Estimation of the Proper Length of Orotracheal Intubation by Chula Formula

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The ideal proper position of the ETT was indicated when the distance from the tip of ETT to the carina and the distance from the upper border of the cuff of ETT to the vocal cords were found to be at least 2 cm.
Objective: *To assess whether Chula formula can predict the proper length of orotracheal intubation.*
Material and Method: *This was a prospective study of 100 patients (50 males and 50 females) who underwent general anesthesia with orotracheal intubation. The Chula formula was used to calculate the length of endotracheal tube (ETT) at the right upper canine = 4 + (body height/10) cm. After intubation, a fiberoptic bronchoscope was inserted into the ETT to measure the distance from the tip of ETT to the carina and the distance from the upper border of the cuff of ETT to the vocal cords.*
Results: *The mean length of oratracheal tube at the right upper canine calculated by Chula formula was 20.8 cm in males and 19.6 cm in females. The mean distance from the tip of ETT to the carina was 4.1 cm in males and 3.0 cm in females. The mean distance from the upper border of the cuff of ETT to the vocal cords was 4.5 cm in males and 4.6 cm in females.*

There were 99 of 100 patients who had the tip of ETT was placed at least 2 cm cephalad to the carina, in only one female patient that the distance from the tip of ETT to the carina was found to be 1.9 cm. In every patient, it was found that the upper border of the cuff of ETT was placed at least 2 cm below the vocal cords.
Conclusion: *In the present study, the Chula formula could be used to predict the proper length of orotracheal intubation in 99 of 100 patients.*

Keywords: *Length, Orotracheal intubation, Chula formula*

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Tracheal intubation is commonly required in anesthetic practices and critical care medicine. A malpositioned endotracheal tube (ETT) is a potential hazard for intubated patient. Insertion of an ETT which is too long may lead to right endobronchial intubation which is associated with left-sided atelectasis and right-sided tension pneumothorax[1-3]. On the contrary; insertion of an ETT which is too short may lead to accidental extubation, vocal cords trauma and laryngeal paralysis as a result of pressure injury by the cuff of ETT[4].

Conrardy et al[5] demonstrated that flexion and extension of the neck might result in a mean movement of 1.9 cm of the tip of ETT toward and away from the carina. Therefore, the proper position of ETT has been determined: the tip of ETT should be located at the midpoint of the trachea, and it should be placed at least 2 cm cephalad to the carina to reduce the risk of mainstem bronchial intubation with patient's head movement; and the proximal end of the cuff of ETT should be placed at least 2 cm below the vocal cords to reduce any impingement on the vocal cords when the patient moves his/her neck.

Several formulas and other methods have been proposed to estimate the optimal ETT length for tracheal intubation[7-14]. The presented preliminary study[6] (Abstract, the Journal of the Medical Association of Thailand 2005, 88; 775-81) found that there were correlations between the length of 2 cm above the carina to the right upper canine and the body height of

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the patient. The relation is formed into a formula named "*Chula formula*":

Length of orotracheal tube = 4 + Height/10 cm

The aim of the present study was to access whether the Chula formula could be used to predict the optimal length of ETT for orotracheal intubation.

Material and Method

The protocol of the present prospective study was approved by the Ethics Committee of King Chulalongkorn Memorial Hospital and written informed consent was obtained from each recruited subject.

One hundred Thai patients, 50 males and 50 females, who required orotracheal intubation for general anesthesia, were recruited into the present study. All patients were above 20 yr, ASA physical status I and II. The patients who had anatomical defects in the face or the neck or upper airway or pulmonary disease that was unable to tolerate hypoxia were excluded from the study.

Before the present study, the length of oral ETT (Portex) was calculated by Chula formula (4 + body height/10) and marked on the side of the ETT. With the patient's head rested on a standard pillow, general anesthesia was inducted and muscle relaxation was given. Then laryngoscope was applied. An ETT number 7.0 for females or 8.0 for males was orally intubated by an anesthesiologist. They placed the mark (that was calculated by Chula formula) on the side of the ETT that lay at the right upper canine of the patient. Capnography was used to document the placement of the ETT within the trachea.

After five min of ventilation with 2% Isoflurane in 100% oxygen 6 L/min, the ventilator tubing was disconnected from the ETT and a fiberoptic bronchoscope (Olympus) was passed through the ETT. When the bronchoscope tip was positioned at the carina, the tip of ETT and the vocal cords (the laryngoscope was used to identify the light of bronchoscope at the vocal cords), the consensus about the best positions were discussed between the two anesthesiologists, and the sequential mark with tapes around the bronchoscope tube were performed at the ETT orifice as mark 1, mark 2 and mark 3 (Fig. 1A, 1B and 1C; respectively).

The bronchoscope was then removed, and ventilation recommenced. Then the authors used a ruler to measure the distance in centimeter. Three distances were measured and calculated (Fig. 2):

1. The distance from the tip of ETT to the carina (mark 1- mark 2).

2. The distance from the vocal cords to the carina or tracheal length (mark 1- mark 3).

3. The distance from the upper border of the cuff of ETT to the vocal cords (mark 2- mark 3 - 6.5 for ETT number 8.0 and mark 2 - mark 3 - 6 for ETT number 7.0, Fig. 3A and 3B; respectively).

The ideal proper position of the ETT was indicated when the distance from the tip of ETT to the carina and the distance from the upper border of the cuff of ETT to the vocal cords were found to be at least 2 cm. If the ETT was not found in the proper position, the ETT should then be adjusted.

All data were analyzed by descriptive statistics SPSS program version 10.0. The data was presented by mean $\pm$ SD, number of patient and percent. As for

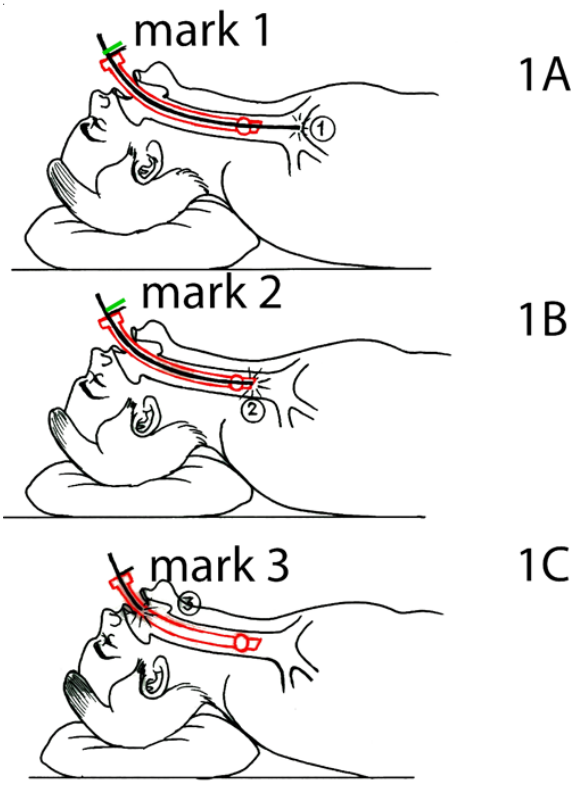


Fig. 1 The three marks of measurement at the ETT orifice
1A: When the bronchoscope tip was positioned at the carina, tapes around the bronchoscope tube were performed as mark 1
1B: When the bronchoscope tip was positioned at the tip of ETT, tapes around the bronchoscope tube were performed as mark 2
1C: When the bronchoscope tip was positioned at the vocal cords, tapes around the bronchoscope tube were performed as mark 3
(ETT = endotracheal tube)

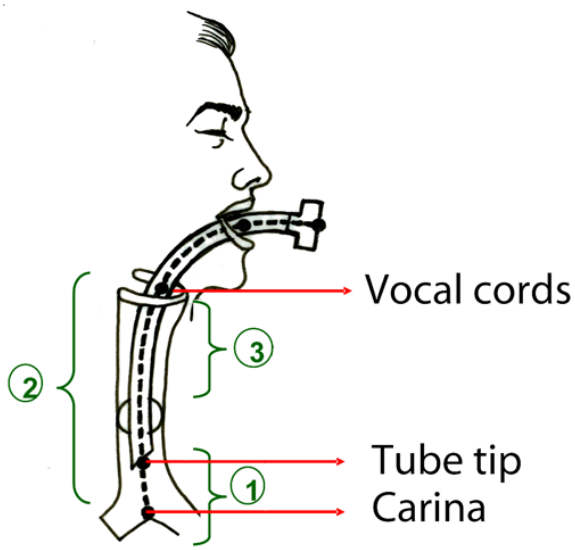


Fig. 2 Three distances were measured and calculated
1 = The distance from the tip of ETT to the carina
2 = The distance from the vocal cords to the carina or tracheal length
3 = The distance from the upper border of the cuff of ETT to the vocal cords
(ETT = endotracheal tube)

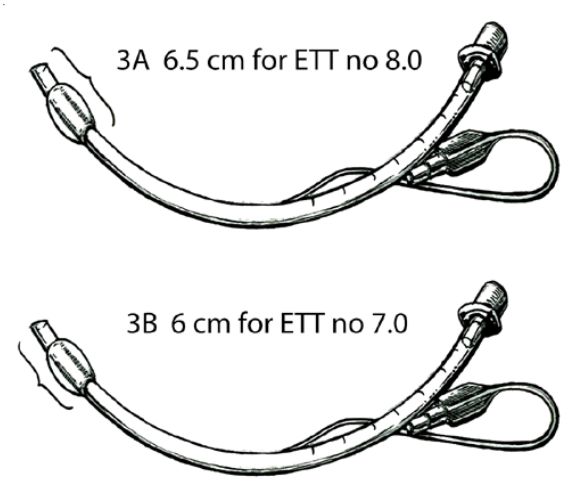


Fig. 3 The distance from the upper border of the cuff to the tip of ETT:
3A: 6.5 cm for ETT number 8.0 (Portex)
3B: 6 cm for ETT number 7.0 (Portex)
(ETT = endotracheal tube)

the calculation of the sample size, the authors estimated a 40% incidence of ETT malposition, based on reported rates of 11-43% from previous studies[6-10]. The authors found that at least 93 patients were minimally required to give 95% power to detect a reduction in this incidence from 40% to 10%. $P < 0.05$ was considered statistical significance.

Results

The demographic data of the subjects, 50 males and 50 females, are exhibited in Table 1. The mean length of oral ETT that calculated from the Chula formula was 20.8 ± 0.7 cm in males and 19.6 ± 0.5 cm in females. The minimum length of oral ETT was 18.8 cm and the maximum length of oral ETT was 22.0 cm (Fig. 4). There were three patients (one male and two females) who had no right upper canine and the authors used the alveolar ridge at the point of the right upper canine and placed the mark on the side of the ETT.

The distance from the tip of ETT to the carina was 4.1 ± 1.0 cm in males and 3.0 ± 0.7 cm in females the minimum distance was 1.9 cm in one female; the maximum distance was 7.5 cm in one male (Fig. 5). The tracheal length was 15.1 ± 0.9 cm in males and 13.7 ± 1.1 cm in females. The shortest trachea was 11.9 cm in female. The distance from the upper border of the cuff of ETT to the vocal cords was 4.5 ± 1.3 cm in males and 4.6 ± 1.3 cm in females; the minimum distance was 2 cm in one male; the maximum distance was 7.5 cm in one male and one female. None had the distance from the upper border of the cuff of ETT to the vocal cords less than 1.9 cm (Fig. 6).

The proper length of orotracheal intubution was defined that the tip of ETT should be placed at least two cm cephalad to the carina and the upper border of the cuff of ETT should be placed at least two cm below the vocal cords. Therefore, the rate of success for placing ETT to its proper length was 99% (99 from 100 patients) according to the Chula formula. Only one female patient had her ETT adjusted about 0.1 cm.

Discussion

In 1976, Conrardy et al reported an average length of 3.8 cm movement of ETT toward the carina when the patent's head was moved from full extension to full flexion (in some patients this movement reached as far as 6.4 cm). This resulted in an average movement of ETT of about 1.9 cm when the head is moved from its neutral position to full extension. It is unlikely that extubation would occur if the tip of ETT is placed at the middle of the trachea or at least 2 cm above the carina[5].

According to the measured data of the present study, the results showed no endobronchial intubation or impingement of the ETT cuff on the vocal cords.

The average distances from the tip of ETT to the carina was 4.1 cm in males 3.0 cm in females; and, the average distances from the vocal cords to the upper border of ETT cuff was 4.5 cm in males, 4.6 cm in females. Only one female had ETT manipulated after an initial insertion because the distance from the tip of ETT to her carina was less than 2 cm (1.9 cm). This finding suggested that the Chula formula is about 99% accurate in estimation of the proper position for orotracheal intubation, similar to a reference from Conrardy et al.

A variety of techniques have been used or suggested to confirm the proper placement of the ETT. Subhash et al described the cuff palpitation at the suprasternal notch to confirm that the tip of ETT is not in the mainstem bronchus; however, this may occur with an inadvertent esophageal intubation[7,8]. Ford et al described a technique of passing ETT so that its cuff advanced 2 cm beyond the vocal cords, but this maneuver should be attempted when the intubation is performed under direct laryngoscope[9]. Brunel et al reported that 60% of mainstem bronchial intubations occurred despite the presence of equal breath sounds from the bilateral chest[10]. Schwartz et al verified the proper position with an auscultation of bilateral breath sounds, symmetrical chest expansion and palpitation of the cuff at the suprasternal notch; however, in 15.5% of the cases according to radiological assessment ETT malposition was found with a higher incidence in females than males[11]. Roberts et al used a 21-cm tube mark for women and 23-cm tube mark for men which can ensure 90% safe depth of placement of orotracheal intubation but these reference marks did not result in ideal positioning of ETT in 33.4% of Asian cases[12,13]. Kazuna et al suggested that the fiberoptic bronchoscope is more reliable than chest auscultation to confirm the position of ETT but it is not routinely performed[14].

The proper placement of ETT does not only depend on its tip and its upper border it should be at least 2 cm away from the carina and the vocal cords, but also on the relationship between the tracheal length and the distance from the upper border of the cuff to the tip of ETT (Fig. 3). The tracheal length must be approximately 4 cm longer than the distance, so that laryngeal trauma and mainstem bronchial intubation will not occur. A patient who has a short trachea but was chosen to have a longer distance from the upper border of the cuff to the tip of ETT, the cuff of ETT may impinge on the vocal cords if the anesthesiologist intends to place the tip of ETT above the carina at least 2 cm. On the other hand, if the anesthesiologist intends to place the cuff of ETT at least 2 cm below the vocal cords, the tip of ETT could be close to the carina. For example, in a patient whose tracheal length is about 11 cm, the distance from the upper border of the cuff to the tip of ETT must be shorter than 7 cm. In fact, the

Table 1. Demographic data and length of oral ETT calculated from the Chula formula

	Male	Female
Age (yr)	52.4±13.4 (29-78)	46.8±14.1 (21-75)
Weight (kg)	66.3±14.2 (45-100)	55.3±8.2 (38-74)
Height (cm)	166.1±16.7 (154-180)	156.1±5.6 (148-173)
Length of oral ETT that calculated from Chula formula (cm)	20.8±0.7 (19.4-22)	19.6±0.5 (18.8-21.3)

Value present mean ± SD (minimum – maximum)
ETT = endotracheal tube

Table 2. Three measured and calculated distances

	Male (n = 50)	Female (n = 50)
The distance from the tip of ETT to the carina (cm)	4.1±1.0 (2-7)	3.0±0.7 (1.9-5)
Tracheal length (cm)	15.1±0.9 (13-17.1)	13.7±1.1 (11.9-16)
The distance from the upper border of the cuff of ETT to the vocal cords (cm)	4.5±1.3 (2-7.5)	4.6±1.3 (2.1-7.5)

Value present mean ± SD (minimum – maximum)
ETT = endotracheal tube

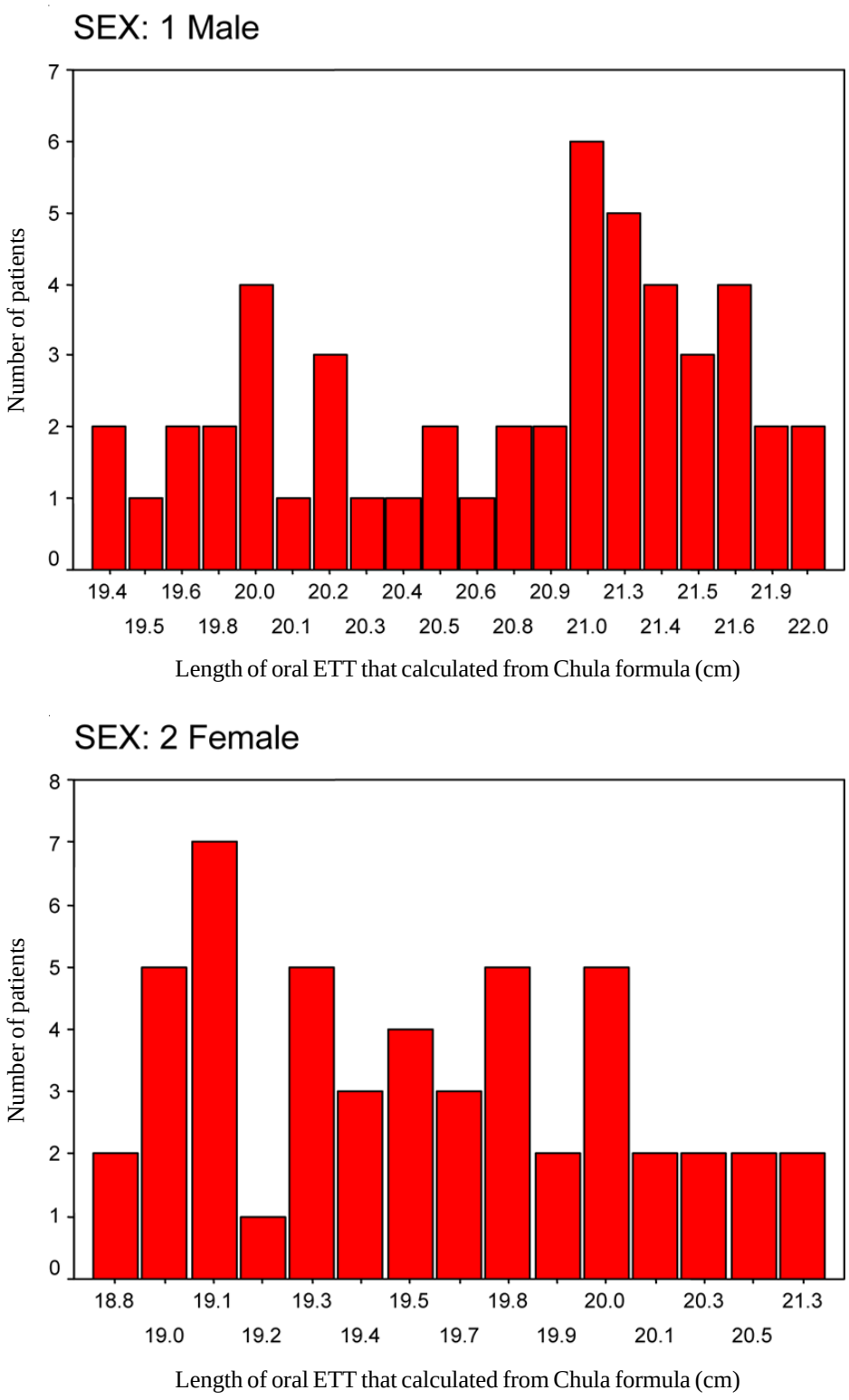


Fig. 4 The frequency (n) of the length of oral ETT that calculated from the Chula formula (cm) in males and females (ETT = endotracheal tube)

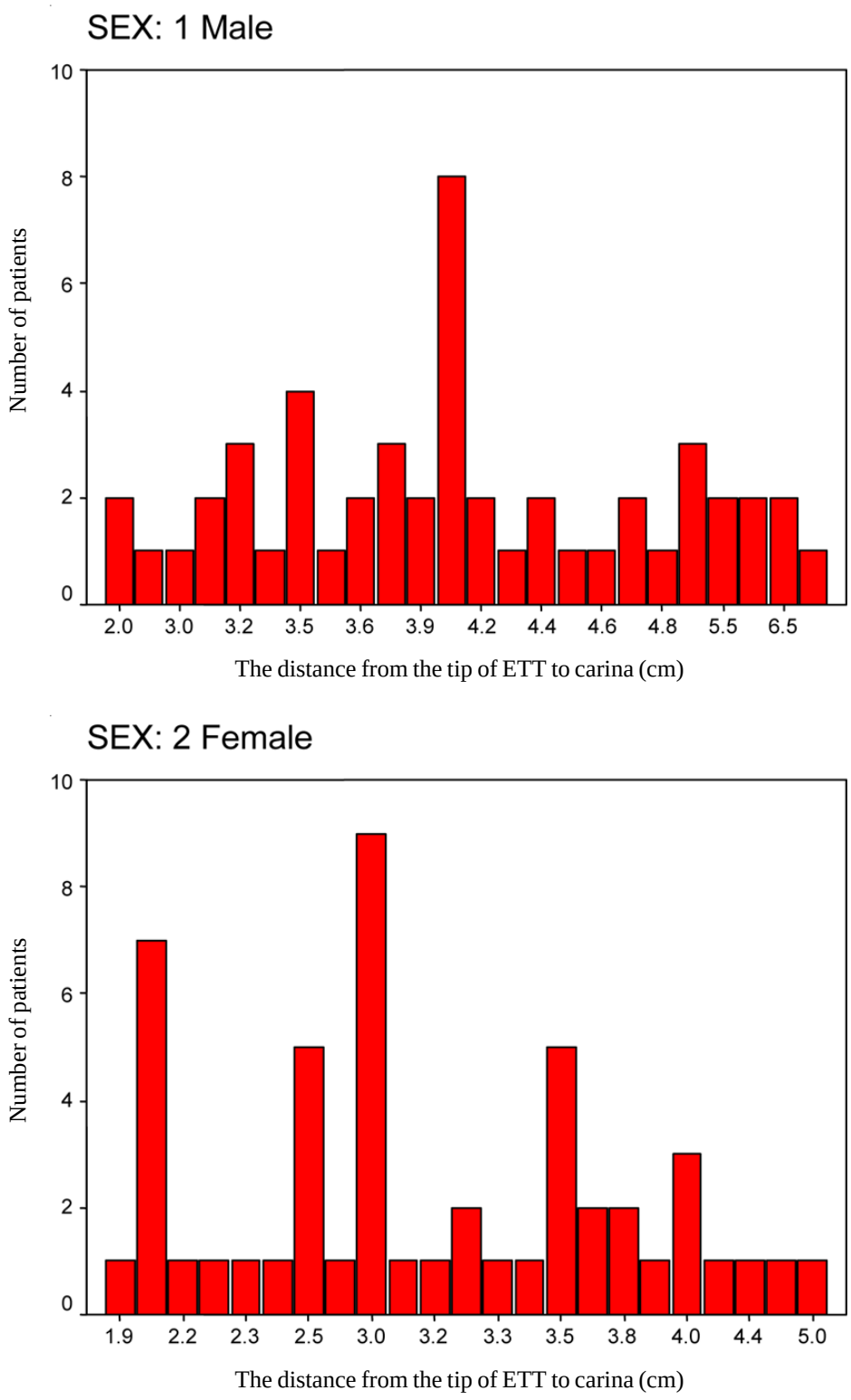
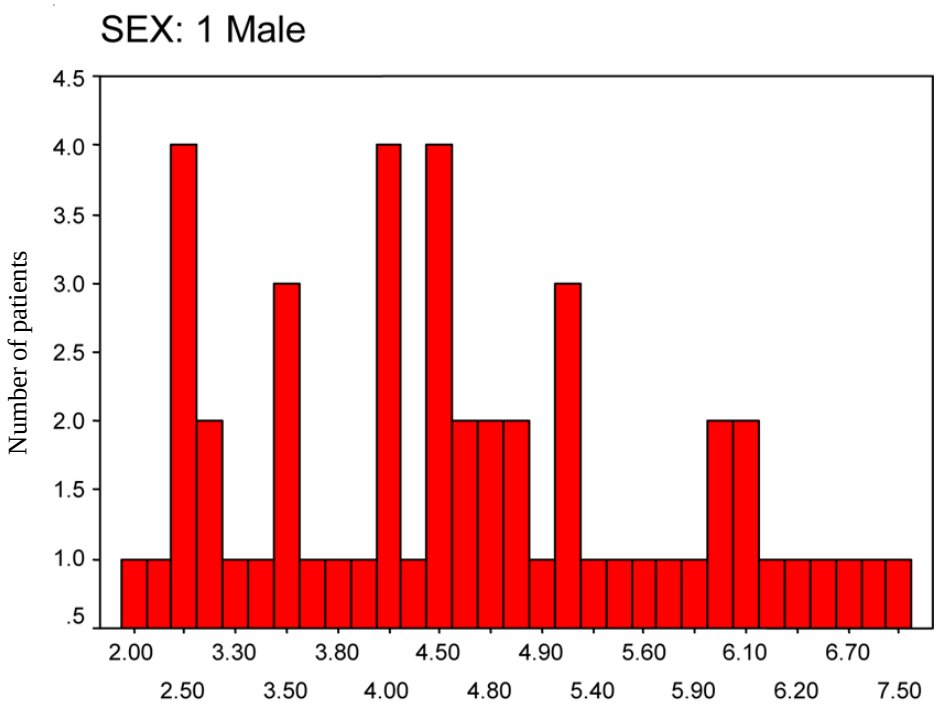


Fig. 5 The frequency (n) of the distance from the tip of ETT to carina (cm) in males and females (ETT = endotracheal tube)



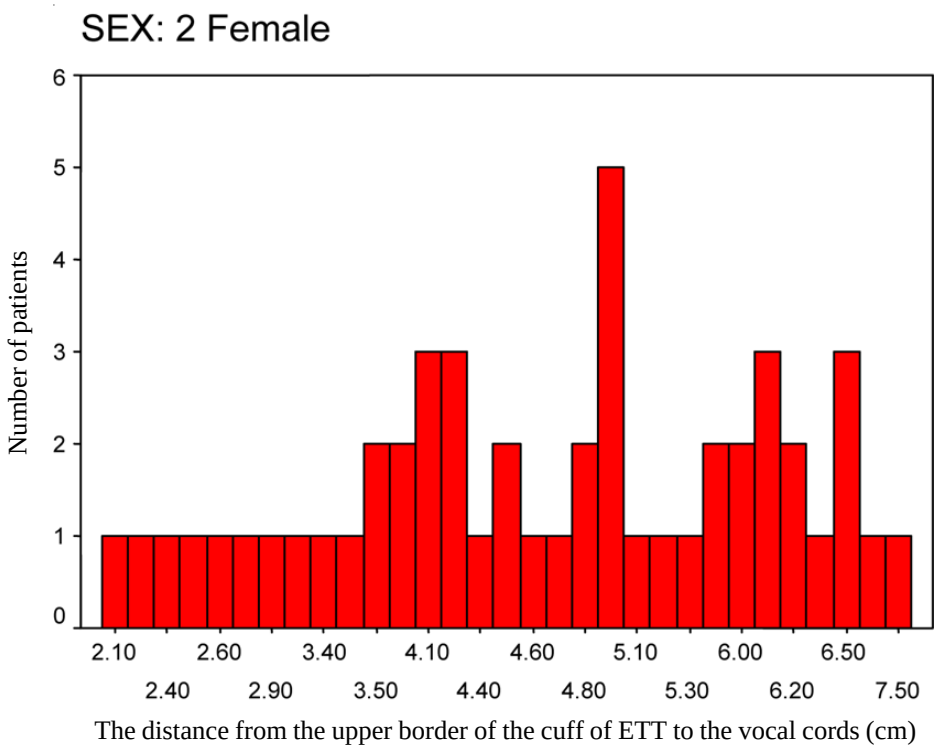


Fig. 6 The frequency (n) of the distance from the upper border of the cuff of ETT to the vocal cords (cm) in males and females
(ETT = endotracheal tube)

distance from the upper border of the cuff to the tip of ETT varies between 5.7-7.5 cm, according to the size and the brand of ETT (for example, the distance from the upper border of the cuff to the tip of Portex ETT is approximately 6-6.5 cm; Fig. 3).

From the authors' previous study of measurement the airway distances with fiberoptic bronchoscope in Thai patients, it was found that there were correlations between the distance from the right upper canine to the carina and the body height (Pearson correlation 0.707; $p < 0.01$), and also the authors got a formula of linear regression that was calculated by subtracting two cm from the distance from the right upper canine to the carina; hence, the authors named it "Chula formula". The authors also suggested that the patients who were short and had short trachea should be intubated by a shorter distance from the upper border of the cuff to the tip of the ETT which decreases the risk of vocal cords injury when they extended their heads.

One limitation of the Chula formula was that the patients who do not know their height, the proper length of the ETT cannot be calculated. The other limitation is that the authors had not tried to study any patients who had anatomical defect in the upper airway.

The present formula can be applied in the operating room, intensive care unit and emergency room. Because in difficult airway intubation patient examples: in patients whose laryngoscopic view is class 3 or 4, in the patient who cannot be used for direct intubation and those who need light wand for intubation, the anesthesiologist or medical physician cannot identify the vocal cords to pass down the ETT so that the cuff may advance 2-3 cm beyond the vocal cords in routine practice[15]. Then the Chula formula calculates the proper length of ETT in orotracheal intubation.

Conclusion

The Chula formula is useful to determine the optimal position of ETT in most patients who require orotracheal intubation. The success rate of a proper positioned ETT is achieved when the tip of ETT was above the carina at least 2 cm and the upper border of ETT cuff was also at least 2 cm below the vocal cords, which was about 99% in the present study.

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ความลึกในการใส่ท่อช่วยหายใจทางปากที่เหมาะสมโดยใช้สูตรจุฬา

อัญชลี เตชะนิเวศน์, กัญญา คำวิลัยศักดิ์, ศันสนีย์ สำราญเริญ

วัตถุประสงค์: *เพื่อทดสอบสูตรจุฬาว่าสามารถคาดคะเนความลึกที่เหมาะสมของการใส่ท่อช่วยหายใจทางปากในคนไทยได้*

วัสดุและวิธีการ: *ทำการศึกษาในผู้ป่วย 100 คน (ชาย 50 คน และ หญิง 50 คน) ที่มารับบริการระงับความรู้สึกที่ต้องใส่ท่อช่วยหายใจโดยใช้สูตรจุฬาคำนวณหาความลึกของท่อช่วยหายใจ และทุกคนจะถูกใส่ให้ความลึกเท่ากับที่คำนวณไว้ที่ตำแหน่งฟันเขี้ยวบนขวา*

ความลึกของท่อช่วยหายใจทางปาก = 4 + (ความสูง (ซม.) / 10) ซม.

หลังการใส่ท่อช่วยหายใจ ใช้ fiberoptic bronchoscope ใส่เข้าในท่อช่วยหายใจ เพื่อวัดระยะทางจากปลายท่อช่วยหายใจถึง carina และระยะจากสายเสียงถึงขอบบนสุดของ cuff ของท่อช่วยหายใจ และระยะทั้งสองต้องไม่ต่ำกว่า 2 ซม. จึงถือว่าท่อช่วยหายใจมีความลึกที่เหมาะสม

ผลการศึกษา: *ความลึกเฉลี่ยที่คำนวณจากสูตรจุฬาเท่ากับ 20.8 ซม.ในผู้ป่วยชาย และ 19.6 ซม. ในผู้ป่วยหญิง ระยะทางเฉลี่ยจากปลายของท่อช่วยหายใจถึง carina เท่ากับ 4.1 ซม.ในผู้ป่วยชาย และ 3.0 ซม. ในผู้ป่วยหญิง ระยะทางเฉลี่ยจากสายเสียงถึงขอบบนของ cuff ของท่อช่วยหายใจเท่ากับ 4.5 ซม.ในผู้ป่วยชาย และ 4.6 ซม. ในผู้ป่วยหญิง*

ผู้ป่วยจำนวนทั้งหมด 99 รายที่พบว่าปลายของท่อช่วยหายใจอยู่ในตำแหน่งอย่างน้อยที่สุด 2 ซม. เหนือ carina มีเพียงผู้ป่วยหญิง 1 ราย ที่พบว่าปลายท่อช่วยหายใจห่างจาก carina เท่ากับ 1.9 ซม. และผู้ป่วยทุกรายพบว่าขอบบนของ cuff ของท่อช่วยหายใจอยู่เหนือสายเสียงอย่างน้อย 2 ซม.

สรุป: *ในการศึกษาครั้งนี้พบว่าสูตรจุฬาสามารถใช้ในการใส่ท่อช่วยหายใจทางปากในคนไทยให้มีความลึกที่เหมาะสมได้สำเร็จถึงร้อยละ 99*