Original article

Determining the minimum number of endotracheal intubation cases necessary to develop the skills of medical students

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Objectives This study aimed to define the minimum number of cases necessary for 5th year medical students to develop endotracheal intubation skills during Anesthesiology Department training by means of the construction of a learning curve.

Methods In this longitudinal descriptive study, 5th year medical students performed endotracheal intubation (ETI) on live patients under the supervision of anesthesiologists. The number of intubation attempts and the results of those attempts were recorded. The generalized linear model (probit family) was used to construct the learning curve. The secondary outcome was determination of the overall confidence of the students in their ETI skill at the end of the session as measured using a 4-point Likert scale.

Results Data of seventy-four students was analyzed in this study. None of the students had had previous experience in ETI with a patient. The mean number of ETI attempts per student was 5.26 (SD 1.23, range 3-10). The probability of a successful ETI was 92.8% in the 3rd attempt and 100% in the 4th attempt. Self-reported levels of overall confidence in their ETI skills were as follows: 55 (74.3%) students would attempt ETI alone, 9 (12.2%) students were completely confident in their ability, 9 (12.2%) students would seek supervision, and 1 student (1.3%) was completely uncomfortable in doing the procedure.

Conclusions During their Anesthesiology Department rotation, medical students should be provided the opportunity to make at least 3 intubation attempts to achieve a 90% probability of a successful ETI. The specific course syllabus should be designed for each individual institution. **Chiang Mai Medical Journal 2021;60(3):317-23. doi: 10.12982/CMUMEDJ.2021.28**

Keywords: endotracheal intubation, learning curve, medical students, medical education research

Introduction

Endotracheal intubation (ETI) is an essential clinical skill for medical students. The Medical Council of Thailand has stated that endotracheal intubation is one of the competency assessment criteria for a National License (1). Due to the specialized nature of this basic skill, the Anesthesiology department plays a major role in the process of developing an effective curriculum. Several studies have shown that practicing ETI with anesthetized patients was easier and the success rate was higher than with non-anesthetized patients (2-4). In Thailand, fifth-year medical students are required to participate in a 2-4 week rotation, depending on the individual institution's curricula, in the Anesthesiology Department. During this session, the medical students learn ETI using a combination of basic theory, manikin practice, and live experience in the operating theatre.

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Assessment of skill level is important to the validation of the utility and effectiveness of the educational curricula (5). In our institution, we recommend at least 3 cases of ETI with a live patient for each student during the 4 weeks period of the anesthesiology rotation. This minimum number was, however, established based on the expected number of patients during this limited period, not on the number needed to develop competency in this valuable skill. This study aimed to determine the minimum number of ETI with live patients necessary for medical students to achieve an anticipated success rate of 90%. We also assessed the self-confidence of the medical students in performing ETI at the end of the session.

Methods

Following receipt of approval by the Institutional Ethical Committee, this longitudinal descriptive observational study was conducted between June 2017 and May 2018 at the Faculty of Medicine, Vajira Hospital, Navamindradhiraj University, Thailand. Seventy-eight fifth year medical students who had completed a four-week training in the Department of Anesthesiology were enrolled into the study after giving their informed consent.

Prior to practicing ETI in an operating theatre, all medical students had to participate in a basic airway management program that includes standard lectures and simulator-based training under the direction of the same instructor team which consists of two anesthesiologists. The medical students had to achieve two consecutive successful ETIs using a high-fidelity manikin during this training to complete the program. After that, the students were allowed to perform actual ETIs in adult patients (age > 18 years) who were scheduled for elective surgery.

The patients were evaluated preoperatively by supervising anesthesiologists. Patients scheduled for emergency surgery, those who were pregnant with a gestational age > 20 weeks, cases where difficult airways were anticipated, e.g., limited mouth opening (less than 3 fingerbreadths), a thyromental distance of less than 6.0 cm, a Mallampati score of 4, limited neck movement, abnormal pathology of the head and/or neck or a previous history of difficult ETI were excluded. Patients' demographic data, including age, gender, weight, height, body mass index (BMI), American Society of Anesthesiologists (ASA) classification, Mallampati classification, and laryngoscopic view grade, were recorded.

On the day of the surgery, the patients were monitored with 3-lead electrocardiography (ECG), non-invasive blood pressure (NIBP), pulse oximetry (SpO_2), and capnography. General anesthesia was induced and muscle relaxants were used to facilitate tracheal intubation. The medical students then performed conventional direct laryngoscopy using a Macintosh blade under direct supervision of the attending anesthesiologists. During the procedure, assistance in handling of the equipment and performance of the backward, upward, rightward pressure (BURP) maneuver by the nurses was allowed when requested by the students.

Successful intubation is defined as achieving direct laryngoscopy, visualization of the endotracheal tube through the vocal cord, and confirmation of correct endotracheal tube (ETT) placement using capnography and auscultation of equal breath sounds in both lungs. The attending anesthesiologists were instructed to intervene with the procedure if a medical student could not perform the proper steps of ETI, if the patient became desaturated (SpO_2 < 95%), and/or if there was potential for an airway injury. Failure to place the ETT into the trachea and any interference or physical assistance by the attending anesthesiologists was recorded as an unsuccessful intubation. If the medical students failed on the first attempt and were allowed to perform a subsequent ETI in the same patient, they had to report both the unsuccessful first attempt at intubation as well as the successful second ETI. The number of intubation attempts, results of each of those attempts and any complications were recorded in the student's logbook after being reviewed and approved by the attending anesthesiologists.

At the end of the session, the medical students were asked to complete a self-assessment of their overall confidence in their ETI skills using a 4-point Likert scale (1=completely uncomfortable, 2 = would seek supervision, 3 = would attempt alone, 4 = completely confident) (6). Numeric data are presented as mean ± standard deviation (SD) or as percentages. Cumulative probability univariate analysis with a generalized linear model (probit family) was used to estimate the probability of a successful intubation and to construct the learning curve. Statistical analyses were performed using STATA V14 (StataCorp LLC, College Station, Texas, USA).

Results

Of the seventy-eight medical students enrolled in this study, four were excluded due to an incomplete record in their student logbooks. Data from a total of 74 medical students were used in the analysis. None of the students had previous experience performing ETI in a live patient. Patient demographic data are shown in Table 1. The patients were mostly female (64.4%) with a mean age of 50.1 (SD 15.2) years. More than half (57.3%) were ASA class II, while 24.7% and 18.4% were ASA class III and I, respectively. The majority of the patients (56.7%) had a laryngoscopic view of either grade I or grade II (41.5%).

Table 1. Patient demographic data

Patient information	
Age (years)	50.1 (SD15.2)
Gender	
Male	138 (35.6%)
Female	250 (64.4%)
BMI (kg/m^2)	24 (SD 4.2)
ASA classification	
I	70 (18%)
II	222 (57.3%)
III	96 (24.7%)
Mallampati classification	
I	187 (48.2%)
II	201 (51.8%)
Laryngoscopic view grade	
I	220 (56.7%)
II	161 (41.5%)
III	5 (1.3%)
IV	2 (0.5%)

Data are presented as mean (SD) or number (%)
BMI, Body mass index; ASA, American Society of Anesthesiologist physical status

A total of 388 recorded intubation attempts were included in this study. The mean number of intubation attempts per student was 5.26 (SD 1.23, range 3-10). The probability of a successful ETI in the first and second attempts were 17.5% and 60.5%, respectively (Figure 1). The probability

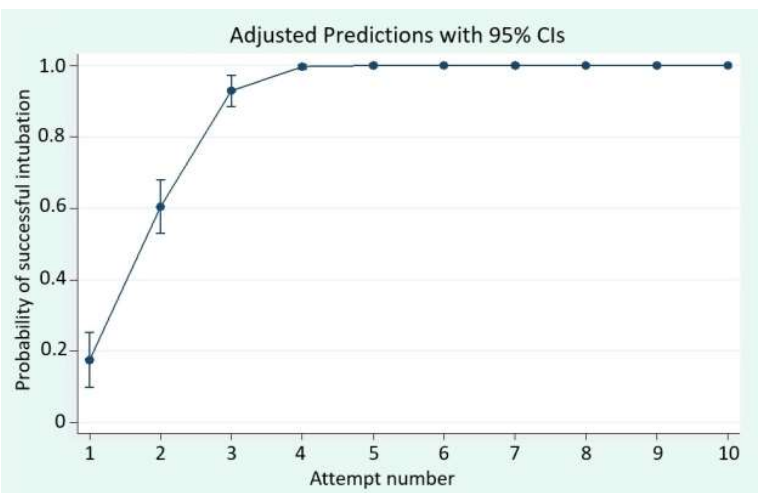

Figure 1. Learning curve of successful tracheal intubation in medical students.
N,number of students in each attempt

of a successful ETI reached 92.8% in the third attempt and finally reached 100% after the fourth attempt. The most common reasons for intubation failure were inability to visualize the vocal cord due to poor laryngoscope position (91.6%) and unexpectedly difficultly in intubation (7.4%). No perioperative hypoxia, respiratory or cardiovascular events were reported.

At the end of the session, overall confidence in their ETI skills were as follows: 55 (74.3%) of the students would attempt to perform the procedure alone, 9 (12.2%) were completely confident in their ability, 9 (12.2%) would seek supervision and only 1 student (1.3%) felt completely uncomfortable to do the procedure (Figure 2).

Discussion

Learning the underlying theory, demonstration of skill proficiency, repetitive skills practice, and constructive feedback are considered part of an effective curricular process for clinical skill education (5,7). It is also necessary to assess the students' skills after a session to evaluate and optimize the effectiveness of the curricula. These evaluation results can be beneficial in validating and augmenting the effectiveness of clinical skills teaching (8,9). Following this fundamental guideline, we developed a basic airway training program for learning intubation skills that consisted of a standard lecture, simulator-based training, and performing ETI with live patients in the operating theatre. The theoretical lecture provides core knowledge and the simulator training enables students to practice and make mistakes without time restrictions and with no risk to the patient (10-12). Our institution has various methods for assessment of ETI skills including observation, a check-list, and Objective Structured Clinical Examination (OSCE). Nevertheless, the most important determinant of skills and knowledge retention is repetition (13). Practicing ETI in living patients is a key process in developing those skills. In this study, we attempted to determine the minimum number of cases necessary for medical students to achieve the goal of a 90% probability of successful intubation by means of constructing a learning curve to identify the optimal number of cases of performing ETI with a living patient during the Anesthesiology training rotation and to further improve the curriculum.

In 2008, Tatiyanupunwong S and co-workers conducted a study to determine the optimum number of ETI with live patients necessary for fifth-year medical students to achieve an 80% success rate in endotracheal intubation (14). The results of that study suggest that 10 cases of ETI experience with a living patient are needed to achieve that goal. In 2011, Tarasi PG and co-workers prospectively reviewed the logbooks of 178 third-year medical students rotating in the Anesthesiology Department and found that the students required at least 17 ETI encounters with a live patient to achieve a 90% predicted ETI success rate (15). In the present study, we found that to achieve a 90% probability of successful intubation, the medical students should attempt at least 3 intuba-

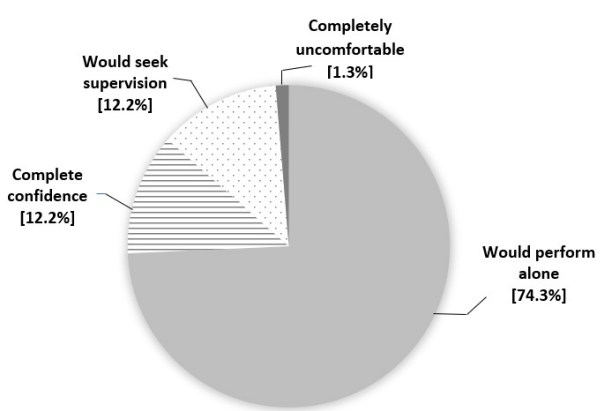

Figure 2. Confidence of intubation skill after the Anesthesiology rotation

tions in the operating theatre. The minimum number of ETI attempts in this study is lower compared to previous studies. Reasons for that difference might include the combination of the use of high-fidelity simulation with specific assessments and the selection of patients.

At our institution, the basic airway training program consists of a 1-hour conventional lecture and 2 hours of manikin practice using high-fidelity simulators (Difficult Airway Management Simulator-Assessment System, Kytokagaku, Japan). Although there is currently only limited data on the general improvement of trainee outcomes compared to low-fidelity simulation for ETI training, the high-fidelity simulators can provide additional objective and quantitative information such as real-time visualization of the laryngoscope position and of the lifting of the epiglottis to expose the vocal cord, the force on the tongue and incisor (in Newtons) and the proper position of the endotracheal tube placement. This allows instructors to give pertinent constructive feedback and specific suggestions for improvement of future attempts. Assessment methods for simulation training at our institution include observation and a checklist. After a 2-hour practice session with a high-fidelity manikin, medical students are required to achieve two consecutive successful ETIs and to complete the 10 steps of the intubation checklist at the objective structured clinical examination (OSCE) station. This process of assessment helps to ensure competency and skill before practicing with live patients. We also specifically excluded patients who are anticipated to have difficult airways in order to avoid harmful complications for the patients. In this study, all patients had Mallampati class I and II. This differs from previous studies which included high Mallampati score patients. We consider that all these factors together played a major role in the success rate observed in our study.

The most common reason for a failed intubation in our study was inability to visualize the vocal cord due to poor laryngoscope position. Discussion with the supervising anesthesiologists and repetition of the exercise improved the success rate in subsequent attempts. At the end of the session, 74% of the medical students indicated they would feel confident to perform ETI alone and 9% were completely confident in their ability to do the procedure.

There are some limitations in this study. First, this was a single-center, observational study. Second, the probability of successful intubation in living patients depends largely on the effectiveness of the basic airway training and the process of assessment and selection of patients for practicing ETI. A different training program model might produce dissimilar results.

Conclusions

Clearly defined learning objectives, proper assessment of trainees, and a well-organized curriculum are important for developing medical clinical skills proficiency. We have found that at least 3 intubation attempts should be provided for medical students to achieve a 90% probability of successful ETI by the end of the Anesthesiology Department rotation in our institution. The specific course syllabus should be adjusted for each individual institution in order to ensure the clinical skill competency of the medical students meets professional standards.

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Conflicts of interest

The authors declare no potential conflicts of interest with respect to the authorship and/or publication of this article. All authors have read and approved the final manuscript.

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การศึกษาหาจำนวนผู้ป่วยขั้นต่ำในการฝึกทักษะหัตถการใส่ท่อช่วยหายใจในนักศึกษาแพทย์

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วัตถุประสงค์ เพื่อหาจำนวนขั้นต่ำในการฝึกใส่ท่อช่วยหายใจสำหรับนักศึกษาแพทย์ปีที่ 5 ระหว่างปฏิบัติงานในภาควิชาวิสัญญี โดยการสร้างกราฟทักษะการเรียนรู้

วิธีการ เป็นการศึกษาแบบไปข้างหน้า โดยให้นักศึกษาแพทย์ชั้นปีที่ 5 ฝึกหัตถการใส่ท่อช่วยหายใจภายได้การกำกับของวิสัญญีแพทย์ บันทึกจำนวนครั้งและผลลัพธ์ มาสร้างกราฟทักษะการเรียนรู้โดยจำลองโมเดลเชิงเส้นแบบโพรบิท (Generalized linear model, probit family) การศึกษารอง คือ ความมั่นใจหลังจบหลักสูตร โดยใช้มาตรวัดของลิเคิร์ท 4 ระดับ (4-point Likert scale)

ผลการศึกษา นักศึกษาแพทย์ 74 คน ไม่มีประสบการณ์ใส่ท่อช่วยหายใจในผู้ป่วยมาก่อน พบว่า ค่าเฉลี่ยในการทำหัตถการคือ 5.26 (ส่วนเบี่ยงเบนมาตรฐาน 1.23 พิสัย 3-10) พบโอกาสความสำเร็จในการทำหัตถการที่ร้อยละ 92.8 และ 100 เมื่อฝึกใส่ท่อช่วยหายใจครั้งที่ 3 และ 4 ตามลำดับ หลังจบหลักสูตรนักเรียน 55 คน (ร้อยละ 74.3) อาจลองปฏิบัติด้วยตัวเองโดยไม่มีผู้กำกับดูแล 9 คน (ร้อยละ 12.2) มั่นใจในการทำหัตถการด้วยตนเอง 9 คน (ร้อยละ 12.2) ยังต้องการผู้กำกับ 1 คน (ร้อยละ 1.3) ไม่มั่นใจที่จะทำหัตถการเลย

สรุป ระหว่างฝึกปฏิบัติงานในภาควิชาวิสัญญี นักศึกษาแพทย์ปีที่ 5 ควรได้รับโอกาสในการฝึกใส่ท่อช่วยหายใจอย่างน้อย 3 ครั้ง เพื่อให้เกิดความสำเร็จในการเรียนรู้ทักษะเกินร้อยละ 90 **เชียงใหม่เวชสาร 2564;60(3):317-23. doi: 10.12982/CMUMEDJ.2021.28**

คำสำคัญ: หัตถการใส่ท่อช่วยหายใจ กราฟทักษะการเรียนรู้ นักศึกษาแพทย์ การวิจัยด้านแพทยศาสตรศึกษา