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ORIGINAL ARTICLE

Shallow nasal RAE tube depth after head and neck surgery: association with preoperative and intraoperative factors

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Abstract

Purpose To evaluate risk factors associated with improper postoperative nasal Ring–Adair–Elwyn (RAE) tube depth.

Methods We retrospectively enrolled 133 adult patients who were admitted to the intensive care unit (ICU) with the nasal RAE tube after head and neck surgery. Postoperative chest radiography was performed to confirm nasal RAE tube depth immediately after the patient was admitted to the ICU. Proper tube depth was defined as the tube tip between 2 and 7 cm above the carina. The patients were divided into the proper-depth group (78 patients) and the improper-depth group (55 patients). Patients' characteristics were collected. The risk factors for improper postoperative tube depth were assessed using logistic regression analysis.

Main results All patients who showed improper tube depth had a shallow tube depth (the tube tip > 7 cm above the carina). Multivariable analysis revealed that tall stature [odds ratio (OR) 1.16; 95% confidence interval (CI) 1.08–1.25; $P < 0.001$], prolonged anesthesia duration (OR 1.16; 95% CI 1.02–1.32; $P = 0.026$), and right-sided surgical field as compared to the left (OR 0.36; 95% CI 0.14–0.93; $P = 0.034$) or median field (OR 0.25; 95% CI 0.07–0.85; $P = 0.027$) were risk factors associated with postoperative shallow tube depth.

Conclusions Tall stature, prolonged anesthesia duration, and right-sided surgical field were independent risk factors for postoperative shallow nasal RAE tube depth.

Keywords Depth · Nasal intubation · Postoperative care · Risk factor · Shallow

Introduction

Nasotracheal intubation has been performed in head and neck surgery for maximizing the surgical field [1]. Sometimes, patients undergoing head and neck surgery are admitted to the surgical intensive care unit (SICU) with a nasotracheal tube for prolonged mechanical ventilation (MV). Thereafter, MV is maintained until airway patency and wound stabilization are achieved.

Proper endotracheal tube depth is an important component for prolonged MV to prevent complications such as inadvertent extubation, vocal cord trauma, or endobronchial intubation [2–4]. Proper endotracheal tube depth has the distal tube tip located at the mid-trachea in the neutral head position. Generally, endotracheal tube placement is considered adequate if the tip is positioned 2–7 cm above the carina, as observed on chest radiography (CXR) [5, 6].

The patients undergoing head and neck surgery expose a risk of endotracheal tube depth changes according to flexion, extension, and rotation of head and neck. Usually, an anesthesiologist evaluates tube depth after intubation by combining various methods, including direct view of the tube cuff during intubation, auscultation using a stethoscope, and analyses of airway pressure curves. However, the evaluation of tube depth is overlooked at the end of surgery despite the possibility that the tube tip is improper after head and neck surgery. Improper depth of tube tip may lead to respiratory

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adverse effects during the handoffs from an operating room to the SICU. Therefore, the aim of study was to evaluate the risk factors associated with improper nasotracheal tube depth among patients undergoing prolonged MV after head and neck surgery.

Methods

After obtaining approval from the Institutional Review Board of our institution, we retrospectively investigated all adult patients (age ≥ 18 years) who were admitted to the SICU with nasal RAE tubes after surgery between January 2008 and December 2016. The enrolled patients had undergone surgery under general anesthesia and immediate postoperative CXR.

During anesthesia induction, the nasal Ring–Adair–Elwyn (RAE) tube (Mallinckrodt™, Covidien, Mansfield, MA, USA) size and the nostril for intubation were selected by the attending anesthesiologist, who had more than 20 years of experience in anesthesia of head and neck surgery. After surgery, if the surgeon demanded absolute stabilization of the surgical site, or if the anesthesiologist determined that airway patency could not be maintained when the patient was extubated, the patient was transferred to the SICU in the intubated condition. As soon as the patient arrived at the SICU, the intensivists administrated sedatives and analgesics and began MV. After the initial assessment by the attending nurses was completed, CXR was performed. When performing CXR, the patient was kept as supine and neutral head positions without surgeon's request to fix the head in one direction.

We defined proper nasal RAE tube depth on the basis of the findings of the first CXR acquired on arrival at the SICU. We measured the distance between the tube tip and the carina on the CXR image and divided the patients into the proper-depth group and improper-depth group. According to previous studies, proper depth is defined as the tube tip being located between 2 and 7 cm above the carina [5, 6]. In contrast, improper depth is defined as the distance between the tube tip and the carina being closer than 2 cm or more than 7 cm.

In the SICU, an attending nurse recorded the nasal RAE tube depth at the nostril. If a surgeon requested restriction of the patient's position for wound stabilization, the patient's position was maintained accordingly. Otherwise, the patient was positioned with the head of the bed elevated at 30° and supine. Ventilator weaning was evaluated by considering the patient's condition, airway patency, and wound stabilization. If the patient met the weaning criteria, sedation drugs were stopped and extubation was performed by an attending intensivist.

We collected the patients' perioperative data from electronic medical records and CXR. Preoperative variables included the patients' demographics and the carina level relative to the vertebral body on CXR. Intraoperative variables included the department of surgery, laryngoscopic grade, nasal RAE tube size, fixed tube depth (cm), operating position of the patient, amount of fluid intake, amount of packed red blood cell transfusion, blood loss and urine output, anesthesia and surgical durations, direction of the surgical field, and the use of intraoperative vasopressors. Postoperative variables included fixed tube depth (cm) recorded by a nurse, sedation depth (Richmond Agitation–Sedation Scale), position of the patient (head of bed elevated or not, and whether the neck was fixed in the left or right side), and nasal RAE tube depth on portable CXR identified on the day of surgery.

Statistical analyses were performed using R version 3.4.0 (the R Foundation for Statistical Computing, Vienna, Austria) and SAS (version 9.4, SAS Inc., Cary, NC, USA). Categorical variables were compared between groups using two-tailed Fisher's exact test or Chi-squared test. Continuous variables were tested for normal distribution using the Shapiro–Wilk test. If the data were normally distributed, the data were analyzed using Student's *t* test and expressed as the mean ± standard deviation. If not, we used a Mann–Whitney *U* test and expressed the data as the median (interquartile range). Thereafter, univariable logistic regression analyses were performed for each perioperative variable. After univariable logistic regression modeling, the significant variables were entered in the multivariable models with Firth bias correction to assess the risk factors for improper postoperative tube depth. We chose a backward stepwise multivariable model with the largest Akaike information criterion (AIC). The results were expressed as odds ratios (ORs) with 95% confidence intervals (CIs) and the relevant *P* values. Receiver operating characteristics analyses and area under the curve (AUC) were used to determine the cutoff values of significant continuous variables in the multivariable model. A P value < 0.05 was considered statistically significant.

Results

In total, 133 patients who underwent head and neck surgery and were admitted to the SICU for ventilator care with nasal RAE tubes were included in this study. Of these patients, 55 showed postoperative shallow nasal RAE tube depth (distal tip of the nasal RAE tube > 7 cm above the carina) and none showed deep tube depth (distal tip of the nasal RAE tube < 2 cm above the carina). The CXR image illustrating shallow tube depth is shown in Fig. 1. The patients were divided into the proper-depth group (78 patients) and the shallow-depth group (55 patients). Preoperative CXR data were missing for one

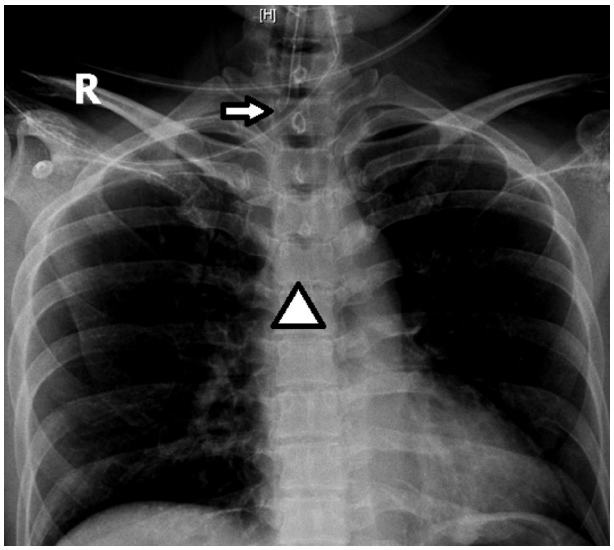

Fig. 1 Postoperative chest radiography performed immediately after admission to the surgical intensive care unit. The arrow indicates the distal tip of the nasotracheal tube. The triangle indicates the carina

patient who had undergone emergency surgery without preoperative CXR because of a deep neck infection. Preoperative CXR data for all other patients were collected. The patients' characteristics and perioperative variables are shown in Table 1.

Several variables were evaluated as risk factors for postoperative shallow tube depth using univariable logistic regression analysis (Table 2). Of these perioperative variables, eight factors were identified as showing significance ($P < 0.05$). The risk factors were male sex, tall stature, high body weight, low carina level on preoperative chest radiography, prolonged anesthesia and surgical durations, right-sided surgical field, postoperative restriction of posture, and deep postoperative tube fixation.

Considering multicollinearity, we chose variables for the multivariable logistic regression analysis from among the significant variables. The multivariable model selected on the basis of the largest AIC is shown in Table 3. This analysis revealed that tall stature (OR 1.16; 95% CI 1.08–1.25; $P < 0.001$), prolonged anesthesia duration (OR 1.16; 95% CI 1.02–1.32; $P = 0.026$), and right-sided surgical field compared to the left (OR 0.36; 95% CI 0.14–0.93; $P = 0.034$) or median field (OR 0.25; 95% CI 0.07–0.85; $P = 0.027$) were independent risk factors associated with postoperative shallow tube depth. The cutoff values that showed the best combined sensitivity and specificity were the height of 168.5 cm (sensitivity 69%; specificity 76%; AUC 0.75; 95% CI 0.67–0.84) and anesthesia duration of 7.5 h (sensitivity 80%; specificity 53%; AUC 0.66; 95% CI 0.56–0.75).

Discussion

We evaluated nasal RAE tube position in patients who underwent head and neck surgery and were admitted to the SICU for ventilator care. All patients who showed improper tube depth had shallow tube depth (distal tip of the nasal RAE tube > 7 cm above the carina) on postoperative CXR. We identified several perioperative risk factors for postoperative shallow tube depth. After adjustment between variables, tall stature, prolonged anesthesia duration, and right-sided surgical field were independent risk factors for postoperative shallow tube depth.

Improper depth of the endotracheal tube leads to several complications such as inadvertent extubation, vocal cord trauma, or endobronchial intubation [2–4]. In addition, repositioning of the endotracheal tube entails risks such as ventilator-associated pneumonia [7]. Hence, many studies have been performed and several formulae have been published for predicting proper endotracheal tube depth [8–16]. Among these studies, most studies on adult nasal intubation included height as a predictor, together with the nares-to-tragus distance, nares-to-mandibular distance, or weight [11, 13, 15, 16].

In the present study, height was a potent risk factor for postoperative shallow tube depth (OR 1.16; 95% CI 1.08–1.25; $P < 0.001$). However, considering that height is a predictor of proper tube depth, it is likely that the tube depth was shallow in some patients with tall stature immediately after intubation, not after surgery. Because the depth of tube fixation was limited by the length from the distal tip to the curvature depending on the tube size, the selection of inappropriate tube size may have affected improper tube depth. Actually, the tube size correlated with height ($r = 0.516$, $P < 0.001$), however, there was no correlation between the tube size and height when compared by dividing sex ($P > 0.05$). In contrast, sex showed a significant correlation with the tube size ($r = 0.711$, $P < 0.001$). As these results, our anesthesiologists seem to have selected the nasal RAE tube considering sex rather than height, which may have caused improper tube depth.

Previous studies using CXR showed that 14–24% of endotracheal tubes were malpositioned after oral intubation [17–19]. Our study showed that 41% of the nasal RAE tubes were at a shallow depth after surgery. One of the reasons why our incidence was higher than that of previous studies could be due to limitations of intubation length according to the features of the nasal RAE tube. Another reason may be the change of tube depth during surgery. Depth changes of the endotracheal tube according to flexion, extension, and rotation of head and neck have been described [20–22]. In this study, prolonged anesthesia duration was another risk factor for postoperative shallow

Table 1 Perioperative variables compared between two groups

Variables	Total ($n=133$)	Proper-depth group ($n=78$)	Improper-depth group ($n=55$)	P value
Preoperative variables				
Sex, female, *n* (%)	33 (25)	29 (37)	4 (7)	< 0.001
Age (years)	58 (45–67)	58 (47–67)	57 (41–67)	0.747
Height (cm)	166 ± 8	163 ± 9	170 ± 6	< 0.001
Weight (kg)	61 (54–68)	60 (52–65)	64 (60–70)	0.007
Body mass index (kg/m^2)	22 (20–25)	22 (20–25)	22 (20–24)	0.868
Carina level on chest radiography, *n* (%)				0.009
T4–5	43 (33)	32 (42)	11 (58)	
T6–7	89 (67)	45 (58)	44 (80)	
Intraoperative variables				
Surgical department, *n* (%)				0.439
Oral and maxillofacial	95 (71)	57 (73)	38 (69)	
Plastic	5 (4)	4 (5)	1 (2)	
Ear, nose and throat	33 (25)	17 (22)	16 (29)	
Laryngscopic grade, *n* (%)				0.424
1	95 (71)	57 (73)	38 (69)	
2	15 (11)	6 (8)	9 (16)	
3	13 (10)	8 (10)	5 (9)	
4	10 (8)	7 (9)	3 (5)	
Tube size, *n* (%)				0.390
5/5.5	3 (2)	3 (4)	0 (0)	
6/6.5/7	128 (96)	74 (95)	54 (98)	
7.5/8	2 (2)	1 (1)	1 (2)	
Tube fixation (cm)	26.0 (25.0–27.0)	26.0 (25.0–27.0)	26.0 (25.0–27.0)	0.717
Transfusion, *n* (%)	25 (19)	16 (20.51%)	9 (16.36%)	0.547
Blood loss (ml)	395 (200–700)	325 (200–700)	450 (200–700)	0.666
Input fluid (ml/min)	5.8 (5.0–7.1)	5.7 (5.1–6.9)	6.0 (4.9–7.4)	0.486
Urine (ml/min)	1.4 (1.0–1.9)	1.38 (1.0–1.9)	1.3 (0.9–2.0)	0.960
Anesthesia duration (min)	510 (395–615)	450 (373–584)	575 (475–675)	0.002
Direction of surgical site, *n* (%)				0.098
Right	44 (33)	20 (26)	24 (44)	
Left	58 (44)	39 (50)	19 (35)	
Median	26 (20)	17 (22)	9 (16)	
Bilateral	5 (4)	2 (3)	3 (5)	
Use of vasopressors, *n* (%)	32 (24)	18 (23)	14 (25)	0.752
Postoperative variables				
Restriction of position, *n* (%)	76 (57)	38 (49)	38 (69)	0.019
Tube fixation (cm)	27.0 (26.0–27.0)	26.50 (26.0–27.0)	27.0 (26.0–28.0)	0.035
Sedation depth, RASS				0.469
< 0	120 (92)	71 (95)	49 (89)	
0	2 (2)	1 (1)	1 (2)	
> 0	8 (6)	3 (4)	5 (9)	

RASS Richmond Agitation–Sedation Scale, *T4–5* fourth–fifth thoracic vertebra, *T6–7* sixth–seventh thoracic vertebra

tube depth. Because long surgeries entail a greater possibility of exposed movements of the head and neck, depth changes of the tube during surgery may contribute to tube malposition.

Interestingly, another risk factor for shallow tube depth was a right-sided surgical field. This could be explained by the depth changes of the nasal RAE tube according to neck rotation. When the surgical site was the same side as the

Table 2 Univariable logistic regression for perioperative variables in relation to postoperative improper tube depth

Variables	Odd ratio	95% confidence intervals	*P* value
Preoperative variables			
Sex, female, *n* (%)	0.13	0.04–0.41	< 0.001
Age (years)			
Height (cm)	1.14	1.08–1.21	< 0.001
Weight (kg)	1.04	1.01–1.07	0.019
Body mass index (kg/m^2)	0.99	0.90–1.09	0.872
Carina level on chest radiography, *n* (%)			
T4–5	Reference		
T6–7	2.84	1.28–6.34	0.011
Intraoperative variables			
Surgical department, *n* (%)			
Oral and maxillofacial	Reference		
Plastic	0.38	0.04–3.49	0.389
Ear, nose and throat	1.41	0.64–3.13	0.396
Laryngscopic grade, *n* (%)			
1	Reference		
2	2.25	0.74–6.84	0.153
3	0.94	0.29–3.08	0.915
4	0.64	0.16–2.64	0.540
Tube size, *n* (%)			
5/5.5	Reference		
6/6.5/7	5.12	0.16–159.63	0.352
7.5/8	7.01	0.09–572.53	0.386
Tube fixation (cm)	1.09	0.86–1.39	0.472
Transfusion, *n* (%)	0.76	0.31–1.87	0.547
Blood loss (ml)	1.00	1.00–1.001	0.746
Input fluid (ml/min)	1.06	0.89–1.26	0.530
Urine (ml/min)	1.18	0.85–1.63	0.320
Anesthesia duration (min)	1.002	1.000–1.004	0.024
Surgical duration (min)	1.002	1.000–1.004	0.026
Direction of surgical site, *n* (%)			
Right	Reference		
Left	0.41	0.18–0.91	0.029
Median	0.44	0.16–1.20	0.110
Bilateral	1.25	0.19–8.23	0.817
Use of vasopressors	1.14	0.51–2.54	0.190
Postoperative variables			
Restriction of position, *n* (%)	2.35	1.14–4.85	0.021
Tube fixation (cm)	1.49	1.09–2.04	0.013
Sedation depth, RASS			
< 0	Reference		
0	1.45	0.09–23.72	0.795
> 0	2.42	0.55–10.58	0.242

RASS Richmond Agitation–Sedation Scale, *T4–5* fourth–fifth thoracic vertebra, *T6–7* sixth–seventh thoracic vertebra

Table 3 Multivariable logistic analysis for evaluating factors related to postoperative improper tube depth

Variables	Odds ratio	95% confidence intervals	*P* value
Height (cm)	1.16	1.08–1.25	< 0.001
Carina level on preoperative chest radiography			
< T6	Reference		
≥ T6	2.42	0.95–6.16	0.064
Anesthesia duration	1.16	1.02–1.32	0.026
Direction of surgical site, *n* (%)			
Right	Reference		
Left	0.36	0.14–0.93	0.034
Median	0.25	0.07–0.85	0.027
Bilateral	2.37	0.26–21.75	0.445

T6 sixth thoracic vertebra

surgeon's dominant hand, neck rotation was more needed than the median or opposite side to prevent the patient's shoulder from interfering with the movement of their hand. Because all the surgeons of this study were right-handed, relatively more neck rotation and corresponding depth changes of the tube may contribute to postoperative shallow tube depth in patients undergoing surgery with a right-sided surgical field. Even though the patient's head returned to the neutral position after surgery, the tube tip would not have returned to its original position.

Contrary to expectations, postoperative tube fixation depth immediately after admission to the SICU was deeper in the shallow-depth group than in the proper-depth group on univariable analysis (median 27.0 cm versus 26.5 cm; $P = 0.035$) (Table 1). Although there was no statistical significance, the mean difference in tube fixation depth at the SICU and induction of anesthesia was greater in the shallow tube depth group than proper tube depth group (the depth at the SICU — the depth at induction of anesthesia: 0.91 ± 1.57 cm versus 0.48 ± 1.50 cm). It is possible that the anesthesiologist felt the tube too shallow in the shallow-depth group and re-fixed the tube more deeply. However, the tube distal tip seems to have not changed by the changes in tube fixation depth. This finding is consistent with that of a previous report that the changes in tube fixation depth were poorly correlated with the changes in endotracheal tube distal tip [23]. This implies that the reliability of tube fixation depth is poor when evaluating proper endotracheal tube depth. Therefore, tube depth was confirmed through CXR or fibrobronchoscopy and not tube fixation depth.

Serious adverse events occur mainly in the period of handoffs from operating room to the intensive care unit. Many hospitals have an own handoff protocol to minimize incomplete handoffs, and an essential factor of handoff protocols is intubation details [24]. Therefore, we focused

on the endotracheal tube management immediately after the patient is admitted to the SICU rather than in the operating room. Although many studies have reported the prediction of proper endotracheal tube depth, no studies have investigated the predictors for improper postoperative tube depth. We believe that our results may affect the management of endotracheal tube at the end of surgery. In other words, the anesthesiologist needs to re-evaluate the tube tip at the end of surgery not only patients with these risk factors, but also all patients receiving prolonged MV before transferring the patients to the SICU.

Our study has several limitations. First, because we could not confirm the depth of tube immediately after intubation, there was a possibility to have a shallow tube depth immediately after intubation in some patients. Second, the criteria of improper tube depth were determined independently of the height, it may not be appropriate to apply it to patients with tall stature. Nonetheless, since it is difficult to apply each criterion according to the height for each patient, we used the criteria of proper tube depth used in previous studies [9, 25, 26]. Third, because the sample size was relatively small, it was likely to be underpowered for several variables. For example, although the preoperative carina level relative to the vertebral body on CXR did not show a significant difference between the two groups on multivariable logistic regression analysis, a significant difference could have been found in a larger study. Fourth, owing to the limitations of the retrospective study design, we could not assess all potential variables such as intubated nostril, neck distance, or number of intraoperative head rotations. Finally, portable CXR might not standardize the patients' positions, and this might have affected our results.

In conclusion, shallow nasal RAE tube depth after head and neck surgery was present in 41% of patients. We identified several perioperative risk factors for postoperative shallow tube depth. After adjustment between variables, tall stature, prolonged anesthesia duration, and right-sided surgical field were independent risk factors for postoperative shallow tube depth. Our study suggests that the anesthesiologist should evaluate the nasal RAE tube depth at the end of surgery and the intensivists need to carefully assess the tube depth on the postoperative CXR in the patients with these risk factors. Nevertheless, further exploration is needed to confirm these potential risk factors associated shallow nasal RAE tube depth after head and neck surgery through observation of the behavior of the surgical team and control of confounding factors.

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Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

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