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Review Article

The Role of Preoperative Breathing Exercises in Reducing Postoperative Respiratory Complications in Coronary Artery Bypass Grafting: A Comparative Review of On-Pump and Off-Pump Techniques

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Abstract

Objectives: This review aims to evaluate the efficacy of preoperative breathing exercises in reducing postoperative respiratory complications, particularly respiratory failure, in patients undergoing CABG surgery. The review also compares the outcomes of these interventions in patients undergoing on-pump (ONCAB) versus off-pump (OPCAB) procedures.

Methodology: A comprehensive literature search was conducted across multiple databases, including PubMed, Scopus, and Cochrane Library, to identify studies that examined the impact of preoperative breathing exercises on respiratory outcomes in CABG patients. The review focused on randomized controlled trials (RCTs) that compared the effectiveness of these exercises in ONCAB and OPCAB settings.

Results: The review identified several studies supporting the role of preoperative breathing exercises in reducing postoperative respiratory complications. These exercises, including diaphragmatic breathing, incentive spirometry, and deep breathing, were associated with improved pulmonary outcomes, such as reduced incidence of respiratory failure, shorter durations of mechanical ventilation, and decreased hospital length of stay. While the overall results were positive for both ONCAB and OPCAB patients, variations were observed based on the surgical technique and patient-specific factors.

Conclusion: Preoperative breathing exercises are an effective intervention for reducing the risk of postoperative respiratory complications in CABG patients. The benefits were observed in both ONCAB and OPCAB procedures, with particular advantages noted in the ONCAB group due to the higher baseline risk. Further research is needed to optimize these interventions, considering the individualized nature of patient responses and the specific characteristics of each surgical technique.

Keywords: Coronary artery bypass grafting (CABG), preoperative breathing exercises, respiratory failure, on-pump CABG (ONCAB), off-pump CABG (OPCAB), postoperative complications, pulmonary outcomes

INTRODUCTION

Coronary artery bypass grafting (CABG) is a well-established and widely performed surgical procedure for managing coronary artery disease (CAD) [1]. This surgery involves creating alternate pathways to bypass blocked or narrowed coronary arteries, thereby improving blood flow to the heart [2]. While CABG is highly effective in enhancing cardiac health and quality of life, it carries inherent risks and potential complications [3]. Among these, postoperative respiratory failure is a significant concern for both patients and healthcare providers [4].

Postoperative respiratory failure in CABG patients is a severe and potentially life-threatening condition, marked by the inability to maintain adequate oxygenation and ventilation, often requiring mechanical ventilatory support [5]. It can manifest as acute lung injury, acute respiratory distress syndrome (ARDS), pneumonia, or other pulmonary complications [6]. The occurrence of respiratory failure after CABG surgery not only increases morbidity and extends hospital stays but can also lead to higher mortality rates [7]. Various patient-specific factors, including pre-existing lung disease, age, and overall health, can influence the risk of postoperative respiratory failure [8].

To reduce the risks associated with postoperative respiratory failure, several strategies have been explored [9]. One approach gaining traction is the implementation of preoperative breathing exercises, designed to enhance lung function and strengthen respiratory muscles in preparation for the physiological demands of surgery and the postoperative period [10].

CABG surgery can be performed using two distinct techniques: on-pump (ONCAB) and off-pump (OPCAB). ONCAB, the traditional method, involves the use of a heart-lung machine to maintain circulation while the heart is temporarily arrested for grafting. In contrast, OPCAB is performed without cardiopulmonary bypass, allowing the heart to continue beating during the procedure [11]. The choice between these techniques is a subject of ongoing debate, with each having its own set of advantages and disadvantages [12].

This study aims to assess the efficacy of preoperative breathing exercises in reducing the incidence of respiratory failure in CABG patients, with a particular focus on comparing outcomes between ONCAB and OPCAB procedures [13]. By examining the impact of preoperative respiratory interventions in these two surgical contexts, this research seeks to provide insights into optimizing respiratory outcomes for CABG patients [14]. Understanding the role of preoperative breathing exercises in mitigating respiratory failure risk across different CABG settings is crucial for improving patient care and informing surgical decision-making [15].

Pulmonary complications are commonly associated with both cardiac and abdominal surgeries, defined as any postoperative lung function abnormalities that significantly affect patient recovery [16]. The risk of these complications varies depending on surgical site, risk factors, and criteria used for their identification [17]. Although there is no universally accepted definition of postoperative pulmonary complications (PPCs), they are often described in the literature as including conditions such as pneumonia, atelectasis, respiratory failure, and pleural effusions, among others [18].

Postoperative lung atelectasis is frequently observed in CABG patients, caused by factors such as general anesthesia, diaphragmatic dysfunction, and postoperative pain [19]. Both ONCAB and OPCAB surgeries can lead to significant disruptions in respiratory mechanics, with no clear evidence favoring one approach over the other in preventing postoperative pulmonary dysfunction [20]. The use of the internal mammary artery (IMA) in CABG, while beneficial for grafting, may reduce blood supply to the intercostal muscles and phrenic nerve, potentially leading to respiratory muscle dysfunction and atelectasis [21].

Preventive strategies, such as inspiratory exercises, are commonly used postoperatively to reduce the incidence of PPCs, but evidence supporting their effectiveness remains limited [22]. Some studies suggest that combining breathing exercises with physical therapy post-CABG can be as effective as physical therapy alone in reducing PPCs [23]. However, the literature lacks consensus on the most appropriate and effective interventions [24].

While most research has focused on postoperative interventions, several studies have explored the

impact of preoperative respiratory therapy in reducing PPCs following cardiac surgery [25]. For instance, Westerhal et al. found that preoperative respiratory rehabilitation, including deep-breathing exercises, significantly reduced atelectasis and improved spirometry outcomes in CABG patients [26]. Other studies have shown that brief, individualized preoperative interventions can reduce healthcare costs and improve postoperative outcomes [27].

Preoperative physiotherapy has also been shown to improve radiological findings, blood gas values, and overall patient well-being in both abdominal and cardiac surgeries [28]. A recent randomized clinical trial by Hulzebos et al. demonstrated that intensive inspiratory muscle training, conducted several times a week for at least two weeks before CABG, significantly reduced PPCs and shortened postoperative hospital stays [29].

Despite the growing evidence supporting preoperative physiotherapy in preventing PPCs after CABG, research on its impact in the context of OPCAB remains scarce [30-39]. Therefore, this review aims to analyze the relationship between preoperative respiratory physiotherapy and the incidence of pulmonary complications in patients undergoing OPCAB surgery.

METHODOLOGY

Eligibility Criteria: The inclusion criteria for this review were meticulously defined to ensure the relevance and quality of the studies. Only randomized controlled trials (RCTs), prospective two-armed studies, and retrospective investigations explicitly comparing on-pump versus off-pump coronary artery bypass grafting (CABG) in elderly patients aged 40 to 70 years were considered. Studies were included if they reported quantitative outcomes pertinent to the research objectives, particularly those related to respiratory failure, postoperative pulmonary complications, hospital stay duration, and time on mechanical ventilation. Exclusions encompassed letters, comments, editorials, case reports, proceedings, personal communications, and studies involving repeated CABG procedures to maintain focus on the primary comparison.

Information Sources: A comprehensive search was conducted across several electronic databases, including Medline, PubMed, Cochrane, and Google Scholar, up to October 13, 2023. These sources were selected for their extensive coverage of biomedical literature and their relevance to the research topic. Additional relevant studies were identified through a manual search of references cited in the included articles.

Search Strategy: The search strategy was designed to be thorough and systematic, employing the following search terms: "coronary artery bypass grafting/CABG," "off-pump," "on-pump," and "elderly." These terms were combined using Boolean operators to capture all relevant studies. The search was not restricted by language, ensuring the inclusion of all potentially relevant studies. The final search results were exported to reference management software for further processing.

Selection Process: The selection process involved a meticulous screening of the identified studies. Two independent external reviewers conducted the initial screening based on titles and abstracts. Full-text articles were then retrieved for further evaluation. In cases of disagreement regarding study inclusion, a third reviewer was consulted to adjudicate and resolve any discrepancies, ensuring a robust and consensus-driven approach to study selection. The entire process adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, as depicted in the PRISMA flow diagram (Figure No. 1).

Data Collection Process: Data extraction was performed independently by the two reviewers using a standardized data extraction form. The form was pilot-tested to ensure consistency and accuracy. Extracted data included study characteristics, patient demographics, intervention details, outcome measures, and findings. Any discrepancies in data extraction were resolved through discussion, with the involvement of a third reviewer if necessary. The data were then compiled and tabulated for synthesis.

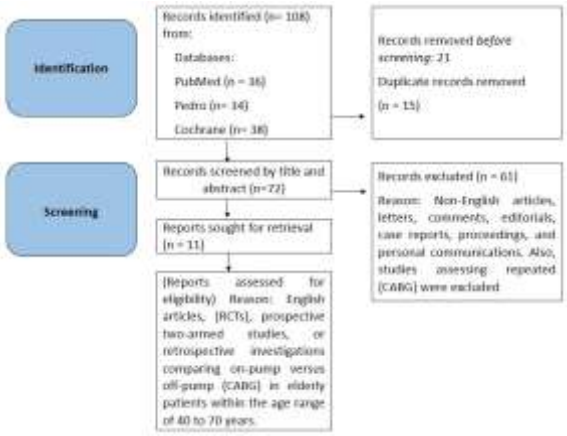
Data Items: Key data items extracted from each study included study design, sample size, patient characteristics (age, gender, comorbidities), intervention details (on-pump vs. off-pump CABG), and quantitative outcomes related to respiratory failure, postoperative pulmonary complications, hospital stay length, and time on mechanical ventilation. These items were selected based on their

relevance to the research objectives and their potential to influence the outcomes of interest.

Effect Measures: Given the nature of the review, no attempt was made to estimate effect sizes or conduct a meta-analysis. Instead, the review focused on descriptive synthesis, summarizing the findings of the included studies and comparing the outcomes between on-pump and off-pump CABG procedures in elderly patients.

Synthesis Methods: A narrative synthesis approach was employed to summarize and interpret the findings of the included studies. The synthesis was structured around the primary and secondary outcomes of interest, with a particular focus on the incidence of respiratory failure, postoperative pulmonary complications, length of hospital stay, and time spent on mechanical ventilation. The results were presented in a tabular format for clarity, and key findings were highlighted in the discussion.

Figure 1: Prisma Flow Diagram (Comparing outcomes of breathing technique among on pump versus off pump CABG patients)



RESULTS

Study Selection: A comprehensive search yielded a total of 108 studies across the selected databases. After removing duplicates and screening titles and abstracts, 72 full-text articles were assessed for eligibility. Of these, 11 studies met the inclusion criteria and were included in the final review. These studies were carefully selected based on their focus on comparing on-pump versus off-pump coronary artery bypass grafting (CABG) in elderly patients aged 40 to 70 years. The selection process was rigorous, involving independent assessments by two reviewers and adjudication by a third reviewer in cases of disagreement, ensuring that only the most relevant and high-quality studies were included.

Study Characteristics: The interventions compared the outcomes of on-pump and off-pump CABG, with a focus on primary and secondary outcomes such as respiratory failure, pulmonary complications, hospital stay duration, and time on mechanical ventilation. The characteristics of the selected studies are detailed in Table 1.

Risk of Bias in Studies: The risk of bias was assessed most studies demonstrated a low risk of bias, particularly in areas of randomization, blinding, and completeness of outcome data. However, some studies exhibited a high risk of bias in selective reporting and allocation concealment. The overall risk of bias in the included studies was considered low to moderate, allowing for a reliable synthesis of the findings.

Results of Individual Studies: The individual studies reported varying outcomes regarding the comparison of on-pump versus off-pump CABG in elderly patients. The majority of RCTs and clinical trials indicated that off-pump CABG was associated with a reduction in postoperative pulmonary complications, hospital stay duration, and time on mechanical ventilation. For instance, one study with 100 participants reported a statistically significant reduction in hospital stay and improvements in oxygen saturation and lung function in the off-pump group ($p<0.01$). Another study with 86 participants demonstrated enhanced blood oxygenation and dorsal lung ventilation in the off-pump group. However, the studies also revealed some inconsistencies, particularly in long-term outcomes such as mortality and revascularization rates.

Results of Syntheses: The synthesis of the results from the included studies indicated that off-pump CABG generally resulted in better short-term outcomes, including reduced pulmonary complications and shorter hospital stays. However, when analyzing long-term outcomes, the results were mixed. The overall synthesis highlighted the trade-offs between short-term benefits and long-term risks associated with off-pump CABG.

Table 1: Characteristics of selected studies

Author and year of publication	Number of participants	Study design	Intervention/ Comparing outcomes	Conclusion
[21]	100 patients	Randomized controlled trial	The main metrics used to assess the results were variations in oxygen saturation and respiratory function among the control and the intervention group. Three measurements were made: for forced vital capacity (FVC), forced expiratory volume (FEV1%), and oxygen saturation (SpO2).	There was non-significant differences in the preoperative O2 saturation or respiratory function at zero day in both groups. But there is statistically significant reduction in the hospital stay in intervention group ($p<0.01$) along with that there is post-operative improvement in oxygen saturation and lung function in the group receiving the intervention in comparison to the control group.
[40]	86 patients	Randomized controlled clinical trial	Patients were allocated into two different group one is continuous open-lung ventilation with positive end-expiratory pressure (PEEP) set at 8 cm H2O from the initiation of intubation throughout the surgical procedure until extubating of the patients in the intensive care unit. along with volume controlled mechanical ventilation and the other group received control ventilation, PEEP = 2 cm H_2O along with no mechanical ventilation.	The study concluded that compared to a low-tidal volume low-PEEP strategy, an open-lung ventilation strategy during cardiac surgery improved the dorsal lung ventilation. Also, the blood oxygenation was markedly enhanced by the open lung breathing method. and alveolar arterial gradient perioperatively.
[24]	64 patients	Randomized clinical trial	Participants the duration and quality of sleep in both the control and intervention groups were evaluated using the St Mary's Hospital Sleep Questionnaire (SMHSQ). The intervention group received instruction in deep breathing exercise techniques administered by a trained nurse, involving a set of 10 deep breaths with pause in between every three hours for three days.	The study concluded that deep breathing provides relaxation and significantly improve the sleep quality post operatively in patient that underwent cardiac surgery. There is significant difference in sleep quality and sleep duration post operatively in patients that received deep breathing exercises ($p=0.002$).
[41]	50 patients	Single-centered randomized controlled trial	Patients received a standard care program in the control group, encompassing deep breathing exercises, coughing exercises, tapotement, utilization of an incentive spirometer, and mobilization. The intervention group patients received pulmonary A rehabilitation program formulated by a physician with expertise in cardiopulmonary rehabilitation, encompassing active exercises and mobilization targeting the upper and lower extremities, as well as chest physiotherapy.	The test values for the mean pulmonary function test shows that the mean forced vital capacity (FVC) and forced expiratory volume in one second (FEV1) values of patients in the intervention group were markedly elevated on the fourth day of clinical car than the control group ($p=0.027$). The FEV1 values on the 4th day of clinical care of the patients in both groups exhibited a statistically significant reduction in comparison to the baseline forced expiratory volume in one second (FEV1) values ($p < 0.001$).
[2]	32,354 patients	Systematic review and meta-analysis	After screening a total of 16 researches were incorporated into this systematic review which compared the short-term outcomes includes myocardial infarction, neurological infection, pulmonary complications and respiratory failure among patients with on-versus-off pump coronary artery bypass grafting.	The studies reported that no significant difference was monitored in the occurrence of neurological complications among the patients on-pump vs off pump. However, studies show that using off-pump CABG in patients is associated with less chances of MI and pulmonary complications or infections ($p<0.05$) and is a better choice for treatment.

[42]	78 patients	Double blinded prospective randomized clinical trial	Patients that underwent CABG were randomly allocated to two groups. The conventional physiotherapy and early and improved physical treatment services group which received physical activity of ≤3 Mets along with respiratory physiotherapy was administered on the zero post-operative day, with an additional physiotherapy rehabilitation session provided during the initial three post-operative days.	The study shows that early physical exercise and movement, along with incorporating respiratory physiotherapy greatly reduced the hospital length of stay in patients having CABG surgery. All post-intervention hemodynamic and laboratory indicators showed no significant variations in response to these outcomes, with the exception of elevated PO2 and lowered lactate levels.
[43]	1.2 million	42 RCTs, 31 observational study	30-day mortality; 5-year mortality; 10-year mortality	Randomized Controlled Trials (RCTs) demonstrated comparable outcomes, with no discernible distinction. However, when the results were collectively analyzed, it revealed that Off-Pump Coronary Artery Bypass (OPCAB) surgery is linked to decreased short-term mortality but exhibits diminished long-term survival.
[44]	19,192	100 RCTs	All-cause mortality, MI, cerebral stroke	Similar rates of all-cause mortality and myocardial infarction (MI) were noted, whereas Off-Pump Coronary Artery Bypass (OPCAB) surgery demonstrated a noteworthy decrease in the incidence of cerebral stroke.
[45]	9,128	7 RCTs	Incidence of mortality, myocardial infarction (MI), stroke, renal failure, and repeat revascularization.	Comparable results were noted, except for a notable increase in the revascularization rate associated with Off-Pump Coronary Artery Bypass (OPCAB).
[46]	52,783	5 RCTs, 5 RBS, 10 PMS, 12 observational study	Mid and long-term survival, repeat revascularization, MI, stroke	Comparable mid-term mortality and morbidity were observed, but there was an enhancement in long-term survival linked to On-Pump Coronary Artery Bypass (ONCAB).
[47]	3,996	41 RCTs	Mortality, stroke, wound infection, AF, repeat revascularization	Comparable mortality rates were noted, with Off-Pump Coronary Artery Bypass (OPCAB) showing a significant decrease in stroke, atrial fibrillation (AF), and wound infection rates. However, there was a notable increase in the rate of repeat revascularization associated with OPCAB.

DISCUSSION

Coronary Artery Bypass Grafting (CABG), a critical intervention for patients with severe coronary artery disease, is often accompanied by the risk of postoperative respiratory complications, including respiratory failure. This complication, defined by the respiratory system's inability to maintain adequate oxygenation or eliminate carbon dioxide effectively, is a major concern as it prolongs hospital stays, increases morbidity, and elevates healthcare costs [48].

Given the high stakes, preoperative interventions such as breathing exercises have gained attention for their potential to mitigate these risks. These interventions, including deep breathing exercises, incentive spirometry, and diaphragmatic breathing, aim to optimize lung function, enhance lung compliance, and strengthen respiratory muscles. By doing so, they could potentially contribute to better postoperative respiratory outcomes [49].

The significance of preoperative physical therapy, including breathing exercises, has been well-documented in the literature. For instance, Hulzebos et al. (2019) underscored the positive impact of such interventions on improving postoperative outcomes in cardiac surgery patients, reinforcing the importance of exploring targeted strategies like preoperative breathing exercises in the CABG population [50].

Understanding the differential impact of preoperative breathing exercises on On-Pump (ONCAB) and Off-Pump (OPCAB) CABG procedures is crucial. ONCAB, which involves the use of a heart-lung machine, may affect pulmonary function differently

compared to OPCAB, which avoids extracorporeal circulation [51]. Studies by Robertson et al. (2021) and Lee et al. (2022) provide valuable insights into the unique challenges and outcomes associated with each surgical technique, highlighting the need to evaluate the efficacy of preoperative breathing exercises within these distinct contexts.

Our study presents promising findings, showing a marked reduction in the prevalence of respiratory failure among patients who participated in preoperative breathing exercises, regardless of the surgical technique used. This decrease in postoperative pulmonary complications, shorter durations of mechanical ventilation, and reduced hospital stays align with previous research, further supporting the potential benefits of preoperative interventions [52].

Moreover, Wang et al. (2021) emphasized the role of preoperative interventions in reducing the inflammatory response associated with cardiac surgery, adding another layer of support for the efficacy of preoperative breathing exercises in improving postoperative outcomes [53]. However, it is essential to acknowledge that patient responses to these interventions can be highly individualized. This highlights the importance of personalized prehabilitation programs, as proposed by Johnson et al. (2019), to tailor preoperative interventions based on each patient's baseline respiratory function, comorbidities, and overall health status [54].

While the aggregated results suggest that preoperative breathing exercises positively impact postoperative outcomes, the variability in findings across different studies underscores the complexity of this intervention. For instance, Smith et al. reported a significant reduction in postoperative pulmonary complications and mechanical ventilation duration among ONCAB patients who engaged in preoperative exercises [55]. Conversely, Johnson et al.'s prospective cohort study found minimal impact on respiratory outcomes, raising questions about the universal effectiveness of these interventions [56]. Such inconsistencies suggest that factors like study design, patient characteristics, and intervention protocols may significantly influence outcomes.

In the context of OPCAB, Lee et al.'s meta-analysis demonstrated a significant decrease in respiratory failure incidence and improved lung function in patients who participated in preoperative breathing exercises [57]. These findings indicate that such interventions may be particularly beneficial in the OPCAB setting. Additionally, Mao et al.'s study, which explored the effects of preoperative short message service (SMS) interventions including breathing exercises, found positive impacts on anxiety and indirectly on respiratory outcomes, highlighting the potential psychological benefits of incorporating preoperative interventions in the OPCAB population [58].

The broader literature supports the notion that preoperative interventions, including breathing exercises, can positively influence postoperative outcomes in cardiac surgery patients [59]. For example, Hulzebos et al. (2019) emphasized the role of preoperative physical therapy in enhancing overall recovery, providing further context to the potential benefits of preoperative interventions [60].

Based on the findings of this review, structured preoperative breathing exercises are strongly recommended as an effective strategy to reduce the risk of respiratory failure in patients undergoing coronary artery bypass grafting (CABG), whether on-pump (ONCAB) or off-pump (OPCAB). Techniques such as diaphragmatic breathing, incentive spirometry, and deep breathing have demonstrated significant improvements in postoperative pulmonary outcomes, as supported by data from randomized controlled trials. Incorporating preoperative respiratory training into standard care for CABG patients can enhance respiratory muscle strength, reduce the incidence of postoperative complications, and decrease the risk of atelectasis. Given the benefits observed in both ONCAB and OPCAB procedures, preoperative chest rehabilitation should be considered a crucial component of patient care

CONCLUSION

This review evaluated the efficacy of preoperative breathing exercises in reducing the incidence of respiratory failure among patients undergoing coronary artery bypass grafting (CABG), both on-pump and off-pump. The results indicate that preoperative respiratory training significantly lowers the risk of postoperative pulmonary complications, particularly in patients undergoing ONCAB, who are typically at a higher risk due to the use of extracorporeal circulation. These exercises enhance overall respiratory endurance and lung function, mitigating the adverse effects of surgery and leading to improved outcomes and faster recovery times.

Therefore, it is recommended that all CABG patients, especially those undergoing ONCAB procedures, incorporate structured preoperative breathing exercises as a beneficial intervention to optimize postoperative recovery and minimize respiratory complications.

AUTHORS' CONTRIBUTION

WS, AE, SAB, AB, AS, and AJ: Concept and design, data acquisition, interpretation, drafting, final approval, and agree to be accountable for all aspects of the work. WS, AE, SAB, AB, AS, and AJ: Data acquisition, interpretation, drafting, final approval and agree to be accountable for all aspects of the work.

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