

# Pulmonary complications following cardiac surgery

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## Abstract

Coronary heart disease is a common diseases of atherosclerosis. Despite the development of noninvasive therapies and the advancement of pharmacological methods and extensive drug regimens, coronary artery bypass grafting surgery is still the ultimate treatment option in many patients. Among the various complications following open heart surgery, one of the common difficulties is pulmonary complications associated with subsequent morbidity and mortality, which should be studied according to preoperative, perioperative, and postoperative factors. Preoperative factors include genetics, age, family history of pulmonary disease, smoking, coexisting disease, etc. Perioperative factors include surgical procedures like sternotomy incision, cardioplegia, and internal mammary artery harvesting; anaesthesia procedure effects like pulmonary collapse, maintenance drugs and morphine administration; and cardiopulmonary bypass pump by systemic inflammatory response syndromes. And finally, postoperative factors, especially mediastinitis and the role of nursing in the intensive care unit. Pulmonary complications after cardiac surgery include atelectasis, pleural effusions, pneumonia, pulmonary oedema, cardiogenic pulmonary oedema, acute respiratory distress syndrome, pulmonary embolism, phrenic nerve injury, pneumothorax, sternal wound infection, and mediastinitis, with different outbreaks in patients reported. Although the preoperative, perioperative, and postoperative factors play an important role in the occurrence of these complications, the preoperative factors, as factors that can be adjusted, should be considered more than the others and explained to the patient, and the preoperative patient's assessment should be noted. Also, postoperative care with the goal of reducing infections and pulmonary complications should be addressed by the nursing team.

**Key words:** pulmonary complications, cardiac surgery, respiratory, cardiovascular.

## Introduction

Cardiovascular disease (CVD) is one of the challenges of medical science not only in developing countries but also in developed countries. Increasing the risk of cardiovascular disease [1–3]. Over time, there is an increase in morbidity and mortality due to CVD. Extensive research suggests an increase in the incidence of atherosclerosis in patients following changes in lifestyle, diet, and genetic and environmental factors such as air pollution. Coronary heart disease (CHD) is one of the common diseases of atherosclerosis, which has been associated with significant

advances in various societies and brings irreparable complications to patients [4–7]. In cases of atherosclerosis, the development of plaques and blood clots in coronary arteries, as well as atherosclerosis, and the risk of heart attacks and tissue necrosis has increased dramatically and causes higher mortality. Despite the development of noninvasive therapies and the advancement of pharmacological methods and extensive drug regimens, coronary artery bypass grafting (CABG) surgery is still the ultimate treatment option in many patients [8–11]. In this method, open heart surgery is performed with or without the use of a cardiopulmonary bypass (CPB) pump, and the vessels are linked. In most cases, this surgery is on pump, which causes the complications of the pump to be imposed on the patient in addition to the various complications of the surgery. Among the various cardiovascular, renal, infectious, and psychiatric complications following open heart surgery, one of the common difficulties is pulmonary complications (PC) associated with subsequent morbidity and mortality [11–14].

The aim of this study was to review PC following cardiac surgery.

### **Pulmonary complications following cardiac surgery**

As stated, pulmonary complications are an unavoidable complication following CABG surgery [15, 16]. Various studies have shown a different outbreak in patients ranging from 3 to more than 50% [17, 18]. However, the occurrence of PC following cardiopulmonary bypass surgery is a multivariate outcome that should be studied according to the preoperative, perioperative and postoperative. Therefore, we will investigate the effective factors in the occurrence of PC following Cardiac surgery during these periods, and then we will explain the various types of pulmonary diseases following CABG surgery.

### **Effective factors in the occurrence of PC following cardiac surgery**

#### **Preoperative factors**

Obviously, preoperative factors are the most important prognostic markers for postoperative complications, and in patients undergoing cardiac surgery these factors are even more important. This suggests that the patient's early history and familiarity with patient history play a significant role in managing the patient's postoperative pulmonary conditions. Although the first effective factor in the disease and the complications resulting from their treatment is genetic predisposition, genetic advancements due to the lack of equipment, cost-effectiveness, the uneven

distribution of existing tests, and even the reluctance of therapist teams, have not yet been able to accommodate. Human genetics should be the first significant factor in patients and should be attentive to the history of the presence of pulmonary diseases in relatives of a candidate for CABG [19, 20]. Clinical studies suggest a family history of pulmonary disease as one of the major risk factors for lung disease, and it is evident that cardiac patients undergoing pulmonary complications, if they have a family history of lung disease, will be more at risk. The patient's age is important, not only for the development of PC, but also for all diseases and treatments, and aging is associated with increased morbidity and mortality. A study done on patients over the age of 60 years [21] showed that the prevalence of pulmonary disease in these patients was significantly higher than the lower intervals, and in other studies people over 80 years old had a higher prevalence [22]. This means that preoperative treatment choices should be specifically addressed in these patients. Although PC after CABG surgery is of special interest with high prevalence, if the patient has preoperative pulmonary disease, postoperative PC is significantly high and will require wider strategies. Among the existing pulmonary diseases, it has been shown that patients with chronic obstructive pulmonary disease (COPD) will have more side effects [23]. Another common cause, which is unfortunately a high prevalence in cardiovascular patients, is smoking. Smoking is an important predictor of postoperative PC because in smokers not only pulmonary function tests and lung capacities are significantly changed, but also histologically the destructive effects on patients' lungs has left [24]. In a study of more than 2000 people, it was reported that postoperative PC in smokers (29.5%) was twice as likely to be the most common in non-smokers (14.7%), and in smoking patients the mechanical ventilation required more time, and 6 h after mechanical ventilation, smokers were more likely to have reflux than non-smokers [25]. In another study, among patients without COPD, only 5.9% of patients had pulmonary complications after surgery, while 32.2% of COPD patients had pulmonary complications [26]. Generally, clinical researchers have suggested that quitting smoking at least one year before surgery reduces the risk of post-operative mortality and reduces the risk of arterial and respiratory diseases in current smokers [27]. Obesity is also considered as an effective factor in the incidence of cardiovascular disease as well as pulmonary diseases. A review of various studies has shown that the incidence of PC following CABG surgery in obese patients is significantly higher than in other patients [28], but some studies have reported that

the body mass index (BMI) of patients with and without PC was similar and the mean BMI in both groups was not statistically significant [26]. Diabetes mellitus (DM) as a prevalent underlying disease in different societies has always been a factor in the occurrence of varied morbidity and mortality. Relative risk rates for CVD in adults with DM have been reported to be between 1 and 3 times for men and from 2 to 5 times more for women than adults without DM [29]. DM patients are also more likely to have pulmonary disease than other patients with associated illnesses. In one study, 123 patients with DM, who were candidates for a surgical procedure, showed that 14% of patients had pulmonary disease [30]. But postoperative PC is controversial in these patients. One study reported that the prevalence of PC after cardiac surgery in patients with and without DM was between 10% and 12%, and it did not have a significant difference [26].

Ultimately, one of the most effective and vital factors is emergency or elective surgery. Indeed, attempting to perform an elective activity, although most of the patients are responsible for the pursuit of illness, but the proper management of the patient by a cardiologist can help prevent an emergency surgery that could increase the risk during operation. In one study that reported postoperative complications in elective and emergency surgery, it was shown that the risk of pneumonia is higher in emergency surgery [31]. However, for each patient, a set of pre-operative factors can be considered, which is why it is the responsibility of the surgeon to have complete coverage of the patient's pre-surgical information.

### Perioperative factors

Although the focus on preoperative factors and patient management can be the most fundamental step in reducing morbidity and mortality of various surgeries – including cardiac artery bypass surgery – the surgical procedure and accompanying events are a critical step in the incidence or absence of morbidity and mortality. In other words, if the patient undergoes surgery in the most stable and remote conditions possible, the main consequence is the outcome of the operation of the surgeon and the clinical team during the operation. Therefore, the importance of perioperative incidents in the occurrence of morbidity and mortality is very important. Although most of the surgical care is similar in practice, CABG surgery, due to both the extent of the surgery and the associated additional procedures, can provide many potential causes for complications such as PC. To further understand the factors affecting pulmonary complications during surgery, these factors are presented in three sections: surgical

procedures, anaesthetic procedures, and cardiopulmonary bypass pump.

### Surgical procedures

A review of various studies suggests that the variables involved in CABG surgery, in turn, can activate or limit the pathway of PC. One of the contributing factors is sternotomy incision (SI) that is under contradictory, and various studies have shown inconsistency findings. One study reported PC after SI at nearly 2% [32]. However, this finding is different from earlier studies [33] that believed that SI had no PC effect. Also, challenges for CPB and cardioplegia and cold effects are still being discussed in other studies. After an aortocoronary bypass graft patient with normothermia exhibited decreases in the alveolus-arterial gradient of CO<sub>2</sub>, shunt fraction, and PA-a O<sub>2</sub>, the central temperature did not appear to significantly influence gas exchange, so normothermia is beneficial for the preservation of pulmonary function after CABG [18, 34]. Also, one of the most important factors is the number of vessel grafts that lead to additional severity of surgery, increased surgical duration and duration of anaesthesia, as well as the duration of the CPB pump [35]. In particular, the internal mammary artery (IMA) is one of the sensitivities for increasing the risk of PC [36]. Unfortunately, very few studies have been carried out on this subject, and even in the review articles that have been widely discussed, no clear conclusions have been drawn; for example, in a study titled pleurotomy during IMA harvesting increase post-operative PC, the only final conclusion was that patients undergoing cardiac surgery suffer from pulmonary function after surgery. Pyloromyotomy seems to combine this with increased atherosclerosis and pleural effusion, although it has no effect on clinical outcomes or duration of hospital stay [37]. The abovementioned factors must be performed in all surgical procedures and are considered to be a real part of the surgery and can lead to PC on their own. But in addition, medical errors can lead to irreversible PC. It can be concluded that damage to neural networks, especially the diaphragmatic paralysis, can be expected.

### Anaesthesia procedure

Anaesthesia is the basis for the development of new surgical procedures, and a basic need for heart surgery. Accepting the risk of anaesthesia is the first step in starting an operation and preventing medical errors during anaesthesia, ensuring the success of the surgery and the health of the patient. Of course, in cardiac surgeries, using CPB and anaesthesia are considered to be two active arms of a segment [38]. Efforts to prove the effect of pulmonary ventilation during CPB pump and

the formation of pulmonary collapse, which will lead to PC, continue to be found in various articles. In fact, lung collapse and damage after reintroduction of post-onset blood flow are factors that cause pulmonary endothelium dysfunction with vascular contraction and increased permeability of the vascular membrane, leading to increased pulmonary, oedema, and hypoxia pressure [39]. Another form of anaesthetic complications is due to anaesthetic drugs that cause PC through immune disorders. In fact, severe changes in immune markers occur both through anaesthetics and after the use of a CPB pump. The use of anaesthetic drugs, especially maintenance drugs, which are given at higher doses, such as propofol, or barbiturates such as thiopental, can provide dramatic changes in the balance of immune markers, which can lead to lung injury [40–42]. Also, the use of opioids such as morphine during anaesthesia is unavoidable because morphine-induced depression, in addition to the involvement of the inflammatory cycle, reduces the activity of macrophages, which subsequently facilitates lung injury. The patient's position is another predisposing factor for lung injury in these patients. CABG candidate patients remain in a supine position for more than 2 h, and the undesired ventilation mentioned above can lead to more harm and to abnormal pulmonary shunt fraction. Generally, the possible damage to the anaesthetic process in patients involves reduction of vital capacity and the functional residual capacity of the lungs and widened alveolar-arterial oxygen gradient, which ultimately leads to hypoxaemia and atelectasis [18, 43–46].

### Cardiopulmonary bypass pump

The use of a CPB pump has led to significant development of open heart surgery. However, in addition to the benefits, this method has many complications, the basis of which is due to systemic inflammatory response syndromes (SIRS) [47, 48]. Many of the factors involved in the CPB, whether they are substance-related (placement of blood exposed to artificial materials), and independent of matter (surgical trauma, ischaemia – reperfusion of organs, changes in body temperature, and release of endotoxins), create multiple inflammatory responses. The CPB circuit has a common blood flow that is very different from normal endothelium, and this condition leads to undesirable reactions. Activation of the complement system is the primary mechanism that initiates and strengthens the acute inflammatory response. In addition to the increased number of activated leukocytes, the number of leukocyte-platelet pairs also increases in patients undergoing cardiac surgery with CPB. Leukocytes are located not only in the myocardium but also in

the lungs and other organs. Isolation of leukocyte is affected by the duration of the aortic and CPB mutual clamping. It is believed that this is one of the major causes of pulmonary damage after on-pump surgery [49–51]. Several studies have been carried out to illustrate the effects of the pump on PC. Staton *et al.* [52], during a study of the consequences of on-pump and off-pump surgery, shown that off-pump patients were extubated significantly faster than on-pump patients. It was also generally stated that off-pump surgery is accompanied by a reduction in the number of postoperative PC and leads to a better exchange of gases. However, for spirometry and lung function, no significant difference is observed. Also, Mack *et al.* [53], in a study aimed at comparing CABG with and without pump, stated that pneumonia was seen in 3.6% of on-pump patients and only 2% of off-pump patients, i.e. significantly lower in off-pump patients. In general, only 4.1% of off-pump patients had postoperative PC, but 9.5% of on-pump patients showed PC. It should be noted that use of the pump as the main cause of the operation in many surgeries cannot be avoided, and efforts to reduce complications can only be achieved by reducing the duration of the pump.

### Postoperative factors

Although preoperative and operational factors play a major role in the incidence of complications, postoperative care, especially nursing, in the intensive care unit (ICU) can have a very important effect on PC. More than any other complication, mediastinitis can be seen in the ICU or even days after leaving the ICU. In addition, by increasing the duration of hospitalisation, mediastinitis can significantly increase mortality by as much as 28% [54]. Therefore, taking care of the patient and preventing the occurrence of mediastinitis is one of the basic requirements of postoperative pain.

### Conclusions

Generally, pulmonary complications after cardiac surgery include atelectasis, pleural effusions, pneumonia, pulmonary oedema, cardiogenic pulmonary oedema, acute respiratory distress syndrome, pulmonary embolism, phrenic nerve injury, pneumothorax, sternal wound infection, and mediastinitis, with different outbreaks in patients reported. Although the preoperative, perioperative, and postoperative factors play an important role in the occurrence of these complications, the preoperative factors, as factors that can be adjusted, should be considered more than the others, they should be explained to the patient, and the patient's preoperative assessment should be noted. Also, postoperative care with the goal of reducing

infections and PC should be addressed by the nursing team.

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### Conflict of interest

The authors declare no conflict of interest.

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