Effectiveness of Preoperative Physical Therapy for Elective Cardiac Surgery

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<LEAP> highlights the findings and application of Cochrane reviews and other evidence pertinent to the practice of physical therapy. The Cochrane Library is a respected source of reliable evidence related to health care. Cochrane systematic reviews explore the evidence for and against the effectiveness and appropriateness of interventions—medications, surgery, education, nutrition, exercise—and the evidence for and against the use of diagnostic tests for specific conditions. Cochrane reviews are designed to facilitate the decisions of clinicians, patients, and others in health care by providing a careful review and interpretation of research studies published in the scientific literature.[1] Each article in this PTJ series summarizes a Cochrane review or other scientific evidence resource on a single topic and will present clinical scenarios based on real patients to illustrate how the results of the review can be used to directly inform clinical decisions. This article focuses on the effectiveness of preoperative physical therapy for elective cardiac surgery. More specifically, does preoperative physical therapy prevent postoperative pulmonary complications in patients undergoing elective cardiac surgery, and, if so, what types of interventions are most effective, and do patients with certain characteristics benefit from therapy?

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The American Heart Association has reported that the total number of inpatient cardiovascular operations and procedures increased 28% between 2000 and 2010, to 7,588,000 in 2010.[2] Despite a decrease in coronary artery bypass graft (CABG) surgery, this surgery remains common; almost 400,000 CABG procedures were performed in the United States in 2010.[3] Although there has been a reduction in overall postoperative mortality, there is ample evidence that the risk of pulmonary complications increases morbidity and mortality.[2,4]

Depression of the respiratory center due to preoperative and postoperative anesthesia and analgesia may result in altered breathing patterns, which can be complicated by restrictive lung volumes secondary to the median sternotomy and decreased chest wall movement. Decreases in essential parameters of vital capacity, functional residual capacity, and forced expiratory volume may directly contribute to atelectasis, which can contribute to postoperative pulmonary complications. Pulmonary function is further compromised by hypoventilation, decreased mucous clearance, decreased respiratory muscle function, increased work of breathing, and hypoxia—all ramifications of the surgical procedure.[5] Additionally, walking ability is limited after CABG surgery,[6] and persistent limitations in the performance of activities of daily living often accompany acute care hospitalization.[7] The deterioration in walking ability after cardiac surgery has been noted especially in women, elderly people, and people diagnosed with diabetes.[6] Therefore, preoperative physical therapy that directly targets these postoperative complications while improving functional status would seem to be a logical intervention for patients scheduled to undergo cardiac surgery.

Although the literature regarding postoperative physical rehabilitation is substantial, reports of well-controlled preoperative trials are limited. It was the intent of Hulzebos et al[8] to undertake a rigorous review of the available literature evaluating the effectiveness of preoperative physical therapy that included an exercise regimen in the reduction of postoperative pulmonary complications. Moreover, Hulzebos et al[8] were interested in knowing whether certain patient characteristics might provide a differential benefit and what, if any, interventions might be most effective. The review included studies that compared inspiratory muscle training (IMT) and mixed-exercise interventions with usual care (control) in patients who were more than 18 years of age and were awaiting cardiovascular surgery that included CABG or valve surgery.

The primary outcomes examined were the occurrence of postoperative pulmonary complications of grade 2, 3, or 4 on the grading scale developed by Kroenke et al[9] (Appendix 1), mortality from all causes, and adverse events. Hulzebos et al[8] made the distinction between pulmonary dysfunction—expected alterations in pulmonary function (eg, hypoxia, increased work of breathing, and ineffective cough)—and pulmonary complications—a clinical finding that is secondary to symptomatic pulmonary dysfunction and that

adversely affects the clinical course. The grading system of Kroenke et al[9] highlights complications that affect the clinical course. The secondary outcomes assessed included length of postoperative hospitalization, pulmonary function measures, postoperative respiratory mortality, health-related quality of life, and economic costs.

Take-Home Message

The Cochrane review by Hulzebos et al[8] comprised an electronic database search of literature through December 2011. The review included 8 randomized controlled trials with a total of 856 participants; participant characteristics are described in Appendix 2. Five studies used IMT as the intervention,[10–14] and the remaining 3 used mixed interventions, including aerobic exercise training, breathing exercises, or both[15–17]; intervention parameters are described in Appendix 2. The study sizes varied: 4 studies had fewer than 50 participants[11,13,14,17]; 1 study, by Weiner et al,[12] had between 50 and 100 participants (n=84); and the remaining 3 studies had more than 100 participants—the largest trial, by Hulzebos et al, had 276 participants.[10,15,16] The numbers allocated for the experimental and control groups in each study are shown in Appendix 2. The duration of the interventional phase in the studies ranged from 2 to 8 weeks. All studies defined "control" as usual care, with the singular exception of Weiner et al,[12] who used a sham therapy (no-resistance inspiratory muscle trainer) control group.

Hulzebos et al[8] did not grade the level of evidence for any of the outcomes. Each domain of risk bias was assessed for each study with 1 of 3 categories: low risk, high risk, and unclear risk. Only masking of participants and personnel showed a high risk of bias, allocation concealment was judged to be more unclear risk than low risk, and all other domains were judged to be low risk. Hulzebos et al[8] were unable to complete any subgroup or sensitivity analyses because of the small number of studies and the lack of studies with inadequate random sequence generation.

A summary of the findings for the primary and secondary outcome measures is shown in the Table. Hulzebos et al[8] concluded that the evidence remained incomplete for different risk groups (low versus high risk of pulmonary complications) or different types of physical therapy with an exercise component. Despite this limitation, it appeared that the available evidence, albeit from relatively limited and small trials, demonstrated that preoperative physical therapy reduced atelectasis and pneumonia and specifically reduced the length of postoperative hospitalization for patients undergoing elective cardiac surgery. Limited data showed preserved or improved physical function, as measured with a 6-minute walk assessment, relative to that in controls.[13] In addition, although the data suggested improvements in measures of physical function on the Medical Outcomes Study 36-Item Health Survey Questionnaire, the degree of change may not have been clinically significant.[16] Postoperative pneumothorax, prolonged (>48 hours) mechanical ventilation, and mortality from all causes did not appear to be influenced by preoperative physical therapy.

Case #25: Applying Evidence to a Patient Before Cardiac Surgery

Can exercise training help this patient?

"Mrs Brown" was a 73-year-old woman admitted to the emergency department complaining of acute shortness of breath and intermittent indigestion for the preceding 3 weeks. A 12-lead electrocardiogram and cardiac enzyme panel confirmed an acute myocardial infarction. Her remaining past medical history was significant for hypertension, hypercholesterolemia, renal disease, rheumatoid arthritis, type 2 diabetes mellitus, and obesity. She was transferred to the cardiac care unit for continued treatment of the acute myocardial infarction and multiple comorbidities and underwent heart catheterization. She was discharged to home 4 days after admission with a referral for home care physical therapy before scheduled nonemergent CABG surgery in 4 weeks. The home care physical therapist noted that Mrs Brown walked only 97.5 m (325 ft) during a 6-minute walk test and was challenged by stair climbing. Mrs Brown's age, sex, renal insufficiency, recent acute myocardial infarction, and poor mobility contributed to increased risks for surgery.[18] Increasing a patient's functional capacity and breathing reserve through increased physical activity and therapeutic exercises before a surgical admission should provide for the retention of a higher level of functional capacity during the entire hospitalization and has the potential to reduce postsurgical complications and decrease mortality. Therefore, home care physical therapy should address Mrs Brown's limited mobility and potential for postoperative pulmonary complications.

How did the results of the Cochrane systematic review apply to Mrs Brown?

Using the PICO (Patient, Intervention, Comparison, Outcome) format, Mrs Brown's home care physical therapist asked the following question: What physical therapist interventions can improve mobility status and functional reserve while reducing the risk of postoperative pulmonary complications for patients undergoing CABG surgery? The

Table.
Summary of the Key Results of the Cochrane Review by Hulzebos et al[8,a]

Primary Outcome Measure	Summary of Findings of Studies Evaluating the Outcome Measure
Primary	
PPC of grade 2 on the grading scale developed by Kroenke et al[9] (atelectasis)	Significantly lower in all 4 studies (n=379)[10,14,16,17] (risk ratio=0.52; 95% CI=0.32, 0.87)
PPC of grade 2 on the grading scale developed by Kroenke et al (any type)	Not significant in 1 study (n=276)[10] (risk ratio=0.77; 95% CI=0.40, 1.48)
PPC of grade 3 on the grading scale developed by Kroenke et al (pneumonia)	Significantly lower in 5 studies (n=448)[10–14] (risk ratio=0.45; 95% CI=0.24, 0.83)
PPC of grade 3 on the grading scale developed by Kroenke et al (pneumothorax)	Not significant in 1 study (n=45)[13] (risk ratio=0.12; 95% CI=0.01, 2.11)
PPC of grade 3 on the grading scale developed by Kroenke et al (any type)	Significantly lower in 1 study (n=276)[10] (risk ratio=0.41, 95% CI=0.20, 0.83)
PPC of grade 4 on the grading scale developed by Kroenke et al (mechanical ventilation for >48 h)	Not significant in 2 studies (n=306)[10,14] (risk ratio=0.55; 95% CI=0.03, 9.20)
PPC of grade 4 on the grading scale developed by Kroenke et al (all types)	Not significant in 1 study (n=276)[10] (risk ratio=0.16; 95% CI=0.02, 1.35)
PPC of greater than grade 2 on the grading scale developed by Kroenke et al (any type)	Significantly lower in 1 study (n=276)[10] (risk ratio=0.51; 95% CI=0.34, 0.78)
Postoperative death (all causes)	Not significant in 3 studies (n=552)[10,14,16] (risk ratio=0.66; 95% CI=0.02, 18.48)
Secondary	
Length of postoperative hospital stay (d)	A meta-analysis of 347 patients showed a significant (>3 d) reduction (mean difference=−3.21 d; 95% CI=−5.73, −0.69)[10,11,17]
Physical function measures (6-minute walk test)	6-minute walk test distance was assessed by Carvalho et al[13] (n=32), and patients receiving the intervention seemingly had significantly worse outcomes than controls receiving usual care (−101.30 m; 95% CI=−163.78,−38.82). However, further analysis of the data published by Carvalho et al revealed that Hulzebos et al[8] apparently mislabeled the intervention and control groups, reversing the data. If the statistical analysis was correct, then the intervention group in fact performed better postoperatively (mean difference=−101.3 m; 95% CI=−163.78,−38.82).
Postoperative death (respiratory causes)	Not significant in 1 study (n=276)[10] (risk ratio=0.14; 95% CI=0.01, 2.70)
Quality of life (SF-36 physical composite score)	Statistically improved in 1 study (n=117)[16] (1.30 points; 95% CI=0.88, 1.72)

[a] PPC=postoperative pulmonary complications, 95% CI=95% confidence interval, SF-36=Medical Outcomes Study 36-Item Short-Form Health Survey Questionnaire.

physical therapist identified the concept of *prerehabilitation*, and the Cochrane review by Hulzebos et al[8] was identified.

Patient relevance. Mrs Brown's characteristics matched the inclusion criteria noted in the studies mentioned in the Cochrane review. Specifically, she was diagnosed with stable angina and was scheduled for elective CABG surgery. Additionally, she had several of the patient-related preoperative risk factors for postoperative pulmonary complications identified in the review, including her age (>70 years old) and her diagnoses of type 2 diabetes mellitus and obesity, which classified her as being at high risk of postoperative pulmonary complications.

Intervention and comparison relevance. The Cochrane review mentioned studies in which multimodal interventions, including IMT, functional training, and aerobic exercise, were used. Because Mrs Brown had limited mobility as a result of a combination of deconditioning, rheumatoid arthritis, and heart failure, aerobic exercise training of sufficient intensity and duration might be difficult to implement. The Cochrane review highlighted the importance of individually prescribed aerobic exercise training, 4 times per week (both performed with supervision and independently performed), for 2 to 8 weeks, at 40% to 70% of a person's functional capacity. A home care physical therapist can implement a lower-intensity (eg, 40%–50% of heart rate reserve) progressive mobility program with the ultimate goal of 30 to 40 minutes of continuous activity. The Cochrane review also highlighted the potential for IMT as an efficacious intervention modality. Several IMT protocols, which emphasized strength or endurance of the respiratory muscles, were

mentioned in the review. The protocols in the review included a threshold loading device and the following workloads:

For strength protocols, workloads started:

- at 30% of peak inspiratory pressure, for 2 weeks, 7 d/wk, 2 times per day, 3 sets of 10 repetitions[13]
- at 40% of peak inspiratory pressure, for at least 2 weeks, 7 d/wk, 3 times per day, 5 sets of 10 repetitions[14]

For endurance protocols, workloads started:

- at 30% of peak inspiratory pressure and then increased incrementally, for at least 20 minutes daily, for at least 2 weeks[10,11]
- at 15% of peak inspiratory pressure for 1 week and then increased 5% at each session up to 60%, for 30 minutes daily, for 2 to 4 weeks

These protocols were based on a physical therapist measuring a patient's maximal inspiratory pressure. This measurement requires a pressure manometer, a device that is not commonly available to a home care therapist. An alternative strengthening protocol that can be implemented when a pressure manometer is not available starts at the highest pressure tolerated by the patient and progresses as the patient is able.[19] A common starting training intensity is 10 to 20 cm of the threshold load, with a goal of advancing the load by 1 to 2 cm of H_2O pressure daily. The patient performs 4 sets of 8 to 10 repetitions, with a 2-minute rest period between sets, 6 or 7 d/wk. The load is continuously advanced on the basis of the patient's symptoms and successful completion of the prescribed numbers of repetitions and sets. The alternative protocol takes approximately 10 minutes per session to complete, allowing time to complete the functional training and aerobic exercise components of the home program.

Additional interventions mentioned in the Cochrane review included health education about disease management, breathing retraining (diaphragmatic breathing and pursed-lip breathing), nutritional counseling, energy conservation, work simplification techniques, stress management, and instruction in common postoperative rehabilitation interventions, such as incentive spirometry, directed and braced coughing, and early mobility.

Outcome relevance. Considering that Mrs Brown had significant risk of postoperative morbidity and mortality, several key outcomes examined in the Cochrane review could be specifically applied directly to this case study. The review noted a reduced risk of postoperative pulmonary complications, including atelectasis and pneumonia, and a significant reduction in the length of stay for patients treated with preoperative physical therapy before undergoing CABG surgery. Additionally, the review noted that physical therapists can safely provide preoperative rehabilitation to patients with known risk of cardiovascular events, as no adverse events were recorded in the 3 studies that addressed this measure.

How well do the outcomes of the intervention provided to Mrs Brown match those suggested by the systematic review?

Mrs Brown underwent successful CABG surgery 4 weeks after the initiation of home-based physical therapy. Her postoperative course was noteworthy for rapid extubation and initiation of physical therapy in the intensive care unit but was complicated by fever related to an intravenous line infection that required prolonged antibiotic treatment. She was discharged to a skilled nursing facility for completion of the intravenous antibiotic treatment and continued rehabilitation services. She was ultimately discharged to home.

Can you apply the results of the systematic review to your own patients?

The findings of this Cochrane review can be applied to patients who have limited functional capacity and are awaiting surgery. The review highlighted the benefits of presurgical physical therapist services, such as the ability to reduce pulmonary complications and hospital length of stay. Prerehabilitation and preoperative physical fitness and activity levels have been shown to influence the outcomes of patients awaiting not just cardiac surgery but also thoracic, abdominal, and orthopedic surgeries. Increasing a patient's functional capacity and breathing reserve through increased physical activity, aerobic training, resistance exercise, and therapeutic interventions directly targeting the respiratory system is important because poor physical condition and poor functional status reduce the ability of patients to cope mentally and physically with hospitalization and surgery.[13,20]

What can be advised based on the results of this systematic review?

A prerehabilitation program consisting of multiple interventions may reduce postoperative pulmonary complications and shorten the hospital length of stay for patients awaiting cardiac surgery. The plan of care should consist of aerobic and functional training as well as therapeutic exercises including breathing retraining and IMT. Aerobic and functional training should be based on an individualized exercise prescription (eg, exercise intensity of 40%–70% of heart rate reserve for a

goal duration of 30 minutes). Physical therapists may not often include IMT as a component of their plan of care, but the evidence indicates that IMT has a beneficial role. The IMT exercise prescription can focus on strength or endurance, as noted in the Cochrane review. Inspiratory muscle training may offer unique advantages: patients can easily perform IMT after proper instruction, and IMT can be performed daily as part of an independent home exercise program. Patients with known cardiac and pulmonary diseases can safely perform this intervention.

Additional research on prerehabilitation programs and IMT could focus on identifying patients who are appropriate candidates, exploring interventions necessary for an optimal plan of care, clarifying the optimal IMT prescription, and identifying the optimal setting (ie, outpatient versus home care). Despite the need for additional research, prerehabilitation programs appear to offer significant promise for improving outcomes for patients after elective CABG.

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Appendix 1.

Operational Definitions of Postoperative Pulmonary Complications[9]

Grade 1

Cough, dry

Microatelectasis: abnormal lung findings and temperature of >37.5°C without other documented cause; results of chest radiograph either normal or unavailable

Dyspnea, not due to other documented cause

Grade 2

Cough, productive, not due to other documented cause

Bronchospasm: new wheezing or preexistent wheezing resulting in a change in therapy

Hypoxemia: alveolar-arterial gradient of >29 and symptoms of dyspnea or wheezing

Atelectasis: radiological confirmation plus either a temperature of >37.5°C or abnormal lung findings

Hypercarbia, transient, requiring treatment, such as naloxone or increased manual or mechanical ventilation

Adverse reaction to pulmonary medication

Grade 3

Pleural effusion, resulting in thoracentesis

Pneumonia, suspected: radiological evidence without bacteriological confirmation

Pneumonia, proved: radiological evidence and documentation of pathological organism by Gram stain or culture

Pneumothorax

Postoperative intubation or reintubation, with the period of ventilator dependence not exceeding 48 hours

Grade 4

Ventilatory failure: postoperative ventilator dependence exceeding 48 hours or reintubation with the subsequent period of ventilator dependence exceeding 48 hours

Appendix 2.

Overview of the Cochrane Review by Hulzebos et al[8]

Eight randomized controlled trials involving a total of 856 participants and published up to December 2011.

Studies were carried out in Australia (n=1), Brazil (n=2), Canada (n=1), India (n=1), Israel (n=1), and the Netherlands (n=2).

Intervention parameters and participants in 3 studies with a mixed-exercise approach:

- 1 study (Arthur et al[15]): 40% to 70% intensity, 2 times per week, for 8 weeks; participants (123 in the experimental group and 123 in the control group) were at low risk and were awaiting coronary artery bypass surgery (CABG)
- 1 study (Rosenfeldt et al[16]): 50% intensity, 2 times per week, for 2 weeks; participants (60 in the experimental group and 57 in the control group) were scheduled for CABG or valve surgery
- 1 study (Rajendran et al[17]): participants attended daily multifaceted instructional sessions for 1 week and then were advised to practice 10 minutes every waking hour; participants (25 in the experimental group and 20 in the control group) had chronic obstructive pulmonary disease and were scheduled for CABG

Intervention parameters in 5 studies with inspiratory muscle training:

- 1 study (Carvalho et al[13]): 30% of peak inspiratory pressure (PIP), twice daily, 3 sets of 10 repetitions, for 2 weeks; participants (16 in the experimental group and 16 in the control group) had been referred for CABG and were at high risk for pulmonary complications
- 1 study (Ferreira et al[14]): 40% of PIP, 7 d/wk, 3 times per day, 5 sets of 10 repetitions, for 2 weeks; participants (15 in the experimental group and 16 in the control group) were 50 years old or older and were awaiting CABG or valvuloplasty
- 2 studies (Hulzebos et al[10,11]): starting at 30% of PIP and increasing incrementally, a minimum of 20 minutes daily, for 2 weeks; participants (139 in the experimental group and 137 in the control group[10]; 14 in the experimental group and 12 in the control group[11]) were at high risk and were scheduled for CABG
- 1 study (Weiner et al[12]): starting at 15% of PIP for 1 week and increasing incrementally at each session up to 60% of PIP, for 30 minutes daily, for 2 to 4 weeks; participants (42 in the experimental group and 42 in the control group) were scheduled for CABG

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