

Higher operating tables provide better laryngeal views for tracheal intubation

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Editor's key points

- Operating table height influences anaesthetist comfort and laryngoscopy view during airway manoeuvres.
- These procedures were performed with the table set at one of four heights relative to the anaesthetist's anatomy.
- Comfort during mask ventilation was best with the patient's face at mid-abdomen height.
- Comfort and view were optimal during intubation with the patient's face at xiphisternum height.

Background. The present study was conducted to investigate the influence of different operating table heights on the quality of laryngeal view and the discomfort of the anaesthetist during endotracheal intubation.

Methods. Eight anaesthetists participated, to each of whom 20 patients were allocated. Before induction of anaesthesia, the height of the operating table was adjusted to place the patient's forehead at one of four landmarks on the anaesthetist's body (the order being determined by block randomization with eight blocks): umbilicus (Group U), lowest rib margin (Group R), xiphoid process (Group X), and nipple (Group N). Next, the anaesthetist began the laryngoscopy and evaluated the grade of laryngeal view. For this 'initial posture', the anaesthetist was not allowed to adjust his or her posture (flexion or extension of the neck, lower back, knee, and ankle). This laryngeal view was then re-graded after these constraints were relaxed. At each posture, the anaesthetist's joint movements and discomfort during mask ventilation or intubation were evaluated.

Results. The laryngeal view before postural changes was better in Group N than in Group U ($P=0.003$). The objective and subjective measurements of neck or lower back flexion during intubation were higher in Group U than in Groups X and N ($P<0.01$ for each). The improvement of laryngeal view resulting from postural changes correlated with the anaesthetist's discomfort score before the postural change ($P<0.01$).

Conclusions. Higher operating tables (at the xiphoid process and nipple level of the anaesthetist) can provide better laryngeal views with less discomfort during tracheal intubation.

Trial registry number. NCT01649973 (clinicaltrials.gov).

Keywords: human engineering; intubation; laryngoscopy; patient positioning

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Operating table height can influence task performance and physical/mental workload.^{1,2} There have been few studies of the correlation between the operating table height and the quality of laryngeal view during direct laryngoscopic intubation.³ In an editorial on anaesthetist stature and patient positioning, Heath³ highlighted the benefits of using an adjustable operating table and the ergonomic benefits of different heights—high during cannulation to prevent back discomfort, a bit lower for airway management, and even lower for short trainees. It has been suggested that the patient's face should be placed at the height of the anaesthetist's xiphoid process for comfortable intubation without requiring the anaesthetist to bend his/her back^{4–6} and that the physician's eyes should

be placed 1 foot (~30 cm) above the patient's face to provide proper angles and distances for laryngoscopy.⁷ However, these results are based on clinical experience rather than scientific validation.

The aim of this study was to evaluate the quality of the laryngeal view (primary variable) and the anaesthetist's discomfort (secondary variable) associated with four different operating table heights during tracheal intubation. Based on our clinical experience, we hypothesized that higher operating tables would improve the quality of the laryngeal view and decrease anaesthetists' discomfort during tracheal intubation by reducing the need to bend their neck or lower back when compared with lower operating tables.

Methods

This study was approved by the Institutional Review Board of Seoul National University Bundang Hospital (IRB no. B-1003-096-012) and was registered on clinicaltrials.gov (registration number NCT01649973).

Study population

A total of 160 patients who were undergoing elective surgery under general anaesthesia through tracheal intubation were included in the study. Written consent was given by each patient after a complete description of the protocol. Twenty patients (ASA I–III) were allocated to each anaesthetist. Each anaesthetist's patients were randomly divided into four groups using sealed opaque envelopes—Groups U, R, X, and N, in whom the height of the operating table was set at the level of the umbilicus, lowest rib margin, xiphoid process, and nipple, respectively, of the anaesthetist. The four body landmarks were chosen because they were in the range of commonly used operating table heights in clinical situations and were easy to check. The following patients were excluded from the study: those with obesity [body mass index (BMI) >30], those aged <18 or >85 yr, those with congenital or acquired airway abnormalities, those with loose teeth or edentulous jaws, and those with increased risk of aspiration.

Study procedure

One day before operation, the airway was assessed by an anaesthesia trainee who was blinded to the patient groups. The airway assessments included measurement of inter-incisor distance, thyromental distance, and neck circumference, and Mallampati classification (Class 1, the soft palate, fauces, uvula, and pillars are visible; Class 2, the soft palate, fauces, and uvula are visible; Class 3, the soft palate and base of uvula are visible; Class 4, the soft palate is not visible).^{8,9} All patients were fasted for >8 h before operation.

Patients were pre-medicated with i.v. midazolam (0.03 mg kg⁻¹) 10 min before anaesthesia and placed in the supine position with a 6 cm pillow under their head. Routine monitoring, including non-invasive arterial pressure measurement, peripheral oxygen saturation (Sp_{O₂}), and electrocardiography, was used. The height of the operating table was adjusted to place the patient's forehead at the level of one of the four landmarks as determined by the patient group assignment: the umbilicus, lowest rib margin, xiphoid process, and nipple level of the anaesthetist (Fig. 1). After pre-oxygenation, anaesthesia was induced with i.v. propofol (1.5 mg kg⁻¹) and alfentanil (0.01 mg kg⁻¹). For muscle relaxation, i.v. rocuronium (0.6 mg kg⁻¹) was administered, and manual ventilation was provided with a gradual increase of inspired sevoflurane to 6–8 vol%. Two minutes after rocuronium injection, tracheal intubation was performed under direct laryngoscopy using a Macintosh curved blade size 3.

Outcome measures

During mask ventilation, the anaesthetist was directed to take 'initial posture,' that is, the natural standing position with his or

her eyes on the face mask or on the chest movement of the patient.

During tracheal intubation, the anaesthetist inserted the laryngoscope into the patient's mouth and evaluated the grade of laryngeal view in the initial posture. In the initial posture, no changes in flexion or extension of the neck, lower back, knee, and ankle of the anaesthetist were allowed. Arm, hand, or both movements were allowed to expose the patient's laryngeal aperture. The laryngeal view was re-graded after the anaesthetist was allowed to adjust his or her posture with no restriction on movement. The laryngeal views were graded using the Cormack and Lehane criteria: Grade 1, complete visualization of the vocal cords; Grade 2, visualization of the inferior portion of the glottis; Grade 3, visualization of only the epiglottis; and Grade 4, non-visualization of the epiglottis.¹⁰

An anaesthesia trainee who was not aware of the details of the study took pictures of the process of tracheal intubation from either the left or the right side of the anaesthetist. The anaesthetist's postural changes, such as wrist deviation, arm elevation, and neck/lower back flexion during mask ventilation, and the degree of arm elevation and neck/lower back/knee flexion during tracheal intubation were recorded from the pictures by a research assistant who was also not aware of the details of the study. The degrees of joint flexion (angles) were measured using a protractor from the line perpendicular to the long axis of the arm, neck, lower back, or thigh. Wrist deviation indicates the degree of upward or downward movement relative to the forearm from the imaginary line drawn from the long axis of the forearm to the base of the middle finger (Fig. 1A).

After completion of anaesthetic induction, the anaesthetist recorded their subjective assessment of wrist exertion during mask ventilation and joint strains (exertion of the wrist or arm, flexion of the neck, lower back, or knee) and tip toeing during tracheal intubation. The degrees of task discomfort during mask ventilation or tracheal intubation were graded (1=no discomfort, 2=mild discomfort, 3=moderate discomfort, and 4=severe discomfort).

Two intubation attempts were allowed and failure to intubate or clinical signs or evidence of desaturation (Sp_{O₂} <90%) led to the patient being excluded from the study.

Sample size analysis

The sample size required for the present study was estimated from a pilot study (10 patients each for Groups N and U) in which the difference in the grade of the laryngeal view (Cormack L. class) before postural changes was 1 (estimated median value was 3 in Group U and 2 in Group N). When a difference of 1 (25% improvement) in the grade was accepted, 33 patients per group were required for a two-tailed α -error of 0.5% (0.05/10, 0.05 was divided by 10 as the group for the pilot study was 2) and a β -error of 10%. Seven patients were added to each group to compensate for the possible loss of data.

Statistical analysis

Continuous variables were expressed as the mean [standard deviation (SD)], whereas categorical variables were presented

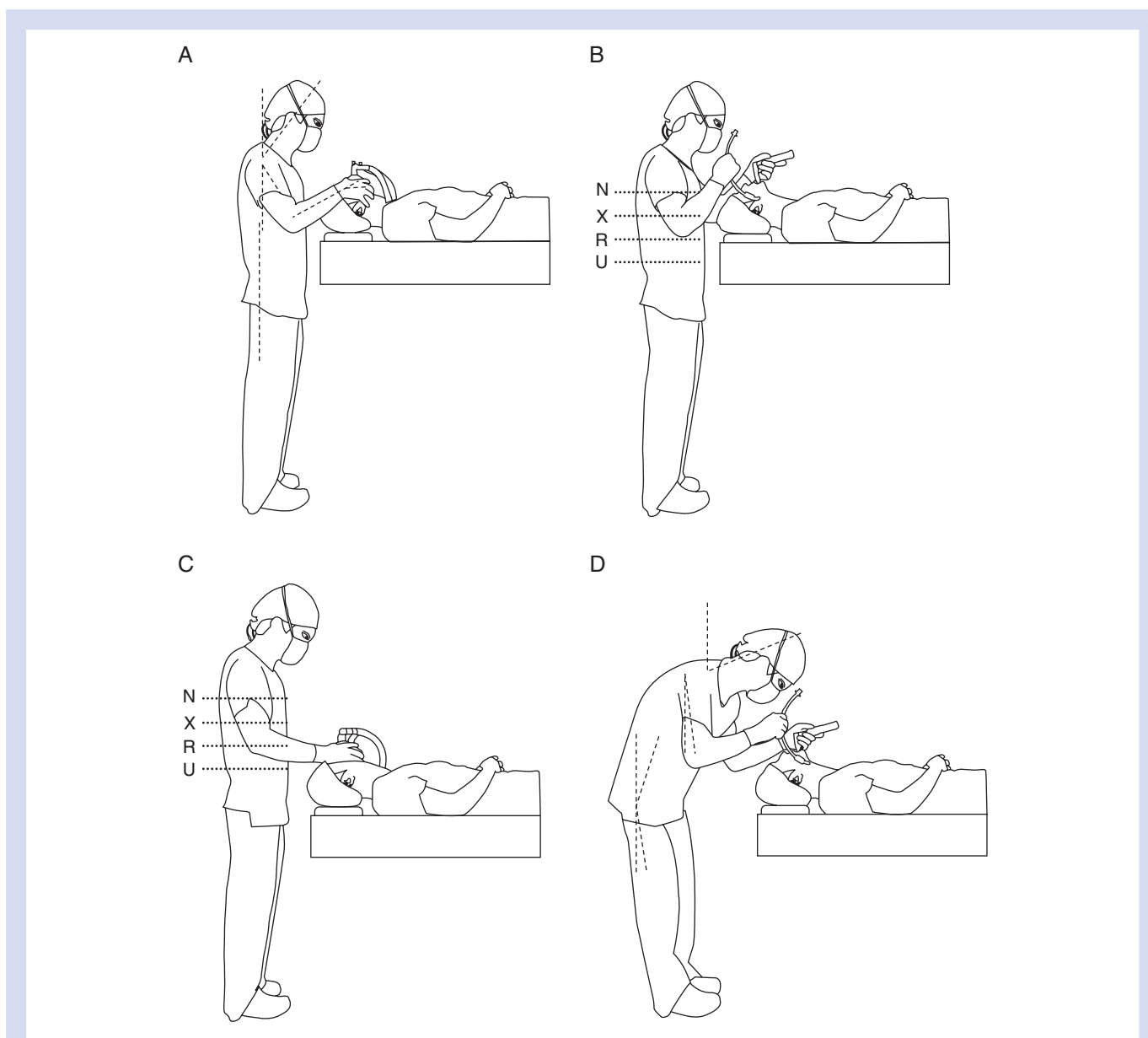


Fig 1 Illustration of the nipple level (A and B) and the umbilicus level (C and D) operating table height during mask ventilation (A and C) and tracheal intubation (B and D). The measured angles of arm elevation, neck, low back, knee flexion, and wrist deviation are indicated with dashed lines. The levels of landmarks are marked as dotted lines. N, nipple; X, xiphoid process; R, lowest rib margin; U, umbilicus.

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as absolute values. Continuous variables were compared using the analysis of variance (age, body weight, BMI, angle of joint flexion, and intubation duration). Categorical variables were compared using the Pearson χ^2 test (gender and subjective measurements of exertion and joint flexion) or the Kruskal–Wallis test (ASA, Mallampati class, laryngeal view, and discomfort score).

A *P*-value of <0.05 was considered statistically significant. The *P*-values of multiple comparisons were corrected by the Bonferroni method. All statistical analyses were performed using SPSS 18.0 for Windows (SPSS, Inc., Chicago, IL, USA).

Results

Eight board-certified anaesthetists (six females and two males) with a mean age of 37 (5.6) yr, weight of 53.6 (8.5) kg, height of 161 (5.5) cm, and no acute or chronic musculoskeletal disease or pain volunteered to participate in the study.

We initially enrolled 208 patients, 32 of whom did not consent to participate in our study and 16 of whom were not eligible. The remaining 160 patients were included and randomized for the study. All the patients completed the study and their data were statistically analysed. Tracheal intubations

were successful at the second laryngoscopy attempt in 2, 1, and 2 patients in the Groups R, X, and N, respectively and they were included in the analysis (Fig. 2).

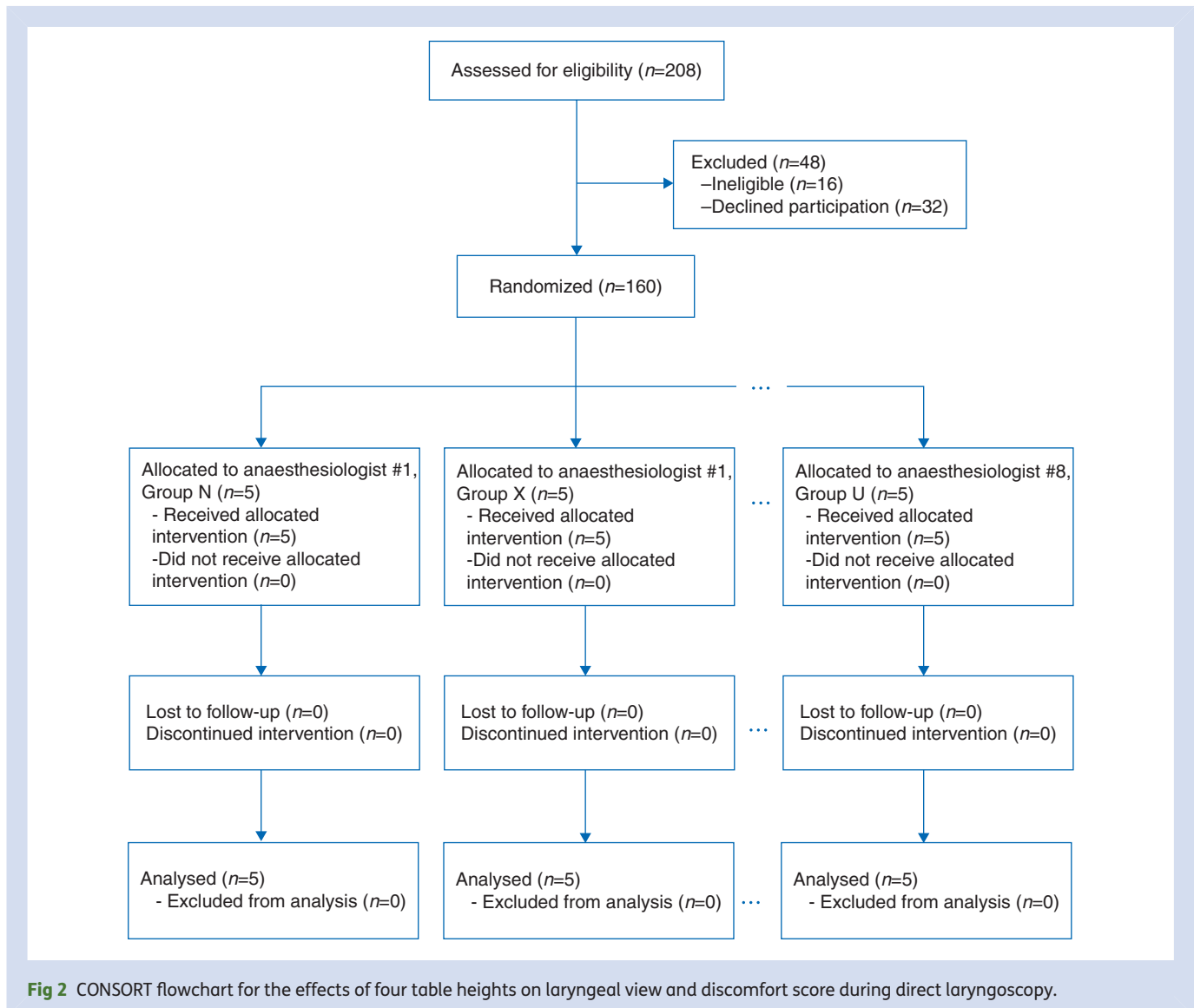
Patient characteristics and pre-anaesthetic airway statuses of the patients were similar between the four groups (Tables 1 and 2).

During mask ventilation, the degree of wrist deviation and arm elevation were higher but the angle of neck flexion was lower in Group N than in the other three groups ($P < 0.01$, Table 3). None of the anaesthetists bent their lower back during mask ventilation. The frequency of wrist exertion was higher in Group N than in Groups U and R ($P < 0.001$, Table 3).

During tracheal intubation, the quality of the laryngeal view before postural changes was better in Group N than in Group U ($P = 0.003$, Table 4). The laryngeal views after postural changes were not significantly different between the four groups ($P = 0.907$, Table 4). This may be attributed to the compensation for table height through postural adjustment by the anaesthetists, such as joint flexion and bending.

During tracheal intubation, the degrees of neck and lower back flexion were greater in Group U than in Groups N and X ($P < 0.01$, Table 5), while the degree of arm elevation was higher in Groups X and N than in Group U ($P < 0.01$, Table 5). The frequency of neck or lower back flexion was higher in Groups U and R than in Groups N and X ($P < 0.01$, Table 5), while the frequency of wrist and arm exertion was higher in Group N than in Groups U and R ($P < 0.001$, Table 5).

Anaesthetists' discomfort scores during mask ventilation were higher in the higher positions (Groups X and N) than in the lower positions (Groups U and R) ($P < 0.001$, Table 3). Anaesthetists' discomfort scores during tracheal intubation were higher in the lower positions than in the higher positions ($P = 0.01$, Table 5). In 11 cases in Group N, the anaesthetists graded discomfort score as 2, and five of them experienced discomfort while inserting the laryngoscope blade into the mouth, extending the patient's neck, or both. One of these 11 cases needed to tiptoe.



The number of attempts and the duration of tracheal intubation were similar between the four groups ($P > 0.05$, Table 4). None of the patients needed an oral airway for adequate mask ventilation.

Table 1 Patient characteristics. Continuous variables are expressed as mean (standard deviation), whereas categorical variables are presented as number of patients. BMI, body mass index in kg m^{-2} ; ASA PS, American Society of Anaesthesiologists Physical Status score

Group	U (n=40)	R (n=40)	X (n=40)	N (n=40)
Gender (M/F)	24/16	16/24	23/17	19/21
Age (yr)	46.4 (46.4)	51.0 (16.0)	52.1 (16.3)	49.7 (16.5)
ASA PS (I/II/III)	30/9/1	25/15/0	26/12/2	24/15/1
Weight (kg)	65.2 (10.4)	61.3 (11.2)	64.1 (9.9)	64.8 (11.9)
BMI (kg m^{-2})	24.1 (3.1)	23.4 (2.8)	23.8 (2.5)	24.5 (3.4)

Discussion

In the present study, the quality of the laryngeal view improved and anaesthetists felt less discomfort during tracheal intubation with higher table heights (xiphoid and nipple positions), which supports our hypothesis.

The results of our study are subject to some limitations. First, it was not possible to blind anaesthetists to the relative table height. Secondly, objective assessment of muscle strains, such as electromyography of the biceps or trapezius, and measurements of three-dimensional orientation¹ were not performed. Thirdly, in more obese anaesthetists, the umbilicus and lowest rib margin have an uncertain vertical relationship to one another. Equally nipple height might mean different things depending on breast size. Fourthly, the laryngeal views were not captured using an endoscope so as to be graded by other blinded investigators. Fifthly, the patient's head and neck posture during laryngoscopy was neither controlled nor monitored. Finally, the study could alternatively have been

Table 2 Pre-anaesthetic airway evaluation. Continuous variables are expressed as mean (sd), whereas categorical variables are presented as number of subjects

Group	U (n=40)	R (n=40)	X (n=40)	N (n=40)
Mallampati (1/2/3/4)	16/16/8/0	20/15/3/2	15/21/3/1	20/15/4/1
Inter-incisor distance (cm)	4.7 (1.1)	4.6 (0.9)	4.4 (0.6)	4.6 (0.6)
Thyromental distance (cm)	8.1 (1.1)	7.3 (0.6)	7.4 (0.2)	7.3 (1.0)
Neck circumference (cm)	35.4 (1.6)	36 (4.9)	34.2 (5.4)	38.4 (3.1)

Table 3 Discomfort score, and objective measured angle of joint deviation or flexion during mask ventilation. Data are presented as the number of patients or mean (sd). * $P < 0.05$ vs Group U. † $P < 0.05$ vs Group R. ‡ $P < 0.05$ vs Group X

Group	U (n=40)	R (n=40)	X (n=40)	N (n=40)	P-value
Mask discomfort (1/2/3/4)	35/4/1/0	36/3/1/0	18/18/4/0 [†]	18/16/5/1 [†]	<0.001
Wrist-deviation angle	10 (8)	7 (8)	14 (10)	21 (6)	<0.01
Arm-elevation angle	23 (7) [‡]	23 (10)	35 (11) [†]	48 (11) [‡]	<0.01
Neck-flexion angle	32 (7) [†]	26 (5)	25 (9) [*]	19 (7) [‡]	<0.01

Table 4 Laryngeal view, discomfort scores for intubation, number of attempts at laryngoscopy, and intubation duration. Categorical variables are presented as the number of subjects, whereas continuous variables are expressed as mean (sd). * $P < 0.05$ vs Group U

Group	U (n=40)	R (n=40)	X (n=40)	N (n=40)	P-value
Laryngeal view (1/2/3/4)					
Before	11/10/11/8	19/12/4/5	11/19/5/5	19/16/5/0 [*]	0.007
After	25/12/2/1	22/15/2/1	24/10/5/1	25/14/1/0	0.907
Intubation discomfort (1/2/3/4)	17/12/7/4	25/11/4/0	28/11/0/1 [*]	28/11/1/0 [*]	0.010
Number of attempts at laryngoscopy (1/2)	40/0	38/2	39/1	38/2	0.757
Intubation duration (s)	15 (6.2)	13 (8.9)	14 (7.0)	15 (5.4)	0.239

Table 5 Subjective exertion or flexion of joint and objective measured angle of joint flexion during tracheal intubation. Data are presented as number of patients or mean (sd). * $P < 0.01$ vs Group U. † $P < 0.01$ vs Group R. ‡ $P < 0.01$ vs Group X. LB, low back; S, subjective; O, objective

Group	U (n=40)	R (n=40)	X (n=40)	N (n=40)	P-value
Wrist exertion (S)	0	0	2	12 [†]	<0.0001
Arm exertion (S)	0	0	1	11 [†]	<0.0001
Elevation angle (O)	27 (6)	28 (7)	34 (6)*	44 (9) [‡]	<0.01
Neck flexion (S)	18	13	3*	0 [†]	<0.0001
Angle (O)	69 (17)	63 (11)	54 (13)*	36 (15) [‡]	<0.01
LB flexion (S)	14	5	0*	0*	<0.0001
Angle (O)	42 (12)	35 (13)	22 (7) [†]	8 (6) [‡]	<0.01
Knee flexion (S)	5	4	2	0	0.1
Angle (O)	18 (13)	15 (13)	5 (8) [†]	1 (3) [†]	<0.01

designed to have within-subject laryngoscopy comparisons which might have carried more weight than individual patient event laryngoscopies.

It has been reported that the workload of anaesthetists is highest when they perform intubation during induction of anaesthesia,¹¹ and a fatigued anaesthetist may result in reduced performance, especially during long-duration monitoring task.¹² Therefore, efforts to decrease discomfort in this period are important for reducing the workload of anaesthetists and improving patient safety.

According to the principle of ergonomics (the science of human factors), workspace design should be based on minimizing discomfort and maximizing performance because human reserves can compensate for poor layout without decrease of performance.¹³ The result of the present study corresponds well with it. With the four different table heights, the laryngeal views after postural changes were not different and it means the compensation of poor layout without decrease of performance. So it is important to place the operating table to minimize discomfort and maximize performance during tracheal intubation.

Generally, working height with a range from 10 cm below to 5 cm above the elbow is recommended for standing workers who are performing precision, light, or heavy work.¹⁴ Elbow height could be between xiphoid process and lowest rib margin, which is quite similar to the height that the authors suggest as an ideal height for the tracheal intubation in the present study. The results of the present study suggest that patients' faces should be placed at the mid-abdomen of the anaesthetist for face mask ventilation and at the xiphoid process for direct laryngoscopy, that the quality of the laryngeal view can improve with higher operating tables, and that tracheal intubation can be performed with less discomfort at higher operation table heights (the xiphoid process and nipple positions). Alternatively, the head-up position, which is currently popular in both obesity subject and in pregnancy,¹⁵ can be helpful to improve the quality of the laryngeal view.

In conclusion, the xiphoid process height, which is the level of the upper abdomen of the anaesthetist, would be more appropriate for tracheal intubation.

Authors' contributions

H.-C.L.: study design, data collection, analysis, and writing the first draft of the paper. M.-J.Y.: study design, data collection, analysis, and writing the first draft of the paper. J.-W.H.: study design and data collection. H.-S.N.: study design and data collection. D.-H.K.: study design and data analysis. J.-Y.P.: study design and data interpretation.

Declaration of interest

None declared.

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