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Teaching Residents Pediatric Fiberoptic Intubation of the Trachea

Traditional Fiberscope with an Eyepiece versus *a Video-assisted Technique Using a Fiberscope with an Integrated Camera*

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Background: The authors' hypothesis was that a video-assisted technique should speed resident skill acquisition for flexible fiberoptic oral tracheal intubation (FI) of pediatric patients because the attending anesthesiologist can provide targeted instruction when sharing the view of the airway as the resident attempts intubation.

Methods: Twenty Clinical Anesthesia year 2 residents, novices in pediatric FI, were randomly assigned to either the traditional group (traditional eyepiece FI) or the video group (video-assisted FI). One of two attending anesthesiologists supervised each resident during FI of 15 healthy children, aged 1–6 yr. The time from mask removal to confirmation of endotracheal tube placement by end-tidal carbon dioxide detection was recorded. Intubation attempts were limited to 3 min; up to three attempts were allowed. The primary outcome measure, time to success or failure, was compared between groups. Failure rate and number of attempts were also compared between groups.

Results: Three hundred patient intubations were attempted; eight failed. On average, the residents in the video group were faster, were three times more likely to successfully intubate at any given time during an attempt, and required fewer attempts per patient compared to those in the traditional group.

Conclusions: The video system seems to be superior for teaching residents fiberoptic intubation in children.

FLEXIBLE fiberoptic intubation of the trachea is a standard technique to establish an airway in pediatric patients who are known or suspected to be difficult to manage by mask ventilation or by standard methods for placement of an endotracheal tube.[1–5] Anesthesiology residents must receive instruction in this technique. Skill acquisition is achieved through reading, didactic lectures, mannequin or model practice (Dexter; Replicant Medical Simulators, Ltd., Wellington, New Zealand),[6] use in patients with normal airway anatomy, and, ultimately, use in patients with abnormal airway anatomy.[7] Anesthesiology residents who train at our children's hospital already have this basic overview and experience in the use of the flexible fiberscope in adult patients. However, flexible fiberoptic intubation in children is not the same as in adults because the airway anatomy of children differs with age.[1,5,8,9] In addition, the characteristics of the commonly used pediatric fiberscopes differ from those used in adults, *i.e.*, they are smaller, have reduced fields of vision, have different ranges of tip angulation, and have an insertion cord that is thinner and more flexible.[1,7–9]

Many intubating fiberscopes do not have an attached camera and monitor. Therefore, only the operator is able to view the progress of the intubation. In contrast, flexible fiberscopes used for a variety of other purposes (*e.g.*, gastrointestinal endoscopy, bronchoscopy) usually have an attached video camera with a monitor. This system enables both the operator and his or her assistants or trainees to view the procedure. Karl Storz Endoscopy-America, Inc. (Culver City, CA) manufactures a fiberscope for pediatric tracheal intubation (OD = 2.8 mm) that integrates a Micro-Video-Module® camera into the fiberscope.

Several articles have addressed methods for teaching flexible fiberoptic intubation; however, none have compared the use in children of two types of visualization systems using fiberscopes that otherwise have the same physical characteristics (*i.e.*, size, tip angulation, component materials).[9–17] Our hypothesis was that instruction would be improved and resident skill acquisition would be faster with the video system because it allows the attending anesthesiologist to receive the same visual information as the resident. Thus, instruction can be targeted to correct particular problems that may occur during the course of intubation. In contrast, with a traditional system, the attending anesthesiologist has only external clues of the progress or problems occurring with intubation. The targeted instruction that can be provided when the video system is used should result in more rapid skill acquisition as measured by time to success or failure of tracheal intubation. To test this hypothesis, two fiberscopes, which are identical except that one has an eyepiece and the other has an integrated camera, were compared for teaching pediatric fiberoptic intubation.

Materials and Methods

After institutional review board approval (Children's Memorial Hospital, Chicago, Illinois), we recruited 20 Clinical Anesthesia year 2 residents with similar experience in adult fiberoptic intubation, but who were novices in pediatric fiberoptic intubation, to participate in a study comparing the video-assisted and the traditional eyepiece methods. Participation by the residents was voluntary. The residents were randomly assigned to one of two groups. The traditional group intubated patients using the fiberscope with a traditional eyepiece and the video group intubated patients using the fiberscope with integrated camera and video monitor system. The residents were further randomized to one of two attending physicians in a balanced fashion such that each attending physician supervised five residents in each group. All residents received the same orientation to using fiberscopes in children before their first intubation attempt. Each resident attempted fiberoptic intubation in 15 patients under direct guidance of the attending anesthesiologist. Patients were chosen from a convenience sample of healthy children (American Society of Anesthesiologists physical status I or II), aged 1–6 yr, presenting for elective outpatient or same-day surgery that necessitated general anesthesia with oral tracheal intubation.

Informed written consent was obtained by one of the investigators from the child's parent or legal guardian on the day of surgery. Children were of either sex and of any ethnic origin. Subjects excluded from the study were those with clinically important cardiac or pulmonary disease, with a known airway anomaly, with a history of difficult intubation, with a syndrome known to be associated with difficult intubation, and those scheduled to undergo emergency surgery or who required precautions against aspiration (*i.e.*, those who would require a rapid sequence induction and intubation). The number of residents and patient intubations chosen was based on the findings of previous studies of flexible fiberoptic airway management skills acquisition.[11,12,15,18]

All children received an inhalation induction with sevoflurane and nitrous oxide in oxygen and were monitored with pulse oximetry, noninvasive blood pressure monitoring, electrocardiography, and end-tidal carbon dioxide monitoring. An intravenous line was inserted, and 0.6 mg/kg rocuronium was administered. Children were preoxygenated with 100% O_2, and 3–5% sevoflurane was administered for at least 3 min before intubation attempts. Each child had his or her mouth suctioned immediately before intubation, but no antisialagogue was administered. The fiberscopes were prepared by using an antifogging solution. Although the Storz fiberscope has a working channel, we elected not to use it for either suctioning or oxygen insufflation. This is consistent with the clinical practice of the investigators. All endotracheal tubes were loaded onto the fiberscope with the Murphy eye up (bevel facing down). This orientation was maintained during passage of the endotracheal tube to facilitate successful placement into the trachea.[19,20] The supervising anesthesiologist secured the child's head in a neutral position and held the mouth open and the jaw subluxed while providing verbal instruction. Instruction for the residents in the video group was based on the shared view of the airway on the monitor during the course of intubation. Instruction for the residents in the traditional group was based on the attending instructor's external observation of the resident and the relation of the transillumination of the tip of the fiberscope to the patient's surface landmarks.

During performance of each intubation, a research nurse used a stopwatch to measure the duration of each intubation attempt and the time from mask removal to confirmation of endotracheal tube placement by end-tidal carbon dioxide detection. An intubation attempt was aborted if there was a decrease in oxygen saturation to 95% before completion of intubation or if the attempt took longer than 3 min. The patients were ventilated with 100% O_2 and 3–5% sevoflurane for 3 min between attempts. The number of attempts required for successful completion of intubation was recorded. If three attempts at intubation by the resident were unsuccessful, the attending anesthesiologist intubated the child and a failure was recorded. The cause of failure, either failure to correctly place the fiberscope or failure to thread the endotracheal tube into the trachea, was noted. The primary outcome was defined as time to the clinical endpoint of success or failure of tracheal intubation. Comparisons of these values were made between the study groups to determine whether one teaching system was superior to the other. Failure rate and number of attempts between groups were also compared.

Statistical Analysis

Data were summarized using means and SDs for continuous variables (cumulative intubation time, patient age, and weight) and frequencies for categorical variables (number of attempts per patient and success or failure). Demographic characteristics (patient age and weight) were compared using t tests. Preliminary comparisons between groups were accomplished by chi-square analysis and weighted t tests.

To determine whether there was a difference between groups in our primary outcome, a mixed-effects Cox proportional hazards regression model[21] was used because this models both success or failure and the time spent on each intubation attempt simultaneously. This type of modeling is considered to be survival analysis, *i.e.*, the number of residents who were successful or did not complete intubation within a given time can be determined and compared between groups. In addition,

an odds ratio of the differences between groups in likelihood of success at any given time can be determined.

Mixed-effects models were used because these statistical models incorporate both fixed covariates (patient age or weight, resident experience) and random covariates (attending physician supervising and the innate skill of each resident performing an intubation). Specifically, this statistical method allowed us to estimate the effect each resident and attending physician had on the outcomes in the form of an intraclass correlation coefficient (ICC) and to isolate that effect from that of other potential fixed covariates. The ICC[22] defines the proportion of variation in the outcome that is attributable to the individual resident's skill and each attending physician's effect. The ICC can vary from 0 to 100%. For example, an ICC of 0 implies that each individual resident's skill level has negligible effect on the outcomes, whereas an ICC of 100% indicates that the resident's skill level accounts entirely for the outcome. Intermediate values imply an intermediate effect of an individual resident's skill.

After adjusting for the covariates of patient age and weight and resident experience, the difference between systems in the likelihood of completing an intubation within any given time was determined. Resident experience was defined as whether the current intubation was among the 1st–5th, 6th–10th, or 11th–15th patients. Kaplan-Meier curves were generated from the Cox regression model. An odds ratio with 95% confidence interval of the relative likelihood of completion between the two groups was estimated.

SAS version 8.2 (SAS Institute, Cary, NC) and S-Plus version 6.1 (Insightful Corporation, Seattle, WA) were used for all statistical analyses. All tests were two sided, and $P < 0.05$ was used as the level of significance.

Results

Each of 20 Clinical Anesthesia year 2 residents attempted fiberoptic intubation in 15 children for a total of 300 attempted intubations. Statistically but not clinically significant differences were found between the study groups with respect to patient age and weight (table 1). No complications occurred, and no patient had oxygen saturations of less than 95%. The Cox proportional hazards model found that residents in the video group were significantly faster than those in the traditional group ($P < 0.0001$; table 2). The Cox model, as illustrated in figure 1, also demonstrated that residents in the video group were three times more likely to intubate the trachea successfully at any given time during an attempt compared with residents in traditional group (95% confidence interval, 2.14–4.19). Patient age and weight were not significant predictors of outcome ($P = 0.31$ and $P = 0.087$, respectively). Resident experience, however, did play a significant role in both groups, with the

Table 1. Patient Demographics and Intubation Attempts

	Video Patients Group	Traditional Patients Group	*P* Value
1 Intubation attempt	142	112	< 0.001
> 1 Intubation attempt or failure	8	48	< 0.001
Failure	3	5	0.73
Age, yr, mean ± SD	3.9 ± 1.6	4.4 ± 1.6	0.006
Weight, kg, mean ± SD	16.9 ± 4.8	19.2 ± 5.8	< 0.001

Patient demographics and the number of patients who required a single intubation attempt *versus* those who required more than one intubation attempt or who did not successfully place the endotracheal tube. In each group, 150 intubations were attempted.

intubation attempts for the first five patients being significantly slower than the 6th–10th patients and the 11th–15th patients; however, there was no difference between the 6th–10th patients and the 11th–15th patients (table 3). The ICC due to individual resident skill and the attending physician providing supervision was 27.7%. The graph of resident experience (*i.e.*, increasing number of patients) *versus* time to successful completion of intubation (fig. 2) seems to show differences between video and traditional groups for the first five patients. However, the model comparing the effect of resident experience for each group separately did not converge; therefore, we could not determine whether there was a difference between the two groups for improvement in skill levels with increasing resident experience.

Table 2. Median Time and 25th–75th Percentile Time Range Required to Complete Intubation

Time to Completion	Median Time, s	25th–75th Percentile, s
Video	49.9	63.6–37.9
Traditional	71.8	133.0–52.4

The median time is that time at which 50% of the residents had successfully completed intubation as obtained by the Cox Proportional Hazards model ($P < 0.0001$). These numbers can be read off of figure 1.
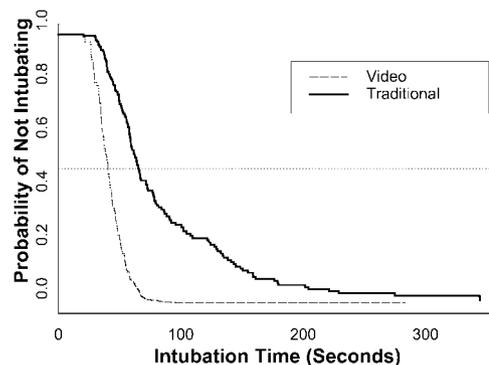

Fig. 1. Kaplan-Meier curves derived from the Cox regression analysis of the probability of not completing an intubation within a particular time limit for the video group and the traditional group.

Table 3. Likelihood with Increasing Experience of a Resident Completing an Intubation

Patient Number	P Value	Odds of Completion	95% Confidence Interval
6–10 *vs.* 1–5	0.0002	1.74	1.30–2.33
11–15 *vs.* 1–5	< 0.0001	2.28	1.69–3.07
11–15 *vs.* 6–10	0.07	1.31	0.98–1.75

Odds of completion of intubation with respect to resident experience (both groups together) as obtained by the Cox proportional hazards model.

For our secondary outcome measures, we found that the overall number of intubation attempts in the traditional group was greater (200 attempts for the traditional group *vs.* 162 for the video group). The proportion of patients who required more than one attempt for successful tracheal intubation or in whom intubation failed was significantly greater in the traditional group (table 1); however, the overall failure rate (2% for the video group and 3.3% for the traditional group) was not significantly different between groups (table 1). In the traditional group, the cause of intubation failure for four of the residents was inability to place the fiberscope into the trachea. In contrast, in the video group, only one resident was unable to correctly place the fiberscope into the trachea. The remaining failures were secondary to failure to thread the endotracheal tube over the fiberscope into the trachea.

Discussion

We designed our study comparing two systems for teaching fiberoptic intubation to maximize patient safety as well as to facilitate resident learning; therefore, patients were anesthetized and paralyzed before intubation. Acquiring fiberoptic intubation skills in anesthetized patients rather than awake patients (as is recommended for intubation of a patient with a difficult airway[4]) is well supported in the literature.[7,9,12,14,23] During the course of each intubation attempt, the attending physician provided jaw thrust and mainta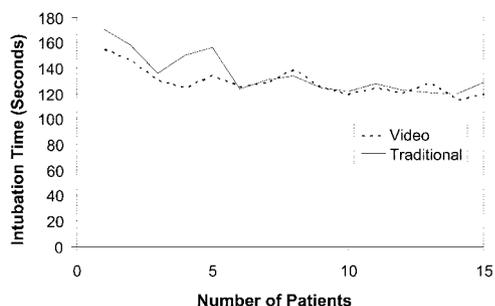ined head stability to improve intubating conditions. As outlined in the American Society of Anesthesiologists difficult airway management practice guidelines[4] and as good medical practice would dictate, optimum conditions for success should be present before any intubation attempt, and a second individual skilled in airway management should be present.

In both groups, essential skill sets were transmitted over the course of resident experience as shown by decreasing time to completion of intubation with increasing number of patient attempts (fig. 1). Visual inspection of figure 2 shows a trend toward greater skill, *i.e.*, faster intubation, in the first five patients for the video group *versus* the traditional group. After the first five patients, this difference seems to go away; however, the data do not have sufficient power to prove this statistically. Also, because the attempts in the first five patients were much slower than in the second or third group of five patients, the first five intubations seem to be where most of the learning occurs regardless of method used. However, on average, the residents in the video group were faster, were three times more likely to successfully intubate any given patient, and required fewer attempts per patient for successful intubation compared with the residents in the traditional group.

There are several possible explanations for our findings. One is that when both the teacher and the student "share" the view, improved interaction between teacher and student may allow skill sets to be transmitted more efficiently. Another possibility is that the sharing of the view actually better evaluates the combined efforts of the supervising anesthesiologist and the resident, whereas use of the traditional system, in which the teacher is essentially "blind," measures to a greater degree only the resident's performance. Therefore, because the skills of two individuals, including an instructor with expertise in pediatric fiberoptic intubation, may be reflected by the video group intubation times, these times would be expected to be shorter than for residents using a traditional fiberscope. Another explanation may be that the view provided by the video fiberscope is larger and airway anatomical features seem to be easier to distinguish; therefore, this skill may simply be easier to perform regardless of instructor input. A final possibility is that there was some degree of instructor bias. Although our hypothesis was that video would be better, in fact, both instructors had never taught with a video system and had taught extensively with a nonvideo system so that there was equal probability of bias toward the nonvideo as there was toward the video system.

We also conducted a *post hoc* power analysis to determine the required sample size that would be required to determine a difference between systems based on outcomes observed in this study. For the primary outcome, a log-rank test framework was used. In this framework, a "success" threshold must be chosen; 60 s was considered to be this threshold time. Success rate at 60 s was

Fig. 2. Mean cumulative time required by residents in each group to complete an intubation or to fail to intubate for each patient number.

92% in video group and 43% in traditional group. To detect a significant difference between these success rates with 85% power at 5% level of significance, and assuming our observed 28% intraclass correlation for the residents, a sample of 8 residents, with 15 intubations per resident, would be required. Our study included 10 residents per group. For the secondary outcome of overall success rate, failure was a rare event, with success rates of 98% in video group and 96.7% in traditional group. Therefore, to detect a significant difference in these two proportions, with 80% power at 5% level of significance, the unadjusted sample size would require 2,400 residents in each group. Obviously, a study of this size would be impractical.

Residents in the video group were faster, were three times more likely to complete intubation successfully within any given time during an attempt, and required fewer intubation attempts per patient. We conclude that the video-assisted technique is superior to the traditional fiberoptic method for teaching residents to perform fiberoptic intubation of infants and children aged 1–6 yr.

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