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Low Tidal Ventilation During Coronary Artery Bypass: Reducing Post–Operative Atelectasis and Pneumonia

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ABSTRACT

Background: Postoperative pulmonary complications are frequent after coronary artery bypass grafting (CABG), and the contribution of low tidal volume ventilation during cardiopulmonary bypass (CPB) to pneumonia and atelectasis prevention is still unclear. The primary objective is to determine the rates of postoperative pneumonia and atelectasis in patients undergoing CABG surgery and LTV ventilation during CPB, and to investigate their relationships with demographic and intraoperative parameters.

Methods: This descriptive observational study was carried out at the Department of Cardiac Surgery, National Institute of Cardiovascular Diseases (NICVD), Karachi. A consecutive non-probability method was used to include 185 patients aged between 30 and 75 years who required urgent CABG. LTV in CPB was 3-4ml/kg ideal body weight, and the respiratory rate was 10breaths/minute. Based on standardized clinical and radiological criteria, there was postoperative pneumonia and atelectasis. SPSS version 26 was used to analyse the data, with a p-value set at 0.05.

Results: The average age was 54.43 ± 6.51years, and 136 (73.5 %) were men. There were 15 patients (8.1%) with pneumonia and 31 patients (16.75%) with atelectasis. No statistically significant correlations were found between these complications and the demographic features, comorbidities, or intraoperative ventilation parameters.

Conclusion: Pneumonia and atelectasis were identified in CABG patients ventilated with LTV during CPB; however, none of the perioperative factors were found to relate significantly to the occurrence of pneumonia or atelectasis.

Keywords: Atelectasis; Pneumonia; Coronary Artery Bypass; Cardiopulmonary Bypass; Tidal Volume; Postoperative Complications.

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INTRODUCTION

Globally, more than 1 billion patients undergo cardiac surgery using cardiopulmonary bypass (CPB) annually, of which coronary artery bypass grafting (CABG) is the most commonly performed procedure [1]. Even though surgical and anesthetic techniques have been improved, postoperative

pulmonary complications are epidemiologically a major cause of morbidity in that they extend the length of hospital stay, heighten the expenditure of medical care, and negatively impact outcomes [2]. Atelectasis and pneumonia are the most commonly observed postoperative pulmonary complications and have been commonly acknowledged as a major cause of post-operative cardiac surgery morbidity [3].

These complications during CPB are propagated by several pathophysiological processes, such as the incidence of inflammation, change in perfusion, discontinuity of ventilation, hypothermia, and postoperative pain, which do not permit productive respiration [4]. The ventilatory approach during CPB is one of the intraoperative factors that is gaining much attention [5]. Conventionally, ventilation is abandoned following the inception of bypass to create a static surgical field [5]. Nevertheless, this method can precondition patients with a lung collapse, decreased compliance, and barriers in the gaseous exchange [6]. Lung-protective Low tidal volume (LTV) ventilation during CPB has been proposed to preserve alveolar recruitment and decrease volutrauma, as well as postoperative pulmonary morbidity [7]. Some randomized studies have observed a lower frequency of pulmonary complications in LTV than in control, whereas others reported no significant difference from traditional ventilation or non-ventilation [8]. The inconsistency in the diagnosis criteria, time period of assessment, and the surgical methods adds to the difficulty of interpretation of the available evidence [9]. Since there is no definite consensus in this area due to the small amount of local data, it is necessary to elucidate the frequency of postoperative pulmonary complications in patients undergoing LTV during CPB, to inform practice in our institution [10].

The purpose of the study is to identify the rate of postoperative pulmonary atelectasis and pneumonia occurrence among the patients undergoing CABG with low tidal volume convention during CPB. These findings will be used as baseline data in our population and will assist in the endeavor to streamline intraoperative ventilatory protocols to decrease the element of pulmonary morbidity.

METHODS

The current descriptive, observational study was conducted in the Department of Cardiac Surgery, National Institute of Cardiovascular Diseases (NICVD), Karachi, from October 2022 to April 2023 (Ref: NIC/116/Aug/2022). A total of 185 patients undergoing urgent coronary artery bypass grafting (CABG) with cardiopulmonary bypass (CPB) were recruited with the non-probability consecutive sampling. The OpenEpi version 3.0.1 (Atlanta, GA, USA) was utilized to calculate sample size on the basis of reported incidence rates of postoperative pulmonary complications and at a 95 % confidence level, 5 % margin of error, and estimated response rate of 90 %.

Inclusion criteria consisted of patients of both genders aged between 30-75 years, with an American Society of Anesthesiologists (ASA) physical status of I-IV, scheduled to receive an isolated CABG operation. The exclusion criteria consisted of patients who had suffered a previous CABG, renal failure, chronic liver disease, CLD, or other diseases/ conditions that had potentially led to an extended period of ventilation. Patients who receive combined valve surgeries, those who need intra-aortic balloon pump support, or preoperative mechanical support devices were also not considered.

Standard preoperative assessment was carried out, and all the subjects signed the written informed consent. The anesthesia was initiated by propofol (1.52 mg /kg), atracurium (0.5 mg /kg), and

nalbuphine (0.4 mg /kg), which was then maintained as per the institutional standard. Mechanical ventilation was commenced with 6-8 ml/kg ideal body weight tidal volume and I:E ratio 1:2, a respiratory rate of 12 to 14 breaths/min, flow rate of 1-2 L/min, and the end-tidal CO 2 waveform to be maintained between 35-45 mmHg. At the time of CPB, low tidal volume ventilation was achieved (3 4 ml/kg of ideal body weight) at a respiratory rate of 10 breaths/min, flow rate of 2 L/min; intermittent vital capacity maneuvers (30 cm H_2O, 5 seconds) were utilized after CPB weaning.

The diagnosis of postoperative pneumonia was achieved with a combination of both clinical (fever, cough, pleuritic pain) and radiographic evidence. Radiological standards of classification of atelectasis were used. SPSS version 26 (IBM Corp., Armonk, NY) was used to analyse the data. Mean and standard deviation were used to describe the quantitative variables, and frequencies and percentages were used to define the qualitative variables. The significance of the statistics was set as $p \leq 0.05$.

RESULTS

Table 1: Baseline Demographic and Clinical Profile of Study Participants (n = 185)

Variable	Mean ± SD / n (%)
Age (years)	54.43 ± 6.51
Body Mass Index (kg/m²)	25.88 ± 3.75
Tidal Volume (ml/kg)	8.23 ± 1.57
Peak Respiratory Pressure (cmH_2O)	18.17 ± 2.55
Perfusion Time (hours)	2.55 ± 1.01
Aortic Cross-Clamp Time (hours)	2.74 ± 0.87
Anesthesia Duration (hours)	7.14 ± 1.19
Gender	Male: 136 (73.5%)
	Female: 49 (26.5%)
Smoking Status	Smoker: 107 (57.8%)
	Non-Smoker: 78 (42.2%)
Diabetes Mellitus	Diabetic: 127 (68.6%)
	Non-Diabetic: 58 (31.4%)

A total of 185 patients who were enrolled in low tidal volume ventilation during cardiopulmonary bypass (CPB) during coronary artery bypass grafting (CABG) procedures were evaluated. The research participants were mainly middle-aged men with a medium body mass index. A large proportion of them had a history of smoking and diabetes mellitus. The ventilator settings and operation parameters, such as operative times, were observed to be normal in CABG operations. **Table 1** illustrates the clinical and demographic baseline characteristics.

Table 2: Comparison of risk factors and clinical characteristics in patients with and without postoperative pneumonia (n = 185).

Variable	Pneumonia Yes (n = 15)	Pneumonia No (n = 170)	95% CI	p-value
Age (years)	53.87 ± 4.73	54.48 ± 6.65	−4.078 to 2.858	0.729
BMI (kg/m²)	25.18 ± 2.58	25.95 ± 3.84	−2.762 to 1.237	0.453
Tidal volume (ml/kg)	8.67 ± 1.71	8.19 ± 1.56	−0.360 to 1.317	0.262
Peak respiratory pressure (cmH_2O)	18.67 ± 2.74	18.12 ± 2.54	−0.818 to 1.904	0.432
Perfusion time (hr)	2.73 ± 1.03	2.53 ± 1.01	−0.334 to 0.742	0.455
Aortic cross-clamp time (hr)	2.93 ± 0.79	2.72 ± 0.88	−0.251 to 0.683	0.363
Anesthesia duration (hr)	7.07 ± 1.10	7.15 ± 1.20	−0.714 to 0.553	0.803
Gender — Male	11 (73.3%)	125 (73.5%)	0.300 to 3.267	0.598
Gender — Female	4 (26.7%)	45 (26.5%)	-	-
Smoking — Smoker	8 (53.3%)	99 (58.2%)	0.284 to 2.364	0.712
Smoking — Non-smoker	7 (46.7%)	71 (41.8%)	-	-
Diabetes — Yes	12 (80.0%)	115 (67.6%)	0.519 to 7.057	0.248
Diabetes — No	3 (20.0%)	55 (32.4%)	-	-

Independent t-test was used for continuous variables and a Chi-square test for categorical variables

The 15 patients (8.1 %) were diagnosed with pneumonia. **Table 2** contains comparative data regarding the correlation between the variables of pneumonia and non-pneumonia groups. Statistically, there was no difference in the age, body mass index, tidal volume, maximum pressure of the respiratory system, the duration of perfusion, aortic cross-clamp time, and duration of the anesthetic procedure. The history of smoking, gender, and diabetes were also alike (all $p > 0.05$). The incidence of pneumonia was low and had no statistical relationship with any demographic, comorbidity, or intraoperative factor.

Table 3: Comparison of Risk Factors and Clinical Characteristics in Patients with and Without Postoperative Atelectasis (n = 185).

Variable	Atelectasis Yes (n = 31)	Atelectasis No (n = 154)	95% CI	p-value
Age (years)	54.61 ± 7.31	54.39 ± 6.36	−2.312 to 2.758	0.862
BMI (kg/m²)	25.82 ± 3.05	25.90 ± 3.89	−1.537 to 1.390	0.921
Tidal volume (ml/kg)	8.35 ± 1.56	8.20 ± 1.58	−0.461 to 0.768	0.623
Peak respiratory pressure (cmH_2O)	18.03 ± 2.47	18.19 ± 2.58	−1.158 to 0.833	0.748
Perfusion time (hr)	2.55 ± 1.09	2.56 ± 0.99	−0.391 to 0.396	0.988

Aortic cross-clamp time (hr)	2.71 ± 0.97	2.74 ± 0.86	−0.373 to 0.312	0.860
Anesthesia duration (hr)	7.26 ± 1.15	7.12 ± 1.19	−0.322 to 0.604	0.548
Gender — Male	20 (64.5%)	116 (75.3%)	0.262 to 1.355	0.213
Gender — Female	11 (35.5%)	38 (24.7%)	-	-
Smoking — Smoker	17 (54.8%)	90 (58.4%)	0.397 to 1.877	0.711
Smoking — Non-smoker	14 (45.2%)	64 (41.6%)	-	-
Diabetes — Yes	23 (74.2%)	104 (67.5%)	0.578 to 3.307	0.466
Diabetes — No	8 (25.8%)	50 (32.5%)	-	-

Independent t-test was used for continuous variables and a Chi-square test for categorical variables

There was intrathoracic atelectasis in 31 patients (16.75 %). **Table 3** reports the comparison of patients with and without atelectasis. There was no significant deviation in any demographic, ventilatory, or intraoperative variable, such as age, BMI, tidal volume, peak respiratory pressure, perfusion time, aortic cross-clamp time, and anesthesia duration. The prevalence of diabetes and gender, smoking status in the samples were also similar (all $p > 0.05$). The incidence of atelectasis was higher compared to that of postoperative pneumonia, but the relationships with demographic or perioperative factors were insignificant.

DISCUSSION

This study was conducted to investigate the incidence of postoperative pulmonary problems following cardiopulmonary bypass (CPB) in patients undergoing low tidal volume (LTV) ventilation during coronary artery bypass grafting (CABG) for pneumonia and atelectasis. Among 185 patients, pneumonia occurred in 15 patients (8.1%), and atelectasis in 31 patients (16.8%). Statistically significant correlations were not identified between the two complications and demographic variables, comorbidities such as diabetes or smoking, or intraoperative parameters, tidal volume, peak respiratory pressure, perfusion time, aortic cross-clamp time, or anesthesia time. This evidence suggests that despite the widespread application of LTV ventilation during CPB in our institution, the percentage of postoperative pulmonary complications remains high and is not well defined in its association with measured perioperative values.

The pneumonia incidence in the current study is quite close to values in the literature, with 7 % to 10 % among patients under LTV ventilation under CPB conditions [11]. Nonetheless, results of other studies in comparable populations show slightly increased rates of respiratory infections of about 15 % and this may be a result of differences in patient differences, perioperative procedures, or infection-surveillance procedures [12,13]. It has been postulated that although LTV ventilation during CPB may alleviate severe respiratory dysfunction, the continuity of pneumonia could be attributed to the multifactorial aspect of such a complication, which is affected by both intraoperative and post-operative factors [14].

Atelectasis occurred in our study was within the range of previous reports (14 % to 18 %) of patients under LTV ventilation during CPB [15]. The difference between studies can be caused by differing imaging requirements, timings of the assessment after the surgery, and the surgical approach [16,17].

Consistently, previous researches show that atelectasis can be included in a list of the most frequent postoperative lung complications which occur following CABG, regardless of ventilator strategy [18]. According to previous literature, low tidal-volume ventilation (LTV) during cardiopulmonary bypass (CPB) is likely to reduce alveolar collapse compared with non-ventilation; however, residual diaphragmatic dysfunction, residual effects of anesthesia, and pulmonary pain may still trigger pulmonary complications. The lack of significant correlations between pneumonia or atelectasis and any of the perioperative measured variables indicates the possible effect of unmeasured factors, such as the timing and needs of postoperative mobilization, sufficiency of analgesia, fluid balance, and the effectiveness of respiratory physiotherapy [20,21]. In controlled LTV protocols, changes in recruitment maneuvers, fraction of inspired oxygen, and the use of extubation protocols are capable of influencing complication prevalence [22]. Therefore, optimizing these can enhance the benefits of LTV ventilation[23,24].

This study has the limitation of being unable to generalize to the population due to its single-center design and suffers from selection bias since a non-probability consecutive sampling approach was used. No comparison group had LTV ventilation, which would allow for conclusions about the protective effect of this intervention. The reliance on chest radiography over advanced imaging may have underrepresented the complications, and not enough confounding factors were accounted for in the multivariable analysis[25]. Future research needs to incorporate multi-center randomized controlled trials using highly standardized diagnostic criteria, longer follow-up of the delayed pulmonary complications, and evaluation of adjuvant approaches, including the application of customized positive-end-expiratory pressure (PEEP) balancing and early physical rehabilitation, to further reduce acute pulmonary insufficiency with coronary artery bypass surgery.

CONCLUSION

Pneumonia and atelectasis postoperative outcomes involved 15 (8.1%) and 31 (16.75%) of patients after LTV ventilation in CPB during coronary artery bypass grafting. No notable correlations were observed between these complications and demographic, comorbidity, or intraoperative factors. Even though LTV is a fundamental of lung protection, it does not exclude the pulmonary complications. The data provided explain the multifactorial nature of postoperative respiratory morbidity and show the need for controlled studies to incorporate ventilation strategies and use other preventive interventions to improve pulmonary performance in patients undergoing cardiac surgery.

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CONFLICT OF INTEREST

None

ETHICAL APPROVAL

The current descriptive, observational study was conducted in the Department of Cardiac Surgery at the National Institute of Cardiovascular Diseases (NICVD), Karachi, from October 2022 to April 2023 (Ref: NIC/116/Aug/2022).

AUTHORS' CONTRIBUTION

All authors contributed equally, as per the ICMJE guidelines.

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