Heart Surgery Forum 2023; 26(6): E863–E868
doi: 10.59958/hsf.6865

Article

Factors Influencing the Incidence of Pneumonia after Coronary Artery Bypass Grafting

Yanbing Zhang[1], Pengyu Zhang[1], Han Li[1], Haitao Chi[1], Nan Zheng[1], Xu Pan[1], Chuzhong Tang[1,*]

[1]Department of Cardiovascular Surgery, Sixth Medical Center, General Hospital of the Chinese People's Liberation Army, 100037 Beijing, China
*Correspondence: tangb39427@163.com (Chuzhong Tang)

Submitted: 22 September 2023 Revised: 20 November 2023 Accepted: 11 December 2023 Published: 27 December 2023

Abstract

Objective: This study aimed to explore and analyze the factors affecting the incidence of pneumonia after coronary artery bypass grafting (CABG) to provide reference for the prevention of such situation. **Methods**: A total of 500 patients who underwent CABG in a hospital were selected. From March 2019 to March 2022, 410 patients without pneumonia and 90 patients with pneumonia were divided into groups A and B. The influencing factors and pathogen composition of postoperative pneumonia were discussed and analyzed. **Results**: Univariable analysis results showed that age, cardiac function grade, occurrence of smoking, operation time, tracheal intubation time, suspended red-blood-cell transfusion and hospital stay in group B were higher than those in group A. Multivariable logistic analysis results showed that operation time, smoking history, and tracheal intubation time were risk factors for pneumonia after CABG. Among the 90 patients with postoperative pneumonia, 90 had pathogens, 81 had Gram-negative bacteria, 4 had Gram-positive bacteria, and 5 had fungi. **Conclusions**: Patients after CABG were more likely to develop pneumonia. Operation time, smoking history, and tracheal intubation time were the risk factors of pneumonia after CABG. Most of these patients had Gram-negative bacteria. Patient intervention based on the influencing factors can effectively prevent the occurrence of postoperative pneumonia.

Keywords

pneumonia after coronary artery bypass grafting; influencing factors; pathogenic bacteria; infusion volume of suspended red blood cells

Introduction

Coronary atherosclerotic heart disease (CHD) is one of the most common and lethal diseases worldwide [1,2]. Coronary artery bypass grafting (CABG) is an operation used to replace the obstructed coronary artery in the body to improve the myocardial blood supply of patients, relieve patients' angina pectoris, and reduce the risk of death from coronary heart disease. It is a common operation in adult cardiac surgery, and its clinical application is becoming increasingly widespread. Owing to the increasing incidence of coronary heart disease [3–5], many patients may suffer from atelectasis, infection, coughing, and other problems after CABG surgery. Pulmonary infection is the most common complication in CABG, which has a rapid onset and dangerous condition. It has a great impact on the prognosis of patients [6–9]. It brings huge obstacles to the work and spirit of patients, as well as huge economic burden and labor loss to families and society [10]. Therefore, how to effectively promote the recovery of lung function of patients is also the focus of clinical intervention [11,12]. By analyzing the factors affecting pulmonary infection in patients undergoing CABG and proposing nursing measures and invasive examination methods, the occurrence of pulmonary infection can be further reduced. The surgical treatment of patients undergoing CABG and improving the prognosis of patients are very critical, but relevant studies are few. The risk factors related to pulmonary infection in patients undergoing CABG have also not been fully determined [13,14]. In the present study, the factors influencing the incidence of pneumonia after CABG were analyzed.

Materials and Methods

General Information

A retrospective study was conducted on 500 patients who underwent CABG in our hospital. From March 2019 to March 2022, the patients were grouped according to the occurrence of postoperative pneumonia. Group A had 410 patients without pneumonia, including 220 males and 190 females. The mean age was (54.36 $\pm$ 4.09) years. Group B had 90 patients with pneumonia, including 54 males and 36 females. The mean age was (58.12 $\pm$ 7.45) years. This study was approved and verified by the hospital ethics committee. Inclusion criteria were as follows: the indications of CABG were met; patients with postoperative pulmonary infection were in accordance with the clinical diagnosis; co-

agulation function was normal; and information was complete. Exclusion criteria were as follows: malignant tumor, preoperative critical case, secondary cardiac surgery, preoperative pulmonary infection, family members refuse to cooperate, and mental illness.

Research Methods

The clinical factors of patients were collected and analyzed. These factors included age, sex, body mass index (BMI), cardiac function grade (registered by the New York Heart Association), basic disease, smoking history, operation time, postoperative endotracheal intubation time, suspended red-blood-cell infusion volume, left ventricular end-diastolic diameter, postoperative second thoracotomy, and hospital stay. The collected factors were analyzed by univariable and multivariable analyses.

For patients suspected of having postoperative pulmonary infection, a disposable sputum aspirator or bronchoscope was used. After disinfection, the end of the intubation entered. Deep sputum samples were collected and sent to the laboratory immediately for bacterial smear, Gram staining, and bacterial culture. Routine separation of respiratory secretions, sputum-culture fluid collection, submission for inspection, culture, drug-resistance analysis, and other processes were conducted in accordance with the national actual operating procedures [15]. The automatic microbial detection system (VITEK-2 Compact, BioMérieux Corp., Shanghai, China) was used to identify bacteria.

Statistical Methods

SPSS 19.0 statistical software (IBM Corp., Armonk, NY, USA) was used for data processing. Measurement data consistent with normal distribution were expressed as ($\bar{x} \pm s$). Independent sample t test was used for comparison between two groups. Statistical data were expressed as relative numbers, and χ^2 test was used for comparison between groups. Clinical indicators with significant differences between two groups were selected by univariable analysis. These influencing factors of pulmonary infection after CABG in elderly patients with coronary heart disease were analyzed by multivariable logistic regression. $p < 0.05$ was considered to be statistically significant.

Results

Univariable Analysis of Pneumonia after CABG

Univariable analysis showed that the age, cardiac function grade, occurrence of smoking, operation time, endotracheal intubation time, suspended red-blood-cell infusion volume, and hospitalization time of group B were higher than those of group A ($p < 0.05$; Table 1).

Logistic Analysis of Risk Factors for Pneumonia after CABG

Factors with significant differences between the two groups screened by univariable analysis were included for multivariable Logistic analysis. According to the results of logistic analysis, operation time, smoking history, and endotracheal intubation time were the risk factors of pneumonia after CABG (Table 2).

Proportion of Pathogens in 90 Patients with Postoperative Pneumonia

Among the 90 patients with postoperative pneumonia, 90 had pathogens, 81 had Gram-negative bacteria, 4 Gram-positive had bacteria, and 5 had fungi (Table 3).

Discussion

More than one million patients with CHD receive clinical CABG every year in the world [16–18]. Pulmonary infection is a common complication after CABG owing to invasive surgery, decreased body resistance, and movement ability. They may be related to mitochondrial damage and other predispose factors in the early postoperative period [19]. Lung infections can affect recovery after surgery and cause multiple organ failure that endangers the patient's life [20–22].

Post-CABG pneumonia is a type of hospital-acquired pneumonia (HAP), which occurs 48 h after the patient is hospitalized without a latent period. More than 80% of HAP is caused by ventilator, that is, ventilator-related pneumonia (VAP). Patients after CABG are prone to VAP. However, inconsistencies in their clinical manifestations (e.g., fever, leukocytosis, and unexplained chest-radiograph abnormalities) lead to difficult VAP diagnosis for specific groups, such as patients after CABG [23,24]. At present, clinicians should diagnose pneumonia after CABG based on typical clinical manifestations and signs such as cough, expectoration, body temperature >38 °C, leukocytosis, *etc*.

In the current study, univariable analysis results showed that age, cardiac function grade, occurrence of smoking, operation time, endotracheal intubation time, suspended red-blood-cell infusion volume and hospital stay in group B were higher than those in group A ($p < 0.05$). Although some survey data show that women have a higher mortality rate than men in postoperative endotracheal intubation, intensive care unit (ICU) stay and hospital stay. Lung infection after CABG is reportedly related to men, but most research results do not support this view. Some foreign scholars have found no significant difference in the incidence of pulmonary complications between male and female patients after CABG [25,26]. The results of this study are similar to those previously reported. The influence factors of gender on pulmonary infection after CABG need to

Table 1. Univariable analysis questionnaire of pneumonia after CABG ($\bar{x} \pm s$).

Project	Group A (n = 410)	Group B (n = 90)	t/χ^2 value	p value
Gender				
Male	220	54	1.3482	0.071
Female	190	36		
Age (years)	54.36 ± 4.09	58.12 ± 7.45	4.0487	0.000
BMI (kg/m^2)	24.32 ± 1.45	24.82 ± 1.11	0.6982	0.005
Smoking history				
Yes	170	35	4.1106	0.043
No	240	55		
Basic diseases				
Hypertension	35	13		
Diabetes	29	8	1.2823	0.085
Hyperlipidemia	20	6		
Cardiac function classification				
I–II	130	45	6.0487	0.001
III–IV	280	45		
Left ventricular end-diastolic diameter (mm)	49.21 ± 5.23	49.33 ± 4.92	0.3512	0.829
Operation time (min)	212.25 ± 24.23	286.54 ± 22.56	16.3528	0.000
Suspended red blood cell infusion volume (U)	4.05 ± 1.45	4.66 ± 2.15	2.3925	0.001
Endotracheal intubation time (hours)	19.12 ± 3.25	48.65 ± 4.66	15.5821	0.000
Secondary thoracotomy after operation				
Yes	30	9	0.8251	0.390
No	380	81		
Hospitalization time (days)	19.25 ± 2.25	43.25 ± 4.23	6.2814	0.054

CABG, coronary artery bypass grafting; BMI, body mass index.

Table 2. Logistic analysis of risk factors of pneumonia after coronary artery bypass grafting.

Influencing factors	B value	S	χ^2	p value	OR (95% CI)
Endotracheal intubation time	0.864	0.392	4.286	0.032	2.391 (1.062~5.128)
Operation time	1.302	0.457	8.339	0.002	3.361 (1.251~8.692)
Smoking history	2.401	1.135	4.382	0.039	11.271 (1.256~56.251)

Table 3. Questionnaire of pathogen constituent ratio of 90 patients with postoperative pneumonia (n, %).

Pathogenic bacteria		Number of plants	Constituent ratio
	Klebsiella pneumoniae pneumonia subspecies	45	50.00
	Burkholderia cepacia	16	17.78
Gram-negative bacteria	Pseudomonas aeruginosa	8	8.89
	Acinetobacter baumannii	6	6.67
	Escherichia coli	6	6.67
Gram positive bacteria	Staphylococcus aureus	4	4.44
Fungus	Candida albicans	5	5.56
Total		90	100.00

be further explored. Older patients are prone to lung infection after cardiac surgery. Compared with patients without lung infection, the average age of patients with lung infection is higher [27]. The reason may be related to the decline in function of various organs and immune function of the human body. After cardiac surgery, the ability of the elderly to resist the invasion of foreign pathogens gradually weakens. Thus, elderly patients become more prone to lung infection. Early studies with a history of diabetes have shown that [28] no significant difference exist in the incidence of postoperative pneumonia compared with patients without diabetes. Some experts have pointed out that [29] the history of diabetes is closely related to pulmonary complications, such as postoperative pneumonia. Postoperative infection and mortality are also high. The history of diabetes is also reportedly an independent risk factor for pneumonia after CABG. Preoperative hyperglycemia increases the mortality of patients and the probability of infection.

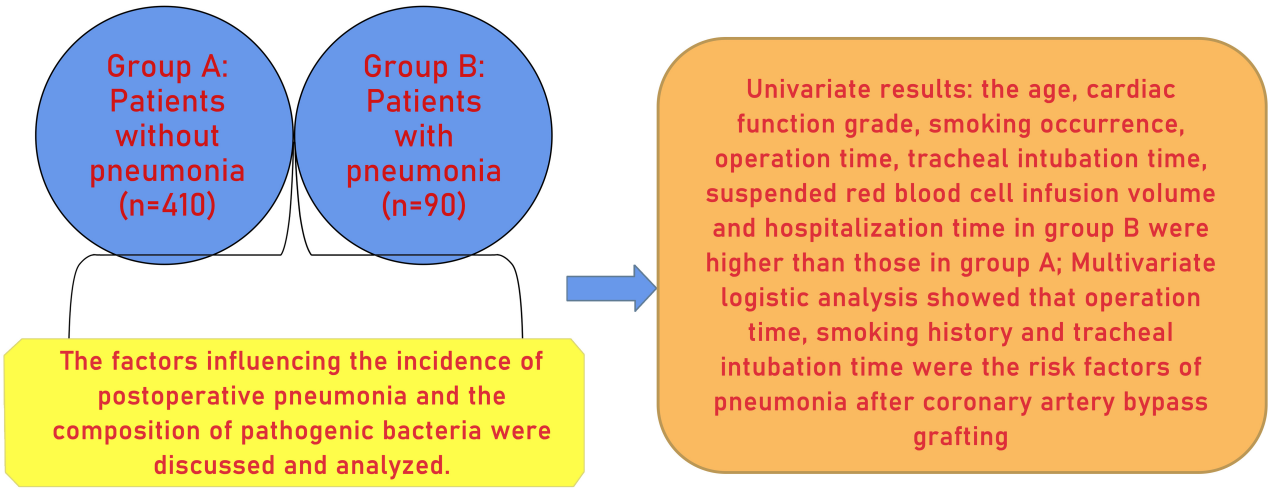

Fig. 1. Factors influencing the incidence of pneumonia after coronary artery bypass grafting.

Pulmonary infection after CABG is related to heart failure. Myocardial echocardiography shows that ventricular thickness, left atrial inner diameter, and left ventricular inner diameter can be used as early diagnostic indicators of chronic heart failure [30]. Therefore, after coronary angiography, cardiac ultrasound has certain application value in predicting intrapulmonary infection. The patient's respiratory function cannot meet the patient's requirements because of long-time tracheal intubation, late recovery after operation, or other organ diseases. If the patient has severe lung infection in the early stage, the patient's stay in the ICU is greatly prolonged.

In the present study, multivariable logistic analysis showed that operation time, smoking history, and tracheal intubation time were the risk factors of pneumonia after CABG ($p < 0.05$). Smoking history, postoperative tracheal intubation, and long postoperative operation time were important reasons for postoperative pulmonary infection (Fig. 1). After smoking, the lungs produce a large amount of tar and nicotine, which reduces the active components of the lungs, thereby damaging the lungs and leading to pulmonary fibrosis. Therefore, CABG patients with a history of smoking are more likely to suffer from lung infection. When the operation time is long, the instruments in the operating room and the bacteria in the air invade and open the thoracic cavity. Consequently, the risk of bacterial infection in the lung and the incidence of postoperative lung infection increase [31]. After the operation, the tracheal intubation time is too long, leading to dependence on the ventilator, destroying the natural barrier of the respiratory tract, bringing foreign bacteria into the patient's body, and damaging the respiratory mucosa. The secretion in the lung cannot be discharged in time, and the ability to clear foreign pathogens is reduced. The catheter stays in the patient for a long time, more likely breeding bacteria and increasing the risk of lung infection [32].

In the current work, among patients with postoperative pneumonia, 90 had pathogenic bacteria, 81 had Gram-negative bacteria, 4 had Gram-positive bacteria, and 5 had fungi. Previous studies have shown that the prevalence of postoperative pulmonary complications after cardiac surgery is 27%–35% [33–35]. In our experiment, this proportion decreased slightly. It may be related to the following reasons. First is the strengthened the control of antibiotics and the standardized management of clinical drugs. Second is the numerous cardiac surgery patients in the ICU. Accordingly, preoperative respiratory care should be strengthened, and preoperative respiratory function training should be carried out with the help of the rehabilitation department. The number of patients with pulmonary infection after CABG surgery can be decreased by reforming the ventilation system, improving the medical conditions, and strictly enforcing hand hygiene. At the same time, the pathogen is relatively single, the drug-resistant bacteria are few, and the sensitive bacteria are still the main ones. No large number of drug-resistant strains such as Acinetobacter baumannii is found. Therefore, the incidence rate and mortality of VAP are lower than those reported abroad [36,37].

If the patient does not get off the intubation line in a short time, to prevent pneumonia, the healing of the chest incision can be evaluated at the initial stage (about 1 week) to reduce dead space in the airway. In the awake state, active exercise and reduced use of sedatives must be implemented for the overall recovery of patients. Improvement in sympathetic tone and appropriate reduction in vasoactive substances such as dopamine and adrenaline should also be considered. An early oral meal can make full use of the digestive tract and reduce the migration of intestinal microorganisms. The core principle of reducing pneumonia after CABG is to grasp the opportunity, shorten the time of using the machine, and restoring the patient's autonomy. Preoperative application of statins can significantly reduce infec-

tion after CABG. This reduction may be owing to its regulation of the immune system, thereby reducing the inflammatory response. Before and after the operation, the use of relatively broad-spectrum, strong bactericidal activity, and safe and inexpensive antibiotics can significantly reduce the incidence of post-operative infection. The risk factors of post-operative pulmonary infection are very small, and reducing the probability of post-operative infection primarily depends on the process. The impact of simple preventive measures on post-operative pulmonary infection is limited. Therefore, formulating specific and feasible comprehensive intervention measures plays a very important role in preventing the occurrence of pulmonary infection [38,39].

Conclusions

Patients with coronary atherosclerotic heart disease after CABG were more likely to have pneumonia. Operation time, smoking history, and tracheal intubation time were the risk factors for pneumonia after CABG. Most of these patients had Gram-negative bacteria. Implementing intervention to patients based on the influencing factors can effectively prevent the occurrence of postoperative pneumonia. The number of cases included in this study was small, and the search for relevant factors was not comprehensive. In follow-up studies, more cases should be included for further in-depth analyses.

Availability of Data and Materials

The dataset analyzed during the current study are available from the corresponding author upon appropriate request.

Author Contributions

YZ contributed to the concept of this study and performed it. PZ, HL and HC contributed to the data collection and analysis. NZ and XP performed to the data collection and manuscript preparation. YZ wrote the manuscript. CT helped perform the analysis with constructive discussions. All authors have reviewed the manuscript and approved this version. All authors contributed to editorial changes in the manuscript. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

This study was approved and verified by the ethics committee of Sixth Medical Center, General Hospital of the Chinese People's Liberation Army (2019017-05A). And patients gave and sighed informed consent.

Acknowledgment

Not applicable.

Funding

This research received no external funding.

Conflict of Interest

The authors declare no conflict of interest.

References

[1] Figtree GA, Adamson PD, Antoniades C, Blumenthal RS, Blaha M, Budoff M, *et al*. Noninvasive Plaque Imaging to Accelerate Coronary Artery Disease Drug Development. Circulation. 2022; 146: 1712–1727.

[2] Golforoush P, Yellon DM, Davidson SM. Mouse models of atherosclerosis and their suitability for the study of myocardial infarction. Basic Research in Cardiology. 2020; 115: 73.

[3] Shaefi S, Mittel A, Loberman D, Ramakrishna H. Off-Pump Versus On-Pump Coronary Artery Bypass Grafting-A Systematic Review and Analysis of Clinical Outcomes. Journal of Cardiothoracic and Vascular Anesthesia. 2019; 33: 232–244.

[4] Khan FM, Hameed I, Milojevic M, Wingo M, Krieger K, Girardi LN, *et al*. Quality metrics in coronary artery bypass grafting. International Journal of Surgery (London, England). 2019; 65: 7–12.

[5] Une D, Sakaguchi T. Initiation and modification of minimally invasive coronary artery bypass grafting. General Thoracic and Cardiovascular Surgery. 2019; 67: 349–354.

[6] Bianco V, Kilic A, Gleason TG, Aranda-Michel E, Wang Y, Navid F, *et al*. Timing of coronary artery bypass grafting after acute myocardial infarction may not influence mortality and readmissions. The Journal of Thoracic and Cardiovascular Surgery. 2021; 161: 2056–2064.e4.

[7] Li Y, Zhang J, He Z. Early Predictive Value of Procalcitonin for the Diagnosis of Pulmonary Infections after Off-pump Coronary Artery Bypass Grafting. The Heart Surgery Forum. 2021; 24: E004–E008.

[8] Liu X, Wang L, Wang S, Zhang W, Yu Y, Chen S, *et al*. Association Between Infection and Thrombosis After Coronary Artery Bypass Grafting: A Cohort Study. Journal of Cardiothoracic and Vascular Anesthesia. 2019; 33: 1610–1616.

[9] Nicolini F, Vezzani A, Romano G, Carino D, Ricci M, Chicco MVD, *et al*. Coronary Artery Bypass Grafting with Arterial Conduits in the Elderly. International Heart Journal. 2017; 58: 647–653.

[10] Mali S, Haghaninejad H. Pulmonary complications following

cardiac surgery. Archives of Medical Sciences. Atherosclerotic Diseases. 2019; 4: e280–e285.
[11] Atik FA, Pegado HM, de Brito LMR, Macedo MT, França EP, Jr, Dias AKA, *et al*. Does the anthropometric profile influence infection morbidity after coronary artery bypass grafting? Journal of Cardiac Surgery. 2021; 36: 1194–1200.
[12] Chen K, Scridon T, Chait R. Inadvertent aortocoronary arteriovenous fistula after CABG: Systematic review of case reports. Catheterization and Cardiovascular Interventions: Official Journal of the Society for Cardiac Angiography & Interventions. 2021; 97: E19–E25.
[13] Gao J, Wang H, Liu X, Song X, Zhong X. Surgical site wound infection, and other postoperative problems after coronary artery bypass grafting in subjects with chronic obstructive pulmonary disease: A meta-analysis. International Wound Journal. 2023; 20: 302–312.
[14] Ho CH, Chen YC, Chu CC, Wang JJ, Liao KM. Postoperative Complications After Coronary Artery Bypass Grafting in Patients With Chronic Obstructive Pulmonary Disease. Medicine. 2016; 95: e2926.
[15] Ge YL, Zhu XY, Hu K, Zhang Q, Li WQ, Zhang C, *et al*. Positive Serum Beta-D-glucan by G Test and Aspergillus Fumigatus Sputum Culture Mimic Invasive Pulmonary Aspergillosis in a Pulmonary Nocardia Patient: a Case Report and Literature Review. Clinical Laboratory. 2019; 65: 10.7754/Clin.Lab.2018.181105.
[16] Ren J. Opportunities and challenges in general practice: A Chinese perspective. International Journal of General Practice. 2022; 1: 21–37.
[17] Wang X. Incidence and prevention of chronic diseases in China: Literature review in the last 5 years. International Journal of General Practice. 2022; 1: 57–70.
[18] Kitamura H, Tamaki M, Kawaguchi Y, Okawa Y. Results of off-pump coronary artery bypass grafting with off-pump first strategy in octogenarian. Journal of Cardiac Surgery. 2021; 36: 4611–4616.
[19] Sandler N, Ho H, Draxler DF, Bain CR, Smith JA, Hauser CJ, *et al*. Characterisation of Plasma Mitochondrial DNA, MMP-9 and Neutrophil Elastase in Patients Undergoing Coronary Artery Bypass Grafting: Effects of Tranexamic Acid and Postoperative Pneumonia. Heart, Lung & Circulation. 2022; 31: 439–446.
[20] Rosenblum JM, Binongo J, Wei J, Liu Y, Leshnower BG, Chen EP, *et al*. Priorities in coronary artery bypass grafting: Is midterm survival more dependent on completeness of revascularization or multiple arterial grafts? The Journal of Thoracic and Cardiovascular Surgery. 2021; 161: 2070–2078.e6.
[21] Gaudino M, Taggart DP. Percutaneous Coronary Intervention vs Coronary Artery Bypass Grafting: A Surgical Perspective. JAMA Cardiology. 2019; 4: 505–506.
[22] Sumi K, Yoshida S, Okamura Y, Isomura T. Minimally Invasive Multiple Coronary Artery Bypass Grafting with Composite Graft Using in situ Right Gastroepiploic and Radial Arteries. Annals of Thoracic and Cardiovascular Surgery: Official Journal of the Association of Thoracic and Cardiovascular Surgeons of Asia. 2021; 27: 286–289.
[23] Modi AR, Kovacs CS. Hospital-acquired and ventilator-associated pneumonia: Diagnosis, management, and prevention. Cleveland Clinic Journal of Medicine. 2020; 87: 633–639.
[24] Puskas JD, Gaudino M, Taggart DP. Experience Is Crucial in Off-Pump Coronary Artery Bypass Grafting. Circulation. 2019; 139: 1872–1875.
[25] Łoś A, Hellmann M. Real-time microcirculation imaging during beating-heart coronary artery bypass grafting. Kardiologia Polska. 2020; 78: 780–781.
[26] Galambos C, Bush D, Abman SH. Intrapulmonary bronchopulmonary anastomoses in COVID-19 respiratory failure. The European Respiratory Journal. 2021; 58: 2004397.
[27] Wang Z, Zhang Y, Duan M, Zhang Y. Chronic active Epstein-Barr virus infection with intrapulmonary shunting: A case report. Journal of Infection and Chemotherapy: Official Journal of the Japan Society of Chemotherapy. 2020; 26: 502–505.
[28] Ngom NF, Sow D, Diedhiou D, Ndour MA, Diop CT, Faye FA, *et al*. Epidemiological, Clinical, Paraclinical and Evolutionary Aspects of Urinary Tract Infection in Diabetics Hospitalized at the Department of Medicine of Abass Ndao Hospital from January 01, 2018, to December 31, 2018. Advances in Infectious Diseases. 2022; 12: 203–215.
[29] Turk Wensveen T, Gašparini D, Rahelić D, Wensveen FM. Type 2 diabetes and viral infection; cause and effect of disease. Diabetes Research and Clinical Practice. 2021; 172: 108637.
[30] Bal T, Kurtdere C, Önlen Y, Çabalak M. Effect of Hepatitis C Infection and Its Clearance on the Frequency of Coronary Artery Disease in Diabetics. Viral Hepatitis Journal. 2020; 26: 167–170.
[31] Ono M, Kawashima H, Hara H, Mancone M, Mack MJ, Holmes DR, *et al*. Impact of major infections on 10-year mortality after revascularization in patients with complex coronary artery disease. International Journal of Cardiology. 2021; 341: 9–12.
[32] Suryawan IGR, Luke K, Agustianto RF, Mulia EPB. Coronary stent infection: a systematic review. Coronary Artery Disease. 2022; 33: 318–326.
[33] Weissman C. Pulmonary complications after cardiac surgery. Seminars in Cardiothoracic and Vascular Anesthesia. 2004; 8: 185–211.
[34] Hulzebos EHJ, Helders PJM, Favié NJ, De Bie RA, Brutel de la Riviere A, Van Meeteren NLU. Preoperative intensive inspiratory muscle training to prevent postoperative pulmonary complications in high-risk patients undergoing CABG surgery: a randomized clinical trial. JAMA. 2006; 296: 1851–1857.
[35] Chen X, Hou L, Zhang Y, Liu X, Shao B, Yuan B, *et al*. The effects of five days of intensive preoperative inspiratory muscle training on postoperative complications and outcome in patients having cardiac surgery: a randomized controlled trial. Clinical Rehabilitation. 2019; 33: 913–922.
[36] Langnau C, Rohlfing AK, Gekeler S, Günter M, Pöschel S, Petersen-Uribe Á, *et al*. Platelet Activation and Plasma Levels of Furin Are Associated With Prognosis of Patients With Coronary Artery Disease and COVID-19. Arteriosclerosis, Thrombosis, and Vascular Biology. 2021; 41: 2080–2096.
[37] Shen Y, Cao Q, Zhuo H, Hu M, Chen S. Early Versus Late Tracheostomy in Stroke Patients: A Retrospective Analysis. Neuropsychiatric disease and treatment. 2022; 18: 2713–2723.
[38] Kolossvary M, Fishman EK, Gerstenblith G, Bluemke DA, Mandler RN, Kickler TS, *et al*. HIV may indirectly accelerate coronary artery disease through enhancing the effects of conventional and non-conventional cardiovascular risk factors. European Heart Journal. 2020; 2: ehaa946. 3310.
[39] Enginoev S, Rad AA, Ekimov S, Kondrat'ev D, Magomedov G, Amirhanov A, *et al*. Risk Factors for Deep Sternal Wound Infection after Off-Pump Coronary Artery Bypass Grafting: a Case-Control Study. Brazilian Journal of Cardiovascular Surgery. 2022; 37: 13–19.