Impact of Operating Table Height on the Difficulty of Mask Ventilation and Laryngoscopic View

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Article

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Abstract: Background/Objectives: Airway management techniques, including mask ventilation and tracheal intubation, are vital across medical settings. However, these procedures can be challenging, especially when environmental conditions are less than ideal. This study explores how the height of the operating table affects the difficulty of surgical procedures involving mask ventilation and tracheal intubation. **Methods**: Twenty anesthesiologists participated in this study. We assessed the difficulty of procedures- such as mask ventilation, Macintosh laryngoscopy, and video laryngoscopy with McGRATH and AWS- on a four-level scale. The operating table's height was adjusted at four points: operator's umbilicus, inferior margin of the 12th rib, xiphoid process, and nipple. **Results**: Mask ventilation was easiest at the operating table's height aligned with the inferior margin of the 12th rib. Conversely, direct laryngoscopic exposure was perceived easier at higher table heights, with nipple height being optimal. McGRATH laryngoscopy showed consistent difficulty across table height, whereas AWS tended to be somewhat more difficult at greater heights. **Conclusions**: The optimal bed height for video laryngoscopy coincided with that for mask ventilation. Video laryngoscopy offers enhanced flexibility in optimal patient positioning compared to Macintosh laryngoscopy, contributing to its advantages in tracheal intubation procedures.

Keywords: airway management; mask ventilation; laryngoscopic view; operating table height

1. Introduction

Airway management techniques, including mask ventilation and tracheal intubation, are essential not only in operating rooms but also in diverse settings, such as emergency rooms, general wards, and disaster sites. In other words, there are various places where patients may require airway management techniques. Therefore, these conditions may not always be optimal for airway management operators. These techniques are crucial because airway management failure is a major cause of cardiac arrest and anesthesia-related fatalities. [1,2] Airway management operators must be aware that the performance of their techniques is affected by the environment. Notably, during respiratory disease pandemics, anesthesiologists may need to perform these procedures outside the operating room. [3,4]

In the operating room, airway management is a routine technique to ensure patient safety post-anesthesia induction. The height of the operating table significantly influences the performance of the airway management technique. [5–8] Therefore, it's imperative to adjust the height of the operating table for each anesthesia procedure to optimize outcomes and prevent musculoskeletal disorders in operators. [9–12] While previous studies have explored the impact of operating table height on airway management techniques using Macintosh laryngoscopy, the influence on video

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laryngoscopy remains unexplored. Recently, various types of video laryngoscopes have become available, and the use of these devices must be discussed.

This study investigated the optimal operating table height for mask ventilation, laryngoscopic exposure, and tracheal intubation. We also compared the optimal operating table height for laryngoscopic exposure and tracheal intubation in direct and video laryngoscopy.

2. Materials and Methods

This study received approval from the Ethics Committee of Hiroshima University Hospital (approval number: E-2417). Anesthesiologists or specialists with significant airway management experience from our hospital participated in this study. Airway management techniques (mask ventilation, laryngoscopic exposure, and tracheal intubation) were conducted using a Laerdal Airway Management Trainer (Laerdal Medical Japan, Tokyo, Japan). A Macintosh laryngoscope (ACOMA Medical Industry, Tokyo, Japan) was utilized as a direct laryngoscope, while McGRATH ™ MAC (Aircraft Medical Ltd., Edinburgh, UK) and Pentax Airway Scope® (AWS-S200NK; Pentax Corporation, Tokyo, Japan) served as video laryngoscopes.

The height of the operating table was adjusted to the operator's umbilicus (height U), inferior margin of the 12th rib (height R), xiphoid process (height X), and nipple (height N) (Figure. 1). The techniques were performed with a "natural upright posture," without flexion of the neck, hips, or knees. In other words, the operator did not squat or bend during the procedure. The difficulty of each technique was subjectively rated by the operator on a 4-garade continuous “Discomfort level” (Evaluation criteria for each grade: grade 1 = no discomfort, grade 2 = mild discomfort, grade 3 = moderate discomfort, and grade 4 = severe discomfort) (Figure. 2). The study comprised three parts: experiment .1, experiment .2, and experiment .3 (Figure. 2).

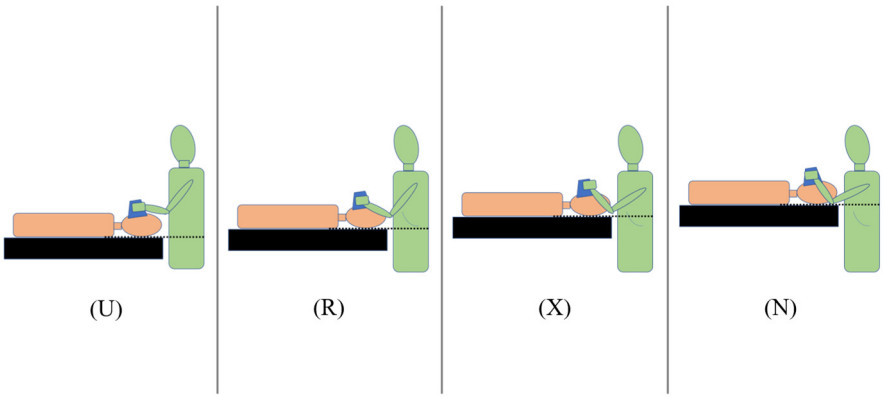

Figure 1. The height of the operating table. The height of the operating table was adjusted at the operator's umbilicus (height U), inferior margin of the 12th rib (height R), xiphoid process (height X), and nipple (height N).

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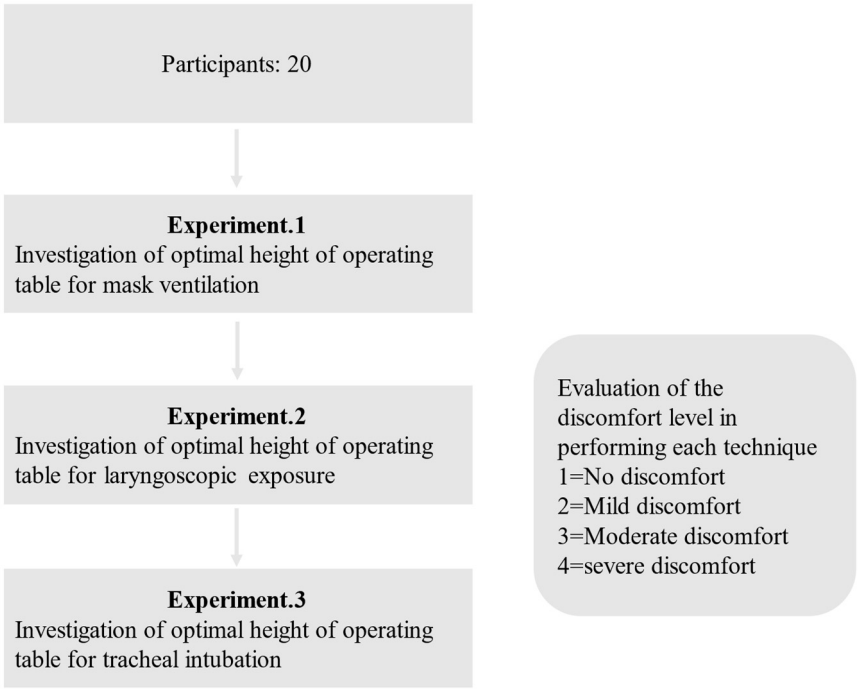

Figure 2. Study protocol and definition of "Discomfort level".

2.1. Experiment.1

The study explored the difficulty of mask ventilation at varying operating table heights (height U to N). Discomfort level during the procedure was evaluated at each table height.

2.2. Experiment.2

The study examined the difficulty of laryngoscopic exposure using Macintosh, McGrath, and AWS at different operating table heights (U–N). Discomfort level during the procedure was evaluated at each table height.

2.3. Experiment.3

The study investigated the difficulty of tracheal intubation using Macintosh, McGrath, and AWS at different operating table heights (U-N). Discomfort level during the procedure was evaluated at each table height.

2.4. Statistical Analysis

We compared the discomfort level at each operating table height in two ways. First, the distribution of difficulty of each technique was compared at different heights (umbilicus, inferior margin of the 12th rib, xiphoid process, and nipple). Then, we aggregated the discomfort level scores at each table height and compared the aggregated scores at each height. A higher total discomfort level score at that table height indicates greater discomfort with that procedure. Statistical analysis employed Kruskal-Wallis and Steel-Dwass tests, with a significant set at $P<0.05$.

3. Results

Twenty anesthesiologists or specialists with significant airway management experience participated in this study. (Figure.2)

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3.1. Experiment.1

The results are shown in Table1 and Figure. 3-1. The total scores of Discomfort level for mask ventilation were 41, 32, 28, and 29 for height U, R, X, and N, respectively. There was a significant difference in the difficulty of mask ventilation with the height of the operating table; comparisons between the two groups showed significant differences between the umbilicus and the xiphoid process, the umbilicus and the nipple, the inferior margin of the 12th rib and the nipple, and the xiphoid process and the nipple.

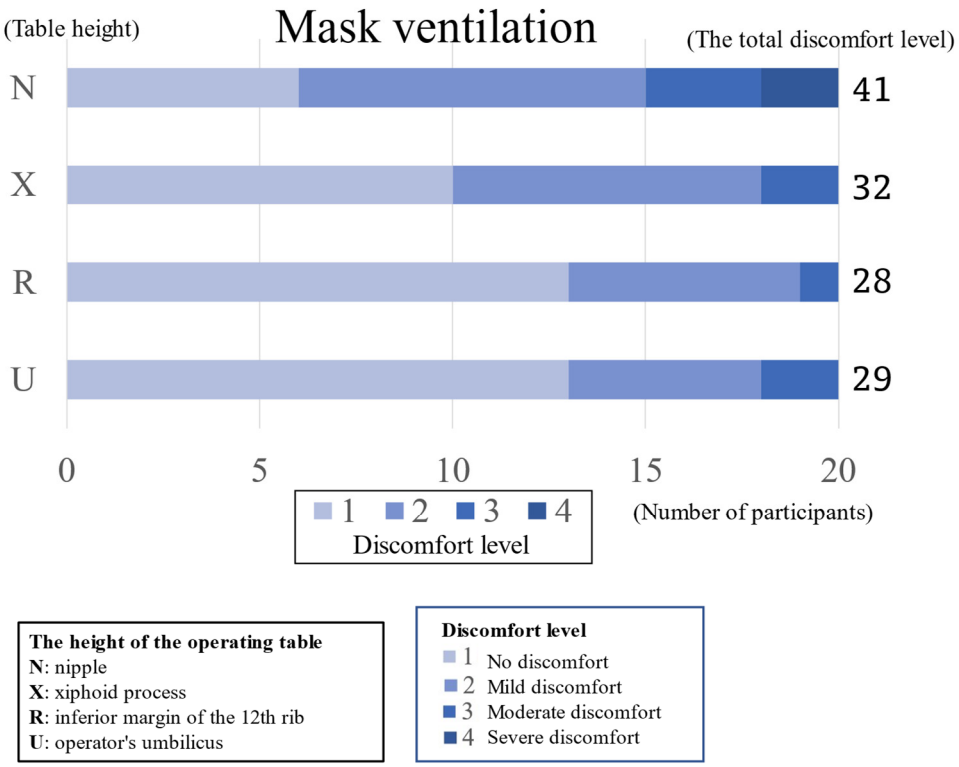

Figure 3. Difficulties in mask ventilation at different operating table heights. The figure shows the distribution of mask ventilation difficulty at each table height. The bar shows the distribution of discomfort levels for each height of the surgical table. Regarding the "Discomfort level," a higher level value indicates that the procedure is more difficult. The number on the right side of the bar is the total score discomfort level of 20 anesthesiologists. Many anesthesiologists felt that mask ventilation at nipple level was more difficult than mask ventilation at any other height. The higher the operating table, the more anesthetists feel uncomfortable.

3.2. Experiment.2

The results are shown in Table1 and Figure. 3-2. The total scores of Discomfort level for laryngoscopic exposure with direct laryngoscopy were 43, 64, 76, and 78 for each height, respectively. The total scores of Discomfort level for laryngoscopic exposure with McGRATH were 27, 24, 22, and 24 for each height, respectively. The total scores of Discomfort level for laryngoscopic exposure with AWS were 42, 32, 24, and 26 for each height, respectively. For direct laryngoscopy, significant differences were observed in laryngoscopic exposure difficulty across operating table heights. Notably, comparisons between the groups showed significant differences between the umbilicus and xiphoid process, the umbilicus and nipple, inferior margin of the 12th rib and nipple, and xiphoid process and nipple. Conversely, McGRATH study found no significant difference in laryngoscopic exposure difficulty at any operating table height. However, with AWS, significant differences were noted in laryngoscopic exposure difficulty, particularly between the inferior margin of the 12th rib and the nipple.

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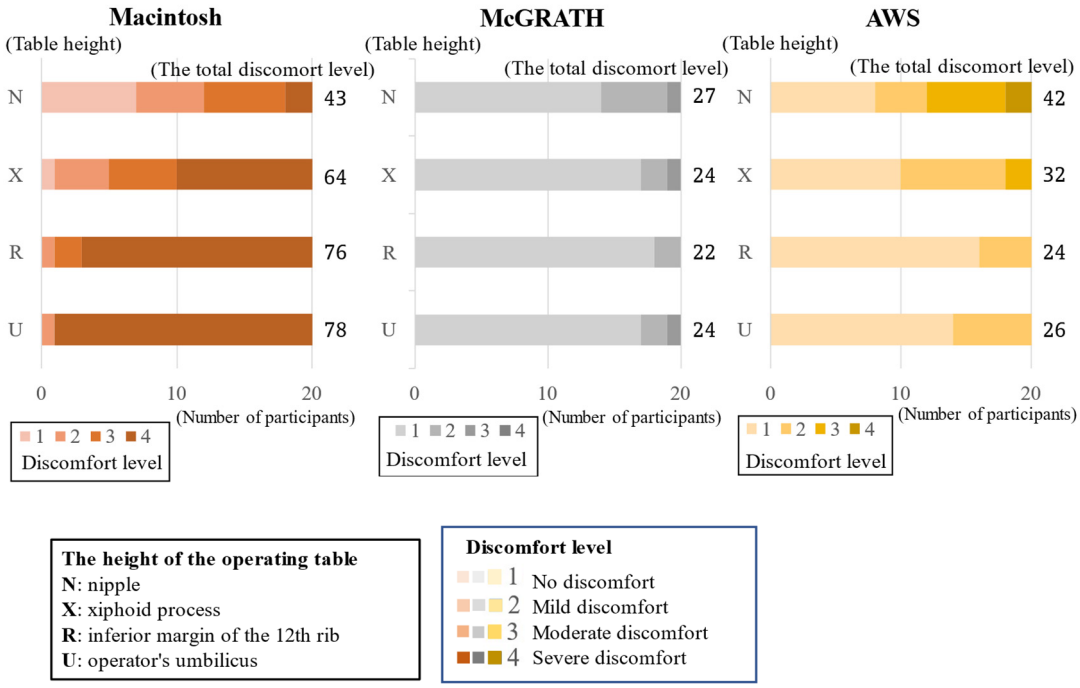

Figure 3. Difficulties in laryngoscopic exposure at different operating table heights. The figure shows the distribution of laryngoscopic exposure difficulty at each table height. The bar shows the distribution of discomfort levels for each height of the surgical table. Regarding the "Discomfort level," a higher-level value indicates that the procedure is more difficult. The number on the right side of the bar is the total score discomfort level of 20 anesthesiologists. In the Mcintosh laryngoscope, many anesthesiologists found the low height of the operating table difficult. In video laryngoscope, many anesthesiologists found no difference in difficulty with the height of the operating table.

3.3. Experiment.3

The results are shown in Table1 and Figure. 3-3. The total scores of Discomfort level for tracheal intubation with direct laryngoscopy were 29, 25, 26, and 32 for each height, respectively. The total scores of Discomfort level for tracheal intubation with McGRATH were 25, 22, 22, and 24 for each height, respectively. The total scores of Discomfort level for tracheal intubation with AWS were 26, 23, 21, and 20 for each height, respectively. There was no significant difference in the difficulty of tracheal intubation in the free posture group. In the McGRATH study, there was no significant difference in the difficulty of tracheal intubation according to the height of the operating table. In the AWS, no significant difference was observed in the difficulty of tracheal intubation according to the height of the operating table. Given the challenge of intubation with the Macintosh laryngoscope in the upright position at low table heights, tracheal intubation difficulty was evaluated in the “free posture”.

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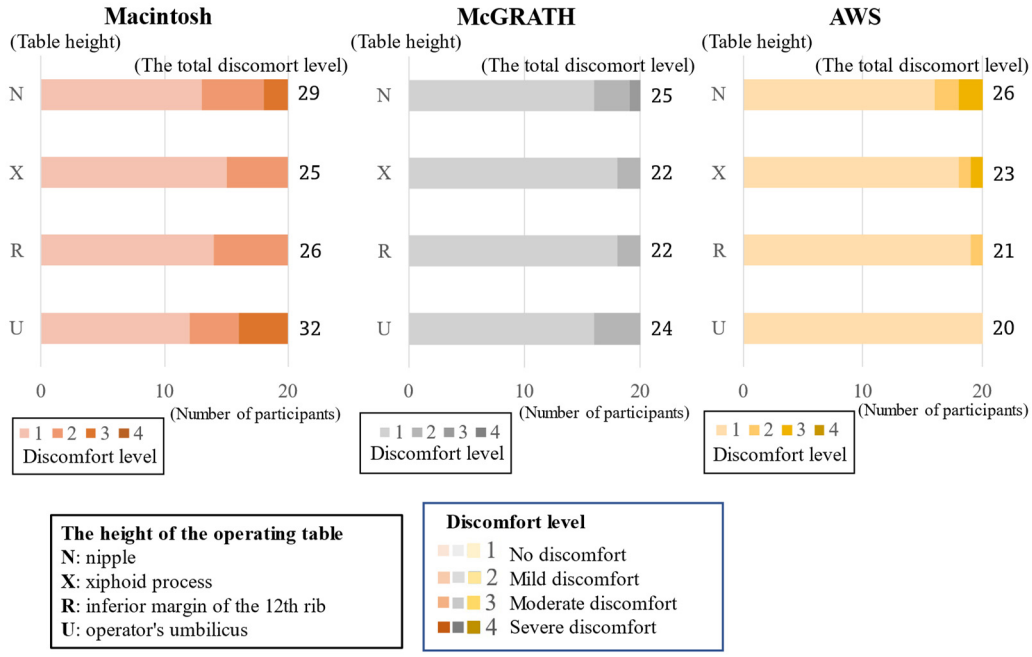

Figure 3. Difficulties in tracheal intubation at different operating table heights. The figure shows the distribution of tracheal intubation difficulty at each table height. The bar shows the distribution of discomfort levels for each height of the surgical table. Regarding the "Discomfort level," a higher-level value indicates that the procedure is more difficult. The number on the right side of the bar is the total score discomfort level of 20 anesthesiologists. Many anesthesiologists found no difference in intubation difficulty at the height of the operating table.

Table 1. Distribution of discomfort levels of mask ventilation, Laryngoscopic exposure, and Tracheal intubation at each operating table height.

Mask ventilation

	U	R	X	N	P value	U vs R	U vs X	U vs N	R vs X	R vs N	X vs N
	13/5/2/0	13/6/1/0	10/8/2/0	6/9/3/2	<0.001	0.062	0.002	<0.001	0.351	<0.001	0.006

Laryngoscopic exposure

	U	R	X	N	P value	U vs R	U vs X	U vs N	R vs X	R vs N	X vs N
Macintosh	0/1/0/19	0/1/2/17	1/4/5/10	7/5/6/2	<0.001	0.757	0.013	<0.001	0.080	<0.001	0.015
McGRATH	17/2/1/0	18/2/0/0	17/2/1/0	14/5/1/0	0.390	0.955	1.000	0.714	0.955	0.381	0.714
AWS	14/6/0/0	16/4/0/0	10/8/2/0	8/4/6/2	0.007	0.889	0.471	0.057	0.163	0.017	0.470

tracheal intubation

	U	R	X	N	P value	U vs R	U vs X	U vs N	R vs X	R vs N	X vs N
Macintosh	12/4/4/0	14/6/0/0	15/5/0/0	13/5/2/0	0.549	0.733	0.555	0.958	0.985	0.952	0.833
McGRATH	16/4/0/0	18/2/0/0	18/2/0/0	16/3/1/0	0.459	0.818	0.818	0.970	1.000	0.582	0.582
AWS	20/0/0/0	19/1/0/0	18/1/1/0	16/2/2/0	0.138	0.749	0.479	0.160	0.925	0.461	0.820

The numbers show the distribution of the number of people by level of discomfort during mask ventilation, laryngoscopic exposure, and tracheal intubation at each operating table height. Height U: operator's umbilicus, R: inferior margin of the 12th rib, X: xiphoid process, and N: nipple. The number of people for each level of discomfort was arranged in the following order: No discomfort/ Mild discomfort/ Moderate discomfort/ Severe discomfort. Statistical analysis employed Kruskal-Wallis and Steel-Dwass tests, with a significant set at $P<0.05$. Mask ventilation was perceived easier at lower table heights. Conversely, direct laryngoscopic exposure was perceived easier at higher table heights. McGRATH laryngoscopy showed consistent difficulty across table height, whereas AWS tended to be somewhat more difficult at greater heights.

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4. Discussion

This study aimed to investigate the optimal height of the operating table that facilitates mask ventilation, tracheal intubation using a direct laryngoscope, and tracheal intubation with a video laryngoscope. This study found that mask ventilation was more difficult at higher operating table heights. The total scores of discomfort level for mask ventilation was lowest when the operating table height was the inferior margin of the 12th rib. In contrast, laryngoscopic exposure with direct laryngoscope was easier at higher operating table heights. The total scores of discomfort level for laryngoscopic exposure with direct laryngoscope was lowest when the operating table height was nipple. Laryngoscopic exposure with the McGRATH showed consistent ease across table heights, while with the AWS, it tended to be more difficult at a greater height. No variation in tracheal intubation difficulty using a video laryngoscope was observed between the McGRATH and AWS.

Tracheal intubation typically involves a series of airway management techniques, each requiring an appropriate operating table height. However, the advantages and disadvantages of adjusting this height have not yet been fully discussed. In our study, the height of the operating table suitable for laryngoscopic exposure using the Macintosh laryngoscope was higher than the height of the operating table suitable for mask ventilation. Therefore, when performing tracheal intubation using a direct laryngoscope, it is better to elevate the operating table after mask ventilation to avoid straining the posture and to achieve the best performance. However, the optimal operating table height for video laryngoscopes (McGRATH and AWS) is similar to that for mask ventilation, revealing that there is no need to adjust the operating table when using these devices for laryngoscopic exposure.

Video laryngoscopy has been reported to be useful for tracheal intubation of difficult airway. [13–15] Our study showed that video laryngoscopy facilitated lower laryngoscopic exposure compared to direct laryngoscopy, suggesting its utility in settings where bed height cannot be adjusted, such as general wards and emergency rooms. [16–19] COVID-19, which has become a global pandemic, has been reported to cause rapid deterioration of respiratory status, and it is expected that there will be more opportunities for tracheal intubation in general hospital wards. [3,4] If the intubator is not accustomed to intubating the trachea outside the operating room, it is important to understand the characteristics of each laryngoscope and choose a video laryngoscope.

The height of the operating table affects the performance of anesthesia techniques [5–8]. Therefore, the height of the operating table must be adjusted for each anesthesia technique. Additionally, anesthesia techniques performed in awkward postures can cause musculoskeletal disorders. [9–11] Anesthesiologists have been reported to have more musculoskeletal disorders than other professions. [10,12]

During anesthesia induction, anesthesiologists handle various tasks, including drug administration, airway management, circulation management, and monitoring, with tracheal intubation being particularly stressful. [20] Fatigue caused by stress loads during anesthesia induction can affect subsequent anesthesia management. Therefore, it is necessary to reduce stress during the induction of anesthesia.

McGRATH and AWS were used in this study. They are the most widely used video laryngoscopes in Japan. In the McGRATH study, no significant difference was observed in the difficulty of laryngoscopic exposure and intubation according to the height of the operating table. In the AWS group, laryngoscopic exposure was slightly difficult when the operating table was higher. One possible reason for this is the difference in blade geometry between McGRATH and AWS. The AWS blade exhibited a near-right-angle bend. Therefore, the blade must be inserted further in front of the patient when inserted into the oral cavity. When the operating table is high, the operator's shoulder joint must be rotated outward, and the operator's elbow must be raised to insert the blade. Many anesthesiologists find this uncomfortable.

This study has some limitations. First, we used a tracheal manikin to estimate patient-induced intubation difficulties. In other words, some of the research data obtained from manikin models may not be directly applicable to clinical patients because the difficulty of laryngeal deployment in manikin models does not perfectly match that in clinical patients. In contrast, we are currently

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investigating the posture during mask ventilation and tracheal intubation. Therefore, we believe it is more appropriate to use a manikin model with fewer individual differences for tracheal intubation. Second, we use "Discomfort level" to assess the difficulty of the airway management techniques. "Discomfort level" indicates stress on the airway management technique and is not necessarily indicative of the difficulty of the airway management technique.

5. Conclusions

This study utilized a tracheal intubation manikin, mask ventilation was easiest to perform when the operating table height was at the inferior margin of the 12th rib. Furthermore, laryngoscopic exposure using a direct laryngoscope was facilitated at the level of the nipple. With video laryngoscopy, there was no difference in the difficulty of tracheal intubation depending on the operating table height, and laryngoscopic exposure did not pose challenges, even at lower table positions. Thus, while direct laryngoscopy necessitates posture adjustments for optimal tracheal intubation following mask ventilation, video laryngoscopy does not require such alterations. We believe that these unique features of laryngoscopes are important factors in choosing a laryngoscope in situations where the patient's height cannot be adjusted, such as emergency departments and general wards.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of Hiroshima University Hospital (approval number: E-2417 approval date: 2021/4/16).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Conflicts of Interest: The authors declare no conflicts of interest.

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