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Orignal Article

Respiratory tract infection after oral and maxillofacial surgery under general anesthesia and related factors

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Abstract

Introduction: We aimed to explore the respiratory tract infection after oral and maxillofacial surgery under general anesthesia and related factors.

Methodology: A total of 494 patients receiving oral and maxillofacial surgery under general anesthesia with tracheal intubation were assigned to a non-infection group (n = 469) and an infection group (n = 25). Another 494 healthy people undergoing physical examination in the same period were enrolled to establish a classification tree model. The distribution of pathogens, drug resistance of main pathogens, and related influencing factors of postoperative respiratory tract infection were analyzed. The influencing factors of respiratory tract infection were screened by logistic regression analysis. After construction of the classification and regression tree (CART) model based on the influencing factors, the accuracy was evaluated by plotting receiver operating characteristic (ROC) curve.

Results: *Pseudomonas aeruginosa* was highly resistant to cefazolin and more sensitive to cefoperazone, ciprofloxacin, norfloxacin and imipenem. *Staphylococcus aureus* was highly resistant to gentamicin and more sensitive to vancomycin. Age ≥ 60 years old, history of lung diseases, operation time ≥ 4 h, anesthesia ventilation time ≥ 120 min, and orotracheal intubation were independent influencing factors of respiratory tract infection ($p < 0.05$). The results of the gain chart, index map, and Risk value indicated a high predictive value of the CART model for the risk of postoperative respiratory tract infection. The area under the ROC curve was 0.869 [95% confidence interval: 0.795-0.947].

Conclusions: The CART model has a high predictive value and may reduce the risk of postoperative infection.

Key words: Oral and maxillofacial surgery; general anesthesia; pathogen; infection; influencing factor.

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Introduction

The respiratory tract is the most vulnerable site to infection after general anesthesia in oral and maxillofacial surgery [1]. The oral and maxillofacial region is closely connected with the digestive and respiratory tracts, and has a complicated physiological structure. Generally, oral and maxillofacial surgery is conducted under general anesthesia with endotracheal intubation. In surgery under general anesthesia, the pipeline of anesthesia machine is thoroughly disinfected by the anesthesiologist strictly in accordance with relevant specifications [2]. The balloon pressure of the tracheal intubation tube is adjusted to block the flow of secretion fluid to the distal end [3]. The blood perfusion of important organs including the lungs is ensured using a blood pressure monitoring device [4]. However, general anesthesia easily causes respiratory and lung infections due to the moist and warm physiological environment of the oral and nasal cavities [5].

Postoperative infection is a common complication of general anesthesia in oral and maxillofacial surgery [6]. In the case of respiratory tract infection, metabolites and toxins act on white blood cells, resulting in fever and inflammatory response and severely affecting the postoperative recovery of patients. Researching the related factors of postoperative infection, formulating corresponding preventive measures, and carrying out targeted prevention and control are conducive to postoperative recovery. For this reason, it is essential to analyze and to control infection-related factors to decrease the risk of postoperative infections and relieve postoperative complications.

In this study, therefore, 494 patients undergoing oral and maxillofacial surgery under general anesthesia with tracheal intubation in our hospital were selected as the subjects. The characteristics of pathogen infection were investigated, and the influencing factors of infection were analyzed, aiming to provide a theoretical basis for decreasing the postoperative infection rate.

Methodology

Clinical data

Four hundred and ninety-four patients receiving oral and maxillofacial surgery under general anesthesia with tracheal intubation in our hospital between November 2018 and February 2021 were enrolled as the subjects according to the following inclusion criteria: (1) patients meeting the Diagnostic Criteria of Nosocomial Infection [7], (2) those without respiratory tract infection before surgery, (3) those without complications of essential organs such as the liver and kidneys, and (4) those without immunity reduction. The exclusion criteria included: (1) patients without informed consent, (2) those with respiratory tract infection before surgery, (3) those with complications of essential organs such as the liver and kidneys, and (4) those with immunity reduction. Besides, 494 healthy people undergoing physical examination in our hospital during the same period were enrolled to establish a classification tree model. This study got approvals from the hospital's ethics committee, as well as the signed informed consent from the subjects and their family members.

Methods

The disease progression, hospitalization time, postoperative infection, and infection site were observed. In addition, the route of administration of antibacterial agents was explored. Moreover, quality control strains were isolated from the patients with postoperative infection and identified using Sensititre ARIS 2X microbiological analyzer (Thermo Fisher Scientific, USA). Duplicate strains at the same site in the same patient were excluded. The infection of postoperative pathogens and related factors affecting infection were analyzed.

Table 1. Distribution of pathogens in patients after surgery (%).

Infection site	n	Constituent ratio
Respiratory tract	25	62.50
Surgical incision	10	25.00
Urinary tract	5	12.50
Total	40	100.00

Table 2. Constituent ratio of pathogens of respiratory tract infection in patients after general anesthesia in oral and maxillofacial surgery (%).

Pathogen	n	Constituent ratio
Gram-negative bacterium	40	78.43
Pseudomonas aeruginosa	15	29.41
Klebsiella pneumoniae	4	7.84
Enterobacter cloacae	4	7.84
Acinetobacter baumannii	4	7.84
Proteus mutans	4	7.84
Others	9	17.65
Gram-positive bacterium	9	17.65
Staphylococcus aureus	6	11.76
Staphylococcus epidermidis	2	3.92
Streptococcus dysgalactiae	1	1.96
Fungus	2	3.92
Saccharomyces albicans	2	3.92
Total	51	100.00

Observation indices and grouping

The distribution of pathogens and the drug resistance of main pathogens were analyzed. The 494 patients were assigned to a non-infection group (n = 469) and an infection group (n = 25) based on the absence or presence of respiratory tract infection. The related factors influencing postoperative respiratory tract infection were analyzed.

Methods for classification and quantification of categorical variables in the classification tree

The clinically diagnosed type and some factors of patients were defined and coded: infection (yes = 1, no = 0), age ≥ 60 years (yes = 1, no = 0), pulmonary ventilation time ≥ 120 minutes (yes = 1, no = 0), operation time ≥ 4 hours (yes = 1, no = 0), history of lung diseases (yes = 1, no = 0), and orotracheal intubation (yes = 1, no = 0).

Statistical analysis

Statistical analysis was carried out using SPSS 22.0 software (IBM Inc., USA). The count data were expressed as rates (%) and compared between groups through the χ^2 test. A statistically significant difference was indicated by $p < 0.05$. The influencing factors of respiratory tract infection in patients receiving oral and maxillofacial surgery after general anesthesia were screened by logistic regression analysis. After the construction of the classification and regression tree (CART) model based on the influencing factors, the classification results were assessed through the gain map, index map, and misclassification probability. The accuracy was evaluated by plotting receiver operating characteristic (ROC) curve. The significance level was $\alpha = 0.05$, the tree was three layers in depth, and the smallest sizes of samples in parent nodes and child nodes were 10 and 5, respectively.

Results

Distribution of pathogens in patients after general anesthesia in oral and maxillofacial surgery

Among the 494 patients, 40 had infections, with an infection rate of 8.10%. The infection was mainly in the respiratory tract (5.06%) (Table 1).

Table 3. Drug resistance of major pathogens after general anesthesia in oral and maxillofacial surgery (%).

Antibiotics	*Staphylococcus aureus* (n = 6)		Pseudomonas aeruginosa (n = 15)	
	n	Drug resistance rate	n	Drug resistance rate
Cefazolin	1	16.67		
Ceftriaxone	1	16.67		
Cefoperazone	1	16.67		
Ciprofloxacin	1	16.67		
Gentamicin	4	66.67		
Vancomycin	0	0.00		
Piperacillin			6	40.00
Cefazolin			14	93.33
Ceftriaxone			3	20.00
Cefoperazone			1	6.67
Amikacin			3	20.00
Ciprofloxacin			1	6.67
Norfloxacin			1	6.67
Imipenem			1	6.67

Table 4. Univariate analysis results of respiratory tract infection in patients after general anesthesia in oral and maxillofacial surgery (n, $\bar{x}$±s).

	Non-infection group (n = 469)	Infection group (n = 25)	χ^2	*p*
Age (years old)			**12.997**	**< 0.001**
≥ 60	125	15		
< 60	344	10		
Gender			**0.109**	**0.741**
Male	241	12		
Female	228	13		
Body mass (kg)			**0.239**	**0.625**
≥ 65	258	15		
< 65	211	10		
History of smoking			**0.021**	**0.884**
Yes	61	3		
No	408	22		
History of lung diseases			**8.844**	**0.003**
Yes	147	15		
No	322	10		
History of diabetes mellitus			**0.106**	**0.745**
Yes	247	14		
No	222	11		
Operation time (h)			**7.880**	**0.005**
≥ 4	47	7		
< 4	422	18		
Anesthesia ventilation time (min)			**10.701**	**0.001**
≥ 120	200	19		
< 120	269	6		
Duration of anesthesia (min)			**0.002**	**0.969**
≥ 120	227	12		
< 120	242	13		
Route of tracheal intubation			**6.202**	**0.013**
Pernasal	117	8		
Peroral	352	17		
Soda lime replacement (time/d)			**0.215**	**0.643**
1	266	13		
< 1	203	12		
Invasive operation			**0.396**	**0.529**
Yes	141	9		
No	328	16		
Postoperative analgesia pump			**0.362**	**0.547**
Yes	215	13		
No	254	12		
Delayed extubation after surgery			**4.678**	**0.031**
Yes	215	17		
No	254	8		
Administration of antibiotics			**0.093**	**0.760**
Yes	155	9		
No	314	16		
Foreign bodies in wounds			**4.202**	**0.040**
Yes	50	6		
No	419	19		
Accidental aspiration			**4.006**	**0.045**
Yes	51	6		
No	418	19		

Constituent ratio of pathogens of respiratory tract infection

Of the 51 strains of detected pathogens, 40 were Gram-negative bacteria, 9 were Gram-positive bacteria, and 2 were fungi (Table 2).

Drug resistance of main pathogens

Pseudomonas aeruginosa showed resistances to cefazolin, piperacillin, ceftriaxone, amikacin, cefoperazone, ciprofloxacin, norfloxacin, and imipenem, being highly resistant to cefazolin and more sensitive to cefoperazone, ciprofloxacin, norfloxacin, and imipenem. *Staphylococcus aureus* was resistant to cefazolin, ceftriaxone, cefoperazone, ciprofloxacin, and gentamicin, with higher resistance to gentamicin and sensitivity to vancomycin (Table 3).

Univariate analysis results of respiratory tract infection

According to univariate analysis, the respiratory tract infection was associated with age, history of lung diseases, operation time, anesthesia ventilation time, route of tracheal intubation, delayed extubation after surgery, foreign bodies in wounds, and accidental aspiration. Fender, body mass, history of smoking, history of diabetes mellitus, anesthesia time, soda lime

Figure 1. Forest map of logistic multivariate analysis on respiratory tract infection in patients after general anesthesia in oral and maxillofacial surgery. HR: Hazard ratio.

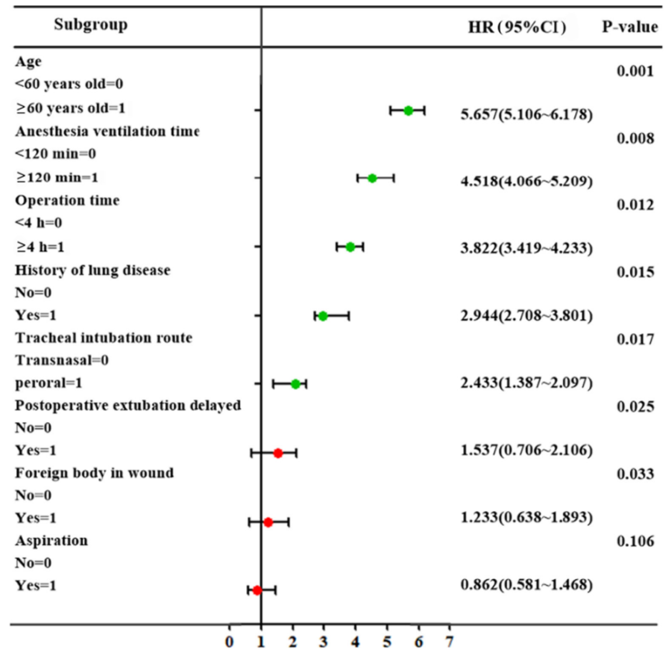
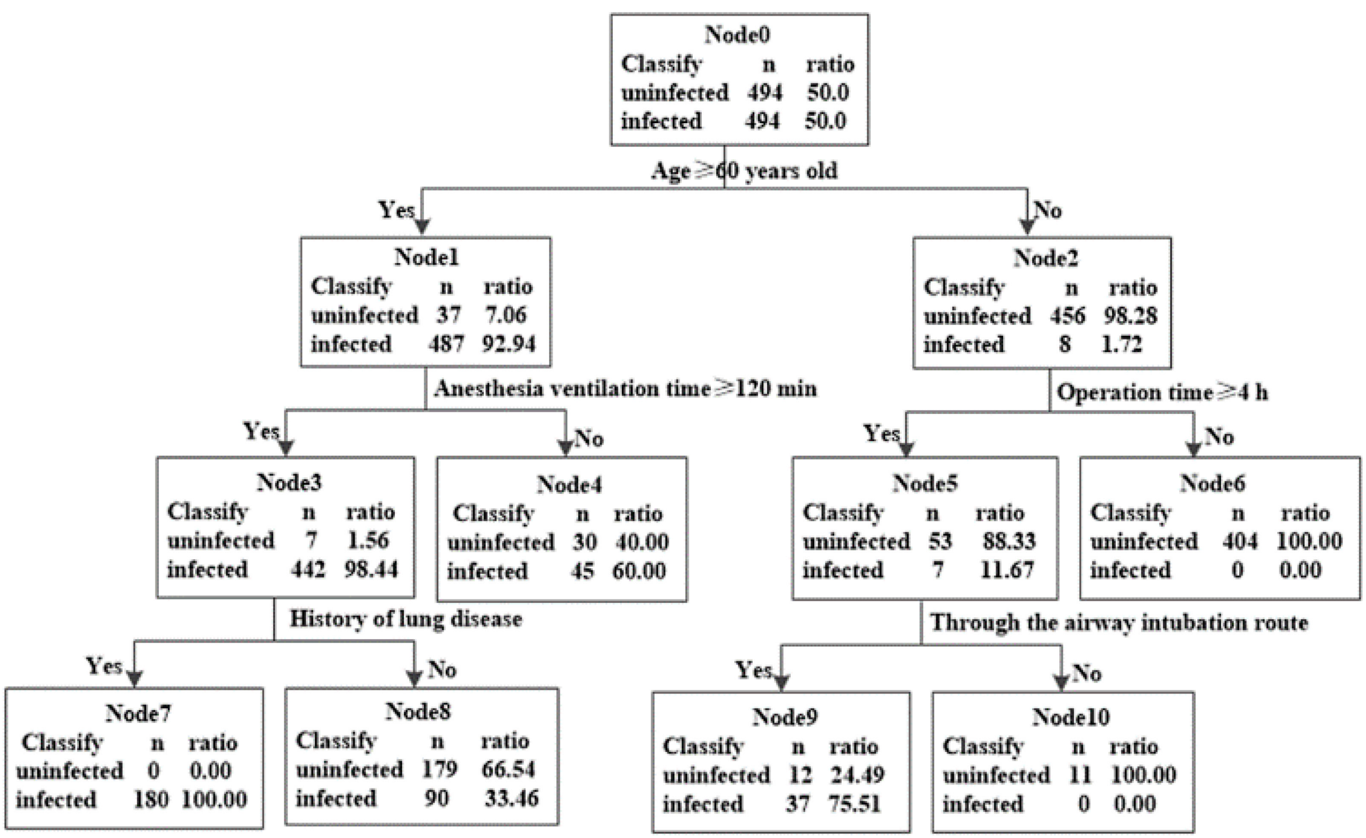


Figure 2. Classification tree prediction model for risks of respiratory tract infection in patients after general anesthesia in oral and maxillofacial surgery.



replacement, invasive operation, postoperative analgesia pump, and administration of antibiotics displayed no statistically significant differences between the two groups ($p > 0.05$) (Table 4).

Multivariate logistic analysis results of respiratory tract infection

The variables with statistically significant differences in univariate analysis were subjected to multivariate logistic regression analysis. The results revealed that age ≥ 60 years old, history of lung diseases, operation time ≥ 4 hours, anesthesia ventilation time ≥ 120 minutes, and orotracheal intubation were independent risk factors for respiratory tract infection ($p < 0.05$) (Figure 1).

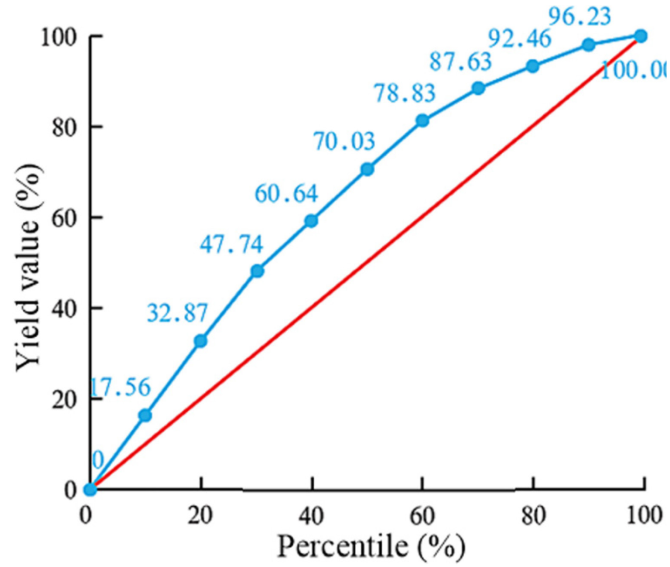
Prediction model for respiratory tract infection

Based on the growth and construction rules, the constructed CART model had three layers and ten nodes, including six terminal nodes. The following five explanatory variables were screened: age, pulmonary ventilation time, operation time, operation time, and orotracheal intubation. The most important influencing factor for respiratory tract infection was age ≥ 60 years old. In detail, 92.94% of patients aged ≥ 60 years old suffered from postoperative infection, much exceeding the proportion of patients aged < 60 years old ($p < 0.05$) (Figure 2). People aged ≥ 60 years old were considered a high-risk group for respiratory tract infection.

Gain chart

In the cumulative gain chart with 0% as the starting point and 100% as the ending point, the gain value of the model rose rapidly towards 100% first and became stable finally, suggesting that the model met the criteria for a good model (Figure 3).

Figure 3. Gain chart of classification tree model for risks of respiratory tract infection in patients after general anesthesia in oral and maxillofacial surgery.



Index map

A good classification tree model should have the index value starting from above 100%, remaining stable along the moving direction, and rapidly reducing to 100%. According to this criterion, this was a good model (Figure 4).

Figure 4. Index map of classification tree model for risks of respiratory tract infection in patients after general anesthesia in oral and maxillofacial surgery.

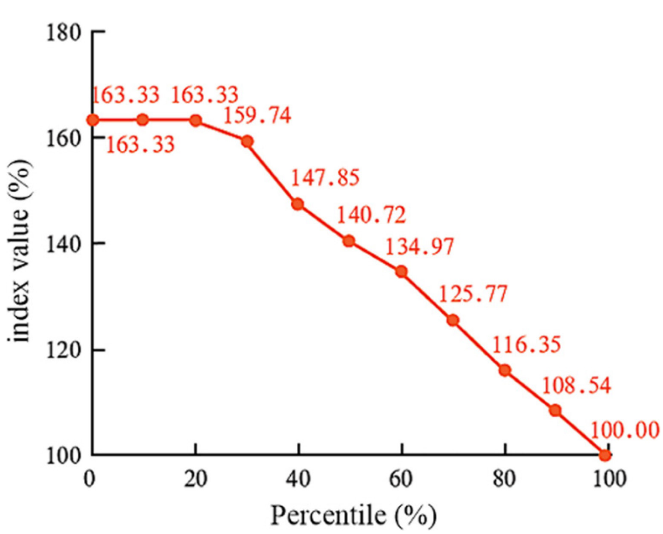
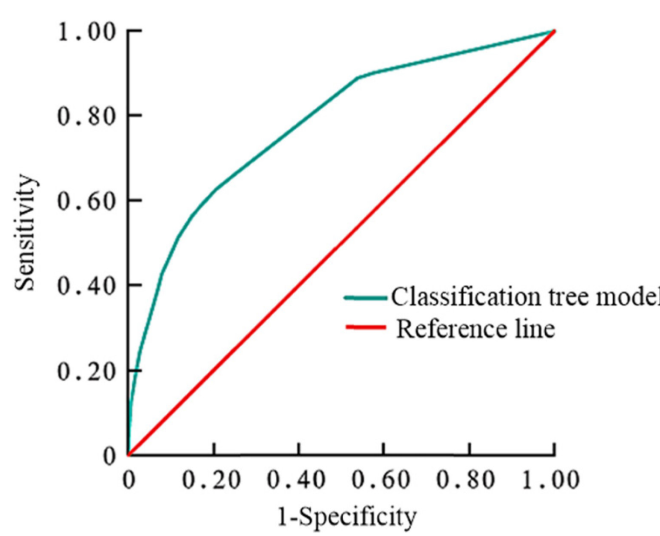


Figure 5. ROC curve of classification tree model in predicting risks of respiratory tract infection in patients after general anesthesia in oral and maxillofacial surgery. ROC: Receiver operator characteristic.



Misclassification matrix and risk statistic

The risk statistic of the CART model was (0.187 ± 0.012), suggesting that this model had an accuracy of 81.3% in predicting the risk of postoperative respiratory tract infection. The prediction results of the misclassification matrix classification table were consistent with those of the risk table (81.30%), implying that the model had a better prediction effect on the risk of respiratory tract infection.

ROC curve analysis results

The ROC curve was plotted based on the predicted and true values according to the predictive variables after the CART model. The results revealed that the area under the ROC curve (AUC) was 0.869, the 95% confidence interval (CI) was 0.795-0.947, and the standard error was 0.012 ($p < 0.001$). When the cut-off value was 0.627, the sensitivity and specificity for predicting postoperative respiratory tract infection were 89.50% (95% CI: 0.792-0.978) and 98.30% (95% CI: 0.965-0.989), respectively (Figure 5).

Discussion

In oral and maxillofacial surgery, general anesthesia with endotracheal intubation is most commonly used. During endotracheal intubation, a tube is prone to contamination after passing through the mouth, damages the respiratory mucosa, and increases local secretions that further promote bacterial reproduction, thus elevating the risk of respiratory tract infections [8]. Gram-negative bacteria are the main pathogens of respiratory tract infection after general anesthesia in oral and maxillofacial surgery [9]. In this study, 51 pathogens were cultured from 25 patients with respiratory tract infection after general anesthesia in oral and maxillofacial surgery, including 40 Gram-negative bacteria (accounting for 78.43%) and 9 Gram-positive bacteria (accounting for 17.65%), dominant by *Pseudomonas aeruginosa* and *Staphylococcus aureus*, respectively. The results are in line with those of a previous literature [10]. Currently, the resistance of pathogens is rising since antibiotics are excessively used [11]. For this reason, analyzing the drug resistance of pathogens and selecting the antibiotics to which pathogens are sensitive can effectively impede the progression of infection.

Among the randomly selected patients with respiratory tract infection after general anesthesia, the proportion of patients over 60 years old is 42.6%, and they have a significantly higher incidence rate than that of patients of other ages [12]. In elderly patients, the respiratory system experiences different degrees of degenerative changes, so the immunity reduces, and the functions of various organs decline. As a result, elderly patients are prone to respiratory tract infection after general anesthesia during oral and maxillofacial surgery [13]. Respiratory tract infection is more likely to occur in patients with a history of lung diseases after general anesthesia [14], because lung compliance and the ability to expel secretions are significantly reduced, giving rise to the residue of secretions after surgery and increasing the risk of pathogen invasion [15]. Longer anesthesia ventilation and operation durations suggest a higher incidence rate of postoperative pulmonary infection [16]. A longer anesthesia ventilation time may lead to cilia damage in the respiratory tract, and a longer time of immune function repression by anesthetics may aggravate pathogen invasion and increase the risk of respiratory tract infection [17]. Compared with nasotracheal intubation, orotracheal intubation is more irritating to patients and elevates the risk of pathogen invasion. In this study, the independent influencing factors of respiratory tract infection included age ≥ 60 years old, history of lung diseases, operation time ≥ 4 hours, anesthesia ventilation time ≥ 120 minutes, and orotracheal intubation. Nasotracheal intubation is given the first priority to reduce the risk of respiratory tract infection after general anesthesia in oral and maxillofacial surgery. If orotracheal intubation is selected, patients' mouth must be adequately disinfected and cleaned. Therefore, the anesthesia ventilation time of patients should be shortened as much as possible during surgery to reduce the risk of pathogen infection. For elderly patients, immunoglobulins can be applied after surgery to enhance their immunity.

The CART model has no special requirements for included variables, which can predict the risk factors of postoperative infection and reveal the relationships between various risk factors [18]. The results of this study showed that the risk factors of respiratory tract infection included age ≥ 60 years old, history of lung diseases, operation time ≥ 4 hours, anesthesia ventilation time ≥ 120 minutes, and orotracheal intubation. Among them, age ≥ 60 years old was the most crucial influencing factor. The model had an accuracy of 81.3% for predicting the risk of respiratory tract infection. Besides, the same result (81.30%) was obtained through the misclassification matrix classification table and the risk table. Hence, the model has an excellent fitting effect. The results of ROC curve analysis exhibited that AUC was 0.869 (95% CI: 0.795-0.947). When the cut-off value was 0.627, the sensitivity and specificity for predicting postoperative respiratory tract infection were 89.50% (95% CI: 0.792-

0.978) and 98.30% (95% CI: 0.965-0.989), respectively, indicating that the CART model was highly reliable for predicting the risk of respiratory tract infection.

Conclusions

In summary, the independent influencing factors of respiratory tract infection after general anesthesia in oral and maxillofacial surgery were age ≥ 60 years old, history of lung diseases, operation time ≥ 4 hours, anesthesia ventilation time ≥ 120 minutes, and orotracheal intubation. The CART model may reduce the risk of postoperative infection. In clinical practice, targeted interventions should be performed to reduce the incidence rate of postoperative respiratory tract infection, and the awareness of infection among medical staff should be improved. Regardless, this study is still limited. The sample size was small, and this was a single-center retrospective study, increasing the risk of selection bias. Hence, in the future, multi-center and prospective studies with a larger sample size should be carried out to validate the accuracy of the prediction.

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