


ORIGINAL RESEARCH

Airway

Impact of bed angle and height on intubation success during simulated endotracheal intubation in the ramped position

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Abstract

Objective: The ramped position is often used during endotracheal intubation to improve oxygenation, improve laryngeal views, and reduce airway complications. We sought to compare the impact of ramp angle and bed height on intubation outcomes during simulated endotracheal intubation.

Methods: We enrolled emergency medicine residents and fourth-year medical students to perform simulated direct laryngoscopy and endotracheal intubation in random order with the mannequin in the following combinations of ramp angles and bed heights; ramp angles of 25° and 45° at bed heights including knee, mid-thigh, umbilicus, xiphoid, and nipple/intermammary fold. Our primary outcome was the reported percentage of glottic opening (POGO) score. Secondary outcomes included number of laryngoscopy attempts and intubation time.

Results: We enrolled 25 participants. There was no difference in reported POGO scores at 25° between bed heights, but at 45°, the umbilicus bed height had an improved reported POGO score (20; 95% confidence interval [CI] 7–33, $P < 0.01$) relative to xiphoid. The nipple/inframammary fold height required longer intubation times in seconds (mean difference [MD] 95% CI) at 25°, (MD, 23.9 [4.6–37.6], $P < 0.01$) and more laryngoscopy attempts at 45° (MD, 0.48 [0.16–0.79], $P < 0.01$) relative to xiphoid. There was no difference in laryngoscopy attempts and video POGO between 25° and 45° at all bed heights, but reported POGO at the umbilicus position was better at 25° than 45° (12 [1–23], $P = 0.03$).

Conclusion: The umbilicus bed height resulted in the highest reported POGO at 45°. Nipple/inframammary fold height resulted in worse intubating conditions.

KEYWORDS

airway management, hypoxia, intratracheal, intubation, laryngoscopy, position, respiratory insufficiency, simulation

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1 | INTRODUCTION

1.1 | Background

Emergency airway interventions including endotracheal intubation (ETI) are critical in the resuscitation of acutely ill and injured patients. Complications with endotracheal intubation include bradycardia, hypoxemia, and even death in up to 4% of patients.^{1,2} Various techniques and airway adjuncts have been proposed to help improve the safety profile of emergent endotracheal intubation including patient position to help facilitate oxygenation and ventilation. Upright positioning facilitates oxygenation and ventilation by using gravity to shift body tissues away from the chest, improving pulmonary compliance and increasing the patient's functional residual capacity.³⁻⁷ Ramped positioning, sometimes referred to as "back-up and head-elevated positioning," is a method of positioning patients before endotracheal intubation to obtain this physiologic benefit. This involves flexing the patient at the hips by 20–45° so that the head and shoulders are elevated above the lower body and may also include approximating the ear and sternal notch in the same horizontal plane or the "sniffing position."⁸

1.2 | Importance

Ramped positioning has been associated with an increased first pass success rate and a decrease in difficult intubations, hypoxemia, esophageal intubations, and pulmonary aspiration during emergent endotracheal intubations.^{9,10} However, there is currently equipoise regarding the impact of ramped positioning on laryngeal views and endotracheal intubation success.⁸⁻²⁰ This may be explained by varying ramp angles and bed heights across studies.

1.3 | Goals of this investigation

Our study sought to compare laryngeal views during simulated endotracheal intubation performed by residents and medical students in the ramp position at commonly reported ramp angles and bed heights.

2 | METHODS

2.1 | Study subjects

We performed a simulated, cross-over, randomized trial comparing intubation outcomes of novice providers at various ramp angles and bed heights. Informed consent was obtained from each participant at the start of the study. A convenience sample of residents and medical students were enrolled on a single day during an educational airway simulation lab. This was approved by the Allegheny Health Network Institutional Review Board.

The Bottom Line

Although often used to aid intubation, the effect of the ramped-up position on glottic view are unknown. This mannequin study found that the bed angle of 45° and height at the umbilicus of the provider resulted in the best percent of glottic opening view. These results need to be validated with real-world clinical evidence before full implementation.

2.2 | Study protocol

Before participating, all subjects were given a brief overview on the study and how to calculate the percentage of glottic opening (POGO) score defined as the directly visualized percentage of the linear distance between the anterior commissure to the interarytenoid notch. No additional information or education regarding the study or protocol was provided to participants. Subjects were then asked to intubate one of two identical mannequins (SimMan ALS, Laerdal, Stavanger, Norway) using direct laryngoscopy with the C-MAC Video Laryngoscope (Karl Storz Corp, Tuttlingen, Germany) at a series of bed heights including knee, mid-thigh, umbilicus, xiphoid, and nipple/inframammary fold at 25° and 45° ramp angles at each height in random order. The bed height was adjusted by approximating the top of the mattress at the head of the bed with the designated body structure on the participant. The ramp angle was adjusted by keeping the foot of the bed parallel to the floor and adjusting the angle of the head of the bed with a standard protractor (Figure 1). The top of the mannequin's head was kept at the edge of the head of the bed so that no portion of the head hung over the edge. The order of ramp angles and bed heights was randomized for each participant using a random number generator (<http://www.random.org>).

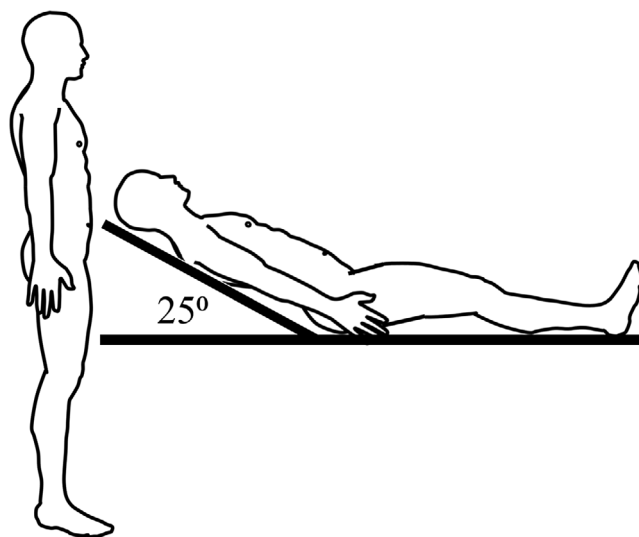


FIGURE 1 Example of bed height at the umbilicus of the intubator and bed angle at 25°

TABLE 1 Provider demographics for 25 participants

Mean provider height in cm (SD)	179 (11.3)
Level of training, n (%)	
Medical student	8 (32)
PGY 1	7 (28)
PGY 2	5 (20)
PGY 3	3 (12)
PGY 4	2 (8)
Median estimated number of clinical endotracheal intubations (IQR)	45 (0, 57)

Abbreviations: IQR, interquartile range; PGY, post-graduate year; SD, standard deviation.

Each participant performed two intubations at each bed height, once at an angle of 25° and once at 45°. The C-MAC video screen was turned away from the participants and they performed endotracheal intubation using direct laryngoscopy.

Participants reported a POGO score for each position. Authors (DAN, RA, JLL, and JSD) recorded the POGO score from the C-MAC video screen, number of laryngoscopy attempts, and time to intubation (defined as time from insertion of the laryngoscope into the oropharynx until confirmation of tube placement in the trachea as visualized through a hole in the anterior neck of the mannequin). Demographic and measured data were collected on spreadsheets in real time.

Our primary outcome was the participant-reported POGO score. Secondary outcomes included number of laryngoscopy attempts (defined as each time the blade of the laryngoscope passed the teeth of the mannequin), time to intubation, and video POGO score as identified by the investigator reviewing the screen at the time. There were no limits placed on the time required for endotracheal intubation or the number of laryngoscopy attempts.

2.3 | Data analysis

As limited data exist comparing ramp angle and bed height, we estimated a minimum of 22 participants would be needed to show a

difference of 10% in the reported POGO score with an alpha of 0.05% and 90% power while accounting for repeated measures.¹⁸ Primary and secondary outcomes above were compared between bed heights at each ramp angle. To account for multiple comparisons, we report the absolute mean differences (MD) with 95% confidence intervals (CI) between techniques. Absolute differences were modeled using a mixed model regression with the xiphoid position as referent, modeling the outcomes (eg, time to intubation) as the dependent variables, each position as the independent variable and each subject as a random effect. Other heights were compared to xiphoid, because xiphoid is the traditionally recommended bed height for endotracheal intubation.²¹ Kaplan-Meier estimates were created to compare time to intubation across techniques. All analyses were created using Stata v 12 (Stata, College Station, TX).

3 | RESULTS

A total of 25 participants were included in the study, including residents (n = 17, 68%) and medical students (n = 8, 32%). The median estimated number of clinical intubations (interquartile range [IQR]) was 45 [0.57]). The mean provider height was 179 cm (SD, 11.3) (Table 1). Each participant intubated their mannequin ten times, at the predetermined ramp angles (25° and 45°) and bed heights (knee, mid-thigh, umbilicus, xiphoid, and nipple/inframammary fold), for a total of 250 intubations among all participants.

With the ramp angle at 25°, the median reported POGO score was similar for all bed heights (Table 2A). With the ramp angle at 45°, knee, mid-thigh, and umbilicus had higher POGO scores (Table 2B).

Median video POGO and number of laryngoscopy attempts were similar between bed heights within each angle group. Video POGO was consistently higher than participant reported POGO at all bed heights in both angle groups. There was variation among median intubation times between bed heights within each angle group. The shortest median intubation time at 25° was knee height and at 45° was umbilicus (IQR, 11 [8,16] and 10 [8,13] s, respectively) (Tables 2A and 2B).

Differences in outcomes relative to xiphoid position were also calculated for each bed height at the 25° and 45° ramp angles (Tables 3A

TABLE 2 Intubation outcomes by bed height

	Knee	Mid-thigh	Umbilicus	Xiphoid	Nipple
(A) Bed ramped to 25°					
Median reported POGO (IQR)	75 (50, 100)	75 (50, 100)	75 (50, 75)	75 (50, 100)	75 (25, 100)
Median POGO on video review (IQR)	100 (100, 100)	100 (100, 100)	100 (100, 100)	100 (100, 100)	100 (100, 100)
Median number of laryngoscopy attempts (IQR)	1 (1, 1)	1 (1, 1)	1 (1, 1)	1 (1, 1)	1 (1, 1)
Median time to Intubation in seconds (IQR)	11 (8, 16)	13 (10, 20)	15 (10, 20)	12 (9, 20)	19 (15, 34)
(B) Bed ramped to 45°					
Median reported POGO (IQR)	75 (50, 100)	75 (50, 100)	75 (75, 100)	50 (50, 100)	50 (25, 75)
Median POGO on video review (IQR)	100 (100, 100)	100 (100, 100)	100 (100, 100)	100 (100, 100)	100 (100, 100)
Median number of laryngoscopy attempts (IQR)	1 (1, 1)	1 (1, 1)	1 (1, 1)	1 (1, 1)	1 (1, 1)
Median time to Intubation in seconds (IQR)	11 (8, 14)	10 (8, 16)	10 (8, 13)	15 (11, 24)	19 (11, 27)

Abbreviations: IQR, Interquartile range; POGO, percentage of glottic opening.

TABLE 3 Differences in outcomes relative to xiphoid position^a

(A) Bed ramped to 25°				
Position	Mean difference in number of laryngoscopy attempts (95% CI)	P value ^b	Time to intubate in s (95% CI)	P value ^b
Knee	0.16 (−0.15 to 0.47)	0.31	2.4 (−11.3 to 16.1)	0.74
Mid-thigh	0.12 (−0.19 to 0.43)	0.45	−5.5 (−8.2 to 19.2)	0.43
Umbilicus	0.08 (−0.23 to 0.39)	0.61	4.9 (−8.8 to 18.6)	0.48
Xiphoid	Referent		Referent	
Nipple	0.48 (0.16 to 0.79)	<0.01	23.9 (4.6 to 37.6)	<0.01
(B) Bed ramped to 45°				
Position	Reported POGO (95% CI)	P value ^b	Time to intubate in s (95% CI)	P value ^b
Knee	7 (−6 to 20)	0.29	−0.6 (−14 to 12.8)	0.94
Mid-thigh	5 (−8 to 18)	0.45	−5.3 (−18.7 to 8.1)	0.44
Umbilicus	20 (7 to 33)	<0.01	−3.6 (−17 to 9.8)	0.6
Xiphoid	Referent		Referent	
Nipple	−6 (−19 to 7)	0.37	10 (−3.4, to 23.4)	0.14

Abbreviations: CI, confidence interval; POGO, percentage of glottic opening.

Other outcomes that were not found to be different (reported POGO and video POGO) have been removed for clarity. Other outcomes that were not found to be different (laryngoscopy attempts and video POGO) have been removed for clarity.

^aDifferences modeled using a mixed model regression with the xiphoid as referent. Time to intubation was modeled as the dependent variable and each position as the independent variable and modeling each subject as a random effect.

^bP values refer to the comparison between relative positions and xiphoid position.

TABLE 4 Differences in outcomes between 25° and 45°

Position	Reported POGO (95% CI)	P value	Time to intubate in s (95% CI)	P value
Knee	2 (−8 to 12)	0.68	1.9 (−12.7 to 16.5)	0.8
Mid-thigh	0 (−12 to 12)	1	−6 (−13.4 to 1.4)	0.11
Umbilicus	12 (1 to 23)	0.03	−3.7 (−12.5 to 5)	0.41
Xiphoid	−6 (−18 to 6)	0.33	4.8 (−0.6 to 10.2)	0.08
Nipple	−5 (−23 to 13)	0.37	−9.1 (−32.9 to 14.7)	0.46

Other outcomes that were not found to be different (laryngoscopy attempts and video POGO) have been removed for clarity.

and 3B). Nipple/inframammary fold height required more attempts at 25° (0.48 [0.16–0.79], $P < 0.01$). Participant reported POGO was similar at 25° among all bed heights, but was higher at the umbilicus position at 45° (20 [7–33], $P < 0.01$). Nipple/inframammary fold height required greater time to intubation at 25°, (23.9 s; 95% CI = 4.6–37.6, $P < 0.1$), but no differences were noted, at any height, at 45°.

There was no difference in laryngoscopy attempts and video POGO between 25° and 45° at all bed heights, and no difference in reported POGO or time to intubation at knee height. At 25° compared to 45°, reported POGO was better at the umbilicus (12 [1–23], $P = 0.03$) (Table 4). Kaplan-Meier estimates of time to intubation were similar at 25° and 45° between bed heights (Figure 2).

4 | DISCUSSION

In our study of simulated endotracheal intubation at various ramp angles and bed heights, we found no difference in reported POGO at the 25° ramp angle with regard to bed height; however, reported POGO was improved at the umbilicus height when the bed was at

45°. The umbilicus height at 25° yielded a higher participant-reported POGO than 45° potentially explaining the equipoise between studies with regard to the effect the ramp position has on laryngeal views.^{8–17}

Prior studies have not evaluated the effect bed height may have on various ramp angles during endotracheal intubation. Our results are similar to a prior observational trial that found no difference in mean-reported POGO scores between various ramp angles; however, previous work has suggested improved first-pass success with increasing ramp angles.¹³ We did not find any difference in first-pass success between 25° and 45° ramp angles overall; however, nipple/inframammary fold height at 25° was associated with an increased number of laryngoscopy attempts. This may have important clinical implications, because, theoretically, an increased ramp angle may improve oxygenation over lower ramp angles. Therefore, a 45° ramp angle may be used to maximize patient oxygenation with no effect on number of laryngoscopy attempts compared to 25°.

Our study differs from prior literature because it investigated the optimal way to perform endotracheal intubation in the ramped position. Although previous studies have suggested that a ramp angle of $\geq 45^\circ$ may improve first-pass success and glottic view,^{9,13} we found

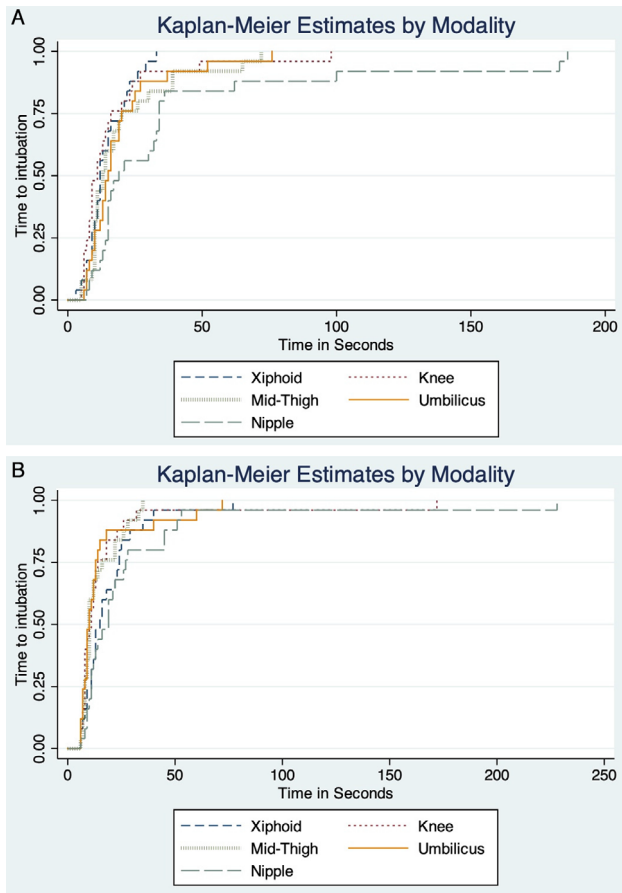


FIGURE 2 Kaplan-Meier estimates by bed height with the bed ramped to either 25° (3a) or 45° (3b). (A) Bed ramped to 25°. (B) Bed ramped to 45°

no difference in the number of laryngoscopy attempts between 25° and 45°, and the highest POGO score at 45° is achieved with the bed height at the umbilicus. Although previous literature suggests that video POGO scores may be greater in the ramp position,¹⁸ we found no difference in number of laryngoscopy attempts or video POGO scores between 25° and 45°. While these results offer an explanation for the equipoise between studies regarding the effect the ramp position has on laryngeal views, this hypothesis requires clinical validation and should not change clinical practice at this time.

5 | LIMITATIONS

Our study had several limitations. We performed a mannequin study; therefore, the mannequin and environment may not be generalizable to the clinical setting. The mannequins are more rigid with less cervical mobility than actual patients; therefore, bed height and angle may have a greater effect on laryngeal views on mannequins. The mannequins simulate patients with normal body habitus; however, clinically, the ramped position may be better indicated for obese patients or those with predicted difficult airways to mitigate hypoxemia and other complications. Future work will be needed to validate our findings in the

clinical setting with a variety of airway and patient populations. Many of our subjects needed to kneel, use a step stool, or even stand on the hospital bed frame to approximate the head of the bed with the desired body structure; this may result in practical barriers to intubating in the ramped position in the clinical setting. We did not assess the effect of the ramp position on other peri-intubation procedures such as bag-valve-mask ventilations. Although we examined video POGO scores, we did not examine the outcome differences if participants were able to use the video component of the C-MAC.

6 | CONCLUSIONS

In our study, examining simulated endotracheal intubation in the ramp position, the umbilicus bed height resulted in the highest reported POGO at 45°. Positioning the bed at nipple/inframammary fold height resulted in worse intubating conditions.

CONFLICTS OF INTEREST

The authors have no conflicts of interest.

AUTHOR CONTRIBUTIONS

All authors have made substantial contributions to the design, acquisition of data, analysis of data, and drafting of the manuscript. All authors have approved the final version of the manuscript.

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