ORIGINAL RESEARCH

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Risk factors of arytenoid dislocation after endotracheal intubation: A propensity-matched analysis

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Abstract

Objective: Arytenoid dislocation (AD) after general anesthesia with endotracheal intubation (EI) is an iatrogenic injury that impairs patient function and requires reduction. We aimed to investigate the risk factors of AD following EI.

Methods: This retrospective case-control study involved surgical adults who received EI for general anesthesia at a single institution from June 2010 to June 2020. Cases included all the patients who had AD. We used a ratio of 1:5 to identify patients in the propensity-matched control group.

Results: Multivariate analysis of 49 cases with AD and 245 controls without AD demonstrated that the use of a nasogastric (NG) tube (odds ratio [OR], 23.9; 95% confidence interval [CI], 6.8–84.1), undergoing abdominal surgery (OR, 3.7; 95% CI, 1.2–11.9), and an operative time longer than 3 h (OR, 5.2; 95% CI, 2.1–12.9) were risk factors for AD. We did not find significant independent associations between AD and 40 years or older age, gender, body mass index, whether a laryngeal mask airway was used, endotracheal tube size, and EI performers' experience.

Conclusion: The use of an NG tube, abdominal surgery, and longer operative time were risk factors for AD. Among these, the NG tube application showed a strong association with AD. Preventive measures of informing the patients of the increased risk and providing high-level patient monitoring can reduce the incidence of AD.

Level of Evidence: III

KEYWORDS
arytenoid dislocation, endotracheal intubation, general anesthesia, risk factor, surgery

1 | INTRODUCTION

Arytenoid dislocation (AD) is a condition in which the arytenoid cartilage moves away from its normal anatomical position in the cricoarytenoid joint capsule under an external force to a position that partially or entirely separates from the cricoid cartilage, resulting in a paradoxical abduction of the involved side during inspiration because of Bernoulli effect,[1] dysphonia, sore throat, coughing and other disorders. AD often occurs after blunt trauma to the larynx or after invasive procedures in the laryngeal cavity, and injury

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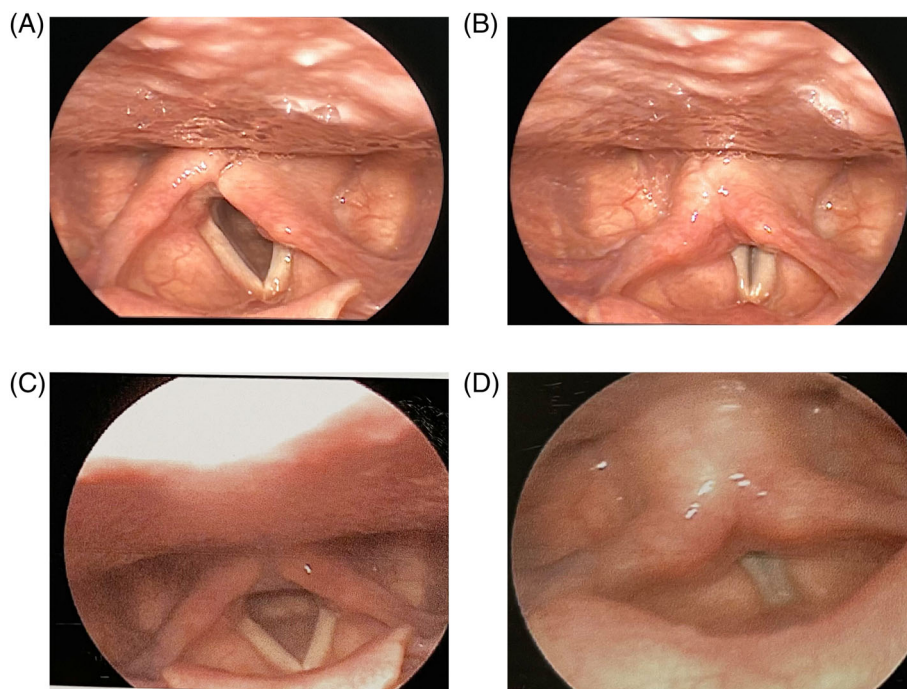Xiangyu Kong and Yang Song contributed equally to this work.

FIGURE 1 Video laryngoscopy images showing arytenoid dislocation (A,B) and vocal folds after closed reduction of arytenoid dislocation (C,D)

associated with endotracheal intubation (EI) is the leading cause.[2] The incidence of AD caused by the intubation was reported as between 0.029% and 0.97%. In recent years, the number of general anesthesia and EI used in surgery has increased, and consequently, the prevalence of AD has increased.[3,4] A recent systematic review found that the incidence of arytenoid subluxation or dislocation in patients who received EI was 0.01%.[5] Previous studies found that risk factors for AD include loosening of cricoarytenoid joint capsule, insertion and extraction of EI using too much force, placement of nasogastric (NG) tube, and prolonged operation time.[6,7] In order to effectively prevent AD in procedures, it is important to learn about any related factors that potentially increase its incidence risk.

In a single institution, the event rate of AD is usually not high enough to identify factors that reach statistical significance when including any types of patient in the analysis. In this study, we conducted a retrospective chart review in our hospital. We applied a propensity score matching (PSM) analysis to investigate the profile of AD following EI and the associated risk factors for AD and provide information for the prevention of AD in patients who receive EI and general anesthesia for surgery.

2 | MATERIALS AND METHODS

2.1 | Study overview

This is a retrospective observational study with a case-control design. We reviewed the records of hospitalized patients in the authors' institution from June 2010 to June 2020. We followed the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines to conduct our research and reporting.[8,9] The First Affiliated Hospital of Dalian Medical University's Medical Ethics Committee approved the study (approval no. 2022053). All participants provided written informed consent.

2.2 | Study population

We included all the surgical adult patients (≥ 18 years) who were diagnosed with AD during the study period as the cases, with the following diagnostic criteria: (a) hoarseness associated with an invasive procedure in the larynx, such as after tracheal intubation or placement of an NG feeding tube; (b) physical and video laryngoscopic examinations found local congestion and swelling on the affected side of the cricoarytenoid joint, the vocal fold was attached to the paramedian position, and the arytenoid cartilage was displaced (Figure 1A,B).[10] For patients with an anterior AD, the arytenoid cartilage was low-hanging, the vocal folds were arc-shaped, and the glottis demonstrated a fusiform shape. For patients with a posterior AD, the arytenoid cartilage was in the posterior position, the vocal fold on the affected side was longer than that on the unaffected side, and the glottis demonstrated a long triangular shape[11]; (c) the laryngeal computerized tomography (CT) scan found disparities in the heights of the vocal folds as well as the angles of the glottis between the affected and unaffected sides, partial or complete separation of the arytenoid cartilage and the cricoid cartilage, and that the joint space was enlarged (Figure 2. Ideally, it is desirable to present CT images at several levels of consecutive sequences. Our CT layer spacing was 0.5 mm and we were not able to include clear, multi-layer images illustrating an entire cricoarytenoid joint in this article)[12]; and (d) the patient's symptom of hoarseness had significantly improved after the closed reduction of AD with topical anesthesia and video laryngoscopy (Figure 1C,D).[13]

FIGURE 2 Computerized tomography images of arytenoid dislocation on the left side. The white arrows show the spaces of the arytenoid joints
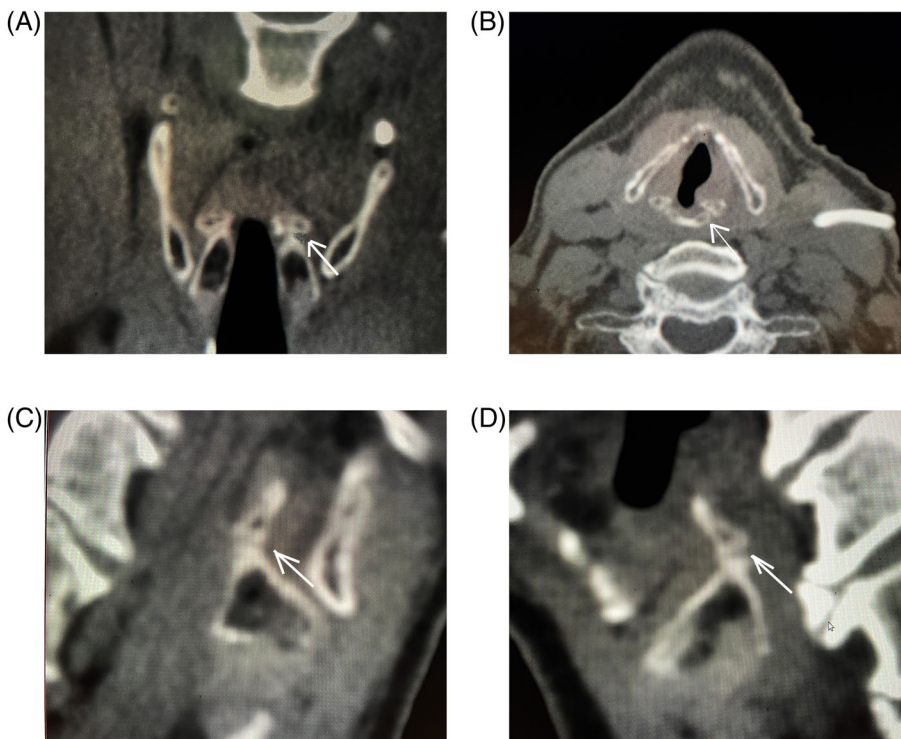
For the propensity-matched control group, we used a ratio of 1:5[14] to randomly select the patients without AD who underwent surgery and were matched by age and gender during the same study period. Patients who did not receive EI were readmitted two or more times, only received local anesthesia for cardiac stent placement, and ophthalmological surgical procedures were excluded.

2.3 | Endotracheal intubation

Every patient in our study underwent a standardized procedure of EI by a well-trained healthcare team. The patients rested in a supine position with their heads tilted back. The operator opened the patient's mouth by slightly lifting the patient's chin forward and upward or placing the right thumb against the patient's mandibular teeth with a rotational force. Holding the laryngoscope in the left hand, when the uvula was seen, the operator lifted the laryngoscope's blade vertically and advanced to expose the epiglottis. The blade was lifted forward and upward so that the hyoepiglottic ligament was forced to lift the epiglottis to move close to the blade, exposing the glottis. Most operators were right handed, but where the operator was left handed, the laryngoscope was held in the right hand, and the tube was placed with the left hand.

When a stylet was used to assist the EI procedure, the operator removed the stylet when the tube's tip arrived at the glottis and before inserting the tube into the trachea. Then, the operator gently and accurately inserted the tube's tip into the glottis, with the tube's advancing direction guided by viewing the anatomy through the narrow gap between the blade and the tube. The depth of the endotracheal tube inserted into the trachea was 4–5 cm for adults, and the distance from the distal tip of the tube to the patient's incisors was 18–23 cm. After the operator had confirmed the correct position of the tube in the trachea, the tube was adequately secured, and the cuff was inflated. End-tidal carbon dioxide was monitored throughout the surgery. Generally, 7.0# endotracheal tubes were used for women, and 7.5# for men. For children, the tracheal intubation selection was based on (age/4 + 4). The endotracheal tube was removed when the patients woke up and within 1 h after the surgery unless mechanical ventilation was required.

2.4 | Closed reduction of AD

The patient was seated, and after local anesthesia of the laryngeal cavity, laryngeal forceps were inserted under video-laryngoscopy to the affected lateral part of the arytenoid cartilage at a depth of 1 cm in the pyriform fossa. The arytenoid cartilage was plucked upward, medially, and posteriorly along the long axis of the arytenoid joint surface for anterior dislocation and upward and anteriorly for posterior dislocation until the hoarseness improved. Video laryngoscopic examinations were performed at 1 and 3 months postoperations.

2.5 | Data collection

We obtained data from the institutional electronic patient records, including patient's age, gender, body mass index (BMI), operative time (divided into patients with <3 h and those with more than 3 h), type

TABLE 1 Demographic and clinical characteristics of patients

Characteristic	AD (N = 49)	Control, no AD (N = 245)	p-value
Age (N)			
< 40 years	1 (2.0)	26 (10.6)	.06
≥ 40 years	48 (98.0)	219 (89.4)	
Gender (N)			
Male	24 (49.0)	121 (49.4)	1.00
Female	25 (51.0)	124 (50.6)	
BMI (kg/m^2)	23.1 (21.2–26.4)	24.1 (21.4–27.8)	.11
Use of nasogastric tube (N)			
Yes	45 (91.8)	41 (16.7)	<.001
No	4 (8.2)	204 (83.3)	
Use of laryngeal mask airway			
Yes	2 (4.1)	27 (11.0)	.543
No	47 (95.9)	218 (89.0)	
Endotracheal tube size			
5	0	3 (1.2)	.696
6	0	4 (1.6)	
6.5	0	15 (6.1)	
7	32 (65.3)	105 (42.9)	
7.5	15 (30.6)	91 (37.1)	
Abdominal surgery (N)			
Yes	40 (81.6)	61 (24.8)	<.001
No	9 (18.4)	184 (75.2)	
Type of surgery (N)			
Abdominal[a]	40 (81.6)	51 (20.8)	<.001
Orthopedic	3 (6.1)	56 (22.9)	
Gynecology	1 (2.0)	28 (11.4)	
Otolaryngology	1 (2.0)	29 (11.8)	
General surgery[b]	0	28 (11.4)	
Vascular	1 (2.0)	10 (4.1)	
Brain surgery	0	11 (4.5)	
Urologic	1 (2.0)	18 (7.4)	
Oral	1 (2.0)	10 (4.1)	
Cardiac	1 (2.0)	4 (1.6)	
Operative time (min)	184 (140–364)	120 (60–240)	<.001
Operative time by groups			
≤ 3 h	23 (46.9)	208 (84.9)	<.001
> 3 h	26 (53.1)	37 (15.1)	<.01
Practicing period of the anesthesiologists (years)	11.0 (5.0–25.0)	12.0 (5.0–26.0)	.71

Note: Continuous variables are presented as medians (Q25–Q75); categorical variables are presented as numbers (percent).
Abbreviations: AD, arytenoid dislocation; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared).
[a]Stomach, liver, bile bladder, pancreas, spleen, intestines, appendix.
[b]Hernia, breast, resection of superficial tumors, debridement, and suture.

of surgery, the experience of the corresponding anesthesiologists who performed the EI, endotracheal tube size, the use of a laryngeal mask airway (LMA), and placement of an NG tube. We compared these variables between the case and propensity-matched control groups to investigate potential risk factors for AD after the EI.

2.6 | Statistical analysis

Statistical data analysis was performed using IBM SPSS Version 22.0 (IBM Corp., Armonk, New York). Probability plotting methods were used to test the distribution of the continuous variables.[15] Differences
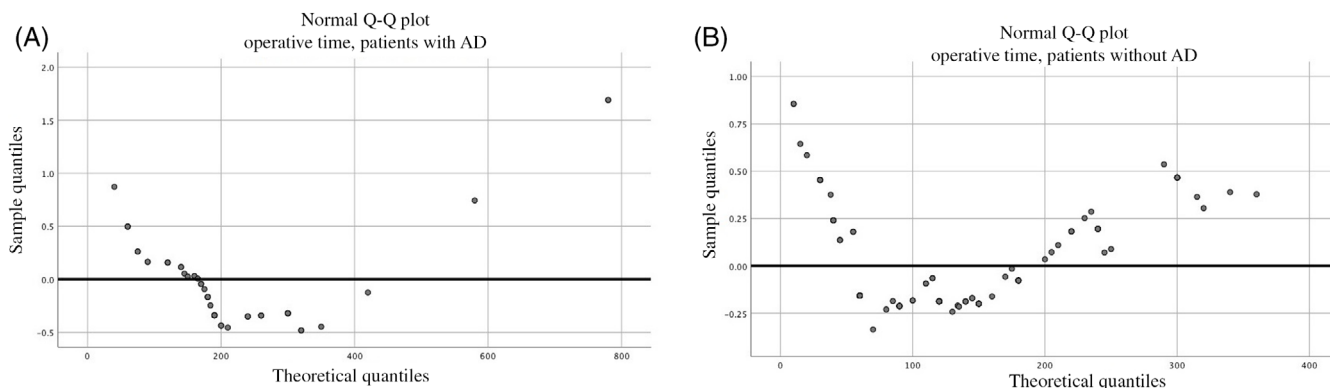
FIGURE 3 Q–Q plots of operative time in case and control groups. AD, arytenoid dislocation

TABLE 2 Risk factors of arytenoid dislocation

Factor	Univariate logistic regression		Multivariate logistic regression	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Use of nasogastric tube	55.98 (19.08–164.21)	<.001	23.95 (6.81–84.15)	<.001
Abdominal surgery	13.41 (6.15–29.21)	<.001	3.70 (1.15–11.86)	.028
Operative time >3 h	6.35 (3.28–12.31)	<.001	5.16 (2.06–12.93)	<.001

Abbreviations: OR, odds ratio; CI, confidence interval.

between groups were compared using the Chi-square test, Fisher's exact test, or Mann–Whitney test. The odds ratios (ORs) and 95% confidence intervals (CIs) were calculated and reported. Variables with *p* < .1 in the univariate logistic regression analysis were included in the multivariate logistic regression model, where *p* < .05 was considered statistically significant.

3 | RESULTS

The case group comprised 49 patients diagnosed with AD. After matching their age and gender by PSM with a ratio of 1:5, we obtained 245 patients without AD as the control group. The mean age of the 294 patients included in the analysis was 56.69 years (SD: 7.36; range: 42–73 years). Among the patients with AD, 48 had an anterior dislocation, and 1 had a posterior dislocation; 34 patients had the AD on the left side, and 15 patients had the AD on the right side. There were no significant differences between the case and control groups in terms of age groups (<40 years or ≥ 40 years), gender, BMI, the use or non-use of the LMA, size of the endotracheal tube, and the experience of the anesthesiologist (*p* > .05; Table 1).

The Q–Q plots showed that the operative time in both groups was not a normal distribution (Figure 3), with a median of 184 min in the case group and 120 min in the control group (*p* < .01; Table 1). In univariate analysis, using an NG tube and abdominal surgery showed significant differences between the two groups (Tables 1 and 2).

Multivariate logistic regression analysis showed that using an NG tube, abdominal surgery, and an operative time of more than 3 h were risk factors for AD (Table 2).

4 | DISCUSSION

In this study of the PMA with 49 cases and 245 controls who had an EI for surgery between 2010 and 2020, we found that patients who used an NG tube (OR: 23.9; 95% CI: 6.8–84.1), underwent abdominal surgery (OR: 3.7; 95% CI: 1.2–11.9), and had an operative time longer than 3 h (OR: 5.2; 95% CI: 2.1–12.9) were at risk of having an AD (Table 2).

The cricoarytenoid joint consists of the articular surface of the cricoid cartilage, the posterior surface of the arytenoid cartilage, the lateral cricoarytenoid muscles, the posterior cricoarytenoid muscles, and the cricoarytenoid ligament.[16] The arytenoid cartilage performs inward or outward rotation along the vertical axis of the joint, and at the same time, it slides along the longitudinal axis to make the vocal folds on both sides approach or separate from each other, thereby opening or closing the glottis.[17] Various causes can induce an AD, including clinical procedures of the EI, insertion of the NG tube, laryngoscope, or neck trauma.[7] During EI, when the tip of the arytenoid cartilage is inserted into the distal end of the endotracheal tube, an anterior and downward AD may occur due to a force to the anterior and downward direction; and a posterior AD may occur when some air remains in the cuff during extubation.[2] Other injuries often accompany an AD caused by neck trauma. AD can also be secondary to systemic diseases, such as long-term use of steroids, diabetes, rheumatoid arthritis, and acromegaly, and induced by specific actions of coughing, sneezing, vomiting, and others.[6]

Lou et al. reported that the stability and movement of the cricoarytenoid joint involved the thyroarytenoid muscles, posterior cricoarytenoid muscles, lateral cricoarytenoid muscles, and cricothyroid

muscles. The thyroarytenoid muscles and cricothyroid muscles maintain joint stability. The lateral cricoarytenoid muscles and thyroarytenoid muscles pull the arytenoids forward to close the glottis, and the posterior cricoarytenoid muscles pull them back to open the glottis. More muscles are functionally involved in forward pulling than backward pulling; therefore, more patients experience anterior than posterior AD.[18] Xu et al. found that there were more left-sided dislocations than right-sided dislocations, possibly because most anesthesiologists tend to hold the endotracheal tube with the right hand, with increased chances of the tip of the endotracheal tube pointing toward the left vocal fold and arytenoid cartilage during the EI procedure.[19] In this study, there were more anterior ($N = 48$) than posterior AD ($N = 1$) and more left ($N = 34$) than right AD ($N = 15$). Our findings are consistent with those of previous studies.[18,19]

4.1 | Severe pain on one side of the larynx following EI as a key feature in distinguishing AD from vocal fold paralysis

The differential diagnosis between AD and vocal fold paralysis, that is, recurrent laryngeal nerve paralysis, has always been challenging. Electronic laryngoscopy alone is not enough to differentiate between the two conditions because the vocal fold immobilization caused by AD or vocal fold paralysis looks identical.[2] There may be a false-positive diagnosis of AD using a CT scan if the patient is not positioned correctly during the examination.[20] The inconsistent left and right arytenoid cartilage densities in the same patient will also blur the 3D reconstructed image, or the incompleteness in the scanning image of the arytenoid cartilage may affect the diagnosis.[12] It has been reported that laryngeal electromyography (EMG) is vital for differentiating AD and vocal fold paralysis. However, laryngeal EMS has not been widely used in clinical practice because of its difficulty and invasiveness and the relatively high diagnostic rate.[2,21] Almost all patients with AD in this study reported severe pain on one side (the affected side) of the larynx after the surgery, which was considered a typical manifestation of joint dislocation, and consistent with the results of a study by Nicholls and Packham.[22] On the contrary, patients with vocal fold paralysis generally demonstrate painless hoarseness. Although EI can also cause sore throat, the pain is generally mild, and the site of pain is primarily located in the middle of the larynx.[6,22]

4.2 | Abdominal surgery is a risk factor for AD

Most (81.6%) of this study's 49 patients with AD underwent abdominal surgery. On average, the annual number of surgeries performed under general anesthesia during the study period in our hospital was more than 30,000. Overall, ~27% of these were abdominal surgeries. Because the incidence of AD was relatively low (<0.02% in our hospital, which was consistent with the previous studies[5]), it would be difficult to explore the statistical association between the risk factors and the outcome if we analyzed the entire surgical patients without sampling. Therefore, we applied the PSM in our study design to identify the participants in the control group (patients without AD) by randomly selecting patients without SD after matching the age and gender with those in the case group with a ratio of 1:5. The potential explanations for abdominal surgery being a risk factor for AD are as follows: (a) lower BMI. Due to the higher likelihood of long-term malnutrition in patients undergoing abdominal surgery, these patients' whole-body muscle mass decreases. Also, the muscles that maintain the stability of the cricoarytenoid joint become weak, resulting in weakened joint stability, and such conditions may increase the risk of dislocation.[18,20,23] (b) longer operation time. Multivariate logistic regression analysis in this study found that longer operative time was associated with a higher risk of AD, and most abdominal operations last more than 3 h, increasing the contact period between the endotracheal tube and the vocal folds. The tube may rub against the trachea and vocal folds with movements of the larynx and cricoarytenoid joint due to swallowing, choking or coughing during the surgery, thus leading to damage to the local mucosal epithelium or the formation of hematoma in the joint capsule and may result in AD.[6,24] However, patients hospitalized in intensive care units who wear a long-term endotracheal tube do not develop AD at our institution. We consider a third possible explanation for the association between abdominal surgery and a higher risk of AD. (3) stimulating the patient's vagus nerve in the performance of abdominal surgery. The vagus nerve has several major branches in the abdomen, including a hepatic branch, a celiac branch, and numerous anterior and posterior gastric branches that supply the pancreas, spleen, kidney, and digestive canal above the left (splenic) colic flexure. The recurrent laryngeal nerve is one of the important branches of the vagus nerve that supplies the mucosa below the glottic fissure and all laryngeal muscles except the cricothyroid muscle.[25] We speculate that traction or damage to the vagus nerve trunks and branches during prolonged abdominal surgery on the stomach, liver, bile bladder, pancreas, intestine, and spleen, may affect the recurrent laryngeal nerve and weaken the innervation of the muscles maintaining cricoarytenoid joint stability; hence, the abdominal surgery increases the risk of AD.

4.3 | An external force is not the only factor that causes AD in EI

Paulsen et al. studied 30 fresh cadavers to induce AD by performing intubation and extubation procedures with greater external force than performing a standard EI but failed to replicate an AD on any cadaver.[26] Wang found that it would require considerable force to induce an AD on seven fresh frozen cadavers. In addition, the hard metal tube used to support the laryngoscope in Wang's[27] study exerted more significant pressure on the cricoarytenoid joint. There was no case of AD in the operations. The external force exerted by EI alone is not the cause of dislocation.[26,27] We investigated the relationship between an anesthesiologist's experience and AD occurrence. We did not find a correlation between them, indicating that the external force of intubation was not a significant factor associated with AD.

4.4 | NG tube placement is a risk factor for AD

In this study, we found that NG tube insertion was an independent risk factor for AD, and the OR value was the largest among all variables in the multivariate logistic regression analysis, indicating that compared with other factors, NG tube insertion was the most likely factor that increased the risk of an AD. In patients wearing a tube, whether the NG or endotracheal tube is inserted first or not, the external force affects the cricoarytenoid joint, resulting in the loosening of the joint capsule. The congested synovium is squeezed into the joint cavity, resulting in edema in the joint cavity and affecting the joint's stability.[26] The increased cricoarytenoid joint instability is associated with a higher risk of AD when another tube is inserted. Furthermore, during the insertion of an NG tube, if the patient experiences nausea and choking, the distal end of the NG tube may directly touch or hurt the arytenoid cartilage, causing its displacement.[2,12] This study found that 45 of the 49 patients had both NG tube and EI for general anesthesia; 20 were intubated with the NG tube first, followed by the EI. We speculate that an existing NG tube may limit the movement of one side of the cricoarytenoid joint. When a laryngoscope vigorously lifts the root of the epiglottis during anesthetic practice, AD is more likely to occur because the narrow space of the arytenoid cartilage prevents escape from the external force. Unfortunately, a relatively small proportion of patients in the control group (41/245, 16.7%) had both NG tube insertion and EI, preventing us from evaluating the association between the insertion sequence of the two tubes and the incidence of AD due to the small event rates in our study population. Consideration should be given to future studies with larger sample sizes to verify our hypothesis that the preplacement of an NG tube is a risk factor for AD.

4.5 | Limitations

In our study, diagnosis of AD was based on symptoms, physical, video laryngoscopic, CT examinations, and effects of closed reduction. This study had some limitations. First, data on patient comorbidities such as diabetes, rheumatoid arthritis, and acromegaly, whether long-term steroids were used, and intra-procedure parameters like cuff pressure were unavailable. We could not evaluate these factors' impact on AD occurrence during the EI. Second, because of the small sample size and especially the low event rates in this study, the 95% CIs for the ORs were wide for all three variables included in the multivariate regression analysis, indicating low precision in our results. Third, in our investigation of patient records during 2010 and 2020, there was a lack of EMG examination for most of the patients, because EMG had not been widely used for AD diagnosis in our institution in earlier years. Finally, this study was undertaken in a single institution; therefore, the generalizability and representativeness of the results may be limited.

5 | CONCLUSIONS

In this retrospective analysis of 294 patients who had EI during general anesthesia for surgery (49 patients with AD and 245 patients without AD), we found that the use of an NG tube, type of surgery, and operative time longer than 3 h were risk factors for AD, of which the NG feeding tube usage had the most significant impact. The findings can facilitate effective surgeon-patient communication. We suggest that in clinical practice, effective preventive measures before the operation can be applied to patients having abdominal surgery with a potential operative time lasting more than 3 h and using an NG feeding tube. Such preventive measures include informing the patients about the increased surgical risk and providing high-level patient monitoring to reduce the incidence of AD.

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