



The predictive role of computed tomography on respiratory complications following coronary artery bypass surgery

Pulmonary risk and coronary surgery

Özlem Erçen Diken¹, Adem İlkay Diken², Adnan Yalçınkaya², Sertan Özyalçın², Muhammed Onur Hanedan³

¹Department of Chest Diseases, Hitit University Faculty of Medicine, Çorum,

²Department of Cardiovascular Surgery Hitit University Faculty of Medicine, Çorum,

³Department of Cardiovascular Surgery, University of Health Sciences Faculty of Medicine, Ahi Evren Research and Training Hospital, Trabzon, Turkey

Abstract

Aim: Pulmonary complications are frequently seen complications following especially after coronary artery bypass grafting. Attempts are made to detect those complications preoperatively by pulmonary function tests and clinical evaluation. In our study, we investigated the effect of computed tomography findings in predicting postoperative complications in patients with normal respiratory function tests. **Material and Method:** Between January 2012 and August 2017, imaging records, intensive care and service follow-up records, and polyclinic follow-up records of 695 patients who underwent elective isolated CABG at the Department of Cardiovascular Surgery in Hitit University Faculty of Medicine were retrospectively reviewed. Computed tomography images, demographic, and clinical data of the patients who met the inclusion criteria were retrospectively evaluated. **Results:** Mediastinal lymphadenopathy, emphysema, interlobular septal thickness/ fibrosis, nodule, pleural thickening, tuberculosis sequel, and band/subsegment atelectasis parameters were evaluated. The most common preoperative radiologic pulmonary pathology was mediastinal lymphadenopathy (n=96, 27.3%), and the least was tuberculosis sequel (n=20, 5.6%). The most common pulmonary complication in the postoperative period was atelectasis (148 patients, 42%). On logistic regression analysis, emphysema was found to be a significant predictor of both prolonged mechanical ventilation and bronchospasm ($p<0.05$). Furthermore, band or subsegmental atelectasis were also predictive for postoperative hypoxemia ($p<0.05$). **Discussion:** It can be claimed that pulmonary complications are observed frequently after CABG in patients even with normal respiratory function in the preoperative period; morphologic data of lungs obtained by computerized tomography in these patient groups may be predictive for some of the postoperative complications.

Keywords

Computed Tomography; Postoperative Complication; Coronary Artery Bypass

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Corresponding Author: Özlem Erçen Diken, Department of Chest Diseases, Hitit University, Çorum, Turkey.

T.: +90 3642230300 F.: +90 3642230323 E-Mail: oercen@hotmail.com

ORCID ID: 0000-0001-8388-9500

Introduction

Coronary artery bypass grafting (CABG) process for coronary revascularization is the primary treatment strategy for many coronary lesions currently. Complications such as respiratory dysfunction, atelectasis, pneumonia, and pleural effusion are common due to the opening of the thoracic cage and the direct effects of the cardio pulmonary bypass in patients undergoing CABG [1]. Although the mortality and morbidity rates of CABG vary in different series, respiratory failure is an important cause in all the series.

Obstructive and restrictive pulmonary diseases rated by pulmonary function tests (PFT) are included in many risk scoring systems that predict mortality and morbidity before CABG [2,3]. While the residual status and functions of the lungs are evaluated in these scoring systems, there is no information about the morphological state of the lung.

The effects of sequel changes secondary to previous lung diseases, emphysema, and bullaecaused by chronic obstructive pulmonary disease (COPD) or the other possible changes in pulmonary functions due to previous pulmonary operations or other possible causes of complications following CABG are not found in the literature.

In our study, the findings on preoperatively performed unenhanced thoracic computed tomography and direct chest radiography were evaluated for patients who had undergone coronary artery bypass grafting surgery and the postoperative effects on pulmonary functions were investigated.

Material and Method

In our clinic, except for emergency cases, unenhanced chest computed tomography is performed routinely to control the aortic cannulation, cross clamp, or side clamp area of the patients who planned to undergo CABG. The results of those computed tomography scans were retrospectively evaluated in the study.

Patients

Imaging records, intensive care and service follow-up records, and polyclinic follow-up records of 695 patients who underwent elective isolated CABG at the Department of Cardiovascular Surgery of the Faculty of Medicine of Hitit University between January 2012 and August 2017 were retrospectively reviewed. Records were excluded for emergency patients because of missing data and for patients who could not tolerate the computerized tomography procedure. Patients with abnormal PFT results ($n = 266$), patients with previous pulmonary surgery history ($n = 3$), patients with bronchial asthma under medical treatment ($n = 48$), and patients who are active smokers ($n = 378$) were also excluded from the study. The data on preoperative imaging findings and postoperative pulmonary complications of 352 patients were evaluated; 343 patients were excluded due to the reasons above.

Patient demographic data, accompanying diseases, smoking history, body mass index (BMI), pulmonary function tests, direct chest X-ray, computerized tomography records, arterial blood gas results, time length of the operation, extubation time, intensive care stay, discharge time, and complications were recorded.

Computed tomography and spirometry protocol

64 slice multidetector spiral thoracic CT scan was used to obtain the images with a 15-s period of apnea at the end of a normal inspiration. The scanning images were taken at 120 kV and 250 mAs. Lung scanning was performed from the apex to the diaphragm. Contrast material was not routinely used.

To assess the pulmonary functions, all patients were submitted to a computed spirometric test in order to analyze the variables of vital capacity (VC), forced vital capacity (FVC), forced expiratory volume in the first second (FEV1), ratio between forced expiratory volume in the first second and forced vital capacity (FEV1/FVC), maximum voluntary ventilation (MVV), and peak expiratory flow (PEF).

Radiographic findings

The computed tomography and direct chest x-rays taken in the preoperative period were evaluated by the same chest diseases clinician and by a radiologist when needed. The pathologies detected by imaging methods are divided into the following categories according to the etiological and clinical features: 1) Mediastinal lymphadenopathy, 2) Emphysema, 3) Interlobular septal thickness and fibrosis, 4) Nodule, 5) Pleural thickening, 6) Tuberculosis sequel, 7) Band or subsegmental atelectasis.

Extubation and discharge criteria

Extubation and discharge of patients were performed according to the same clinical protocol. The criteria for extubation:

- Restoring of awareness and neuromuscular blockage by mild stimuli (restoring of muscular strength)
- Normothermia ($>36^{\circ}\text{C}$)
- Amount of drainage <50 mL/hour
- Breathe through a T tube for at least 30 minutes (fraction of inspired oxygen of less than 0.40) and a respiratory rate less than 25 breaths/min
- Sufficient cardiac performance
- cardiac index >2 L/min/m²
- systolic blood pressure >100 -120 mmHg
- heart rate <120 bpm
- absence of arrhythmia
- Arterial blood gases (ABG)
- $\text{PO}_2/\text{FiO}_2 > 150$
- $\text{PCO}_2 < 50$ mmHg
- pH 7.35-7.45

Patients who met the criteria for discharge from the intensive care unit are taken to the clinic ward on the first day after the operation. Those criteria are as following:

- Hemodynamic stability -extubated patient
- Good oral intake and nutrition
- No drainage
- Comfortable mobilization, conscious and cooperative
- No radiological findings of pulmonary complications on postoperative chest x-rays
- Patients who are hemodynamically stable with normal biochemical data and free of postoperative complications (infection, sterna dehiscence, etc.) were discharged after four nights of follow-up.

Statistical Analysis

Statistical analysis was performed using the SPSS version 17.0 statistical software package. All P values <0.05 were considered as statistically significant. Normal distribution of measured data was shown by mean ± standard deviation, and comparisons between the groups were performed by t-test. Qualitative variables were tested using x2 or Fisher’s exact test. To identify risk factors of major postoperative complications further analysis was performed via multiple logistic regression analysis. The covariate of regression analysis included computed tomography findings such as lymphadenopathy, emphysema, interlobular septal thickness and fibrosis, nodule, pleural thickening, tuberculosis sequel, and band or subsegmental atelectasis.

Results

The mean age of the study group was 65.1±9.8 and mean peripheral oxygen saturation was 96.1±3.1. Of the 362 patients, 165(47%) were female.

Preoperative radiologic pulmonary pathologies are grouped in Table 1. The most common preoperative radiologic pulmonary pathology was mediastinal lymphadenopathy (n=96, 27.3%),

Table 1. Pulmonary pathologies prior to surgery

| Patients | N=352 |
|--|------------|
| Mediastinal lymphadenopathy | 96 (27.3%) |
| Emphysema | 42 (11.9%) |
| Interlobular septal thickness and fibrosis | 42 (11.9%) |
| Nodule | 86 (23.8%) |
| Pleural thickening | 36 (10.2%) |
| Tuberculosis sequel | 20 (5.6%) |
| Band or subsegmental atelectasis | 64 (18.2%) |
| NORMAL | 186(52%) |

Table 2. Postoperative Complications

| Patients | N=352 |
|----------------------------------|-------------|
| Atelectasis | 148 (42%) |
| Pleural fluid | 124 (35.2%) |
| Bronchospasm | 128 (36.4%) |
| Prolonged mechanical ventilation | 28 (7.9%) |
| Pneumonia | 24 (6.8%) |
| Pneumothorax | 6 (1.7%) |
| Hypoxemia | 142 (40.3%) |

Table 3. Postoperative Pulmonary Complications

| | Atelectasis | Pleural Fluid | Broncho spasm | Prolonged Ventilation | Pneumonia | Hypoxemia |
|---|-------------------------|-------------------------|------------------------|------------------------|------------------------|-------------------------|
| Lymphadenopathy n:96 | 30(31.3%, p: 0.097) | 36(37.5%, p: 0.626) | 32(33.3%, p: 0.682) | 2(2.1%, p: 0.117) | 6 (6.3%, p: 1) | 34(35.4%, p: 0.482) |
| Emphysema n:42 | 14(33.3%, p: 0.428) | 16(38.1%, p: 0.723) | 32(76.2%, p< 0.001) | 10(23.8%, p: 0.014) | 0 (0%, p: 0.365) | 22(52.4%, p: 0.205) |
| Interlobularseptalthicknessandfibrosis n:42 | 8(19.0%, p: 0.027) | 18(42.9%, p: 0.399) | 18(42.9%, p: 0.470) | 4(9.5%, p: 0.671) | 4 (9.5%, p: 0.636) | 22 (52.4%, p: 0.205) |
| Nodule n:84 | 38 (45.2%, p: 0.558) | 34(40.5%, p: 0.363) | 36 42.9%, p: 0.272) | 4 (4.8%, p: 0.525) | 6 (7.1%, p: 1) | 28 (33.3%, p: 0.338) |
| Pleuralthickening N:36 | 16 (44.4%, p: 0.778) | 20 (55.6%, p: 0.049) | 14(38.9%, p: 0.770) | 2 (5.6%, p: 1) | 8 (22.2%, p: 0.022) | 14(38.9%, p: 0.943) |
| Tuberculosissequel n:20 | 12 (60%, p:0.322) | 4 (20%, p: 0.497) | 12 (60%, p: 0.171) | 4 (20%, p: 0.178) | 2 (10%, p: 0.510) | 6 (30%, p: 0.742) |
| Bandorsubsegmentalatelectasis n:64 | 32 (50%, p:0.272) | 22 (34.4%, p: 0.973) | 26(40.6%, p: 0.526) | 0 (p: 0.078) | 6 (9.4%, p: 0.452) | 14 (21.9%, p: 0.023) |

and the least was tuberculosissequel (n=20, 5.6%).Emphysema was observed in 42 patients (11.9%) and interlobular septal thickness and fibrosis was observed in 42 patients (11.9%). Nodule was observed in 86 (23, 8%) patients, pleural thickening was observed in 36 (10.2%) patients; band or subsegmental atelectasis was observed in 64 (18.2%) patients. Atelectasis, pleural thickening, bronchospasm, prolonged mechanical ventilation, pneumonia, and hypoxemia were the assessed postoperative pulmonary complications. The most common pulmonary complication in the postoperative period was atelectasis (148 patients, 42%).Postoperative pleural fluid on the non-drained side was observed in 124 (35.2%) patients. 128(36.4%) patients had bronchospasm which required bronchodilator therapy. Prolonged mechanical ventilation (over 24 hours) was recorded in 28 (7.9%) patients. Pneumonia in 24(6.8%) cases, pneumothorax in 6 (1.7%) cases and hypoxemia in 142(40.3%) cases (in postoperative day 1) were recorded. No pulmonary complications were observed in 48 of the patients (Table 2).

Of the 42 patients with emphysema, bronchospasm was observed in 32and prolonged mechanical ventilation was observed in 10 (P< 0.001, P=0.014, respectively). 8 out of 42 (19%) patients had atelectasis in the postoperative periodwho hadalso had interlobular septal thickness and fibrosis preoperatively (P= 0.027). 20out of 36 cases with preoperative pleural thickening had also postoperative pleural fluid (P=0.04), however 8 (22.2%) patients had pneumonia in the postoperative period (P= 0.02). Hypoxemia was observed in 14of the 64patients with preoperative band or subsegmental atelectasis (P= 0.023). Lymphadenopathy, nodules, and tuberculosis sequel were not found to be associated with any postoperative complication (Table 3).

Logistic regression analysis was performed to determine whether or not the preoperative radiologic pulmonary pathologies were predictive for postoperative pulmonary complications following coronary bypass surgery. Emphysema was a significant predictor forboth prolonged mechanical ventilation and bronchospasm (P<0.05). Furthermore, band or subsegmental atelectasis was alsopredictive for postoperative hypoxemia (P<0.05).

Discussion

Determining the relationship between the morphological changes in the lungs in the preoperative period and the complications that may develop in the postoperative period consti-

Table 4. Logistic Regression Analysis

| Patients | Prolonged Ventilation | Hypoxemia | Pneumonia | Atelectasis | Broncho Spasm | Pleural Fluid |
|--------------------------------------|-----------------------|--------------|------------------|--------------|---------------|---------------|
| | | | | | | |
| Lymphadenopathy | 0.1(0.009-1.5) | 0.7(0.3-1.5) | 0.2(0.01-3.9) | 0.4(0.2-1.0) | 0.8(0.3-1.7) | 1.2(0.5-2.5) |
| Emphysema | 6.2(1.4-27.1) | 1.8(0.6-5.1) | 0 | 0.7(0.2-2.0) | 6.7(2.2-20.3) | 1.2(0.4-3.4) |
| Interlobarseptalthicknessandfibrosis | 2.3(0.3-13.8) | 2.0(0.7-5.5) | 4.6(0.1-153.9) | 0.3(0.1-1.0) | 1.1(0.4-3.3) | 1.2(0.4-3.4) |
| Nodule | 0.2(0.02-3.1) | 0.6(0.2-1.4) | 3.0-(0.2-46.8) | 1.5(0.6-3.5) | 0.9(0.4-2.3) | 1.4(0.6-3.3) |
| Pleuralthickening | 1.3(0.07-25.0) | 1.2(0.3-4.3) | 0.7(0.03-13.6) | 1.0(0.3-3.5) | 0.6(0.1-2.5) | 3.1(0.9-10.3) |
| Tuberculosissequel | 5.8(0.5-64.7) | 0.6(0.1-3.2) | 38.7(0.5-2872.7) | 1.7(0.4-7.3) | 2.4(0.5-10.5) | 0.3(0.05-1.7) |
| Bandorsubsegmentalatelectasis | 0 | 0.3(0.1-0.8) | 0.2(0.02-3.4) | 1.4(0.6-3.3) | 1.6(0.6-3.8) | 0.9(0.3-3.8) |

tute the main results of this study. Morphological findings of pulmonary pathologies are either absent or quite superficial in the operative risk assessment scales that are in use today [2,3]. Pulmonary function tests are the most commonly used method for the pulmonary evaluation of a patient waiting for coronary artery bypass grafting. According to the results obtained in the study, 352 patients with no obstructive or restrictive pulmonary disease with regard to the results of preoperative PFT, various pulmonary complications were observed in 48 of them in the postoperative period.

When these common complications are considered in this group of patients with normal preoperative PFTs, it is noteworthy that the existence of emphysema and band atelectasis was significantly more prevalent in these patients. It can be said that PFT is inadequate for detection in these patients and additional imaging methods are needed.

Pulmonary complications have an important role following CABG. These problems may vary from a clinically insignificant mild hypoxemia to acute respiratory distress syndrome [1,4]. The main reason for the hypoxemia seen after surgery is ventilation / perfusion mismatch occurrence due to interruption of ventilation [1,4-7]. The use of CPB may also double the risk of postoperative hypoxemia compared to patients without CPB [1,4,6,7]. In a well-designed observational study by Rodrigues and his colleagues on patients with CABG, a 24% increase in collapsed lung tissue, a significant reduction in pulmonary gas volume, an increase in the amount of extravascular pulmonary fluid, and a significant decrease in normally ventilated parenchyma were seen [1].

As a result of all these pathologies, deterioration of gas exchange occurs. Apart from hypoxemia, pleural effusion is also a very common finding in the first week following surgery and can be seen at a rate as high as 90% [8,9].

An emphysematous lung often causes an abnormal result in the PFT and can be diagnosed clinically. However, in our study, cases with no evidence of PFT abnormality but with preliminary evidences of emphysematous CT findings were found to be at higher risk for bronchospasm and prolonged mechanical ventilation in the postoperative period. No research has been found in the literature to investigate this relationship. The presence of atelectasis is a pathology that will cause problems in both operative and postoperative procedures for almost any type of surgery performed under general anesthesia. This negative relationship has been addressed in many studies and the importance of correcting this pathology preoperatively with various cautions has been highlighted [10-12]. Also parallel to the studies known so far, it has also been demonstrated that even band

atelectasis is a risk for postoperative hypoxemia. In addition to these significant findings, findings such as lymphadenopathies, nodules, and tuberculosis sequel which were observed more frequently during the examination of the patients and relatively frequent were not related to any negative clinical outcome.

Computed tomography is not routinely used in preoperative evaluation at most centers and it is only used when there is an indication. Only a few reports stated that the use of CT as a routine part of preoperative evaluation may provide clinical benefits [13-15]. The main issue addressed in these studies is the clinical benefit of preoperative CT in reducing the risk of perioperative stroke development; thus, performing preoperative CT at least on the patients who are at risk can provide clinical benefits. Pulmonary complications are not among the examined parameters. There are not many studies on routine computed tomography imaging and preoperative extracardiac pathologies in CABG candidates.

On the other hand, the types and incidence of incidental extracardiac pathologies were evaluated in some studies which were aiming to evaluate the results of computed tomography (CT) during the postoperative period for various reasons (such as graft patency control, etc.) [16,17]. When these evaluations are examined, it is seen that the pulmonary pathologies are not sufficiently detailed.

In this study, the relationship between some pathologies detected by preoperative CT imaging performed as a clinical protocol for the first time in this region and postoperative pulmonary complications is presented for a large sample.

The present study inherits all the limitations of retrospective studies. The utilized data depends on the accuracy of hospital records. Chest CTs were performed to detect aortic calcifications without using intravenous contrast material which causes suboptimal evaluation for some pulmonary pathologies. Patients with abnormal PFTs were excluded from the study to prevent selection bias. It would be more informative to compare those groups of patients either with normal or abnormal PFTs.

In conclusion, in our study pulmonary complications were observed frequently following CABG in patients with normal respiratory functions in the preoperative period. It can be claimed that morphological data of lungs obtained by CT in these patient groups may be predictive for some of the postoperative complications. For this purpose, it is necessary that CABG risk scoring systems be updated to include morphological data of lungs.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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