

Essentials of Physiotherapy after Thoracic Surgery: What Physiotherapists Need to Know. A Narrative Review

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Physiotherapy has recently become an essential part of enhanced recovery protocols after thoracic surgery. The evidence-based practice of physiotherapy is essential for the effective management of postoperative patients. Unfortunately, only a small body of literature has discussed the rationale of the physiotherapy interventions that are routinely implemented following thoracic surgery. Nonetheless, we can integrate the available knowledge into our practice until new evidence emerges. Therefore, in this review, the principles of physiotherapy after thoracic surgery are presented, along with a detailed description of physiotherapy interventions, with the goals of enhancing the knowledge and practical skills of physiotherapists in postoperative care units and helping them to re-evaluate and justify their traditional practices.

Key words: 1. Physiotherapy
2. Management
3. Postoperative
4. Thoracic surgery

Introduction

Over the past century, thoracic surgery has been the primary intervention used to treat pulmonary, pleural, chest wall, and mediastinal disorders. The main presenting problems of postoperative patients who have undergone thoracic surgery include improper patient positioning; incision and/or chest drain pain; ineffective cough; reduced lung volume; postoperative pulmonary complications (PPCs), which can be non-infectious (e.g., atelectasis and respiratory failure) or infectious (e.g., pneumonia); impaired airway clearance; frozen shoulder on the thoracotomy side; postural abnormalities; and persistent chest wall tightness [1,2]. These problems, particularly PPCs, can lead to delayed patient recovery, prolonged

hospitalization, and increased morbidity and mortality. Physiotherapy has been routinely implemented after thoracic surgery as a fundamental component of postoperative management. Recently, physiotherapy has been recommended by the European Society of Thoracic Surgeons, the European Respiratory Society, and the American College of Chest Physicians, and it is now considered an essential element of enhanced recovery protocols (ERPs) or “fast-track” protocols in thoracic surgery that accelerate the functional recovery of postoperative patients and minimize the length of the hospital stay [3,4]. Therefore, the role of physiotherapy in these “fast-track” protocols after thoracic surgery warrants further clarification.

Unfortunately, in practice settings, little is currently known about clinically evidence-based physi-

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Table 1. Postoperative initial patient assessment

Variable	Content
Database information (from medical records)	<ul style="list-style-type: none"> • Preoperative investigations: chest X-ray, computed tomography scan, pulmonary function tests, or 6-minute walk test • Surgical procedure and incision • Concise medical history: personal history, present history, relevant past history (i.e., previous surgery), drug history including respiratory and/or cardiac medications
Subjective information	<ul style="list-style-type: none"> • Detailed medical history: personal history, smoking history, history of alcohol or drug abuse, chief complaint, present history, past medical and surgical history, social history, family history • Open-ended questions: how do you feel? • Pain assessment: a verbal descriptor scale or a visual analogue scale is used to measure incision or shoulder pain. The patient should be asked about the efficiency of the postoperative analgesia method in delivering adequate pain relief. • Cough and sputum assessment: the patient's ability to cough and expectorate should be assessed. The colour, volume, and consistency of sputum should be observed.
Objective information (from clinical examination, monitoring tools, and postoperative investigations)	<ul style="list-style-type: none"> • Clinical examination: inspection, palpation, percussion, and auscultation • Method of pain control: the physiotherapist must be aware of the various routes of analgesia (i.e., intravenous, epidural, paravertebral, and intercostal nerve blocks). If a patient-controlled analgesia pump is used, it should be verified that the patient can use it properly. • Oxygen delivery system: level of fraction of inspired oxygen • Type of chest drain • Postoperative complications: pulmonary, cardiovascular, wound, neurological, musculoskeletal, gastrointestinal, renal, and central nervous system complications. • Cardiovascular and respiratory status: the clinical stability of postoperative patients should be assessed by checking their heart rate and rhythm, blood pressure, respiratory rate, and oxygen saturation. • Range of motion assessment: for the shoulder and trunk on the operated side • Biochemical data, arterial blood gas analysis, chest X-ray

otherapy following thoracic surgery. Furthermore, there is a lack of standardized postoperative physiotherapy programs after thoracic surgery. In addition, in research work, few well-designed studies have been conducted with robust methodologies capable of identifying ideal physiotherapy treatment protocols based on scientific evidence [5]. Likewise, limited research reviews have been done on physiotherapy interventions for postoperative patients who have undergone thoracic surgery. Therefore, the purposes of this review were to explore the role of physiotherapists in “fast-track” protocols following thoracic surgery and to present evidence-based strategies for postoperative physiotherapy management. This review sheds light on the role of physiotherapy within ERPs in thoracic surgery and may enhance the clinical practice of physiotherapists in postoperative care units by helping them to re-evaluate and justify their traditional practices.

Postoperative physiotherapy assessment

Appropriate postoperative physiotherapy treatment plans can only be designed and/or initiated based on

an accurate initial assessment of postoperative patients [6]. Ongoing re-assessment is also recommended to judge the effectiveness of treatment, to modify the treatment plan, and to identify new problems. Following the initial assessment, a problem list for postoperative patients can be developed, which most commonly includes pain, a poor breathing pattern, reduced lung volume, ineffective coughing, retained secretions, and reduced shoulder range of motion (ROM) [2]. Table 1 presents the components of the initial postoperative patient assessment.

Postoperative physiotherapy treatments

Patients who undergo lung surgery using the posterolateral thoracotomy approach need more physiotherapy treatment than other patients who undergo the same extent of surgical lung resection via video-assisted thoracoscopic surgery (VATS). This is because open thoracotomy is associated with more PPCs than muscle-sparing VATS [7]. PPCs are considered to be the most frequent cause of postoperative death after lung resection and account for about 84% of such deaths [8]. Chest physiotherapy can ef-

fectively reduce the overall rate of pulmonary complications after lung resection [9]. Physiotherapy treatment must be started postoperatively between 4 and 12 hours after recovery from general anaesthesia. The estimated session time is 30 minutes, with 2–3 daily sessions [3].

1) Physiotherapy pain management

Thoracic procedures are considered to involve some of the most painful surgical incisions and are associated with severe postoperative pain. This is one of the reasons why various alternative modalities have been developed to replace the standard posterolateral thoracotomy, such as muscle-sparing techniques and VATS [10]. Pain impairs the patient's ability to take deep breaths or to cough effectively, which could lead to reduced lung volume and sputum retention, making re-intubation more likely. Pain also induces sympathetic stimulation; which leads to increases in the respiratory rate, heart rate, and blood pressure, which can affect the hemodynamic stability of surgical patients. Moreover, pain can restrict shoulder and scapula ROM, leading to frozen shoulder. Finally, pain increases patients' anxiety, and causes sleep disturbance and daytime tiredness, which may lead to poor cooperation during physiotherapy sessions [11]. For these reasons, pain assessment has recently become a standard component of each physiotherapy session, so that early proactive steps can be taken to optimize patients' requirements for analgesia prior to physiotherapy treatment. Physiotherapists should work closely with the medical team to ensure the adequacy of analgesia for each patient [12]. The aim of physiotherapy pain relief interventions is not to substitute for analgesic medications, but to reduce the total dose of analgesic medications received by postoperative patients, thereby reducing their unavoidable side effects.

(1) Transcutaneous electrical nerve stimulation: Transcutaneous electrical nerve stimulation (TENS) is a complementary postoperative analgesic modality that is safe and effective in alleviating postoperative pain and improving patient recovery, resulting in better outcomes after thoracic surgery. The current evidence shows that TENS treatment is ineffective when used alone in patients with severe post-thoracotomy pain (i.e., after a posterolateral thoracotomy incision), but useful as an adjunct to other analgesic medi-

cations in moderate post-thoracotomy pain (i.e., after a muscle-sparing thoracotomy incision) and very effective as the sole pain-control treatment in patients with mild post-thoracotomy pain (i.e., after a VATS incision) [13].

Hence, TENS therapy can reduce the need for additional analgesic doses, thus minimizing the total dose of analgesic medications and thereby reducing their side effects. TENS relieves postoperative incision pain and ipsilateral referred shoulder pain. It can also be used for persistent incision pain after removal of an epidural or paravertebral block [2].

TENS has multiple mechanisms of action, the first of which is closing the gates of pain perception in the brain. The second mechanism is that TENS stimulates the release of endogenous opioids. For effective postoperative analgesia with TENS, the intensity of the electric current should be strong, but comfortable for the patient. The duration of TENS application can be for 20–30 minutes at 3-hour time intervals on the day following surgery. The frequency of the electric current can be either high-frequency or low-frequency, although it is also possible to alternate high and low frequencies of 2–100 Hz [14]. Stimulation with alternating high and low frequencies was found to be the most effective method because the alternation of high and low frequencies causes the release of different neurotransmitters, which have a synergistic effect with exogenously administered opioids. Furthermore, alternating high- and low-frequency TENS has the advantage of delaying the development of opioid tolerance by approximately 5 days compared to either low- or high-frequency TENS alone [15].

(2) Cryotherapy (cold therapy): After major surgery, the application of simple ice packs over the incision dressing during the first 24 hours following surgery and afterwards is known to produce remarkable relief of incisional pain and less need for narcotic painkillers [16]. The cold reduces pain by reducing the sensitivity of the nerve endings to pain and by inducing vasoconstriction, which reduces inflammation and swelling. Ice packs can also be used before or during coughing and deep breathing exercises to reduce the aggravation of incision pain by these postoperative physiotherapy interventions [17].

(3) Wound support: It is very important to support the patient's incision and intercostal drain sites

with firm but gentle pressure, taking care not to press directly on the incision or drain site. This reduces pain and allows the patient to breathe in deeply and/or to cough with little discomfort. Different methods for wound support can be used during coughing, huffing, sneezing, and/or deep breathing exercises. One method can be done with the physiotherapist standing on the contralateral side, with one hand placed on the anterior chest wall to stabilize the incision from the front, and the other hand placed on the posterior chest wall to stabilize the incision from behind, while at the same time the physiotherapist's forearms stabilize the entire chest and create a "bear-hug" hold. Another method for wound support can be done by the patient, by placing the hand of the un-operated side across the front of the thorax as far as possible, resting firmly over the incision and drain sites, while the other hand reinforces the hugging hold by clasping the opposite elbow and pulling it against the thoracic wall. Alternatively, the patient may be taught to hold a pillow firmly against the incision while coughing, or to wear an external thoracic support [18].

2) Positioning

After thoracic surgery, the easiest method to increase functional residual capacity and to prevent lung atelectasis is early appropriate positioning [19]. Positioning patients after thoracic surgery utilizes gravity to provide 2 major benefits: the first is to enhance ventilation, perfusion, and gas exchange; and the second is to help clear excess bronchial secretions.

(1) Gravity-assisted positions to improve ventilation and gas exchange:

(a) Early upright sitting: The optimal postoperative position is the upright sitting position in or out of bed, which should be emphasized as soon as the patient is woken following surgery to facilitate lung ventilation. After being woken, the patient may sit in a chair out of bed with the endotracheal tube still in place [20]. Positioning is considered an important part of postoperative management. The benefits of upright positioning include an increase in diaphragmatic excursion, improved ventilation and increased lung volume and capacity, improvements in oxygenation with a reduced need for supplemental oxygen, and enhanced forced expiratory flow [21]. Many patients can sit out of bed in a chair the day

of or the first day after surgery. If they cannot sit in a chair, they should be encouraged either to sit upright in bed or to adopt a high side-lying position with the operated lung on top, but they should not be allowed to be in a supine or in a slumped position in bed, as these positions reduce lung volume [19].

(b) Lateral (side-lying) positioning: High side-lying with the operated lung on the top may be encouraged in some circumstances. The reason for keeping the non-operated lung at the bottom is to ensure adequate ventilation-perfusion matching, as gravity directs perfusion to the non-operated lung, which is at the bottom, thereby improving oxygenation [19]. Another reason is to allow for adequate expansion of the operated lung, which is placed on the top. However, after pneumonectomy, if the side-lying position is adopted for draining the remaining lung, the patient should be positioned carefully on the operated side, because if patient lies on the non-operated side, the bronchial stump may be bathed with fluid if the anastomosis is not well sutured [18,20].

(2) Gravity-assisted positions to assist the clearance of bronchial secretions: The modified (horizontal) postural drainage position is recommended first, instead of the classical (head down) position, in postoperative patients, as the latter can lead to decreased arterial oxygenation [22], and could induce more cardiovascular stress [23]; furthermore, it may increase the risk of aspiration in postoperative patients with uncontrolled or unprotected airways.

3) Early mobilization and ambulation

The term postoperative mobilization refers to a change in the patient's position from the supine or slumped position in bed to upright sitting in or out of bed (e.g., in a bedside chair), standing, or walking. According to the European Society of Intensive Care Medicine statement on physiotherapy for adult patients with a critical illness [24], the physiotherapist should be responsible for starting early mobilization and exercise prescription, and should make the appropriate recommendations for progression of these interventions together with other team members. Mobilization and walking in patients after cardiothoracic surgery should be based on scientific principles. The aim of mobilization is to stress the cardiopulmonary system of the postoperative patient

at a level sufficient to increase minute ventilation and cardiac output while still being within safe physiological limits. Mobilization, conventionally, should be started on the first postoperative day by having the patient sit on the edge of bed or in a chair out of bed, and then taking short steps to walk around the bed [1,20]. However, it has been shown that earlier mobilization, with sitting in bed at 3.5 hours after surgery, maintaining a sitting position for 30 minutes, and then ambulation in the fourth hour following surgery led to better recovery of pulmonary function than conventional mobilization (walking on the first postoperative day) in patients who underwent lobectomy [25].

(1) Safety guidelines for early mobilization and/or ambulation:

(a) An appropriate assessment of the clinical stability of postoperative patients is extremely important before mobilization. Mobilization should only be initiated for patients with clinically stable cardiopulmonary and cardiovascular conditions. A patient's clinical status is considered unstable if the vital signs exceed any of the following thresholds: heart rate less than 40/min or greater than 140/min, respiratory rate less than 8/min or greater than 36/min, oxygen saturation less than 85%, and blood pressure less than 80 or more than 200 mm Hg systolic or greater than 110 mm Hg diastolic [26], mean blood pressure <65 mm Hg, and extremes of temperature that are also highly suggestive of clinical instability. In addition to core temperature, skin and extremity temperatures have been correlated with patient outcomes. It has been shown that patients with cool extremities have a lower cardiac output than patients with warm extremities [27].

(b) After becoming eligible for mobilization, clinically stable patients should receive continuous and close monitoring by the physiotherapist during and immediately after mobilization. This ongoing monitoring is essential because even clinically stable patients may have some potential to become unstable during and/or after mobilization [1].

(c) An appropriate assessment of organ perfusion is also important prior to ambulation. Urine output and capillary refill time (CRT) are frequently used as clinical surrogates of organ perfusion. Postoperative oliguria suggests inadequate renal perfusion and reduced cardiac output. A postoperative CRT >4.5 sec-

onds was also found to be correlated with poor peripheral perfusion [27].

(d) All patient's connections should be checked before mobilization and/or ambulation, and care should be taken not to pull any of the patient's lines, drains, or tubes during mobilization to avoid dislodgement. Nasogastric tube dislodgement may increase the risk of aspiration [1]. In case of accidental dislodgement of an intercostal drain, the patient is asked to immediately breathe out, and firm pressure with a sterile dressing is applied to the insertion site at the end of expiration. While maintaining pressure, the patient is asked to breathe normally till medical help arrives [20].

(e) Adequate analgesia must be given before mobilization for patients after thoracotomy, as pain from the incision and/or from chest drain can be quite severe, limiting patients' ability to cooperate during physiotherapy mobilization sessions [1].

(f) Before upright mobilization, in addition to the previously mentioned guidelines, the patient's ability to follow commands should be assessed, sitting balance should be checked, and the sensory and motor functions of the lower limbs should be tested, especially in patients who have received spinal block [20]. Once a postoperative patient is able to sit unsupported on the edge of the bed for 5 minutes and can perform a full bilateral knee extension along with clinically acceptable vital signs, the patient can progress to standing and ambulation [28].

(g) Upon standing, it is important to check for orthostatic hypotension, which can manifest by a drop in systolic blood pressure of >20 mm Hg and a drop in diastolic blood pressure of >10 mm Hg, and/or in the form of symptomatic dizziness or light-headedness. It can even cause the patient to feel faint. It has been recommended that 2 people should provide assistance when a patient stands or walks for the first time because of the risk of postural hypotension [20]. If the hospital does not have enough manpower, a physiotherapist can make it easier for the patient to stand by using a tilt table.

(h) For patients' safety, patients should start ambulation with a high level of assistance, as mentioned earlier either by 2 or 3 personnel or by using assistive devices such as a wheeled walker, dynamic orthotics, or a mechanical lift. Then, as the patient progresses with ambulation and shows good outcomes,

the physiotherapist may reduce the level of assistance. In addition, using a gait belt while transferring or walking a postoperative patient provides increased safety and security for both the patient and the physiotherapist. Furthermore, for patients with stable vitals while sitting, but profound weakness of the lower extremities, the use of standing lifts can be helpful during transfer to avoid injury to the staff [28].

(i) A graduated walking program should be adopted for mobilizing postoperative patients [20]. The physiotherapist must start low and go slow; that is, to start with sessions that are short (i.e., 3–5 minutes), more frequent (i.e., 2–3 times/day), and relatively non-intense (inducing a level of patient effort of <13 on the rating of perceived exertion [RPE] scale or at 60% of maximum heart rate [HR_{max}]) [28]. This is because postoperative patients at this stage have limited cardiopulmonary reserve due to their medical or surgical conditions. Later on, patients can progress to more intense, less frequent, and longer walks.

(j) Stair climbing is initiated once the patient can walk for a considerable distance on a flat surface with optimum cardiovascular and cardiopulmonary stability. Stair climbing generally can occur on the fourth or fifth day after thoracic surgery, but it can be initiated as early as the third postoperative day in low-risk cases [20].

(k) During all mobilization activities, careful attention should be paid to subjective symptoms of exercise intolerance, such as shortness of breath, chest pain, dizziness, cold sweating, leg fatigue, and pain, and these symptoms should be monitored carefully during mobilization. In such cases, activities must be stopped immediately until hemodynamic stability returns and then these stressful activities should be modified in subsequent mobilization sessions. The RPE can be used to assess patients' perceived feeling of exertion, and patients are initially encouraged to mobilize with an effort not exceeding a breathlessness of 13 on the RPE scale, which corresponds to about 60% of HR_{max} [12,28]. The use of breathing control during mobilization activities may improve exercise tolerance (i.e., walking at a pace that leaves the patient slightly short of breath).

(l) When walking a patient with an underwater seal drainage tube still in place, the patient must re-

ceive appropriate analgesia prior to ambulation because chest drains can cause severe pain, limiting the patient's ability to ambulate and to cooperate with the physiotherapist. Furthermore, the physiotherapist should make sure that the drainage system is working properly; symptoms of tachypnea, dyspnea, increased use of the accessory muscles, orthopnea, a restless or increased heart rate, or cyanosis may indicate malfunctioning of the drain system. Moreover, if no swing is seen in the underwater seal tube, this may indicate kinking of the chest tube, a loop in the chest tube filled with fluid, or clotting in the tubing; alternatively, the patient may be lying on the tube. Care should also be taken that the patient keeps the drainage system upright and below the level of the patient's chest by least 0.5 m during all mobilization activities. Mobilization activities for patients who are connected to wall suction include bed-side marching on the spot or doing steps up on a fixed single step [1,20]. Additionally, the physiotherapist should be aware of emergency procedures, such as chest tube clamping, if unexpected tube disconnection occurs.

(m) When walking a patient who is receiving supplemental oxygen, the physiotherapist should monitor oxygen saturation the entire time, and the amount of oxygen given to the patient must be enough to keep oxygen saturation $\geq 90\%$ during ambulation. If oxygen saturation drops below the prescribed minimum level, the physiotherapist should increase the amount of delivered oxygen to keep the saturation in the prescribed range, and may also choose to reduce the intensity and/or the duration of patient's activities [28].

(n) When walking a patient with an epidural still in place, the physiotherapist must pay great attention to avoid pulling on the epidural catheter during activities. The physiotherapist must be aware of common side effects of epidural analgesia. Thus, an assessment of the muscle strength of the lower extremities and orthostatic hypotension is needed before upright ambulation. Some postoperative care facilities restrict mobilization when an epidural catheter is in situ. Thus, physiotherapists should be aware of unit-specific policies [1].

(o) Ambulation is not allowed in: postoperative patients with unstable vital signs; patients who are not able to follow commands; patients with untreated deep venous thrombosis or pulmonary embolism; pa-

tients on high ventilatory support (i.e., a high fraction of inspired oxygen of >80%, positive end expiratory pressure (PEEP) or continuous positive airway pressure [CPAP] of more than 10 cm H₂O); patients with orthopaedic injuries or neurological limitations to ambulation [28]; patients with hypotension, uncontrolled arrhythmia (e.g., atrial fibrillation), uncontrolled decompensated heart failure, or recent myocardial infarction, as these conditions can lead to severe compromise of cardiac output during ambulation activities; and patients with acute renal failure. In such cases, the patient can start with deep breathing and airway clearance techniques in bed.

(p) All Patients unable to be mobilized and/or ambulated can start breathing exercises, circulatory exercises, and/or airway clearance techniques in bed.

(q) After mobilization and/or ambulation has been ended; the physiotherapist should re-assess the patient's vital signs for any abnormal responses.

4) Lung expansion manoeuvres

After thoracic surgery, lung volume and functional residual capacity are reduced due to anaesthesia, chest wall pain, and/or recumbency. This can lead to lung atelectasis, which is considered to be one of the most significant non-infectious PPCs. Clinically, this condition manifests through progressive hypoxaemia, increased breathing frequency, dyspnoea, increased heart rate, decreased breath sounds, fine late inspiratory crackles (crepitations), a dull note on percussion, and areas of opacification on a chest X-ray. Some physiotherapy interventions and adjunct therapies aim to improve lung expansion and to increase lung volume and capacity following thoracic surgery. These include deep breathing exercises, incentive spirometry, and inspiratory muscle training (IMT). These techniques aim to reduce the likelihood of lung atelectasis, improve hypoxaemia, and/or reduce the need for re-intubation. No individual lung expansion manoeuvre is significantly superior to another, and a combined approach may be more effective than a single intervention [29].

(1) Deep breathing exercises: Because lung volume is affected by body position, deep breathing exercises are most often performed in the erect sitting position, but they can be also practiced while the patient is in high side-lying position or in a modified postur-

al drainage position. Deep breathing exercises induce large and sustained increases in trans-pulmonary pressure, which in turn increase lung volume, improve ventilation and oxygenation, prevent basal atelectasis, re-inflate collapsed lung regions, and reverse minimal postoperative atelectasis [29,30]. Because periodic deep breathing is very important for lung inflation, a recommended protocol for deep breathing exercises that can be prescribed to postoperative patients is 5 deep breaths with a 3-second end-inspiratory hold per every waking hour [31]. Techniques for supporting the incision wound and drain sites oneself during all deep breathing exercises can be taught to patients to allow them to take in large breaths with little pain.

(a) Thoracic expansion exercises (lateral costal breathing exercises): Thoracic expansion exercises (TEEs) are deep breathing exercises that emphasize inspiration. Inspiration is active and may be accompanied by a 3-second hold at the end of deep inspiration. TEEs include apical, upper lateral, middle, lower lateral, and posterior basal expansion exercises, and can be unilateral or bilateral [32]. Unilateral TEEs are preferable in postoperative patients after thoracotomy. These exercises are most efficiently performed in the high side-lying position, with the operated side on the top and the arm on the involved side brought to abduction at the level of the head [28]. First, the physiotherapist should support the incision site by applying gentle but firm pressure with his or her hand. Placement of the physiotherapist's hand over the operated region can also induce tactile stimulation, which facilitates lung expansion [19]. Then, the patient is asked to breathe in slowly, as deep as possible, to push the physiotherapist's hand up, to hold his or her breath for 2-3 seconds, and finally to exhale gently from the mouth. Roughly 3 expansion exercises are appropriate. It is also important to support the chest drain site during TEEs to reduce pain, allowing the patient to breathe in deeply with little discomfort. Alternatively, bilateral basal TEEs can be employed postoperatively for surgical patients in the erect sitting position [1].

The slow inspiratory flow rate that occurs in TEEs improves ventilation to the dependent lung regions that are most strongly affected following surgery [33]. Moreover, the 3-second end inspiratory hold

helps recruiting collateral ventilatory pathways and allows time for asynchronous ventilation to take place, thereby promoting a greater increase in lung expansion [34]. Additional increases in lung volume can also be achieved by the "sniffing manoeuvre" at the end of deep inspiration, which stimulates further diaphragmatic descent. This simple manoeuvre can be done as follows: after reaching maximum inspiration, the patient is asked to take in a quick and a short breath using strong inspiratory effort [34]. Furthermore, physiotherapists may apply a quick stretch of the intercostal muscles before the beginning of inspiration, this technique is thought to encourage maximal inspiration [35]. Quick stretch can be done as follows; with hands on both sides of the chest, and just before the patient starts to breathe in, the physiotherapist quickly pushes in and down on both sides of the patient's chest wall. The physiotherapist may also choose to give a slight resistance throughout the beginning of inspiration, followed by sudden release of this resistance. This creates an action known as "rib springing", which immediately opens up the thoracic cage and allows for larger amount of air to be sucked and inhaled into the airways.

(b) Deep diaphragmatic breathing: Diaphragmatic movement is inhibited by pain following thoracic surgery. Therefore, deep diaphragmatic breathing should be emphasized postoperatively. Deep diaphragmatic breathing should be practiced while the patient is sitting upright, with his or her back supported and the pelvis in the posterior tilting position. The posterior pelvic tilt position optimizes the length-tension relationship of the diaphragm, which facilitates efficient diaphragmatic breathing [28]. The patient is asked to relax the upper chest and shoulder and to breathe in from the nose as deeply as possible, trying to make his or her abdomen swell like a balloon by expanding the lower chest and abdominal regions, and then to exhale gently. If the patient still cannot relax the accessory muscles of respiration, a contract-relax technique can be used prior to diaphragmatic breathing [28].

(c) Deep breathing exercises coupled with arm or trunk movement: The patient may be taught to coordinate deep breathing with arm flexion, arm abduction, trunk extension, or trunk side flexion away from the operated side, while coordinating exhalation

upon returning to the starting position (i.e., coordinating exhalation with arm extension, arm adduction, trunk flexion, or trunk-side bending towards the operated side). Support of the incision and drain sites should be provided during these activities.

(d) Sustained maximal inspiration (3-second hold at total lung capacity): This technique refers to holding one's breath for 3 seconds after reaching deep inspiration. This is of great importance in facilitating more equal filling of the lung regions, as it allows for variation in time constants among different lung regions [1].

(2) Incentive spirometry: Incentive spirometry is a visual feedback system used to encourage and motivate postoperative patients to perform deep breathing and to engage in sustained maximal inspiration (i.e., a 3-second end inspiratory hold) to open up atelectatic alveoli. There are 2 types: flow-incentive spirometry and volume-incentive spirometry. In flow-incentive spirometry, the magnitude of air flow achieved during inhalation is indicated by the number of balls and the level to which they rise. In volume-incentive spirometry, the volume of the air displaced during inhalation is indicated on a scale located on the device. The patient is asked to breathe in slowly and deeply for as long as possible through the mouth piece of the device to maximally distribute ventilation, and then holds the deep breath for a period of 5 seconds, which is then followed by a normal expiration [36]. Although incentive spirometry is used routinely after thoracic surgery, there is no evidence that it is superior to deep breathing exercises or even augments physiotherapy sessions; however, it is a useful tool to assess the ability of the postoperative patient to effectively take a deep breath after thoracic surgery, as poor performance may indicate pulmonary deterioration [37]. Guidelines no longer recommend the routine use of postoperative incentive spirometry [29].

(3) Inspiratory muscle training: IMT is a major component of preoperative pulmonary rehabilitation programs. However, its postoperative role and its possible superiority to other components of a standard physiotherapy program, including deep breathing exercises and early ambulation, for increasing lung volume or preventing atelectasis still need further research. A recent study by Brocki et al. [38] has shown that the addition of IMT to standard post-

operative physiotherapy improved hypoxaemic status in high-risk patients after lung cancer surgery, but had no additional benefit for preserving respiratory muscle strength.

5) Airway clearance techniques

The inability to cough and clear airway secretions leads to an increased risk for infection and the development of postoperative pneumonia [29].

Airway clearance techniques refer to manual or mechanical procedures that are used to assist the mobilization of secretions from the airway after thoracic surgery [28]. These include supported coughing, huffing, the forced expiration technique (FET), the active cycle of breathing technique (ACBT), modified postural drainage positioning with or without vibration, and the positive expiratory pressure (PEP) therapy. An airway clearance technique should be started as soon as the patient wakes on the day of surgery and/or on the first postoperative day. It should be repeated every 30 minutes [20]. Following thoracic surgery, lung secretions become persistent as a result of anaesthesia, infection, or dehydration [2]. Because of this, the following sequence should be followed: (a) opening up the airway with nebulized bronchodilators; (b) thinning out secretions with heated humidification, mucolytic agents, and ensuring adequate systemic hydration of the patient himself (by increasing oral or intravenous fluid intake); (c) and clearing out secretions by choosing the most suitable airway clearance technique [39]. Airway clearance techniques may aggravate incision pain, so the physiotherapist must coordinate the treatment sessions with the peak effect timing of analgesic medications and may ask about an additional bolus dose of analgesia before the physiotherapy session if the pain is severe. For patients using patient-controlled analgesia (PCA), the physiotherapist should ask patient whether he or she prefers to use the PCA system before the session. If the PCA system is in the "lock-out" mode, the physiotherapist should postpone the session till the lock-out signal is cleared. Wound support while performing an airway clearance technique is also required, and the use of ice packs over the incision dressing before deep breathing and coughing may be helpful.

There is a lack of evidence supporting the use of any airway clearance technique over another. Therefore,

patient preference is the most important consideration when prescribing a chest clearance technique to a postoperative patient, because patient preference improves adherence. For example, patients who prefer being independent might prefer airway clearance techniques that can be self-administered [19].

(1) Supported cough: Prior to coughing, the patient sits upright and takes several deep breaths. For effective coughing, the patient tilts the shin up, supports the wound with a pillow, takes a deep breath combined with trunk extension, and momentarily holds his or her breath. Then, while maintaining wound support, the patient carries out a series of sharp expirations while leaning forward to increase intra-abdominal pressure [28]. Coughing can trigger incision or drain site pain, so the physiotherapist may ask whether a patient wants to use PCA before the treatment session or may request an additional bolus dose of analgesia before treatment. One major disadvantage of coughing is that the higher intrathoracic pressure generated triggers incision pain, which may be not tolerated by patients. Furthermore, the increased intrathoracic pressure can lead to premature airway collapse and air trapping in postoperative patients with unstable airways (e.g., those with co-existing chronic obstructive pulmonary disease or bronchospasm), which in turn leads to reduced forced expiratory flow and failure to clear secretions [1].

(2) Huffing: Compared to coughing, the forced expiration occurs in huffing without closure of the glottis. Physiotherapists can employ huffing in postoperative settings as an alternative to coughing for patients who find coughing too painful [28]. Huffing instead of coughing is better tolerated by postoperative patients, as it requires less effort due to the lower intrathoracic pressure generated [20].

(3) The forced expiration technique: The FET is a combination of 1–2 forced expirations (huffs) and a period of breathing control [40]. It has been reported that the FET may be the most effective component of chest clearance physiotherapy [19]. When compared to coughing, the FET can loosen and propel distal lung secretions towards larger airways and the trachea, where they can then be expelled by coughing. It is best suited for postoperative patients for whom explosive expirations during coughing are very painful [39]. The FET has 2 components as follows.

(a) **Huffing:** To loosen and mobilize distally situated secretions, the patient is asked to take a medium-sized breath; and then with mouth and glottis open, to breathe out forcefully and slowly (i.e., as if trying to steam up a mirror). The huff should be long enough to be effective in mobilizing the distally situated secretions. However, it should not be too long, as too long a huff may lead to unnecessary paroxysmal coughing, with a subsequent rise in intrathoracic pressure. Likewise, it should not be too short, as too short a huff is ineffective. However, when secretions have reached the upper airway, a shorter huff or cough with high lung volume may be sufficient to clear them. To carry out a huff or cough with high lung volume; the patient is asked to take a deep breath, and then to exhale forcibly, squeezing air out from the chest [19].

(b) **Breathing control:** An essential part of the FET is the pause for breathing control after 1 or 2 huffs to prevent any further compression and narrowing of the airway. Breathing control is tidal breathing at the patient's own rate and depth, while the patient adopts relaxed diaphragmatic (abdominal) breathing [32,41]. For breathing control, the patient is instructed to rest one hand on the abdomen and to keep his or her shoulders and upper chest relaxed. Then, the patient is asked to let the air flow in from the nose (if possible), to feel the abdomen rise as he or she does so, and to feel it fall while he or she breathes out. The length of the breathing control period varies from patient to patient. In patients with bronchospasm or unstable/collapsible airways, a longer pause for breathing control is needed, while in other patients with no bronchospasm, the pause may be shorter.

(4) Active cycle of breathing technique: The ACBT refers to a cycle of breathing control, TEEs, and FET. It can be used in postoperative patients to clear excess bronchial secretions with or without assistance. The patient should start with breathing control for 20–30 seconds. The patient then practices TEE 3–4 times. In addition to increasing lung volume, TEEs play an important role in clearing excess bronchial secretions. The mechanism is that TEEs with a 3-second inspiratory hold allow the air to flow via collateral channels and to come in behind the sputum stuck in small airways and mobilize it towards the larger airways. The patient then re-starts breathing

control again (20–30 seconds or 6 breaths). Finally, the patient practices the FET. According to whether secretions are distal or proximal, a medium-sized breath with a long huff or large-sized breath with a shorter huff should be practiced, respectively. The whole cycle should be repeated 2–3 times every waking hour. The ACBT can be practiced in a sitting position, or occasionally in a gravity-assisted positions. The ACBT is flexible and can be adapted for each patient individually. For example, one set of TEEs may be followed by the FET, but if the secretions loosen slowly, it may be more appropriate to use 2 sets of TEEs interspersed with a period of breathing control, followed by 2 sets of the FET [32,34].

(5) The positive expiratory pressure technique: Unlike CPAP, patients who use PEP therapy only receive positive pressure at the end of the expiration. PEP is most commonly applied with physiotherapy sessions once or twice daily to aid chest clearance [19]. There are 3 types of PEP devices; (a) a flow resistor, through which patients exhale against a fixed-size orifice chosen according to age and expiratory flow; (b) a threshold resistor, where patients exhale against an adjustable spring-loaded valve or reverse Venturi device; and (c) vibratory PEP (acapella and flutter), where patients exhale against a threshold resistor with an expiratory valve oscillating at 10–30 Hz. If the aim is to clear retained secretions, as in postoperative patients, then a vibratory PEP device is the most appropriate choice [39]. PEP can be performed against high or low pressure. For proper PEP application, (a) the patient sits upright or leans slightly forward with his or her elbows supported on a table and holds the mouthpiece or the mask firmly against his or her face; (b) the patient is asked to slowly take in a larger than normal breath with a short breath hold (3–5 seconds) and to exhale through the PEP device with active but not forced expiration against an expiratory resistor, giving a resistance that ranges from 6 to 25 cm H₂O; (c) the patient breathes for 10–20 breaths/cycle with a total of 4–8 cycles/session or for a maximum of 20 minutes; and (d) after each cycle, the FET or supported coughing may be practiced by the patient to clear the already mobilized secretions. For postoperative patients, short periods of PEP every waking hour have been recommended as a prophylactic treatment [19,32,39].

(6) Modified postural drainage positions: Modified positions are much more likely to be used postoperatively in patients where classical (head-down) positions are not well tolerated or may cause aspiration, vomiting, breathlessness, cardiovascular compromise, and/or pulmonary hypoxaemia. The recommended modifications include approximating the position as closely as possible to the original classical position using the horizontal lateral decubitus and supine positions [39] or the leaning forward position from sitting. For example, a modified position to drain the lateral segment of the right lower lobe would be the side-lying position with the bed flat, rather than the head-down position. However, in postoperative patients after lobectomy or pleurectomy, if the modified position proves to be ineffective in mobilizing distally situated secretions, the head-down position may be used with caution (e.g., less time spent in the position), as the head-down position is not absolutely contraindicated in such circumstances [1]. Modified postural drainage positions can be used exclusively or in combination with any other airway clearance techniques. In order to drain all the affected lung regions, different positions are used in each treatment session, and each position should be maintained for 5–10 minutes or as tolerated. The patient's face should always be in the frontal view, so that any signs or expressions of position intolerance are monitored. Postural drainage positioning is immediately discontinued as soon as the patient complains of breathlessness, cyanosis, haemoptysis, dizziness, nausea, vomiting, anxiety, tachycardia, bronchospasm, hypertension, and/or any musculoskeletal pain or discomfort [28].

(7) Manual chest physiotherapy techniques: Shaking the chest wall following thoracic surgery is not an appropriate choice due to the presence of a chest wall incision, but a compressive support may be a better choice to promote the clearance of secretions [19]. Furthermore, manual chest percussion with postural drainage positions is rarely used after thoracic surgery [1]. This may be due to the presence of: (a) chest wall problems, such as a chest wall incision and/or pain, healing tissues, subcutaneous emphysema, the presence of monitoring leads, or recent pacemaker placement; (b) haemodynamic instability and/or cardiac arrhythmia; (c) PPCs, such as bronchopleural fistula, pulmonary oedema, pulmonary embolism, em-

pyema, large pleural effusion, or unstable pneumothorax; and/or (d) cachexia or osteoporosis, particularly in elderly postoperative patients. Chest vibration during exhalation over the affected lung regions below the incision is better tolerated than percussion in postoperative patients, and is considered to be a useful alternative [28,42]. Manual vibration is implemented in conjunction with modified postural drainage positions to aid in secretion clearance. To perform manual vibration properly, the palmar aspect of the physiotherapist's hands should be in full contact with the patient's chest wall, or one hand may overlap the other hand. Then, after the end of deep inspiration and throughout exhalation, the physiotherapist gently exerts an oscillating pressure on the patient's chest wall till the end of the exhalation. Mechanical vibrator devices can also be used, but manual vibration is preferable, as the physiotherapist can assess the depth and the pattern of breathing during vibration and coordinate the oscillating pressure of vibration with the patient's breathing pattern [28].

6) Postural correction

Post-thoracotomy patients tend to side-flex their trunk towards the thoracotomy side; that is, to drop the shoulder and raise the hip on the operated side, because this is less painful. The patient is discouraged from adopting this protective posture, and is encouraged to keep moving the shoulder on the operated side [18]. Patients should also be educated to keep both shoulders at the same level and the trunk straight while sitting, standing, or walking.

7) Shoulder ROM exercises and gentle scapula mobilization exercises

After thoracotomy, approximately 80% of patients have shoulder pain on the side of the incision [43], which may cause them to immobilize the arm on the thoracotomy side, potentially leading to frozen shoulder. For this reason, auto-assisted or active ROM exercises for the shoulder (e.g., arm elevation) within pain limits can be started as early as possible, starting on the first postoperative day [19,20], with attention to the chest tube site. In addition, the scapula on the operated side can be mobilized gently through its full range of protraction, retraction, elevation, and depression, while the patient is in the

side-lying position. These exercises need to be performed 3–4 times daily [10,18]. However, shoulder abduction and external rotation are initially avoided to prevent increased stress on the incision.

8) Leg, trunk, and thoracic mobilization exercises

Non-resistance leg exercises (i.e., quadriceps and ankle exercises) can be started on the first postoperative day to minimize circulatory stasis and to prevent circulatory problems such as deep vein thrombosis and pulmonary embolism [20,44]. The patient can also start non-resistance arm exercises and thoracic mobilization exercises on the first postoperative day with the aims of increasing thoracic cage mobility, easing deep breathing with subsequent increased lung volume, and preventing chronic restrictions in chest wall expansion [20]. Thoracic mobilization exercises include thoracic extension exercises, chest wall rotation exercises, and thoracic lateral flexion exercises [19]. For thoracic extension exercises, the patient is seated on a chair with back support and is asked to put his or her hands behind the neck, to move the head backwards, and to slowly extend the thoracic spine, using the edge of the back support as a fulcrum for the movement. For chest wall rotation exercises, the patient is asked to cross his or her arms across the chest and to slowly turn the body, as if trying to look behind one way, and then the other. For thoracic lateral flexion exercises, the patient is asked to put his or her hands behind the neck or across the chest, and to slowly bend the trunk from side to side. Thoracic mobilization exercises should be performed 5 times daily with adequate pain relief and/or wound support.

9) Discharge and home program

Patients can be discharged from physiotherapy treatment at varying points according to their recovery. A low-risk patient without postoperative complications may need only 3–4 days of physiotherapy. However, high-risk patients and those suffering from pulmonary complications may need more days of physiotherapy. Once discharged, patients should be provided with a detailed home program to stick with. They are advised to continue regular breathing exercises, to gradually increase their mobility and daily activities, and to practice an airway clearance technique whenever necessary [2]. A grad-

uated walking program can be initiated following hospital discharge, as follows. Immediately after discharge, the postoperative patient should start walking at a moderate level of effort for about 3 times a day for 5 minutes each time for a total of 15 minutes/day. Then, the patient should gradually increase the total walking time each week by 5 minutes, so that he or she becomes able to walk for a total of 30 minutes either intermittently or continuously by the first month postoperatively. The patient can be educated to self-monitor effort intensity during walking. This can be achieved by observing his or her ability to talk during walking without feeling short of breath. That is, if the patient is able to keep talking while walking without interruption in speech or feeling difficulty in breathing, this means that he or she is walking at a moderate intensity. However, if during walking, the patient feels unable to keep talking continuously (i.e., his or her speech is interrupted), and/or feels shortness of breath while talking, this means that his or her walking intensity has risen above the moderate level. At that point, the patient can slow down and pace walking with breathing to return to the targeted moderate intensity level of exercise.

10) Postoperative exercise training

After discharge from the hospital, patients may still suffer from incision pain, breathlessness, and easy fatigability, resulting in limitations in their activities of daily living and poor quality of life [5]. This can persist despite the instructions of a home program; which may be because not all patients follow postoperative home programs properly, depending on patient compliance and family or caregiver supervision, awareness, and support. This emphasizes the need for supervised exercise training programs on a treadmill or cycle ergometer in the postoperative phase. A small number of studies with controversial results have investigated the impact of exercise training after thoracic surgery. One study showed that supervised aerobic training was safe and feasible for postoperative patients, and that aerobic exercise training was associated with significant improvements in quality of life and cardiopulmonary end points [45]. However, a more recent study investigated the effect of a 12-week multidisciplinary rehabilitation program that began 1 month post-

Table 2. Summary of postoperative physiotherapy treatments

No.	Summary
1	Physiotherapy pain management: transcutaneous electrical nerve stimulation; cold therapy; and wound support
2	Positioning: early upright positioning; and modified postural drainage positions
3	Early mobilization and ambulation: as soon as the first postoperative day for clinically stable patients; implemented on a scientific basis and with strict guidelines
4	Lung expansion manoeuvres: deep breathing exercises (deep diaphragmatic breathing, thoracic expansion exercises, deep breathing coupled with arm and trunk movement, sustained maximal inspiration); incentive spirometry (flow-incentive spirometry, and volume-incentive spirometry); inspiratory muscle training
5	Airway clearance techniques: supported coughing; huffing; forced expiration technique; active cycle of breathing technique; positive expiratory pressure technique; modified postural drainage positions; and manual chest physiotherapy techniques
6	Postural correction
7	Shoulder range of motion exercises and gentle scapula mobilization exercises
8	Leg, trunk, and thoracic mobilization exercises
9	Home program
10	Postoperative exercise training

operatively on quality of life and exercise tolerance in thoracotomy patients. It showed that walking tolerance improved in those patients, but at the cost of more pain and more physical limitations. Moreover, no effect of the rehabilitation program on quality of life was seen. It was concluded that rehabilitation should be postponed for 3 to 4 months after hospital discharge [46].

Conclusion

This study aimed to clarify evidence-based physiotherapy strategies for physiotherapists in thoracic postoperative care units in order to improve their practice. High-level evidence for deciding upon optimal postoperative physiotherapy interventions, unfortunately, does not exist. Furthermore, the evidence-based rationale of some routinely used physiotherapy interventions following thoracic surgery is lacking. However, until more research is done and further information is available, physiotherapists can continue to base their practice upon the available scientific literature about the fundamentals of postoperative physiotherapy after thoracic surgery. Physiotherapists should use this evidence-based knowledge to evaluate their routine postoperative practice following thoracic surgery. Postoperative management of patients after thoracic surgery begins with a thorough initial patient assessment, so that an accurate clinical problem list can be created. This represents the first step of successful postoperative

physiotherapy management, as the physiotherapy treatment plan should be designed individually for each patient according to his or her own problems and needs. Thus, efficient postoperative physiotherapy can be applied reducing the risk for PPCs, accelerating the functional recovery of postoperative patients, and shortening the length of the hospital stay. Early upright positioning and mobilization improve functional recovery and reduce the hospital stay. Safety guidelines should be followed when mobilizing and/or walking a postoperative patient following thoracic surgery. TENS and ice packs are very effective in relieving postoperative incision pain, which can reduce the additional need for analgesia. Wound support should be provided during deep breathing exercises, coughing, FET, and arm or trunk ROM exercises. Deep breathing exercises have been traditionally used for postoperative patients as prophylactic treatment against PPCs. Certain airway clearance techniques, but not all, are more likely to be used for postoperative patients. The patient's preference for a specific physiotherapy intervention should be taken into consideration. Postural correction and education about postural awareness are important following thoracic surgery. Shoulder, scapula, trunk, and leg mobility exercises are main components of postoperative physiotherapy. A PEP device and heated humidification are useful adjuncts to postoperative airway clearance physiotherapy. Upon discharge, patients must receive advice and a detailed prescription of home program activities.

Postoperative exercise training results are not conclusive and need further investigation. Given the small number of high-quality studies investigating patients who have had thoracic surgery, further research in this field and more studies, particularly randomized controlled trials, are strongly recommended to clear up the best postoperative physiotherapy practices after thoracic surgery. A summary of postoperative physiotherapy treatments is shown in Table 2.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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