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Laryngoscopic Intubation

Learning and Performance

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Background: **Many healthcare professionals are trained in direct laryngoscopic tracheal intubation (LEI), which is a potentially lifesaving procedure. This study attempts to determine the number of successful LEI exposures required during training to assure competent performance, with special emphasis on defining competence itself.**

Methods: **Analyses were based on a longitudinal study of novices under training conditions in the operating room. The progress of 438 LEIs performed by the 20 nonanesthesia trainees was monitored by observation and videotape analysis. Eighteen additional LEIs were performed by experienced anesthesiologists to define the standard. A generalized linear, mixed-modelling approach was used to identify key aspects of effective training and performance. The number of tracheal intubations that the trainees were required to perform before acquiring expertise in LEI was estimated.**

Results: **Subjects performed between 18 and 35 laryngoscopic intubations. However, statistical modeling indicates that a 90% probability of a "good intubation" required 47 attempts. Proper insertion and lifting of the laryngoscope were crucial to "good" or "competent" performance of LEI. Traditional features, such as proper head and neck positions, were found to be less important under the study conditions.**

Conclusions: **This study determined that traditional LEI teaching for nonanesthesia personnel using manikin alone is inadequate. A reevaluation of current standards in LEI teaching for nonanesthesia is required.**

COMPETENCY in laryngoscopic tracheal intubation (LEI) is essential for many healthcare professionals. Failure to perform successful LEI can sometimes result in patient death. In a recent report by an urban emergency medical system in the United States, 25% of tracheal tubes inserted by paramedics in prehospital emergencies were misplaced, and approximately 50% of those patients with a misplaced tube died in the emergency department.[1] Unfortunately, there is little information to indicate the extent of the training required for competence in LEI, or even what signifies true competence. In general, airway training programs for healthcare personnel, such as paramedics and respiratory therapists, are not standardized and may be inadequate. This inadequacy is a grave concern, given the serious consequences of failed airway management.

With regard to the teaching of LEI to anesthesiology residents, Konrad *et al.*[2] defined "success" arbitrarily as "adequate technical performance" without the assistance of a staff person. They described a learning curve that reached a 90% "success" rate after a mean of 57 attempts. However 18% of the residents still required assistance after 80 intubations. Unfortunately, no further analysis was carried out beyond "success" or "failure."

Traditional teaching of LEI has focused on certain key aspects of successful intubation, including the technical details of proper head positioning with laryngoscope blade insertion and lift, as well as a timely and atraumatic performance.

The purpose of this prospective study was to determine how much LEI training experience is necessary before a novice can be considered competent. In addition, we assessed features of the process of LEI that were critical to a "good" intubation and signified competence.

Materials and Methods

Study Population

Following institutional review board approval (Dalhousie University, Halifax, Nova Scotia, Canada) and informed consent, we recruited respiratory therapy students, paramedic students, and medical students scheduled to do a rotation in anesthesia. Any trainees with prior LEI experience or training were excluded. All trainees were formally trained in the theoretical aspects of LEI by a staff anesthesiologist (O. R. H.) and were required to perform a minimum of 20 successful intubations on manikins (Laerdal Medical Inc., Wappingers Falls, NY) prior to participating in the study. Healthy surgical patients with American Society of Anesthesiologists (ASA) physical status class I or II were recruited to the study, and informed consent was obtained. These patients showed no evidence of a potentially difficult LEI, and all required an endotracheal tube as part of their anesthetic management. Under a standardized anesthesia technique with muscle relaxation (2–3 μg/kg fentanyl, 1.5–2.5 mg/kg propofol, and 0.07–0.1 mg/kg vecuronium), these patients underwent LEI by the trainees, with an attending anesthesiologist present and providing ongoing supervision. Patients were excluded from the

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Table 1. Objective and Subjective Criteria to Evaluate Tracheal Intubations Performed by the Trainees

Objective criteria	
1	Proper neck flexion
2	Proper extension of the atlantooccipital joint
3	Proper insertion of the laryngoscope
4	Proper lifting of the laryngoscope
5	Appropriate request for help by the intubator (*e.g.*, requesting the anesthesiologist apply laryngeal pressure or BURP maneuver[3])
6	Completion of LEI
7	Completion of LEI in less than 30 s
8	The presence of complications
9	The unsolicited intervention of the attending anesthesiologist (*e.g.*, the anesthesiologist assists in lifting the laryngoscope)
10	Successful tracheal intubation after one attempt
Subjective criteria	
1	The reviewer was also asked to provide a subjective "yes" or "no" confidence score to the question "Would you let this trainee perform a LEI on you?"

BURP = backward upward rightward pressure; LEI = laryngoscopic endotracheal intubation.

study if they had ASA physical status class III or greater or when an unexpected difficult LEI occurred. The goal was to evaluate between 20 and 30 trainee intubations. In addition, 18 LEIs were performed under study conditions by five staff anesthesiologists to serve as a control group. Each LEI was videotaped for analysis by a single independent staff anesthesiologist who was not involved in the study. To minimize the reviewer's recall (bias) of a specific trainee's intubation experience while reviewing the videotapes, each LEI was recorded randomly by 1 of 50 videotapes. The videotapes were then randomly reviewed by an independent anesthesiologist.

Evaluation of LEI

Failure to intubate was defined as either an inability to place the endotracheal tube after three attempts or, at the discretion of the staff anesthesiologist, when there was a significant alteration of the hemodynamic (hypertension and tachycardia) and respiratory parameters (O_2 saturation $< 90\%$) during LEI, requiring the intervention of the staff anesthesiologist. An attempt at LEI was defined as a single episode in which the laryngoscope was placed inside the oropharynx of the patient for the purpose of visualizing the laryngeal inlet to perform LEI. The total time of laryngoscopy (TTL) was defined as the sum of the times of all attempts at LEI for a given patient. The TTL and number of attempts, failures, and complications were recorded, as well as pertinent patient demographic information. All videotapes were reviewed by an anesthesiologist independent of the study who judged (scoring 0 for failure and 1 for success) each LEI attempt based on a number of objective and subjective scores as outlined in table 1.

Statistical Analysis

The data collected in this study consisted of repeated measurements on trainees and as such was complicated by the necessity to deal appropriately with the within-trainee dependence. Although a nuisance factor, this dependence must be taken into account to draw valid inferences. Recently, Heagerty[4] proposed marginally specified generalized linear mixed models, which are ideally suited to data of this format. Hence, a model was constructed using this approach and served both to define important criteria necessary for proficiency in LEI as well as to estimate the number of LEIs required to ensure competence (see Appendix).

Results

A total of 472 patients (158 male, 314 female; average age 45.6 ± 17.5 yr) underwent LEI during this longitudinal study. Of these, only 456 were suitable for analysis due to several incidences in which video footage was lost, information was missing, or an unanticipated difficult laryngoscopy was encountered. Eighteen of these patients were intubated by staff anesthesiologists to create the control group, resulting in 438 trainee LEIs studied. The mean (±SD) number of tracheal intubations by the trainees was 23.0 ± 4.1 (ranged between 18 and 35 tracheal intubations).

There were 20 trainees in total; 7 medical students (5 male, 2 female), 1 respiratory therapy student (female), and 12 student paramedics (9 male, 3 female). There were 41 failed intubations (9.4%). The mean (±SD) number of failures per trainee was 2.1 ± 1.8 (ranged between 0 and 6 failures). Among the 20 trainees, 5 did not have any failed LEIs. There were 104 complications (23.7%). Apart from one chipped tooth, all the complications were either minor mucosal lacerations or bleeding.

Total time of laryngoscopy, success rate, complication rate, and rate of "good" LEI are compared with the control group (staff anesthesiologists) and summarized in table 2. The relationship between LEI and TTL is shown in figure 1.

Having categorized each LEI attempt as "good" or "bad," a statistical model was constructed using the Heagerty method (see Appendix). The model predicts that if a subject inserts and lifts the laryngoscope successfully and asks for appropriate help, he or she will have a 90% probability of performing a "good" LEI on trial 47 ± 11.2. Note that this result is outside the range of the data collected and therefore assumes the same learning process continues from trial 35 to trial 50. Alternatively, if we were to require that our estimate remain within the range of the data collected, we could set n (the number of trials) equal to 35. Fitting our model would then yield an estimate of the probability of per-

Table 2. Summary of Laryngoscopic Intubation Performance

Number of LEI	TTL (s)	Success Rate	Complication Rate	Good Rate
1–5 (n = 20)	62.3 ± 34.0	0.86 ± 0.35	0.24 ± 0.43	0.10 ± 0.31
6–10 (n = 20)	53.8 ± 33.7	0.86 ± 0.35	0.17 ± 0.38	0.20 ± 0.40
11–15 (n = 20)	47.6 ± 27.6	0.92 ± 0.28	0.15 ± 0.36	0.34 ± 0.48
16–20 (n = 20)	46.2 ± 32.7	0.93 ± 0.25	0.19 ± 0.40	0.30 ± 0.46
21–25 (n = 17)	42.4 ± 25.2	0.98 ± 0.14	0.08 ± 0.27	0.40 ± 0.49
26–30 (n = 3)	48.2 ± 41.9	1 ± 0	0.22 ± 0.44	0.50 ± 0.53
31–35 (n = 1)	23.0 ± 5.7	1 ± 0	0 ± 0	0.80 ± 0.45
Control	12.9 ± 2.9	1 ± 0	0 ± 0	0.94 ± 0.23

Success rate is 1 if LEI was achieved and 0 otherwise; complication rate is 1 if any complications occurred and 0 otherwise; and good rate is 1 if the reviewing anesthesiologist expressed subjective confidence in the trainee and 0 otherwise.

LEI = laryngoscopic endotracheal intubation; n = number of nonanesthesia health care providers who performed laryngoscopic endotracheal intubation; TTL = total time of laryngoscopy.

forming a "good" LEI. We found that our model estimates that there is an 80% probability of performing a "good" intubation after 35 trials (fig. 2).

Discussion

It appears that considerable experience is required before a trainee becomes proficient in LEI. Our model predicts that if subjects insert and lift the laryngoscope successfully and ask for help when appropriate, they will have a 90% probability of performing a "good" intubation on trial 47 ± 11.2 (*i.e.*, a successful intubation in < 30 s). This is consistent with the findings of Konrad's study.[2] They described a learning curve that reached a 90% "success" rate after a mean of 57 laryngoscopic intubations.

It must be emphasized that only uncomplicated LEIs under ideal and controlled conditions were included in this study. It has been estimated that between 1–3% of surgical patients have "difficult airways," making laryngoscopic intubation difficult and sometimes impossible.[5] Clearly, the trainees, such as anesthesia residents, would require more than 47 laryngoscopic endotracheal intubations before gaining experience in managing the airway of a patient with a difficult or challenging laryngoscopy.

In terms of key predictors of a good LEI, it seems noteworthy that the traditional emphasis on optimal head and neck positions (sniffing position *i.e.*, neck flexion and atlanto-occipital extension) do not significantly influence the perceived quality of an LEI in this study. This is in contrast to the emphasis given to head and neck positions in traditional teaching and the control group's reliable performance. It is possible that these head and neck positions may be of significance only in patients with difficult laryngoscopy and intubation and that "good LEI" can be achieved in most cases with less than traditionally taught or recommended tech-

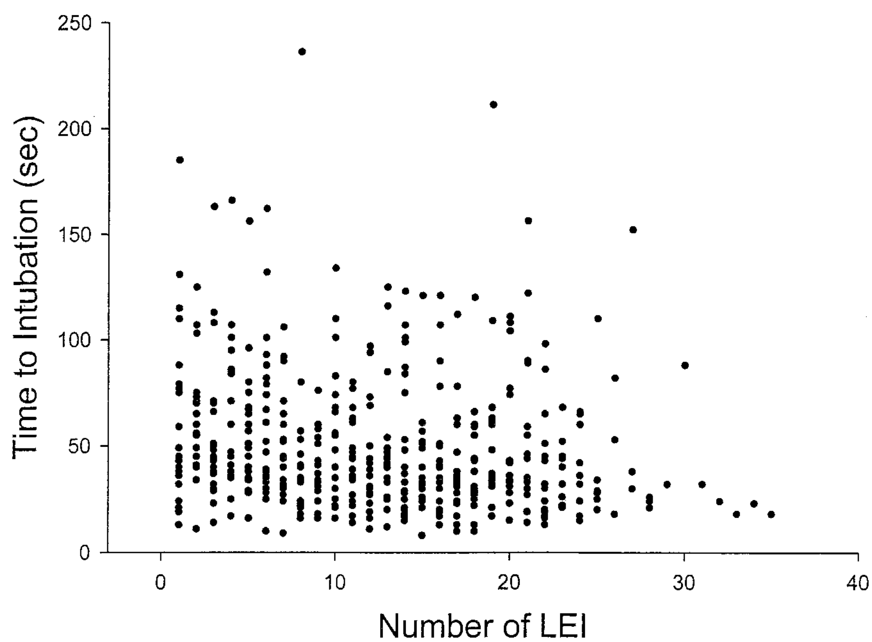

Fig. 1. Scatterplot of the number of prior laryngoscopic tracheal intubation (LEI) attempts to the total time taken for the intubation attempt (seconds). Note that the data becomes sparse as the number of prior attempts increases and is due to restrictions (resulting from rotations, *etc.*) on the length of time trainees could be involved in the study.

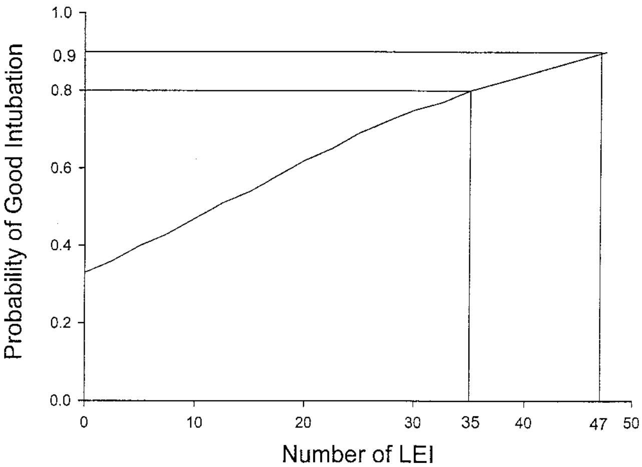

Fig. 2. The probability of good intubation as estimated by the generalized linear mixed model *versus* the covariate of primary interest: number of laryngoscopic tracheal intubation (LEI) attempts. The model predicts that an 80% success rate is achievable after approximately 35 LEI attempts, while a 90% success rate cannot be achieved until over 47 attempts.

nique or positioning. It is also possible that these findings may well reflect the fact that many of the videotape records began with the patient resting comfortably in the supine position with a pillow under the head, leaving the head and neck already well positioned for LEI. Furthermore, the findings of a recent study suggest that the traditional teaching using the "sniffing position" may not be helpful for direct laryngoscopy and tracheal intubation.[6] Using magnetic resonance imaging, Adnet *et al.*[6] showed that the classic "sniffing position" did not improve the alignment of the oral, pharyngeal, and laryngeal axes for direct laryngoscopy in awake volunteers. They also showed that simple extension of the atlanto-occipital joint alone in a patient lying on the table is beneficial in terms of glottic exposure. In a follow-up study with 456 anesthetized patients, Adnet *et al.*[7] showed that the sniffing position did not provide a significant advantage over simple head extension for tracheal intubation. However, their data showed that the sniffing position appeared to be advantageous in patients with obesity or with a limited head extension. Clearly, the findings of our study and Adnet's studies[6–7] suggest that further evaluation of the "sniffing position" for optimal laryngoscopic condition is warranted.

Other potential study limitations include the following: (1) There are no well-defined, acceptable TTLs in the literature. As a consequence, for the purpose of this study, reviewer confidence was solicited and 30 s was determined to be an acceptable limit. (2) It was assumed that the patients undergoing LEI and training experiences were all similar and that our study subjects represent typical nonanesthesia healthcare providers being trained in LEI. (3) Although none of the trainees performed more than 35 LEIs in this study, the statistical analysis predicts that approximately 47 LEIs are required to assure competence. Future studies will be necessary to validate these results. (4) As all of the videotapes were reviewed by the same anesthesiologist, it is difficult to determine the reliability and validity of reviewer assessment of all the laryngoscopic intubations. However, with respect to the reviewer setting the standard, the control group exceeded the students in all areas of the 10-point score, suggesting that the reviewer can reliably identify the experienced from the novice.

This study has the advantage of providing a large sample of data that has been prospectively and consistently obtained, is longitudinal in nature, and is amenable to complex statistical analysis and meaningful interpretation. The statistical method can also be readily extended to identify key educational components in performance of technical skills in anesthesiology, such as insertion of epidural, arterial, and central venous catheters.

Though it has been possible with this study to demonstrate specific quantitative and qualitative objectives for successful training in LEI, it is doubtful that current training programs for other nonanesthesia personnel reflect these learnings. In fact, most of the current LEI training for many healthcare providers, including paramedics and nurses, primarily involves laryngoscopic intubation in manikins (*e.g.*, during advanced cardiac life support training), with minimal experience in patients.[8] Despite effectively and successfully performing 20 tracheal intubations in manikins before the study, most trainees experienced initial LEI difficulties during the study even under ideal and controlled conditions with an average time to intubation of more than 1 min (table 2). These findings clearly suggest that the existing direct laryngoscopic intubation training, often using standard manikins alone, is inadequate for nonanesthesia healthcare workers. Understandably, the cost effectiveness of "adequate" training for these healthcare providers is an important issue. However, innovative methods in airway management training, delivered by highly qualified instructors using tools such as airway manikins with difficult airway features, or high-fidelity difficult airway simulators, may be possible solutions.[9–10] Future studies are required to determine the effectiveness of these difficult airway simulators in assessing LEI performance, as well as the LEI skills development and retention of these personnel. Strategies and directives in the development of guidelines and standards in airway training programs must be established to ensure LEI success as well as patient safety. Furthermore, emphasis should also be placed on effective ventilation and oxygenation using a bag-mask, laryngeal mask airway, and Combitube (Kendall-Sheridan Catheter Corp., Argyle, NY).

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Appendix

To derive a suitable model for the data collected in this study, we must first define a response variable Y_{ij}. We therefore take Y_{ij} equal to 1 if individual i performs a "good" LEI on trial j and 0 otherwise. Examination of the control group established, for purposes of the study, what we could consider to be a "good" LEI. All LEIs performed by this group were completed successfully and in a short period of time, suggesting that a concise definition of a "good" LEI should include two elements: successful completion as well as some measure of the time required for the procedure. A preliminary analysis of trainee performance and subjective reviewer confidence suggested that "successful LEI completion in under 30 s" was a reasonable definition of a "good" LEI. Fitting models using "under 45 s" and "under 60 s" were also investigated and confirmed that "under 30 s" was the appropriate criterion. A "bad" LEI is one which falls outside of the limits defining a "good" intubation, that is, an unsuccessful attempt or one which takes more than a 30 s TTL.

Having categorized each LEI attempt as "good" or "bad," a model was then constructed using the Heagerty method. The number of prior attempts at intubation was selected for scientific reasons and was therefore the covariate of primary interest. Preliminary model selection reduced the number of relevant covariates to four: number of attempts, insertion of the laryngoscope, lifting of the laryngoscope, and requesting help. The final model took the form:

$$\mathrm{logit}P(Y_{ij} = 1X_i) = \beta_0 + \beta_1 X_{ij1} + \beta_2 X_{ij2} + \beta_3 X_{ij3} + \beta_4 X_{ij4}$$

where $\mathrm{logit}(x) = \log(x) - \log(1 - x)$, $P(Y_{ij} = 1X_i)$ is the probability trainee i performs a good LEI attempt j, and X_{ijk}, $k = 1, \ldots, 4$ represents the important covariates (categories). For example, X_{ij2} is 1 if trainee i properly inserts the scope on LEI attempt j. β_0 through β_4 are the corresponding estimated coefficients, which can be transformed and reported as odds ratios (along with their SEs) as given in table 2. By way of illustration, the odds ratio for insertion of the laryngoscope can be interpreted as comparing the probability of performing a successful LEI for those who insert the laryngoscope successfully as compared to those who do not. That is, those who properly insert the laryngoscope are 2.56 times as likely to perform a successful LEI compared to those who could not insert the laryngoscope properly.

Table 3. Odds Ratios and Standard Errors for Laryngoscopic Endotracheal Intubation Categories

Variable	Heagerty Method
Neck flexion	NS
Head extension	NS
Insertion of the laryngoscope	2.56
Lifting of the laryngoscope	6.17
Request for help	2.18
Completion of attempt	NS
Completion of attempt in <30 s	NS
Presence of complication	NS
Anesthesiologist intervention	NS
Number of attempts at LEI	1.35
Log (σ)	-0.49 ± 0.49

LEI = laryngoscopic endotracheal intubation; NS = no statistical significance.

Our model also requires a second component to handle the possible correlation between the Yij. This second component is an additional parameter σ interpreted as the individual-level heterogeneity. The maximum likelihood estimate for the heterogeneity parameter was $\sigma = 0.61$ ($e^{-0.49}$), indicating fairly small trainee-to-trainee variation in the odds of performing a "good" LEI (table 3).

The model can be used to predict how many LEIs must be performed before a trainee can be considered competent. That is, by requiring that each relevant LEI category be completed in a satisfactory manner (*i.e.*, successful insertion of the laryngoscope) and also requiring a 90% probability of performing a "good" LEI, we are left with only one unknown in the model. Upon solving for this unknown (number of attempts at LEI), we found that the model predicts that if a subject inserts and lifts the laryngoscope successfully and asks for appropriate help, he or she will have a 90% probability of performing a "good" LEI on trial 47 ± 11.2. Note that this result is outside the range of the data collected and therefore assumes the same learning process continues from trial 35 to trial 50. Alternatively, if we were to require that our estimate remain within the range of the data collected, we could set n equal to 35. Fitting our model would then yield an estimate of the probability of performing a "good" LEI. We found that our model estimates that there is an 80% probability of performing a "good" intubation after 35 trials.