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Effects of bed height on the performance of endotracheal intubation and bag mask ventilation

JUN YOUNG HONG[1], JE HYEOK OH[1], CHAN WOONG KIM[1], SUNG EUN KIM[1], DONG HOON LEE[1], JUNG-HO SHIN[2]

[1] Department of Emergency Medicine, College of Medicine, Chung-Ang University, Seoul, Republic of Korea
[2] Department of Internal Medicine, College of Medicine, Chung-Ang University, Seoul, Republic of Korea

Corresponding author:
Je Hyeok Oh
Department of Emergency Medicine
College of Medicine, Chung-Ang University
84 Heukseok-ro, Dongjak-gu, 06974 Seoul, Republic of Korea
Phone: 82-2-6299-1820
Fax numbers: 82-2-6299-2558
E-mail: jehyeok.oh@gmail.com; jehyeokoh@cau.ac.kr

ABSTRACT

Objectives. This study was performed to evaluate whether different bed heights affect the performance of airway procedures.

Methods. Thirty three medical doctors performed endotracheal intubation (EI) and bag mask ventilation (BMV) using three different bed heights; knee height, mid-thigh height, and anterior superior iliac spine (ASIS) height. For EI, performance was assessed based on intubation time, intubation success, and damage to teeth. For BMV, performance was assessed based on tidal volume, ventilation rate, peak pressure, minute ventilation, and airway opening. In addition, three numeric rating scales (NRS; 1 to 10) were used to assess the level of difficulty for each procedure and the doctors' self-confidence. NRS scoring was based on posture (comfortable to uncomfortable), handling (easy to hard), and visual field (good to bad).

Results. No significant differences in performance were observed for EI or BMV at the three different bed heights. However, all of the NRS scores were significantly different among the different bed heights (P<0.001), and were poorest for the knee height beds: knee height (EI: posture 5.8~7.3, handling 4.3~5.7, visual field 3.9~5.5; BMV: posture 7.1~8.0, handling 5.9~7.2, 95% CI), mid-thigh height (EI: posture 2.9~4.0, handling 2.9~4.0, visual field 2.7~3.8; BMV: posture 2.4~3.2, handling 2.3~3.5) and ASIS height (EI: posture 2.2~3.5, handling 2.6~3.8, visual field 2.1~3.4; BMV: posture 2.9~4.4, handling 4.7~6.1).

Conclusions. Although the participants reported that the knee height beds were the least comfortable, hardest to handle, and made seeing the vocal cord difficult, these caveats did not affect their performance during airway procedures.

Key words: endotracheal intubation, positive pressure ventilation, bed, cardiopulmonary resuscitation

INTRODUCTION

A patient's airway must remain open during cardiac arrest to prevent respiratory failure and aspiration. Thus, emergency endotracheal intubation (EI) is often required in such situations. (1) In addition, bag mask ventilation (BMV) is required to ventilate such patients prior to EI. (2)

The recommended bed position for EI is with the patient's head located beneath the operator's sternum. This provides an adequate view of the patient's airway. (1) There is no recommended bed height for BMV; however, to effectively perform ventilation, the face mask should be sealed tightly on the patient's face. Thus, the optimal bed height for BMV is expected to be lower than that for EI.

Another important consideration for bed heights is that chest compressions are routinely required on patients experiencing cardiac arrest. The efficiency of chest compressions during cardiopulmonary resuscitation (CPR) is highest at the height of the rescuer's knee; (3,4) however, one complexity is that the rescuer's knee may be too low for other airway procedures. Thus, in this study, we tested the hypothesis that the performance of airway procedures would differ according to bed height.

METHODS

Study design

This study was designed as a prospective randomized crossover simulation trial. It was approved by the Chung-Ang University Hospital Institutional Review Board (approval number: C2015023(1481)) on 13 Feb 2015 and was registered to the clinical trial registry platform (Clinical Research Information Service; KCT0001424) on 27 Mar 2015. All of the participants provided verbal informed consent prior to the trial (written informed consent was waived by the institutional review board).

Study population

Medical doctors working in the university hospital were recruited for participation. The inclusion criteria were as follows: interns or resident physicians with less than 3 years clinical experience, and completion of the Basic Life Support for Healthcare Providers course from the American Heart Association. Participants who did not meet these criteria were excluded from the study.

The sample size was calculated based on the mean intubation time. A two-tailed level of significance was set at 0.05 and the statistical power was set at 80%. The mean intubation time based on a previous study was 8.7±2.5 s, and the difference in intubation times between two different bed heights was 1.5 s. (5) Using these data and web-based software (sample size calculator: two crossover-sample means), (6) the sample size for this study was calculated to be 11 participants in each group.

Study setting and protocol

All participant training and experimentation were performed in the simulation center of the university hospital. All of the participants were trained in performing the airway procedures prior to experimentation. Two airway procedures, EI and BMV, were used due to their importance and frequency during advanced cardiovascular life support (ACLS). Participant training included a 30 min video on how to perform EI and BMV with standardized equipment, followed by a 20 min hands-on training session. (1,2) All of the training was provided by two ACLS specialists.

The experiments utilized three different bed heights: knee height (from the floor to the participant's tibial tuberosity), mid-thigh height (mid-height between the knee and anterior superior iliac spine [ASIS]), and ASIS height. The knee height experiment was included because that height is considered best for achieving optimal chest compressions during CPR. (3,4) The ASIS height was included because it is the recommended height for EI. (1) All of the experiments were performed in random order. Participants were allowed a single attempt at the EI experiments, and were instructed when to begin and end their trial. EI trials were terminated immediately after the endotracheal tube passed the vocal cord of the test subject. BMV experiments were performed for 2 min, and participants were instructed to perform BMV every 5–6 s (10–12 times/min).

The following materials were used during the experiments: the Stryker Trauma Stretcher (Stryker Medical, Portage, MI, USA), the Laerdal®Airway Management Trainer (Laerdal Medical. Stavanger, Norway), the Laryngoscope with American Macintosh blade #4, endotracheal tubes with stylet and an internal diameter of 7.5 mm, RespiTrainer®Basic (IngMar Medical, Pittsburgh, PA, USA), and a Laerdal Silicone Resuscitator (Laerdal Medical) with a 1600 mL sized bag, and Adult size 4–5 Laerdal Silicone Mask (Laerdal Medical). The settings for the RespiTrainer®Basic were adjusted for normal lung physiology (i.e., resistance: 5 cmH2O/L/s; compliance: 50 mL/cm H2O).

Outcome variables

EI trials were assessed using the following primary outcome variables: intubation time (in s), intubation success (successful or not), and the presence of broken teeth (yes or no). BMV trials were assessed using measurements of tidal volume (mL), ventilation rate (breaths per min), peak pressure (cm H2O), minute ventilation (mL/min), and the presence of an open airway (open or not). The BMV data were collected using Respi®Trainer Advance software (v1.2; IngMar Medical). The secondary outcome variables included five numeric rating scales (NRS; 1 to 10) reflecting the level of difficulty and the patients' self-confidence. The experimental supervisor asked each of the secondary outcome questions to the participants immediately after each experiment. For the EI trials, these pertained to: posture (NRS = 1 to 10; comfortable to uncomfortable), ease of handling (NRS = 1 to 10: easy to hard), and visual field (NRS = 1 to 10: good to bad). For the BMV trials, the secondary variables were posture and ease of handling.

Analytical methods

All of the statistical analyses were performed using the SPSS software package for Windows (v 20.0; IBM, Armonk, NY, USA). Continuous variables are presented as the means (SD), and the categorical data are expressed as percentages. One-way analysis of variance with post hoc multiple comparisons tests using the Bonferroni correction was performed to evaluate differences in the continuous variables. Pearson's chi-square tests were conducted to evaluate differences in categorical variables. A P value < 0.05 was considered statistically significant.

RESULTS

Participant characteristics

In total, 33 medical doctors (26 males, 7 females) participated in this study, and included 16 interns and 17 resident physicians. The mean age of the participants was 28.7 (2.7) years. The average height, ASIS height, mid-thigh height, and knee height of the participants were 171.9 (7.5) cm, 98.2 (5.9) cm, 71.2 (4.0) cm, and 44.2 (2.4), respectively.

EI performance in the three different bed heights

There were no differences in intubation times or success rates between the three different bed heights (table 1). Although the frequency of broken teeth was lowest in the ASIS height, this difference was not statistically significant.

NRS for the level of difficulty and patients' self-confidence during EI

Although there was no difference in the performances of the EIs, the NRSs reflecting the levels of difficulty and the participants' self-confidence were significantly different for the different bed heights (table 2). All of the NRS values (for posture, handling, and visual field) were highest for the knee-height beds, whereas no significant differences were observed between procedures performed using the mid-thigh and ASIS height beds. Considering the NRS data, the participants indicated that the mid-thigh and ASIS height beds were superior for EI, compared to the knee height bed.

BMV performances using the three different bed heights

No significant differences for any parameters (tidal volume, ventilation rate, peak pressure, minute ventilation, airway opening) were observed for the BMV trials using the different bed heights (table 3). Although the frequency of airway opening was highest using the mid-thigh height beds compared to the knee and ASIS height beds, this difference was not statistically significant.

NRS for the level of difficulty and patients' self-confidence during the BMV trials

The NRS values for posture were highest for procedures performed using the knee height beds, compared to those performed using the mid-thigh and ASIS height beds. No significant differences were observed between the mid-thigh and ASIS height beds (table 4). The NRS values for handling were different between all of the bed heights. Trials using the knee height beds exhibited a higher NRS for handling, followed by those for the ASIS height trials. The NRS for handling was lowest in trials using mid-thigh height beds. For the BMV trials, the mid-thigh height was deemed most appropriate.

DISCUSSION

BMV and EI are the most frequent procedures performed for the management of airways in the emergency department. (7) Although the overall success rate for rapid sequence intubation is 96%, the success rate on the first attempt is only 82%. [8] In addition, multiple obstacles occur during emergency EIs, including the limited ability to examine the airway, limited equipment and poor positioning, limited personnel support, difficult or inadequate pre-oxygenation, and the presence of additional life-threatening conditions. (7)

This study was concerned with the obstacle of bed height. Many cases arise where advanced airway procedures are required and have the potential for respiratory arrest. In fact, 12% of all intubations are performed because of cardiac arrest. (8) During hospitalization, CPR with BMV is performed first with cycles of 30 compressions and 2 breaths. (9)

Although the CPR guidelines recommend that healthcare providers limit hands-off time to 10 s, an exception is allowed for the insertion of an advanced airway because it provides many advantages, including an alternative route for medication and enabling continuous chest compressions while avoiding gastric insufflation. Therefore, BMV and EI are routinely used during in-hospital CPR. One complication is that chest compression should continue during airway procedures. Previous studies have shown that chest compression depths increased with bed heights at the height of the rescuer's knee. (3,4) However, little is known about how bed heights affect airway procedures.

Experts have recommended that bed heights be adjusted so the patient's head is level with the lower portion of the rescuer's sternum; (1) however, there are limited data to support this suggestion. One ergonomic study tested the effects of bed height on the success of EI; (5) however, no conclusions were drawn regarding bed height. Two bed heights (62 cm versus 96 cm) were compared, but the only factor that affected outcome was the experience of the participant.

In this study, we more accurately tested the differences in bed height on procedure outcome. No differences in the performance of either EI or BMV were observed, although participants reported that knee height beds were the least comfortable, hardest to handle, and made seeing the vocal cord difficult.

No EI failures occurred during this study, possibly due to multiple reasons. First, although the level of clinical experience for the participants was short, all of the participants passed clinical examinations for airway procedures as medical students (within 3 years). Second, the participants performed the experiments immediately after 50 min of intensive training. Third, the simulated model is a relatively easy airway model.

This study was performed as a pilot trial to evaluate whether the bed height affects the performance of routine airway procedures. Although there were no differences observed among the different bed heights, additional studies should more comprehensively evaluate the effects of bed height. The frequency of broken teeth may be significantly different with a larger number of participants or participants' performances may be different in a more difficult airway model. Moreover, patients' performance may be different when longer periods of time elapse between the pre-experiment training and the experiments themselves.

There were a couple of limitations to this study. First, the experiments were performed as simulated trials. Second, the participants of the study were limited to junior medical doctors, and therefore, the interpretations of the data should be restricted to those populations.

CONCLUSIONS

Although the participants reported that the knee height beds were the least comfortable, hardest to handle, and made seeing the vocal cord difficult, these caveats did not affect their performance during airway procedures.

Table 1. Endotracheal intubation performances in the three different bed heights. Values are mean (SD) or number (proportion).

Parameters	Knee height (n=33) (95% CI)	Mid-thigh height (n=33) (95% CI)	ASIS height* (n=33) (95% CI)	p value
Intubation time (sec)	19.1 (7.6) (16.4 to 21.8)	18.3 (5.1) (16.4 to 21.8)	19.1 (6.7) (16.4 to 20.1)	0.839 (16.7 to 21.4)
Success	33 (100%)	33 (100%)	33 (100%)	N/A†
Broken tooth	5 (15.2%)	6 (18.2%)	3 (9.1%)	0.559

ASIS, anterior superior iliac spine; †N/A: not applicable.

Table 2. Numeric rating scales for the level of difficulty and patients' self-confidence during endotracheal intubation. Values are mean (SD).

Parameters	Knee height (n=33) (95% CI)	Mid-thigh height (n=33) (95% CI)	ASIS height* (n=33) (95% CI)	p value
Posture NRS†	6.5 (2.0) (5.8 to 7.3)	3.4 (1.6) (2.9 to 4.0)	2.8 (1.8) (2.2 to 3.5)	<0.001

T‡	a	b	b	
Handling NRS§	5.0 (2.0) (4.3 to 5.7)	3.4 (1.5) (2.9 to 4.0)	3.2 (1.6) (2.6 to 3.8)	<0.001
T‡	a	b	b	
Visual field NRS¶	4.7 (2.2) (3.9 to 5.5)	3.3 (1.6) (2.7 to 3.8)	2.8 (1.9) (2.1 to 3.4)	<0.001
T‡	a	b	b	

ASIS, anterior superior iliac spine, †Posture NRS, posture numeric rating scales (1 to 10: comfortable to uncomfortable).
‡The same letters indicate non-significant difference between groups based on multiple comparison tests under Bonferroni correction; §Handling NRS, handling numeric rating scales (1 to 10: easy to hard); ¶Visual field NRS, visual field numeric rating scales (1 to 10: good to bad).
A p value < 0.05 is presented in bold.

Table 3. Bag mask ventilation performances using the three different bed heights. Values are mean (SD) or number (proportion).

Parameters	Knee height (n=33) (95% CI)	Mid-thigh height (n=33) (95% CI)	ASIS height* (n=33) (95% CI)	p value
Tidal volume (mL)	499.2 (182.2) (434.6 to 563.8)	500.3 (123.7) (456.4 to 544.1)	504.0 (170.0) (443.8 to 564.3)	0.992
Ventilation rate (breaths/min)	10.9 (1.9) (10.2 to 11.5)	10.6 (1.9) (9.9 to 11.3)	10.9 (2.1) (10.2 to 11.7)	0.744
Peak pressure (cmH2O)	10.4 (3.7) (9.1 to 11.7)	10.1 (2.5) (9.2 to 10.9)	10.1 (3.4) (8.9 to 11.3)	0.917
Minute ventilation (mL/min)	5339.5 (1844.8) (4685.4 to 5993.6)	5215.8 (1228.2) (4780.3 to 5651.4)	5414.1 (1790.4) (4779.2 to 6048.9)	0.885
Airway opening	22 (66.7%)	23 (69.7%)	22 (66.7%)	0.955

ASIS, anterior superior iliac spine.

Table 4. Numeric rating scales for the level of difficulty and patients' self-confidence during the bag mask ventilation trials. Values are mean (SD).

Parameters	**Knee height (n=33) (95% CI)**	**Mid-thigh height (n=33) (95% CI)**	**ASIS height* (n=33) (95% CI)**	**p value**
Posture NRS†	7.5 (1.3) (7.1 to 8.0)	2.8 (1.2) (2.4 to 3.2)	3.6 (2.0) (2.9 to 4.4)	<0.001
T‡	a	b	b	
Handling NRS§	6.5 (1.8) (5.9 to 7.2)	2.9 (1.7) (2.3 to 3.5)	5.4 (1.9) (4.7 to 6.1)	<0.001
T‡	a	b	c	

ASIS, anterior superior iliac spine; †Posture NRS, posture numeric rating scale (1 to 10: comfortable to uncomfortable).
‡The same letters indicate non-significant difference between groups based on multiple comparison tests under Bonferroni correction; §Handling NRS, handling numeric rating scale (1 to 10: easy to hard).
A p value < 0.05 is presented in bold.

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