Original Article

First-Pass Success Rates of Endotracheal Intubation Using Ramped versus Supine Positioning in the Emergency Department

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Background: Endotracheal intubation is a common life-saving procedure performed in the emergency department. Recent studies have found that ramped positioning during intubation may present benefits over traditional supine positioning. However, the results of previous studies have differed depending on setting and study design.

Objective: The authors compared the first-pass success rates of ramped and supine positioning in intubation. Secondary outcomes included Cormack-Lehane grade of the glottic view and endotracheal intubation (ETI)-related adverse events in each position.

Materials and Methods: This was a prospective observational study of non-traumatic, non-arrest patients intubated by trained emergency medicine residents or an experienced attending emergency physician at the emergency department between April 2018 and April 2019. The intubation position used – i.e., ramped (head of the bed elevated 20 to 30 degrees) or supine – was decided upon by the attending physician.

Results: A total of 267 patients were enrolled, 135 (50.6%) and 132 (49.4%) who were intubated in the ramped and supine position, respectively. The first-pass success rates of patients the two positions were similar (ramped = 86.7% vs. supine = 78.0%, $p = 0.066$). Multivariate analysis showed no significant relationship between position and first-pass success. However, intubation in the ramped position resulted in better laryngoscopic visualization (81.5% vs. 62.9%, $p = 0.001$), though a higher percentage of patients experienced minor airway trauma (3% vs. 0% $p = 0.046$).

Conclusion: Ramped positioning improved laryngoscopic visualization but did not improve first-pass success compared with supine positioning for intubation performed at the emergency department.

Keywords: Endotracheal intubation, First-pass success, Ramped position, Patient positioning

J Med Assoc Thai 2020;103(Suppl. 6): 51-7
Website: http://www.jmatonline.com

Endotracheal intubation is an essential life-saving procedure commonly performed in critically ill patients in emergency departments (ED) worldwide[1-3]. Notwithstanding, this procedure may result in endotracheal intubation (ETI)-related adverse events including airway trauma, hypoxemia, esophageal intubation, hypotension, aspiration, cardiac arrest, and death[4-6]. Multiple intubation attempts are associated with increases in these complications[7-9]. Accordingly physicians should prioritize successful intubation during the first attempt in order to minimize the occurrence of these adverse events[4,10].

A proper intubation positioning is essential for optimal laryngeal visualization during laryngoscopy[11,12]. The "sniffing position" (neck flexed forward and head extended), in which the body is in the supine position, is widely recognized as the standard intubation position for optimal glottic exposure[13,14]. Alternative laryngoscopy positions have recently been proposed to increase the chances of first-pass success. Previous studies[15-20] have compared ETI among critically ill adults placed in the conventional supine position with that performed in the "ramped", "head-elevated", or "non-supine" position, in which the torso and head are elevated together toward the point at which the external auditory meatus and sternal notch are aligned[15,16,21]. However, the findings of these studies have differed depending on setting and study design. In our emergency department, we have recently begun performing intubation using ramped positioning.

The goal of our study was to compare first-pass success, Cormack-Lehane grade of the glottic view, and ETI-related complications between emergency intubation performed in the ramped and supine position by trained emergency medicine (EM) residents and experienced

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How to cite this article: Chanthawatthanarak S, Tangpaisarn T, Kotruchin P, Phungoen P, Ienghong K, Apiratwarakul K. First-Pass Success Rates of Endotracheal Intubation Using Ramped versus Supine Positioning in the Emergency Department. J Med Assoc Thai 2020;103(Suppl.6): 51-7.

attending emergency physicians in the emergency department.

Materials and Methods

Study design and selection of participants

This single-center prospective observational study was conducted in the ED of a tertiary care university hospital with approximately 70,000 annual ED visits (Khon Kaen University's Srinagarind Hospital; Khon Kaen, Thailand) from April 2018 to April 2019 (13 months). The authors enlisted non-traumatic, non-arrest patients undergoing endotracheal intubation at our emergency department. Patients were excluded if they were ≤18 years of age. The study protocol was approved from the Khon Kaen University Ethics Committee in Human Research (HE611138).

Sample size calculation

The sample size in the present study was calculated by estimating the difference between two proportions[22]. The authors hypothesized that the difference in first-pass success between the two groups would be approximately 15%[17]. Hence, we determined that the required sample size was 138 patients per group, with a confidence of 95% and power of 80%.

Methods and measurements

Once the physician decided to intubate, pre-oxygenation with routine monitoring (including pulse oximetry, electrocardiography, and automatic blood pressure measurement) was performed. The decision as to whether or not to perform rapid-sequence induction (RSI) was based solely upon clinical judgment. Prior to laryngoscopy, physicians were asked to set the head of the patient's bed to a position of their choosing: supine or ramped. Patients in the supine position were placed on a flat bed with a pillow under their heads to elevate the occiput. The ramped position is defined as the head of the bed raised to an angle of 20 to 30 degrees relative to the floor (ramp zone), as shown in Figure 1. If intubation failed after 3 attempts, it was considered "failed intubation" and a supraglottic airway/airway team/cricothyroidotomy was deployed, depending on the situation.

Operator training

Prior to study initiation, all involved emergency medicine residents and staff were trained on how to position and intubate patients in the ramped and supine positions by experienced faculty during an airway practice session. The practice session consisted of an approximately 3-hour long airway management concept lecture, a video demonstration, and hands-on intubation training with high-fidelity adult mannequins (Laerdal Medical Incorporation, Norway) in both ramped and supine positions.

Data collection

After each intubation, the physician completed the airway registry form, which included patient demographics, operator level, indication for intubation, difficult airway characteristics, bed angle during intubation, method of intubation, paralytic agent, sedative agent, number of attempts at intubation, Cormack-Lehane grade of the glottic view, and ETI-related adverse events of each intubation attempt. An endotracheal intubation attempt was defined as insertion of the device into the mouth regardless of whether an attempt was made to pass the endotracheal tube. Successful intubation was defined as passing the endotracheal tube into the trachea, as confirmed by end-tidal CO_2 ($EtCO_2$).

Figure 1. The tool used to measure the angle of the bed head (a small plumb attached to a protractor). The ramped zone is displayed in green (20 to 30 degrees).

During the study period, two authors (TT, PP) reviewed the airway registry form every weekday. If the form had any missing data, it was returned to the physician for completion.

Outcomes

The primary outcome was the difference in first-pass success between ramped and supine positioning. Secondary outcomes included Cormack-Lehane grade of the glottic view and endotracheal intubation (ETI)-related adverse events in each position.

Data analysis

Categorical variables were expressed as percentages. Continuous data were expressed as mean and SD. Differences in baseline characteristics between the two groups were compared using an independent sample t-test. A Pearson's Chi-squared test was applied to compare outcomes between patients in the two groups. A two-tailed $p<0.05$ was considered statistically significant. Factors associated with first-pass success were analyzed using univariate and multivariate binary logistic regression. Clinically relevant factors or those with p-values of less than 0.20, based on univariate logistic regression analysis were included in subsequent multivariate logistic regression analysis. All data analyses were performed using Stata version 10 (StataCorp, College Station, TX).

Results

Characteristics of the study subjects

A total of 465 patients were intubated by EM residents at the ED during the study period. Of those, 173 did not meet inclusion criteria due to cardiac arrest (n = 148) or trauma (n = 51), and 25 were excluded due to age (<18 years; n = 25), leaving 267 who underwent analysis (Figure 2). Overall, the mean age was 67.46 years with males comprising 62.5% of patients. The most common indication for intubation was hypoxemic respiratory failure (51.7%), followed by cardiac failure (13.1%) and sepsis (10.9%). Most patients were intubated via direct laryngoscope (86.9%). Induction was performed in 77.2% of cases, with paralysis induced in 23.6%. Of those, 135 (50.5%) were intubated in the ramped position. Details regarding patient demographics, indications for intubation, and operator characteristics are listed in Table 1. There were no significant differences between groups with respect to age, sex, O_2 saturation before preoxygenation, systolic blood pressure prior to induction, difficult airway characteristics, laryngoscopic device, or operator level. However, there were significant differences in terms of indication for intubation, sedative used, and paralytic used.

Main results

The overall first-pass intubation success rate was 82.4%. It was higher in the ramped group than in the supine group (86.7% vs. 78.0%, p = 0.066), but the difference was not statistically significant. Multivariate analysis showed no significant relationship between position and first-pass success. Factors independently associated with first-pass success were greater operator experience (AOR 3.256; 95% CI: 1.088, 9.741) and laryngoscopic view grade I-II (AOR 3.256; 95% CI: 1.088, 9.741), as shown in Table 3. The factor independently associated with decreased first-pass success was limited neck mobility (AOR 0.093; 95% CI 0.020, 0.443), as shown in Table 4.

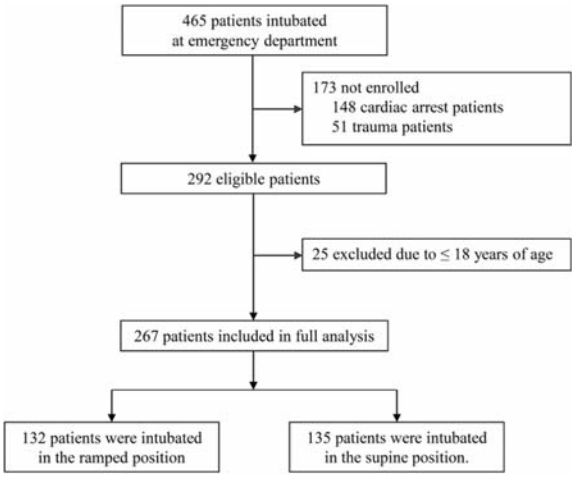

Figure 2. Study flow chart.

In terms of secondary outcomes, intubation in the ramped position resulted in better laryngoscopic visualization when compared to that in the supine position (81.5% vs. 62.9%, p = 0.001), but a higher percentage of patients experienced minor airway trauma (3% vs. 0%, p = 0.046). After multivariate analysis, factors associated with improved laryngoscopic visualization were ramped positioning and the use of a video laryngoscope device.

Discussion

The present study demonstrated that intubation in the ramped position resulted in better laryngoscopic visualization than in the supine position. Nevertheless, the first-pass success rates of the two techniques were similar. After controlling confounding factors, the authors found that the independent factors associated with an increased in first-pass success rate were greater operator experience and laryngoscopic view grade I-II.

The results of previous studies that have examined the first-pass success rates of patients undergoing endotracheal intubation in the ramped position have varied. While some found the ramped position to be beneficial[8,17,21]. Semler et al found a lower first-pass success rate in critically ill patients intubated in the ramped position in the intensive care unit. However, a recent multi-center retrospective study from Bernhard et al revealed that the first-pass success rates between non-supine and supine groups were similar, which was in-line with our findings. These contrasting results may be due to differences in the degree of head elevation among trials. Turner et al found that the first-pass success was highest in patients intubated with the head of the bed elevated to 45 degrees or higher. Consequently, every 5-degree increase increased the likelihood of first-pass success[17]. Notably, the head of the bed in the present study was elevated to just 20 to 30 degrees. It is possible that increasing the angle of head elevation would have increased first-pass success in patients intubated in the ramped position.

Over the past several years, the ramped position has been accepted as an alternative intubation position for obese patients, and its use in intubation in the ED has increased[18]. Half of the operators in our study preferred to perform intubation with the patient in the ramped position. Further analysis (Table 5) revealed that diagnoses of hypoxemic respiratory failure or heart failure were associated with intubation performed using ramped positioning. This is because many patients with these conditions are unable to tolerate being in the supine position, as it causes pulmonary function and symptoms (i.e., hypoxemia, and dyspnea) to worsen. The ramped position physiologically improves the patient's pulmonary function by increasing ventilation-perfusion matching[15] making it a more attractive option for physicians or operators in these cases.

Regarding complications, a higher number of patients experienced airway trauma in the ramped group. However, there was no significant difference between the groups in this respect after multivariate analysis. Furthermore,

Table 1. Patient demographics, indication for intubation, and operator characteristics

Characteristics	Overall (n = 267)	Supine (n = 132)	Ramped (n = 135)	*p*-value
Age, years ±SD	67.46±14.88	67.14±14.28	67.79±15.50	0.720
Male sex, n (%)	167 (62.5)	85 (64.4)	82 (60.7)	0.537
O_2 saturation before preoxygenation, %	89.18±12.38	89.3±12.21	89.0±12.59	0.815
SBP before induction, mmHg	138.51±38.03	134.5±38.72	131.4±34.46	0.147
Indication for intubation, n (%)				0.002
Hypoxemic respiratory failure	138 (51.7)	59 (44.7)	79 (58.5)	
Cardiac failure	35 (13.1)	13 (12.1)	22 (16.3)	
Sepsis	29 (10.9)	16 (9.8)	13 (9.6)	
Altered mental status	27 (10.1)	19 (14.4)	8 (5.9)	
Stroke	24 (9.0)	19 (14.4)	5 (5.2)	
Other	14 (2.5)	6 (4.5)	8 (5.9)	
Difficult airway characteristics, n (%)				0.241
Limited mouth opening	12 (4.5)	8 (6.1)	4 (3.0)	
BMI >30	12 (4.5)	7 (5.3)	5 (3.7)	
Limited neck mobility	10 (3.7)	6 (4.5)	4 (3.0)	
Airway mass	5 (1.9)	3 (2.3)	2 (1.5)	
OSA	3 (1.1)	2 (1.5)	1 (0.7)	
Bleeding per oral	3 (1.1)	3 (2.3)	0 (0)	
Laryngoscopic device, n (%)				0.09
Direct laryngoscope	232 (86.9)	119 (90.2)	113 (83.7)	
Video laryngoscope	35 (13.1)	13 (9.8)	22 (16.3)	
Induction use, n (%)				<0.001
Midazolam	90 (33.7)	45 (34.1)	45 (33.3)	
Propofol	51 (19.1)	15 (11.4)	36 (26.7)	
Ketamine	29 (10.9)	7 (5.3)	22 (16.3)	
Etomidate	30 (11.2)	15 (11.4)	15 (11.1)	
Ketamine	29 (10.9)	29 (10.9)	22 (16.3)	
Diazepam	11 (4.1)	7 (5.3)	4 (3)	
Paralytic use, n (%)				0.003
Succinylcholine	53 (19.9)	18 (13.6)	35 (25.9)	
Rocuronium	10 (3.7)	3 (2.3)	7 (5.2)	
Operator level, n (%)				0.083
1st year resident	105 (39.3)	54 (40.9)	51 (37.8)	
2nd year resident	87 (32.6)	52 (39.4)	35 (25.9)	
3rd year resident/faculty staff	75 (28.1)	32 (24.2)	43 (31.9)	

Table 2. First-pass intubation success and endotracheal intubation-related adverse events rates

Variable	Supine (n = 132)	Ramped (n = 135)	OR (95% CI)	*p*-value
First-pass success, n (%)	103 (78.0)	117 (86.7)	1.830 (0.96, 3.488)	0.066
Laryngoscopic view, n (%)			0.385 (0.220, 0.674)	0.001
Grade I-II	83 (62.9)	110 (81.5)		
Grade III-IV	49 (37.1)	25 (18.5)		
Complication, n (%)				
Hypotension	9 (6.8)	7 (5.2)	0.747 (0.270, 2.069)	0.574
Airway trauma	0 (0)	4 (3.0)	0.498 (0.441, 0.562)	0.046
Aspiration	0 (0)	2 (1.5)	0.502 (0.445, 0.566)	0.160
Esophageal intubation	1 (0.8)	1 (0.7)	0.978 (0.061, 15.794)	0.987
Desaturation (SaO_2 <90%)	0 (0)	2 (1.4)	0.502 (0.445, 0.566)	0.160
Cardiac arrest within 30 min	3 (2.3)	1 (0.7)	0.321 (0.033, 3.125)	0.303
Number of intubation attempts, n (%)				0.195
1	103 (78.0)	117 (86.7)	1	
2	25 (18.9)	16 (11.9)	0.565 (0.266, 1.170)	
3	3 (2.3)	2 (1.5)	0.588 (0.048, 5.240)	
≥4	1 (0.8)	0 (0)	0.889 (0.001, 34.667)	

Table 3. Logistic regression result on first-pass success

	OR (95% CI)	Adjusted OR (95% CI)
Age	1.014 (0.993, 1.035)	1.008 (0.985, 1.032)
Ramped position	1.830 (0.960, 3.488)	1.732 (0.826, 3.631)
Operator level		
Second year resident	0.842 (0.416, 1.703)	0.744 (.343, 1.613)
Third year resident	1.971 (0.817, 4.751)	3.256 (1.088, 9.741)
Laryngoscopic view grade I-II	4.969 (2.563, 9.634)	4.902 (2.243, 10.717)
Video Laryngoscope device	0.833 (0.340, 2.040)	0.478 (0.153, 1.497)
Induction use	1.562 (0.773, 3.156)	1.385 (0.600, 3.199)
Paralytic use	1.951 (0.827, 4.604)	2.014 (0.671, 6.044)
Limited neck mobility	0.127 (0.034, .468)	0.093 (0.020, 0.443)
Limited mouth opening	0.133 (0.040, .440)	0.397 (0.0897, 1.759)

Table 4. Logistic regression results per laryngoscopic view

	OR (95% CI)	Adjusted OR (95% CI)
Ramped position	2.598 (1.484, 4.546)	2.341 (1.304, 4.202)
Video Laryngoscope device	7.425 (1.735, 31.78)	6.747 (1.357, 33.550)
Paralytic use	2.806 (1.306, 6.027)	1.385 (0.603, 3.184)
Limited neck mobility	0.240 (0.066, 0.876)	0.345 (0.086, 1.386)
Limited mouth opening	0.175 (0.051, 0.599)	0.243 (0.066, 0.895)

Table 5. Factors associated with patients in ramped position

	OR (95% CI)	Adjusted OR (95% CI)
Operator level		
Second year resident	1.573 (0.886, 2.794)	1.726 (0.932, 3.195)
Third year resident	0.778 (0.434, 1.431)	0.859 (5.449, 1.643)
Video Laryngoscope device	1.782 (0.857, 3.707)	1.269 (0.539, 2.990)
Induction use	3.471 (1.859, 6.478)	2.128 (1.033, 4.384)
Paralytic use	2.387 (1.321, 4.314)	1.5146 (0.752, 3.050)
Indication for intubation		
Hypoxemic respiratory failure	5.088 (1.796, 14.413)	3.326 (1.086, 10.184)
Cardiac failure	6.431 (1.936, 21.356)	4.498 (1.252, 16.165)

the rates of other ETI-related complications in the two groups were also similar. These results indicate that after a brief training session, emergency medical residents were able to perform intubation with the patient in the ramped position safely and without increasing the risk of complications.

Strengths and limitations

One strength of the present study is that it was performed prospectively, allowing us to control the head angle (20 to 30 degrees) of all patients intubated in the ramped position. Another is that it was conducted in the emergency department, with every patient triaged into a resuscitation room where there were sufficient resources in terms of both medical personnel and equipment. This allowed both groups to be intubated in the same controlled environment. However, there were some potential limitations. First, there was a limited used in rapid sequence intubation (RSI), which is the method of choice in ED airway management[23]. As a consequence, RSI was performed in just 30% of patients in the present study. This may limit the generalization of our results to settings in which RSI intubation is infrequently performed. However, there were other reasons for the limited use of paralytic agents in our study. First, patients who were near death and required treatment based on the crash airway algorithm were included in the study. Second, performing RSI required a team of at least 2 doctors and 2 nurses, which was not possible due to the high volume of patients at the ED.

Conclusion

Ramped positioning improved laryngoscopic visualization, but not the intubation success rate, compared

with supine positioning when performed in emergency settings. The independent factors associated with an increased in first-pass success rate were greater operator experience and laryngoscopic view grade I-II.

What is already known in this topic?

The "sniffing position" in which the body is in the supine position, is widely recognized as the standard position for endotracheal intubation. However, recent studies have demonstrated benefit of ramped positioning intubation over traditional supine positioning.

What this study adds?

The present study demonstrated that intubation in the ramped position resulted in better laryngoscopic visualization than that the supine position. Nevertheless, first-pass success rates and other ETI-related complications of the two techniques were similar. These results indicate that after a brief training session, emergency medical residents were able to perform intubation with the patient in the ramped position safely and without increasing the risk of complications.

Acknowledgements

The authors would like to thank Dylan Southard for his editing of this manuscript.

This study was granted by Faculty of Medicine, Khon Kaen University, Thailand (Grant Number IN61250).

Potential conflicts of interest

The authors declare no conflict of interest.

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ผลของการใส่ท่อช่วยหายใจในท่าศีรษะสูงและท่านอนหงายที่ห้องฉุกเฉิน

สิวิชญ์ ฉันทะวัฒนรักษ์, ธนัท ทั้งไพศาล, แพรว โคตรุฉิน, ปริวัฒน์ ภู่เงิน, กมลวรรณ เอี้ยงฮง, กรกฎ อภิรัตน์วรากุล

ภูมิหลัง: การใส่ท่อช่วยหายใจในห้องฉุกเฉินนิยมใส่ในท่านอนศีรษะราบ แต่ในการศึกษาระยะหลังพบว่าการใส่ท่อช่วยหายใจในท่าศีรษะสูงมีข้อดีเหนือกว่าท่านอนศีรษะราบ อย่างไรก็ตามผลการศึกษาก่อนหน้านี้ยังมีความแตกต่างกันในวิธีการศึกษาและกลุ่มประชากร

วัตถุประสงค์: วัตถุประสงค์หลักเพื่อเปรียบเทียบอัตราการใส่ท่อช่วยหายใจสำเร็จในครั้งแรกระหว่างท่าศีรษะสูงและท่าศีรษะราบ วัตถุประสงค์รองเพื่อศึกษาความแตกต่างของระดับการมองเห็นกล่องเสียง และภาวะแทรกซ้อนที่เกิดขึ้นจากการใส่ท่อช่วยหายใจในท่าศีรษะสูงและศีรษะราบ

วัสดุและวิธีการ: งานวิจัยนี้เป็นการศึกษาไปข้างหน้าแบบสังเกตในผู้ใหญ่อายุมากกว่า 18 ปี ที่ได้รับการใส่ท่อช่วยหายใจในห้องฉุกเฉินโดยแพทย์ประจำบ้านเวชศาสตร์ฉุกเฉินหรืออาจารย์แพทย์เวชศาสตร์ฉุกเฉิน (ไม่รวมผู้ป่วยอุบัติเหตุหรือผู้ที่อยู่ในภาวะหัวใจหยุดเต้น) ระหว่างเดือนเมษายน พ.ศ. 2561 ถึง เดือนเมษายน พ.ศ. 2562 การตัดสินใจว่าจะใส่ท่อช่วยหายใจในท่าศีรษะสูง (ยกหัวเตียงขึ้น 20 ถึง 30 องศา) หรือศีรษะราบนั้นขึ้นกับดุลยพินิจแพทย์ผู้ทำการใส่ท่อช่วยหายใจ

ผลการศึกษา: จำนวนผู้ป่วยที่ทำการศึกษาทั้งหมด 267 คน โดยแบ่งเป็นผู้ป่วยที่ได้รับการใส่ท่อช่วยหายใจในท่าศีรษะสูง 135 คน (50.6%) ศีรษะราบ 132 คน (49.4%) จากผลการศึกษาพบว่าการใส่ท่อช่วยหายใจสำเร็จในครั้งแรกของทั้ง 2 กลุ่มไม่มีความแตกต่างกัน โดยกลุ่มศีรษะสูงสามารถใส่สำเร็จในครั้งแรกร้อยละ 86.7 ส่วนกลุ่มศีรษะราบร้อยละ 78.0 ($p = 0.066$) จากการวิเคราะห์แบบพหุตัวแปลพบว่าผลสำเร็จในการใส่ท่อช่วยหายใจทั้ง 2 ท่าไม่แตกต่างกัน พบว่าระดับการมองเห็นกล่องเสียงในท่าศีรษะสูงดีกว่าอย่างมีนัยสำคัญ (81.5% และ 62.9%, $p = 0.001$) และอัตราการบาดเจ็บของทางเดินหายใจมากกว่าในกลุ่มศีรษะสูง (3% และ 0% $p = 0.046$)

สรุป: การใส่ท่อช่วยหายใจในท่าศีรษะสูงทำให้ระดับการมองเห็นกล่องเสียงดีขึ้น อย่างไรก็ตามไม่ช่วยเพิ่มอัตราการใส่ท่อช่วยหายใจสำเร็จในครั้งแรกเมื่อเทียบกับการใส่ท่อช่วยหายใจในท่าศีรษะราบ