconnects resuscitator bag |
| 3:39 | Laryngoscope in, "this (EOA) looks like it's in the trachea" |
| 3:45 | EMP asks for suction |
| 3:50-3:56 | Laryngoscope out; airway suctioned |
| 4:03 | Anesthesiologist "Just ventilate him again and take it (EOA) out and change to an ET tube." |
| 4:07 | EMP ventilates through EOA |
| 4:32 | Cricoid pressure on; EOA cuff deflated |
| 4:45 | Repeat laryngoscopy |
| 5:01 | EOA out |
| 5:21 | Conventional tracheal tube insertion begins |
| 5:33 | Tube inserted on third attempt |
| 5:42 | Ventilating with resuscitator bag |
| 6:00 | EMP listens to both sides of chest and stomach |
| 6:21 | Anesthesiologist delegates anesthesia fellow to manage a second AA patient admission |
| 6:23 | Ventilating with resuscitator bag; anesthesiologist measuring distance ET tube in trachea. Listens to chest. |
| 6:45 | Anesthesiologist connects ventilator |
| 6:57 | Pulls the ET tube back |
| 7:33 | Change ventilator setting from pressure support to mandatory ventilation |
| 7:52 | $ETCO_2$ monitored |
| 8:36 | ET tube taped in place |

Table 2: Major events and elapsed time (mm:sec) since admission during resuscitation of patient two*

| Elapsed Time | Event |
|---|---|
| 00:00 | Patient arrives in admitting area |
| 00:18 | $O_2$ mask on |
| 00:35 | Ventilate patient by mask and resuscitator bag<br>Physical examination begins. No recordable BP<br>Femoral pulse palpated at HR 114/min |
| 01:02 | "Intubate" (Team leader) |
| 01:35 | Succinylcholine injected IM into tongue |
| 01:52 | CRNA inserts nasotracheal tube |
| 01:57 | Gagging noise as nasal tube advanced |
| 02:15-02:55 | Repeated patient vomiting out of nasal tube |
| 03:28 | IV access achieved via Cordis. HR 145/min |
| 03:56 | Team requests "fat boy BP cuff" |
| 04:34 | Succinylcholine given IV. Cricoid pressure on |
| 04:39 | Patient holding suction catheter pushing anesthesia personnel away |
| 05:19 | CRNA bagging patient |
| 05:22 | Cordis connected to Level One infuser |
| 05:39 | Still no recordable BP |
| 06:38 | Intubation |
| 07:21 | HR 146/min. Still no BP obtained |
| 08:22 | O+ packed RBC 2 units started |
| 10:32 | Team complains "we don't even have any BP and the guy's been here ten minutes." |
| 11:20 | BP is "over 100 mm Hg" (palpation) |
| 11:28 | End-tidal $CO_2$ monitored |
| 11:34 | HR down to 133/min. Temp monitored = 36°C |
| 12:39 | Another BP cuff placed on right arm |
| 14:04 | Subclavian line placed |
| 14:50 | BP 110/46 by arterial line |
| 15:18 | 3L crystalloid, 2 units RBC's, warm plasma given |
| 22:35-30:23 | X-rays |
| 29:58 | Still rapid infusion. HR 122/min BP keeps drifting down. Bleeding from GSW |
| 30:54 | Fresh frozen plasma ordered |
| 31:16 | Request made to move to OR as team suspects aorta and vena cava are injured |

* For confidentiality and medicolegal reasons, and because it does not change the issues described and discussed, the adult male patients one and two are not further identified.

Table 3: Comparison of real anesthesia environment to simulated environment*

| Real Anesthesia Environment | Simulated Anesthesia Environment |
|---|---|
| Unlimited variability of patients and clinical scenarios. | Variability limited by constraints of simulated patient and clinical simulations. |
| Uncertainty for all anesthesia personnel. | Uncertainty restricted to those using the simulator. |
| Occurrence of unique events. | Events limited by numbers and types of simulations available. |
| Can result in unrelenting, long-duration high stress in multiple sequential or simultaneous patients. | Stress limited by duration of simulation. Only one patient simulated. |
| Many different management strategies possible. | Management strategies generally more restricted. |
| Performance decrements, chronic fatigue and illness. | Performance decrements, momentary fatigue. |
| Extensive training necessary | Limited training required. |
| Complex interactions (patient, team, OR staff, drugs, etc.). | Simple interactions (no real patient, or team, OR staff acting, no real drug responses etc.). |
| Patient monitors may not work because of patient, electrical, blood, vomit or movement interference. | Patient monitors are usually simulated and therefore real interferences do not occur. |
| Cause of alarms may be artifactual or not clinically relevant (e.g. probe not attached, ventilator known to be not connected). | Alarms more contrived and may indicate a more noteworthy event for the participant. |
| Patient fatality possible. | Absence of adverse patient outcome. |
| Adverse peer and medicolegal consequences for errors. | No medicolegal implications but lower peer rating for errors. |
| Group decision-making [anesthesiologist(s), nurse(s) and surgeon(s)]. | Individual or limited group decision-making. |

* Adapted in part from S.G. Hart; Workload: A new perspective. Table 2, p19 NASA report? What is reference? Vol. # ? year.

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VIDEO ANALYSIS OF TWO EMERGENCY TRACHEAL INTUBATIONS IDENTIFIES ERRORS IN DECISION MAKING

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Summary Two video tapes of real emergency tracheal intubations show how a chain of errors can result from a single inappropriate decision. The tapes also identify errors precipitated by an inexperienced laryngoscopist and by lack of familiarity with alternative devices for emergency airway management. Lastly the tapes demonstrate impaired vigilance due to distractors and the effects of stress on verbal communications between supervisor and trainee.

We studied video tapes of two emergency tracheal intubations in which a combination of unusual circumstances, erroneous information, inappropriate decision making and judgement errors occurred. Video analysis of decision making of the anesthesia team during these stressful intubations was used to determine whether there were any changes required in our algorithm or protocols for emergency management of the trauma patient's airway.

Methods Video tapes were acquired by a miniature camera suspended from the roof of two resuscitation areas at MIEMSS. The field of view included the anesthesiology team and the audio channel captured team communications. The physiological monitors were interfaced to a PC which included video overlay technology. Continuously updated physiological data (heart rate, blood pressure, end tidal $CO_2$ ($ETCO_2$) and $O_2$ saturation ($SaO_2$)) were overlaid onto the video image in real time during tracheal intubation when they were monitored. The video tapes were analyzed with OCS Tools a commercial video analysis software package.

**Results** The first patient (PT1) had tightly clenched jaws, an unrecordable blood pressure due to hemorrhage from an abdominal gun shot wound and no intravenous (IV) access because he was a drug abuser. The second patient (PT2) had an "arrest" in the field ? head injury, ? drug effect, ? seizure and was inadequately ventilated with an esophageal obturator airway (EOA).

The trauma team leader requested immediate tracheal intubation of PT1 after he was initially ventilated by face mask. Succinylcholine (SUX) was given into the tongue by the anesthesiologist and a nasal intubation attempted by a nurse anesthetist. The patient gagged and vomited repeatedly when the tube was in the nasopharynx. SUX was given IV after cut-down gave access 3 1/2 min later. SUX took 1 1/2 min to circulate and produce relaxation adequate for tracheal intubation.

PT2 was unconscious and hand ventilated through and EOA which appeared clinically adequate. Ventilation was then delegated to an emergency medicine fellow (EMF) undergoing tracheal intubation training. SUX and 50 mg pentothal was given IV. The EMF had difficulty visualizing the cords but stated "the EOA is in the trachea." The anesthesiologist told the EMF to "ventilate again and take it (the EOA) out and change to an ET tube." Cricoid pressure was applied, the EOA removed and the trachea intubated by the EMF with some difficulty. The patient was ventilated by Ambu bag and right endobronchial intubation was discovered and corrected. The ventilator was connected but had been accidentially switched to pressure support mode and therefore initially failed to ventilate the patient.

Discussion PT1 IM SUX is a reasonable IV alternative that did not act because of poor perfusion. There was a failure to use available $ETCO_2$ monitoring. The decision was erroneous to abandon face mask ventilation. That error was compounded by attempted nasotracheal intubation which precipitated a dangerous regurgitation of stomach contents with no airway access. Discussion PT2 The anesthesiologists were not completely familiar with the EOA. In retrospect, blood gases show that the EMF incorrectly diagnosed that the EOA was in the trachea. This error precipitated the risky maneuver of removing the EOA before the ET tube was in place. This decision could have caused aspiration of gastric contents. The anesthesiologist was anxious about the EMF's skill and could have personally checked the EOA placement before deciding to remove it. Endobronchial intubation distracted him from determining the cause of the ventilator failure.

**Conclusion** The algorithm for airway management was modified, when no IV access and clenched jaws occur with low perfusion, to provide mask ventilation then cricothyroidotomy or mask ventilation until IV access is secured. These two patients illustrate that protocols for emergency intubation should include $ETCO_2$ monitoring. The two videotapes identify hazards to the patient including 1) inexperienced airway management, 2) information uncertainty leading to inappropriate decisions, 3) unfamiliarity with equipment (EOA), 4) judgement impaired by stress and 5) failure to use available $ETCO_2$ monitors that could have prevented unwarranted actions that put the patient at risk.

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## DECISION MAKING BY ANESTHESIOLOGISTS DURING TRAUMA TREATMENT: EFFECTS OF STRESS ON TEAM INTERACTIONS

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Of particular interest in settings where skilled individuals function as a team are the relationships between team performance and individual decision-making and how overt behaviors influence one's teammates. Verbal communications among teammates are especially critical to effective team performance and can serve to either increase group cohesion or work to its detriment. As part of a multi-disciplinary investigation of "naturalistic" decision-making under stress, in collaboration with the University of Maryland Anesthesiology Research Laboratory, we are analyzing video recordings of trauma teams treating patients upon admission to a Level One trauma center. The data to be reported here focus on the frequency, content, and patterning of verbal communications among the trauma team. In that our primary interest has been on anesthesiologist decision-making, the placement of the microphone favored the recording of anesthesiology team interactions near the patient's head, although comments by any team member that were sufficiently loud to be heard by the entire group were also discernable. Verbalizations were categorized and related to the stressfulness of the conditions under which the teams were functioning. Comparisons were made between cases involving high and low injury severity and between various segments of particular cases, i.e., pre-, post- and during the induction/intubation of the patient. Retrospective ratings of the scenarios along six dimensions of stress/workload confirmed that the high severity patients and induction/intubation segment of a case placed the most task demands on the trauma team. Preliminary results have indicated that there were systematic differences in verbal communications during periods entailing different levels of stress. During periods when the team functioned under higher stress, verbalizations tended to increase, often occurring simultaneously, and their content became more focused on task-relevant comments, particularly requests for assistance and information. Surprisingly, strategic decisions were not often communicated explicitly. The results suggest training strategies for improving communications and team performance in this and related settings.

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