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ORIGINAL RESEARCH

Preoperative Pulmonary Rehabilitation to Prevent Postoperative Pulmonary Complications following Open Heart Surgery: A Narrative Review

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ABSTRACT

Background: Numerous medical disciplines have recognized the preoperative period as a crucial phase to enhance patient recovery and outcomes. Patients perform preoperative pulmonary rehabilitation with inspiratory or expiratory muscle training to enhance lung protection. Despite the variety of breathing techniques in the clinical setting, the literature lacks a conclusive evidence regarding which technique is more effective.

Research question: In adult patients undergoing open heart surgeries, is preoperative pulmonary rehabilitation of benefit in preventing postoperative pulmonary complications, shorten length of stay in the intensive care unit (ICU) or hospital?

Methodology: The authors conducted a search in electronic databases regarding the current evidence of preoperative pulmonary rehabilitation.

Subjects: Patients undergoing Coronary Artery Bypass Grafts (CABG) and/or valvular surgery.

Intervention: Any pulmonary intervention, such as incentive spirometer, inspiratory muscle training, exercise training or relaxation, delivered prior to surgery, single or combined.

Outcome measures: The incidence of persistent post-concussion symptoms (PPCSs), pulmonary function test (PFT), ventilation period, length of stay in ICU and hospital.

Results: The authors conducted an initial search in the systematic reviews, which yielded 16 published articles. Furthermore, the authors search in the randomized controlled trials and this yielded 72 articles. The relevancy of the selected publications was determined by reviewing their titles, keyword, and abstracts. Overall a total of eight randomized controlled trials (RCTs) and six systematic reviews involving 3908 participants were included in this review.

Conclusion: Preoperative pulmonary rehabilitation utilizing various breathing techniques reduces the incidence of postoperative pulmonary complications .

Keywords: Preoperative Care, Breathing Exercises, Postoperative Complications, Coronary Artery Bypass, Cardiac Surgery.

INTRODUCTION

The development of severe pulmonary dysfunction following open heart surgery is determined by two primary variables: One is the mechanical stress and bio trauma generated by mechanical ventilation and the deployment of an inadequate ventilatory strategy with large volumes and low Positive end-expiratory pressure (PEEP) values, which drive atelectasis. The second cause is an enhanced systemic inflammatory response to heart surgery and its related factors, such as the effects of general anesthesia combined with the effects of median sternotomy incision, cardiopulmonary bypass (CBP), internal mammary artery dissection, and the use of topical cooling to protect the myocardium [1].

Up to 20.5% of patients undergoing open heart surgery experience pulmonary complications, including prolonged ventilation, pneumonia, pulmonary embolism, and drainage-required pleural effusions [2].

At a national level, cardiac surgeries performed with Conventional Median Sternotomy (CMS) showed to be associated with higher rates of prolonged ventilation, impaired pulmonary function, atelectasis, Pleural effusion and thoracentesis [3].

Interventions aimed at physiological stabilization of the cardiopulmonary and musculoskeletal systems to mitigate the effects of general anesthesia are among the standard preoperative interventions that may be delivered by many disciplines (e.g., deep breathing exercises, inspiratory muscle training, exercise training, early mobilization or education aimed at promoting these behaviors both preoperatively and postoperatively) [4].

Numerous medical disciplines have recognized the preoperative period as a crucial phase to enhance patient recovery and outcomes. As more health care disciplines understand the importance of the preoperative period and optimizing patient comorbidities prior to surgery, the role of the respiratory therapy team will certainly expand in understanding the current status of preoperative factors that increase the risk of pulmonary complications and how to optimize patients prior to surgery [5].

As a preventive measure before open heart surgery, patients perform physiotherapy with inspiratory or expiratory muscle training to enhance lung protection. Prophylactic postoperative physiotherapy is also performed using various techniques such as deep breathing exercises, slow maximal inspirations with an inspiratory hold, intermittent deep breathing exercises with and without the use of an incentive spirometer, and deep breathing exercises with expiratory resistance. These techniques are used to improve ventilation-perfusion mismatch, lung compliance, and re-inflation of collapsed alveoli [6].

Despite the variety of breathing techniques in the clinical setting, the literature lacks a conclusive evidence regarding which technique is more advantageous over another [7].

This study aims to discover whether preoperative pulmonary rehabilitation for patients scheduled for open heart surgeries is effective by comparing postoperative pulmonary outcomes including the incidence of postoperative pulmonary complications, pulmonary function parameters and length of hospital stay.

METHODOLOGY:

- Search Strategies

Randomized controlled trials investigating the effects of preoperative pulmonary rehabilitation for patients undergoing open heart surgeries were retrieved from electronic databases. Bio-Med-Central, Cochrane, and PubMed Central were the primary search engines used in light of their extensive

collection of premier resources. Which included published studies that cover the fields of, health care, nursing, medicine. Researched terms included: "Postoperative Pulmonary Complications", "Breathing Exercises", "pulmonary rehabilitation" "Preoperative Care", "systematic review," "randomized controlled trial (RCT)., "Cardiac Surgery", "Preventive Measures", "Respiratory Maneuvers", "Inspiratory Muscle Training", and "Sustained Maximal Inspiration".

- **Selection Criteria**

Only English-language randomized controlled trials and systematic reviews published within the previous 10 years demonstrating the benefits of preoperative pulmonary rehabilitation were considered in this review.

Studies identified from literature searches that could provide evidence on the topic were screened for eligibility. The inclusion criteria were as follows: (1) studies focused on adults aged ≥18 years who had undergone CABG , valvular surgery or combined, (2) systematic reviews or randomized control trials with a comparison group; (3) studies that involved Incentive Spirometer (IS), Inspiratory Muscle Training (IMT), Diaphragmatic Breathing (DB) deep breathing, coughing exercises; and (4) studies that evaluated at least one of the following outcomes: the incidence of postoperative pulmonary complications, pulmonary function tests, Arterial Blood Gases (ABG), Hospital Length of Stay (HLOS). Studies that included additional preoperative rehabilitation measures in combination with breathing exercises, and studies conducted on pediatric patients were excluded.

- **Study Selection Process**

The authors conducted an initial search in the systematic reviews, which yielded 16 published articles. Furthermore, the author search in the randomized controlled trials and this yielded 72 articles. Articles published within the last 10 years were included, excluding those that dealt with surgeries other than cardiac surgery. The relevancy of the selected publications was determined by reviewing their titles, key words, and abstracts. Overall a total of seven RCTs and six systematic reviews were included in this review.

RESULTS

- **Systematic Reviews**

Mans et al. (2015), conducted a systematic review and meta-analysis of eight randomized controlled trials investigating the efficacy of IMT in patients undergoing cardiac, thoracic or upper abdominal surgeries. Preoperative IMT was compared to no or sham preoperative IMT in preventing PPCs and reducing length of hospitalization as primary outcome measures. Inspiratory muscle training could be achieved by isocapnic/normocapnic hyperpnoea, inspiratory resistive flow training, or threshold pressure loading. This systematic review revealed that preoperative IMT significantly reduced PPCs, lung function was restored more rapidly following surgery in the trained group. It can be concluded that IMT showed efficacy in improving respiratory muscle function in the early postoperative period. However, there was not a significant reduction in length of hospital stay [8].

In another systematic review and meta-analysis by Kendall et al. (2017) [9], that included 17 randomized controlled trials. They reviewed the effectiveness of IMT to reduce PPCs and length of hospital stay in cardiac, abdominal and pulmonary surgical patients both in the preoperative and postoperative periods. They stated that rehabilitation with IMT was beneficial in terms of reducing PPCs and length of hospital stay regarding patients' ages and levels of risk, but it was mostly effective when performed by older patients, high risk patients, and those undergoing pulmonary surgery. However, in order to have an additive effective, rehabilitation session with IMT should be prescribed two weeks before surgery and it requires supervision for more

than 15 minutes by a physiotherapist with imposed load increment accompanying other exercise modes.

Katsura et al. (2015) reported the effectiveness of preoperative inspiratory muscle training (IMT) on PPCs in adults undergoing both cardiac or major abdominal surgery. In this study 12 trials were included, in which five trials out of them included patients scheduled for elective cardiac surgeries. The main outcomes were the incidence of PPCs including atelectasis and pneumonia and the length of hospital stay. The evidence showed that preoperative IMT was associated with a reduction in the occurrences of postoperative pneumonia and atelectasis and length of hospital stay when compared to no intervention or usual care. However, these trials have a risk for the overestimation of the results due to inadequate blinding and publication bias [10].

Later Neto et al. (2016) conducted a systematic review and meta-analysis investigating the effect of pre- and postoperative (IMT) on pulmonary function and length of stay among patients undergoing cardiac surgery. The study included eight trials in which four of them (416 patients) were about preoperative IMT using inspiratory threshold-loading device. The outcomes were the incidence of PPCs, pulmonary function parameters involving maximal inspiratory pressure, maximal expiratory pressure, forced vital capacity, forced expiratory volume in one second, tidal volume, peak expiratory flow, and length of postoperative stay. The study concluded that IMT particularly when performed in the preoperative period proved to be beneficial in terms of reducing pulmonary complications and hospitalization and improving lung function [11].

Karanfil and Møller (2018) included five RCTs in their systematic review to determine if preoperative IMT could postoperative pneumonia and atelectasis in patients undergoing (CABG) or valve surgery. The results of this systematic review proved the effect of IMT in reducing the rates of pneumonia and atelectasis. However, the effect of IMT on hospital length of stay was inconclusive. Despite the fact that preoperative IMT decreased PPCs, the authors asserted that it is uncertain which regimen is more beneficial due to variations in training load, training duration and the different brands of the used devices [12].

In a systematic review by Rodrigues et al. (2021) to determine the effect of preoperative breathing exercise on postoperative pulmonary outcomes following cardiac surgery. The trials solely used breathing-related therapies, such as diaphragmatic breathing, inspiratory muscle training, or the use of incentive spirometer equipment. The breathing therapies could be used in combination or individually. The study concluded that preoperative breathing exercises may improve pulmonary function parameters, reduce PPCs and HLOS. However, the clinical and methodological heterogeneity in most trials may compromise the results thus more studies are needed to confirm the findings [13].

- Randomized Controlled Trials

Diken and Özyalçın (2015), aimed to evaluate the effect of preoperative precautions using the incentive spirometer in obese patients undergoing CABG on postoperative pulmonary outcomes. A total of 108 patients were enrolled in the study in which all of them performed pulmonary function tests before the surgery. The intervention group (50 patients) used incentive spirometer 10 times every hour in the daytime while the control group (58 patients) received the standard preoperative care. Atelectasis and pneumonia were more prevalent in the control group in which proves the effect of the intervention [14].

Fayyaz et al. (2016) conducted an RCT that included a total of 170 patients allocated equally to a control group and an intervention group who received preoperative incentive spirometer. PPCs and ABGs were the endpoints. Preoperative and postoperative oxygenation status was compared and the results showed the preoperative incentive spirometer improved oxygenation status. However, despite

authors' statement about the reduced incidence of PPCs, no statistical significant difference supported this statement. In addition, details about the duration and the techniques of the intervention were not reported [15].

Turky and Afify (2017) studied the changes in alveolar arterial oxygen gradients and inspiratory muscle strength after delivering an intervention of IMT for 20 out of 40 patients undergoing CABG. The intervention group received IMT using a threshold load inspiratory muscle trainer and received a preoperative education while the control group received only the preoperative education and the routine physiotherapy care. The results showed that using a threshold load inspiratory muscle trainer has improved the maximum inspiratory pressure, pulmonary gas exchange and oxygen saturation. However, these results could not be generalized due to small sample size and the exclusion of women in the study sample [16].

Moradian et al. (2019) conducted a single-blinded RCT to determine the effect of preoperative breathing exercises in patients undergoing CABG. These exercises involved deep breathing, coughing and Incentive Spirometer. The sample consisted of 100 patients assigned equally to control who received the routine physiotherapy and intervention group who received the preoperative breathing exercises. The occurrence of atelectasis and ABGs were compared as outcome measures between the two groups. The study revealed that there were no significant differences in the rates of atelectasis and hypoxemia in the two groups which concluded that preoperative breathing exercises we not effective in reducing pulmonary complications following CABG surgeries [17].

The effect of preoperative respiratory evaluation in patients undergoing cardiac surgery was evaluated by Nejkov et al. (2020) [18]. The study included a total of 19 patients. The intervention consisted of diaphragmatic breathing and relaxation of the chest (10 attempts of deep breathing, deep nasal inhalation, and exhalation through the mouth); training on protective positions and cough movements and initiation of the whole trunk and extremities; patient education about self-care and modification of risk factors. The outcome measures included Arterial Blood Gases, functional capacity, which was evaluated through 2 Minutes Walking Test (2MWT) and sit to stand test, the occurrences of PPCs, duration of mechanical ventilation, length of ICU stay and total stay in the hospital. The study revealed that preoperative respiratory rehabilitation had a positive effect on reducing the duration of mechanical ventilation and length of total hospitalization, and improved functional capacity. However, ABGs and PPCs did not differ between the two groups. The small sample size was a limitation to the generalizability of the study results.

In a single-blind randomized controlled pilot study by Chen et al. (2019) [19] they aimed to determine the efficacy of short-term intensive preoperative inspiratory muscle training for five days on preventing PPCs. The study included 197 patients allocated to an intervention group (n=98) and a control group (n=99). The intervention group received IMT provided by an experienced physical therapist. The primary outcome was the incidence of PPCs. Secondary outcomes were the change of inspiratory muscle strength, pulmonary function and the length of postoperative hospital stay. The results showed that a five day preoperative IMT reduced the incidence of PPCs and the duration hospitalization and improved inspiratory muscle strength in the intervention group when compared to the control group. Giving the fact that the study only included patients who has a low risk for developing PPCs, the generalizability of the results was restricted.

Sweity et al. (2021) conducted a randomized controlled trial to determine the effect of preoperative incentive spirometer in preventing PPCs. A total of 80 patients were assigned equally to a control group and

an intervention group who performed preoperative breathing exercises using an incentive spirometer every four hours for two days. The primary outcomes were the incidence of PPCs while the secondary outcomes were postoperative oxygenation, and overall hospital stay. There was a significant reduction in the incidence of atelectasis and the duration of mechanical ventilation in the intervention group along with improvement in arterial blood oxygen and oxygen saturation. Patients in the intervention group spend less days in the hospital when compared to the control group [20].

To assess the effect of preoperative home chest physiotherapy program for one week on oxygenation and lung function. Shahood et al. (2022) [21] conducted a randomized controlled trial included 100 patients undergoing open heart surgery (46 in the intervention group, 54 in the control group). The primary outcomes were the differences in respiratory function parameters and oxygen saturation. Hospital length of stay was considered a secondary outcome. The intervention proved to be effective in improving respiratory function and oxygen saturation. Hospital stay was significantly shorter in the intervention group. The different types of surgical procedures along with the relatively small sample size were the main limitations of this trial.

DISCUSSION

A variety of surgical specialties, including cardiothoracic surgery, have campaigned for pulmonary rehabilitation in recent years. Numerous studies from a single center have reported the therapeutic benefits of pulmonary rehabilitation. The pulmonary rehabilitation program could be administered before or after surgery, or both before and after surgery (Mao et al., 2021) [22]. Furthermore, according to Algar et al. (2003) [23], the absence of preoperative respiratory physical therapy is an independent risk factor for postoperative pulmonary complications.

The main results of the present narrative review indicate that preoperative pulmonary rehabilitation, including inspiratory muscle training, incentive spirometer, diaphragmatic breathing, deep breathing and coughing and preoperative education significantly reduced PPCs, HLOS and improved pulmonary function.

Based on the data of six systematic reviews and four RCTs, there was a significant reduction in the risk for developing PPCs in the groups that received preoperative breathing exercises. One trial concluded that deep breathing, coughing and incentive spirometer did not reduce the incidence of atelectasis and pneumonia and ABGs values (Moradian et al., 2019 [17]). Other two trials did not include PPCs as endpoints (Nejkov et al., 2020 [18]; Shahood et al., 2020 [21]).

None of the selected studies have mentioned patients' adherence rates in the intervention, in addition details about intervention supervision by a health care professional were also not included.

In some studies, details concerning the steps and the duration of the breathing exercises in order to get a positive outcome were not mentioned (Fayyaz et al., 2016 [15]; Turky and Afify ,2017 [16]). Which could contribute to variations in the implementation of breathing exercise (incorrect or inefficient performance of the training).

Lack of blinding in some studies could possibly result in bias, overestimation or underestimation of the interventions.

No study evaluated the inclusion of high-risk individuals, such as those with underlying respiratory disease. Due to the patients' low risk for acquiring PPCs, it cannot be asserted that the interventions are responsible for the beneficial outcomes. A recent systematic review using post-hoc meta-analysis indicated evidence for a larger effect of training when only trials with patients at high risk for post-operative pulmonary problems were included (Mans et al., 2015 [8]).

CONCLUSION

In the present review 14 studies involving 3908 participants were eligible for inclusion. This review concluded that preoperative pulmonary rehabilitation results in a reduction in the development of PPCs in patients undergoing cardiac surgeries. Preoperative pulmonary rehabilitation has a positive effect on HLOS and improving pulmonary function.

Although preoperative pulmonary rehabilitation seems to decrease the risk of developing post-operative pulmonary complications, it remains unknown which training regime is more effective. Further research would help in establishing the clinical significance and implications of these findings. The potential for overestimation of treatment effect needs to be considered when interpreting the present findings.

Future trials should consider the combination of multiple pulmonary rehabilitation techniques in the preoperative period, as it has proven to be an effective method for improving pulmonary function.

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TABLES

Table (1): Systematic Reviews and Meta-analyses Assessing The Effects of Preoperative Pulmonary Rehabilitation on PPCs

Authors, Year	Subjects	Technique	Included studies	Outcomes	Results
Mans et al., 2015[8]	Patients undergoing cardiac, thoracic or upper abdominal surgeries	IMT	8 RCTs	PPCs HLOS	PPCs↓ HLOS→ Respiratory muscle function↑
Kendall et al., 2017[9]	Patients undergoing cardiac, thoracic or upper abdominal surgeries	IMT	17 RCTs	PPCs HLOS	PPCs↓ HLOS↓
Katsura et al., 2015[10]	Patients undergoing cardiac or major abdominal surgeries	IMT	12 RCTs	The incidence atelectasis and pneumonia and HLOS	Pneumonia ↓ Atelectasis ↓ HLOS↓
Neto et al., 2016[11]	Patients undergoing cardiac surgeries	IMT	8 RCTs	The incidence of PPCs, pulmonary function parameters, and length of postoperative stay.	PPCs↓ pulmonary function↑ HLOS↓
Karanfil and Møller, 2018[12]	CABG valve surgery	IMT	5 RCTs	The incidence atelectasis and pneumonia and HLOS	PPCs↓ HLOS→
Rodrigues et al., 2021[13]	Cardiac surgeries	Diaphragmatic breathing, IMT, Incentive spirometer	10 RCTs One observational cohort study	Pulmonary function parameters, PPCs HLOS	PPCs↓ HLOS↓ pulmonary function parameters ↑

IMT, Inspiratory Muscle Training, CABG, Coronary Artery Bypass Graft, HLOS, Hospital Length of Stay, PPCs, Postoperative Pulmonary Complications, IS, Incentive spirometer, DB, diaphragmatic breathing, ↑, increase; →, inconclusive; ↓, decrease.

Table (2): Randomized Controlled Trials Assessing the Effects of Preoperative Pulmonary Rehabilitation on PPCs.

Authors, Year	Subjects	Intervention	Outcomes	Results
Diken and Özyalçın , 2015[14]	n= 108 Obese patients undergoing CABG	IS 10 times hourly	The incidence atelectasis and pneumonia	Pneumonia ↓ Atelectasis ↓
Fayyaz et al., 2016[15]	n= 170 patients undergoing CABG	IS	ABGs PPCs	ABGs↑
Turky and Afify , 2017[16]	n= 40 patients undergoing CABG	Threshold load IMT, preoperative education	Maximum inspiratory pressure, pulmonary gas exchange and oxygen saturation	Maximum inspiratory pressure ↑ pulmonary gas exchange↑ oxygen saturation ↑
Moradian et al., 2019[17]	n= 100 patients undergoing CABG	Deep breathing, coughing and Incentive Spirometer	Atelectasis and ABGs	Atelectasis → Hypoxemia →
Nejkov et al., 2020[18]	n=19 Patients undergoing cardiac surgeries	DB ,relaxation of the chest, postural education patient education about self-care and modification of risk factors.	ABGs, 2MWT, Sit to stand test, PPCs, MV, length of stay in ICU, HLOS	MV↓ HLOS↓ ABGs→ PPCs↓ 2MWT, Sit to stand test↑ (in both groups)
Chen et al., 2019[19]	n=197 patients aged ≥ 50 years, scheduled for cardiac surgery	Short-term intensive IMT for five days	PPCs Inspiratory muscle strength, pulmonary functions HLOS	PPCs↓ HLOS↓ Inspiratory muscle strength↑ pulmonary functions↑
Sweity et al., 2021[20]	n= 80 patients undergoing CABG	IS every four hours for two days	PPCs, HLOS, postoperative oxygenation	PPCs↓ HLOS↓ Postoperative oxygenation ↑
Shahood et al., 2022[21]	n= 100 patients undergoing open heart surgery	Home chest physiotherapy using incentive spirometer for one week	Respiratory function and oxygen saturation	Respiratory function ↑ oxygen saturation↑

IMT, Inspiratory Muscle Training, CABG, Coronary Artery Bypass Graft, HLOS, Hospital Length of Stay, PPCs, Postoperative Pulmonary Complications, IS, Incentive spirometer, DB, diaphragmatic breathing, ↑, increase; →, inconclusive; ↓, decrease.