

## Chapter 9

# Performance Metrics

Based on the data obtained from the Intubation Analysis (IA) forms completed by Subject Matter Experts (SMEs), the task performance by the anesthesia care providers could then be measured.

### 9.1 Task performance: Are all the steps equally important?

A first question about the task list in Table 6.1 is the relative importance of each task in the list. To obtain a consensus about the relative importance of the tasks in the list, a survey was distributed to the anesthesia care providers. The survey was to measure the relative rank in terms of clinical importance. Table 9.1 is the result of the survey. Note that task relative importance changes slightly when the task urgency of intubation changes.

#### 9.1.1 Task omissions

Using the task analysis questionnaire, the tasks accomplished among the normative intubation task sequence (Table 6.1) could be determined from the videotapes. One of the questions in determining the significance of task omissions is: whether task omissions were due to efficiencies in shedding low priority tasks that could easily be completed at a later, less critical time period, or whether these were errors due to omission of high priority tasks. We hypothesized that such task omissions were efficiencies due to time pressure rather than omission errors due to a failure to carry out important tasks.

The task omissions identified on videotape review were compared before and after weighting with priority rankings. Task omissions were determined as shown in Figure 9.1 as the mean number of tasks not completed divided by the total number of tasks, expressed as percentage. To take into account the relative importance, the task omission rates were weighted by their relative importance scores in Table 9.1.

The results in Figure 9.1 show that the task omission rates dropped after weighting, suggesting that task shedding did occur. However, even accounting for this task shedding, there were still a greater percentage of relatively high priority tasks omitted in preparation for emergency than elective intubations. Thus if our hypothesis were true, that task omissions occurred in emergency intubations because of task shedding, the least

Task names	EL	SE	RE
Pre-Intubation			
In-Line stabilization of the neck	1.90	1.17	1.27
Suction Ready	1.20	1.08	1.25
IV Running Pre-induction	1.27	1.08	1.25
Drugs Given Appropriately	1.18	1.25	1.17
Pre-Oxygenation	1.50	1.17	1.42
Cricoid applied correctly	1.78	1.33	1.25
S <sub>a</sub> O <sub>2</sub> monitored Pre-induction	1.73	1.83	2.33
Heart Rate monitoring Pre-induction	1.73	1.58	2.25
Stethoscope available	1.64	1.83	1.83
Head Positioning	2.20	2.00	2.08
BP monitored Pre-induction	2.18	2.08	2.67
ETCO <sub>2</sub> monitored Pre-induction	3.42	3.33	3.27
During Intubation			
Intubation equipment ready	1.00	1.00	1.00
Cricoid maintained until ET tube position determined	1.60	1.00	1.08
Auscultation of both sides of the chest	1.33	1.33	1.33
Re-oxygenation if O <sub>2</sub> sat. <95%	2.00	2.00	2.18
Re-oxygenation after 3 attempts	2.08	2.00	1.91
Tube insertion distance checked	1.92	2.08	2.00
Auscultation of both sides of the chest by the intubator	2.25	2.25	2.17
Auscultation of the upper abdomen	2.08	2.00	1.92
Tube cuff inflated to just seal	2.33	2.42	2.42
Check of neuromuscular block (NMB) before Laryngoscopy	3.25	3.42	3.75
After Intubation			
Check ETCO <sub>2</sub> within 2 minutes of intubation	1.50	1.25	1.50
Listening to the chest after connection of the ventilator	1.58	1.58	1.58
Tube held till taped or tied	2.42	2.17	2.17
Check of NMB prior to giving the non-depolarizer	2.73	3.00	3.42

Table 9.1: Importance scores for tasks in intubation. Subject matter experts scored the importance on a scale of 1–4, with 1 being the most important and 4 the least important. The scores shown here are the averages across 12 subject matter experts who had extensive experience in the studied center. EL: elective intubation, carried out more than 30 minutes after the patient's arrival at the Shock Trauma Center; SE: semi-emergency intubation, carried out within 10 to 30 minutes of the patient's arrival; RE: emergency intubation, carried out within 10 minutes of the patient's arrival.

important tasks would be shed and we would not expect to detect these differences between emergency and other types of tracheal intubation. We can conclude, therefore, that on average the tasks omitted in preparation for emergency intubations were omission errors not task shedding.

## 9.2 Comparing Performance of Experts with That of Non-Experts

The results of the completed IA forms from 50 videotapes showing intubation of patients, all of which were admitted to the trauma center, were analyzed to determine if experts performed better than non-experts in the task of intubation. Since a number of cases were reviewed by multiple SMEs, it was possible to assess inter-rater reliabilities. The intraclass correlation coefficient (Shrout & Fleiss, 1979) was used for this purpose.

Intra-rater reliability was assessed on 22 cases which were reviewed by multiple reviewers. Since it was possible that certain cases might be more difficult to the anesthesia care providers than others, we classified the cases into three categories according to the urgency of intubation: emergency, semi-emergency, and elective. These three categories were defined by the elapsed time between the patient's arrival and the start of intubation. They were respectively defined as occurring within 10 minutes of the patient's arrival, 10 to 30 minutes, and more than 30 minutes. The experience of the person who performed intubation (intubator) was measured by the duration of experience: experts were those who had at least 18 months of intubation experience and non-experts were those with less than 2 months of experience. There were no subjects in the collected data who had between 2 to 18 months of experience. The psychomotor skills, number and duration of direct laryngoscopy (DL) attempts, all of which were collected as part of the IA forms, were used as dependent variables.

Intraclass correlation coefficients among different raters were .2–.99 (fair to excellent). There were differences ( $p < 0.05$ ) between expert and non-expert intubators in the duration of the first DL, and the time for DL to cuff inflation after tracheal intubation (Figure 9.2). However, the number of DL attempts was no different (Figure 9.3). Psychomotor skills were subjectively evaluated ( $p < 0.05$ ) among the experts and non-experts and during elective intubations, but comparisons during semi-emergency and elective intubation showed no differences.

The results show that videotaping and video analysis can identify differences between performance of tracheal intubation by experts and non-experts. The lack of difference during performance of semi-emergency and elective intubations may be because the non-experts intubators were closely supervised by an anesthesiologist but the non-experts intubators were given sufficient leeway during elective intubations to allow evaluation of expertise.

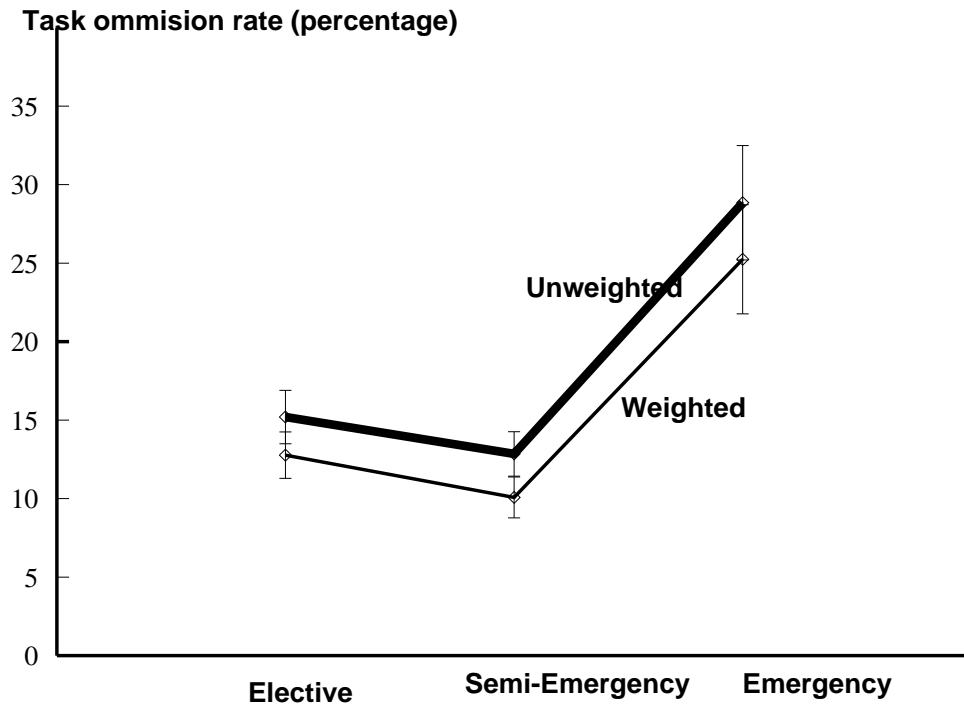


Figure 9.1: Task omission, before and after weighting of importance.

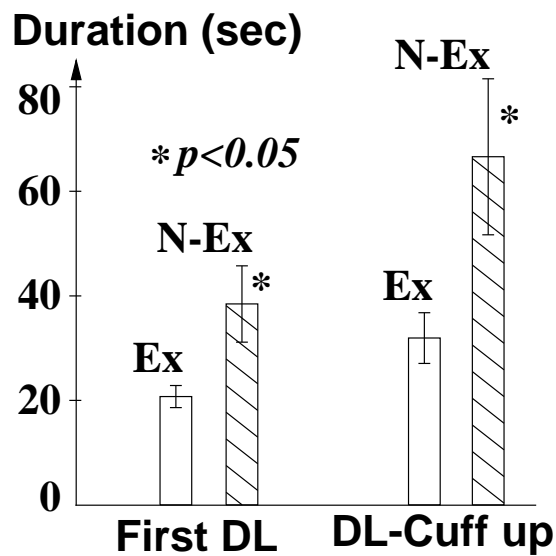


Figure 9.2: Comparison of duration of accomplishing intubation. Ex = expert; N-Ex = Non expert; DL = direct laryngoscopy.

### 9.3 Comparison of Elective and Emergency Tracheal Intubation

Twenty-three video tapes were analyzed in which eleven patients had elective tracheal intubation carried out in the trauma operating room and the remaining twelve video tapes show emergency tracheal intubation in the trauma patient admitting area. Emergency tracheal intubation was required for life threatening situations including shock (systolic blood pressure <80 mm Hg) (n=3) unconsciousness (n=7) or low blood oxygen levels (n=2). Level of patient injury (assessed by the abbreviated injury score), anesthetic risk (ASA status), and trauma anesthesia grade were no different between the electively and emergently intubated patients. However the Glasgow Coma Scale (assessed level of consciousness) was 15 + SE 0 (=awake) in elective and was less ( $p < 0.05$ ) at 9 + SE 0.89 (=impaired) in emergently intubated patients. Figure 9.4 shows the percentage of preparatory items carried out in the elective and emergency intubation sequences from a 12 item check-list before, 7 checks during and 6 checks after intubation. There were significantly fewer ( $p < 0.05$  unpaired t-test) preparatory checks completed before emergency than elective tracheal intubation.

Subjective assessment of errors and stressors identified no errors in the elective intubations and 6 errors in the emergency intubations. Time stress from surgeons for anesthesia (and therefore surgery) to commence was present in 3/6 elective intubations. Among emergency intubations there were multiple simultaneous stressors including workload, time stress, uncertainty, non-anesthesia team adverse interactions, noise and patient-induced stressors (combativeness, intoxication, etc.). There were errors in drug administration and/or dosages in 3 emergency intubations, two of which resulted during the occurrence of 3 simultaneous stressors (patients #1 and #5), three errors occurred in airway management each of which caused a cascade of detrimental events none of which fortunately adversely affected patient outcome.

The number of physiological monitors in use to provide patient data to the anesthesia care providers was 4 + SE 0.11 for elective intubations and was greater ( $p < 0.05$  unpaired t-test) than the 2.83 + SE 0.16 monitors in use for emergency intubation. Identical monitoring systems are present in both the trauma operating rooms and admitting areas. Pre-oxygenation before induction of anesthesia (a safety feature to allow less hypoxemia during induction and intubation) was shorter ( $p < 0.05$ ) before induction and intubation for emergency than elective intubations (Table 9.2).

Psychomotor skills required to intubate the trachea appeared to be sharpened for emergency intubation. Only one elective intubation required multiple (2) attempts whereas 5 of 12 emergency intubations took a mean of 3 attempts before tracheal intubation was achieved. Despite the greater number of attempts, the time between insertion of the laryngoscope (an instrument to visualize the larynx and allow tracheal tube insertion) and ventilation through the successfully placed tracheal tube was no different (Table 7.1). The duration between tracheal intubation and checking of the correct placement of the tube (by listening to the chest with a stethoscope or looking at the end tidal carbon dioxide (ETCO<sub>2</sub> monitor) was different in elective and emergency intubation. In no elective intubations but in 6 of 12 emergency intubations listening to the chest was delegated to a non-anesthesia team member. This task shedding suggests there was a greater workload associated with emergency than elective tracheal intubation. Monitoring

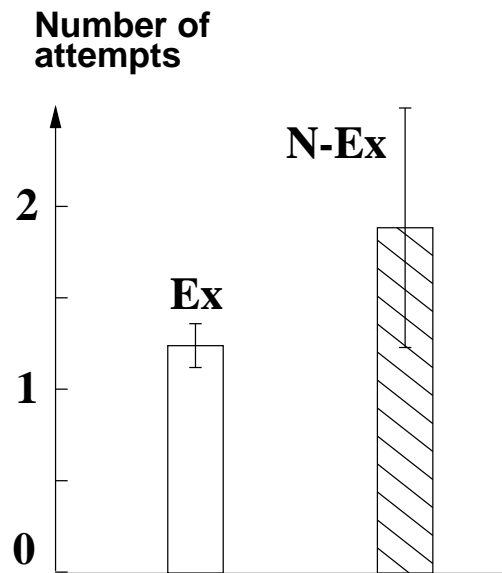


Figure 9.3: Comparison of number of attempts to accomplish intubation. Ex = experts; N-Ex = non-experts.

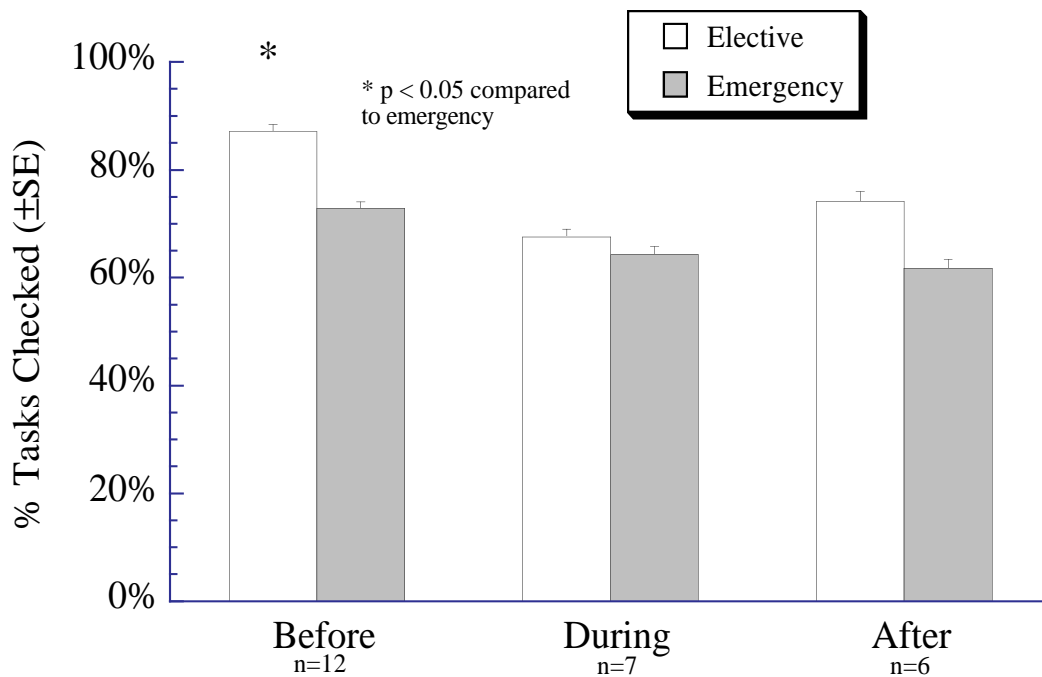


Figure 9.4: Percentage of task completed before, during and after intubation. Three stages were separately analyzed: before, during, and after intubation; two types of intubation were compared: elective and emergency intubations.

of ETCO<sub>2</sub> is a double-check to ensure that transmitted sounds from intubation of the esophagus (when no ETCO<sub>2</sub> is detected) are not confused with breath sounds from ventilator of the lungs. Observation of the ETCO<sub>2</sub> monitor occurred later ( $p < 0.05$ ) after emergency than elective tracheal intubation (Table 1). In one patient (not included in this data) failure to connect the ETCO<sub>2</sub> monitor on ventilation occurred in association with undetected esophageal intubation. Confirmation of correct tube placement is vital to all patient resuscitations so that this delay in observing the ETCO<sub>2</sub> monitors after emergency intubation suggests that task prioritization is inappropriate.

In 5/11 elective intubations but only 1/12 emergency intubations was ETCO<sub>2</sub> monitored before intubation. This occurred because a resuscitator bag is used for initial ventilation in the admitting area during resuscitation and this has no port for connection of the ETCO<sub>2</sub> monitor, whereas an anesthesia circuit (which already includes the ETCO<sub>2</sub> monitor) is used for ventilation in the operating room.

Emergency airway management decision tree contingencies occurred in 5 of 12 emergency tracheal and no elective intubations. In one emergency intubation an event unique to all the participating anesthesiologists occurred; so far this is not described in the literature. At least two other circumstances occurred in association with emergency management of tracheal intubation that are not described in any management algorithms or simulations of emergency airway management.

## 9.4 Discussion

Video analysis has shown that during emergency airway management task-shedding occurs and short-cuts are taken. Prioritization may also be affected by workload associated with emergency circumstances compared to elective airway management.

Many issues including the failure of ETCO<sub>2</sub> monitoring in the admitting area, the delay in observing ETCO<sub>2</sub>, and the fewer preparatory checks completed before emergency intubation are procedural issues that could be improved by training. Much of the uncertainty about patient status during emergency airway management could be reduced by better use of physiological monitors. In addition, some of the errors in management (e.g. esophageal intubation) maybe avoided because of warnings provided by these physiological monitors which are available within arms-reach of the anesthesia care providers. As noted in analysis of pilot errors in the cockpit, problems encountered are often due to the crews failure to use resources that are readily available (Helmreich, 1984).

The video analysis did identify several ergonomic factors which make airway management more cumbersome, and less ideal in the patient admitting area than in the operating room. There is more space and there are fewer people around the head of the patient in the operating room. Patient physiological monitors are placed more conveniently alongside the patient's head next to the anesthesia care providers rather than behind them as occurs in the admitting area. This arrangement in the patient admitting area allows access for patient examination, therapy and diagnosis. The ventilating circuit already contains the ETCO<sub>2</sub> analyzer in the operating room.

The domain of the anesthesia care provider is more clearly defined in the operating room

than in the admitting area, so that roles of the surgeon and anesthesia care provider are more distinct and physically separated. In the admitting area the overlapping roles of surgeons and anesthesiologists (insertion I.V.'s, taking and synthesizing information from the patient's vital signs) can lead to unfavorable interactions and stress among both groups. While the surgeon is the team leader, their expertise does not include emergency airway management. As a result controversies occur over this issue, especially the surgeons failure to appreciate the difficulties and relative risks of one airway management approach over another.

Event	Emergency Intubation	Elective Intubation
Preoxygenation, before anesth.	234 ± 12.5*	92 ± 6.0
Preoxygenation, before DL	310 ± 10.2*	145 ± 6.1
Duration of DL	31 ± 2.1	32 ± 2.4
Duration: DL to ventilate	41 ± 2.5	30 ± 1.3
Duration: Ventilation to Listen to chest	10 ± 0.7	38 ± 5.9
Duration: ventilation to ETCO2 observe	52 ± 5.3*	205 ± 16.8

Table 9.2: Task durations of intubation events. Mean and standard error of duration (in secs) of events in the intubation sequence among 11 elective and 12 emergency tracheal intubation. \*: significant at  $p < 0.05$ .