Chest Physiotherapy in Lung Resection Patients: State of the Art

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The role of chest physiotherapy in limiting postoperative pulmonary complications and in the recovery of pulmonary function and exercise capacity after lung surgery is still unclear because of the lack of conclusive, well-designed clinical trials. In this article the available literature on these topics is reviewed, and the effects of respiratory physiotherapy, instituted preoperatively or administered after surgery to patients undergoing lung resection, are commented on. The authors conclude that chest physiotherapy improves preoperative exercise capacity; this is a parameter highly predictive of postoperative pulmonary complications. Also physiotherapy administered during the immediate period after lung resection probably decreases frequency of pulmonary complications. Finally, further investigation is required for a better understanding of the effects of long-term chest physiotherapy after hospital discharge in lung resection patients.

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Although surgery-related mortality has decreased in lung cancer patients, the prevalence of postoperative complications is still high, with such problems mainly being cardiorespiratory in origin. In Europe according to the European Society of Thoracic Surgeons database, current hospital mortality after lobectomy for lung cancer is as low as 1.9%, but postoperative cardiopulmonary complications occur in up to 23% of patients after scheduled lobectomy and 32% after bilobectomy. The high frequency of cardiorespiratory complication seems reasonable because more than one-third of lobectomy cases exhibit chronic obstructive pulmonary disease (COPD) criteria, and some form of coronary disease is present in 50% of patients scheduled for pneumonectomy and 9% of all lung resection cases. Among postoperative pulmonary complications (PPCs), hospital-acquired pneumonia and atelectasis are the most frequent and are also preventable. This is the reason why perioperative chest physiotherapy is considered a must in thoracic surgical patients and in most patients undergoing major surgery, with the exception of cardiac patients, and easy access to chest physical therapy facilities are recommended in all centers practicing lung resection. Unfortunately, although sound evidence exists on the benefits of respiratory rehabilitation in COPD, the recommendation for chest physiotherapy in patients undergoing lung resection is still based on weak scientific evidence.

The aim of this article is to review the available literature on the physiological effects and clinical benefits of respiratory physiotherapy before and after lung resection, its costs, and recommended procedures.

EFFECTS OF THORACOTOMY AND LUNG RESECTON ON PULMONARY FUNCTION AND EXERCISE CAPACITY

Patient-related factors (advanced age, COPD, tobacco smoking, and increasing age) as well as...
procedure-related risk factors (type of surgical approach and anesthetic management, extent of resected lung parenchyma, duration of surgery) have to be considered as variables predictive of postoperative cardiac and respiratory complications. Lung resection is followed by some degree of oxidative damage, which is less pronounced in video-assisted procedures, and deterioration in right ventricular hemodynamics that could be related to the development of cardiopulmonary complications. Chest physiotherapy is not expected to have a favorable influence on these or cardiac complications; therefore, we are paying attention to the changes in pulmonary volumes, diffusing capacity of the lung for carbon monoxide (DLCO), and exercise capacity and their relation to the development of PPC.

**EARLY POSTOPERATIVE CHANGES IN LUNG VOLUMES, DLCO, AND EXERCISE CAPACITY**

In the immediate period after pulmonary lobectomy, an important decrease of forced expiratory volume in one second (FEV₁) can be seen (Fig. 1), slowly recovering during the first 6 postoperative days but never reaching the estimated post-resectional FEV₁. FEV₁ decrease is caused not only by the removal of the lung parenchyma but also by impairment of the diaphragm and chest wall motility, leading to an increase of pulmonary residual volume that is strongly associated with postoperative morbidity. Immediate postoperative FEV₁ decrease is lower in COPD patients, who demonstrate an early volume reduction effect that becomes more evident several months after surgery.

DLCO is one of the most valuable parameters in risk assessment for pulmonary resection, and the relevance of its routine measurement has been recently emphasized in all patients, but more importantly in cases undergoing induction chemotherapy. Studies on early postoperative DLCO trends are scant in the medical literature, but some data have been published demonstrating that on hospital discharge, observed DLCO values were 12% lower than predicted after lobectomy and recovered after 3 months.

In the immediate period after major lung resection, exercise desaturation can be demonstrated in around 15% of patients, compromising further recovery and representing a risk for delayed complications. Also, exercise capacity on hospital discharge, measured with the stair-climbing test, shows an important reduction with respect to the preoperative test that is directly related to patient age. The initial drop of exercise capacity after lung resection seems to be a consequence of both circulatory and ventilatory limitations. Once the injury to the chest has been healed, improvement in ventilatory limitation is followed by improvement in exercise capacity.

![Figure 1. Comparison of preoperative FEV₁, ppo FEV₁, and measured postoperative FEV₁ on postoperative days 1-6. (Reprinted with permission from Varela et al. 14)](image-url)
LONG-TERM CONSEQUENCES OF LUNG RESECTION ON PULMONARY FUNCTION, EXERCISE CAPACITY, AND QUALITY OF LIFE

Lung resection will result in variation to functional respiratory capacity, exercise capacity, and quality of life (QOL), depending on the extent of resection. The extent of these changes cannot be predicted immediately after lung resection and will vary depending on the individual and timing of measurement. Interestingly, the changes occurring after lung resection in patients with COPD might not follow the usual pattern.

Functional Changes 1 Month After Surgery

A recent prospective study\(^{22}\) found that 1 month after hospital discharge there were no functional differences in FEV\(_1\) or DLCO of patients who had undergone lobectomy when compared with measures taken in the immediate postoperative period (lower than the estimated predicted postoperative [ppo] values by 11% and 12%, respectively). The FEV\(_1\) and DLCO levels also remained unchanged after 1 month in patients who had undergone pneumonectomy. Another prospective study\(^{26}\) demonstrated that 1 month after lung resection the daily ambulatory activity of patients (measured by using a pedometer) was globally decreased compared with preoperative values, except in very active patients who usually walked >12,500 steps/day. After-lobectomy patients showed a 25% mean decrease in ambulatory activity, with aerobic activity preserved. In pneumonectomy patients daily total activity was reduced up to 50%, and aerobic activity almost disappeared (Fig. 2). Recently, a prospective study\(^{27}\) attempted to identify factors related to early restoration of exercise capacity after lung resection; all respiratory parameters were decreased below baseline 2 weeks after surgery, except for the FEV\(_1\)/forced vital capacity (FVC) ratio, and all factors, including maximal oxygen consumption (VO\(_2\)max), improved significantly toward baseline by 1 month after surgery. After an extensive and detailed analysis of the possible preoperative and intraoperative factors predictive of early recovery, only limited thoracotomy and avoidance of extensive mediastinal lymph node dissection were identified. Prospective QOL assessment by using different scales\(^{28}\) identified that lung cancer patients undergoing lung resection demonstrated lower preoperative QOL scores than the general population, and after surgery, physical scales showed significant reduction in QOL 30 days after resection, whereas mental scales remained unchanged. There was also no difference in QOL between high-risk and younger, fitter patients. They concluded that QOL measures had poor correlation with functional parameters (FEV\(_1\), DLCO, and exercise test performance), and therefore specific instruments for QOL measurement should be used.

Changes 3 to 6 Months After Resection

Functional and exercise capacity parameters 3-6 months after surgery have been extensively studied; a prospective evaluation of patients undergoing lung resection (n = 47)\(^{29}\) demonstrated a significant decrease in FEV\(_1\) and maximal workload capacity 29-200 days after surgery, with more important differences observed in the pneumonectomy group. Another interesting finding of this article was that lower limb discomfort made an important contribution to exercise limitation, and dyspnea was rarely the only limiting factor at maximal exercise. Subsequently, Bolliger et al\(^{30}\) demonstrated that conventional pulmonary function tests alone overestimated the decrease in functional capacity after surgery, and that after pneumonectomy, functional parameters were significantly lower when compared with preoperative values, not recovering to baseline until 6 months after surgery. It was also found that dyspnea was the most significant limiting factor to exercise; this was due to significantly smaller breathing reserve and also the lower arterial oxygen tension (PaO\(_2\)) at peak exercise associated with reduction in area available for gas exchange. These factors are probably responsible for a permanent reduction in exercise capacity of 20%. A retrospective study\(^{31}\) confirmed most of these conclusions and found no differences in recovery of functional and exercise ca-
pacity parameters except for a significant difference in recovery of FEV$_1$ between left and right pneumonectomy.

The imprecision of the prediction of postoperative function by using ppo values has been demonstrated 3 months after resection$^{22}$; when comparing observed versus estimated ppo FEV$_1$ and ppo DLCO values, it has been shown that ppo FEV$_1$ predicted more poorly at the lower level of ppo FEV$_1$, and ppo DLCO was constantly lower than the observed values at every ppo DLCO level. VO$_2$max value can also be estimated, but recovery of VO$_2$max seems to be directly associated with the preoperative VO$_2$max and observed postoperative FEV$_1$ and DLCO and inversely related to age and body mass index.$^{32}$ Six months after surgery QOL is still affected, with pain and functional impairment important negative factors in this population.$^{33}$ In this study poor scores in almost all subscales were related to postoperative DLCO, the lower the DLCO, the poorer the QOL at 6 months after surgery. It is interesting that over time, preoperative chemoradiation, extent of resection, postoperative complications, and adjuvant therapy lost importance and did not adversely affect functional health status or QOL 6 months after surgery.

**Long-Term Evolution**

*(6 Months to 2 Years After Lung Surgery)*

A prospective study$^{34}$ analyzing the recovery of functional variables in lung cancer patients receiving induction chemoradiotherapy (from the preoperative period up to 1 year after surgery) found a significant decrease (22.8%) of DLCO 4 weeks after induction and before surgery and then showed a progressive increment of all the observed parameters from 1 month up to 1 year after surgery, with DLCO presenting a significant increase. The population of this study was classified according to age, and a significant decrease in vital capacity, FEV$_1$, total lung capacity, and residual volume was seen in those older than 65 years of age, but not in the younger group. Over the longer-term, observed recovery period exercise capacity can reach up to 95% of the preoperative value, and the anaerobic threshold per square meter of body surface area is restored to the preoperative level in lobectomy patients$^{35}$ 1 year after resection. An American group$^{36}$ studied the influence of smoking habits before surgery and found smoking cessation immediately before surgery had no influence on not only frequency of PPCs but also long-term recovery of respiratory parameters.

QOL might continue to be impaired 24 months after lung resection.$^{37}$ Most indicators return close to baseline; however, physical function, pain, and dyspnea might remain significantly impaired, especially after pneumonectomy when compared with lobectomy or bilobectomy. Probably the most interesting finding of this study is that after major lung resection there is a greater impact on QOL than after other types of major surgery (pancreaticoduodenectomy or esophageal resection) where there is an immediate decrease in QOL, followed by a slow period of recovery to preoperative levels.

**SPECIFIC PROBLEMS IN PATIENTS WITH COPD**

There is increasing evidence that patients with COPD recover in a different way. In a prospective series of patients with COPD undergoing lobectomy or bilobectomy$^{38}$ with a mean preoperative FEV$_1$ of 53%, DLCO 65%, and VO$_2$max of 17.8 ml/kg/min, observed postoperative FEV$_1$ and DLCO 3 months after surgery were not significantly changed; meanwhile, VO$_2$max showed a significant decrease that was not predicted by the functional variables. In another retrospective study$^{39}$ with a larger number of cases all characterized as stage II Global Initiative for Obstructive Lung Disease (GOLD),$^{2}$ PAO$_2$ and PACO$_2$ showed no significant changes over time, and functional parameters significantly improved to almost baseline 3 months after surgery, remaining stable at 6 months. A multicenter retrospective study$^{40}$ that analyzed the functional effect of lobectomy 3-15 months after lobectomy in a series of patients, including 66% with COPD, concluded that those with a preoperative FEV$_1$ >80% demonstrated a slight postoperative decrease in FEV$_1$/FVC ratio and significantly decreased FEV$_1$; when preoperative FEV$_1$ was <65%, both parameters significantly increased. In this series patients with mild to severe COPD have a better longer-term preservation of pulmonary function after lobectomy than healthy patients. These results were confirmed by a prospective analysis$^{41}$ concluding that patients with moderate to severe COPD show a smaller decrease in FEV$_1$ and VO$_2$max 6 months to 1 year after lobectomy. In another interesting study comparing the influence of the site of the lobectomy and the presence of COPD on pulmonary function parameters up to 6 months after resection,$^{42}$ the percentage of variation of FEV$_1$ and DLCO was significantly higher in patients with COPD 6 months after surgery. The authors also concluded that in patients without COPD, right upper lobectomy had a more negative impact in functional...
parameters than lower lobectomy procedures. A different group\(^5\)^ found that a lower lobectomy in patients with COPD can reduce decrease in postoperative function parameters by 15%. Furthermore, it has been observed\(^19\) that segmentectomy (for stage I non-small cell lung cancer [NSCLC]) offers no functional advantage for patients with normal spirometry. This finding can be attributable to the lung volume-reduction effect of the lobectomy procedure over that of segmentectomy. The functional loss of segmentectomy and lobectomy and the effects on the residual lung have been measured by different authors, finding controversial results that are out of the scope of this review.\(^{44-46}\) Lower FEV\(_1\) impairment 1 year after pneumonectomy has been described in patients with major preoperative airway obstruction.\(^{47}\) It is thought that resection of a certain amount of nonfunctional parenchyma and the associated mediastinal shift produce an improvement of the chest cavity conditions, acting as lung volume-reduction effect.

CHEST PHYSIOTHERAPY FOR PATIENTS UNDERGOING LUNG RESECTION

Chest Physiotherapy for Preoperative Conditioning

Although respiratory rehabilitation relieves dyspnea and improves disease control in COPD patients,\(^9\) there is no strong evidence for the effects of such preoperative training on fitness in patients undergoing lung resection.

As published in a meta-analysis a few years ago, impairment of preoperative exercise capacity is the best predictor of cardiorespiratory complications after lung resection.\(^{48}\) Thus, it could be hypothesized that by improving exercise capacity, the rate of postoperative cardiorespiratory adverse events would be decreased. Preoperative physiotherapy improves exercise capacity and preserves pulmonary function after lung resection,\(^{49,50}\) but whether this is followed by a decrease in the rate of postoperative adverse events is unknown. In fact, it has been published that preoperative exercise training does not improve postoperative QOL after lung resection, and significant declines in QOL after surgery were mainly related to cardiorespiratory problems.\(^{51}\) In a recent pilot study\(^{52}\) an 8-week inpatient respiratory rehabilitation program for patients with severely impaired pulmonary function significantly improved functional exercise capacity and peak exercise capacity. Similarly, in an observational study on lung cancer patients undergoing lung resection, Cesario et al\(^{53}\) showed that a shorter (4-week) period of inpatient pulmonary rehabilitation significantly improved respiratory function (FEV\(_1\), FVC, and peak expiratory flow) and exercise capacity (distance in 6-minute walking test) when compared with a control group.

A preoperative training period for functionally nonoperable patients has been recommended\(^54\) after a study that demonstrated that 80% of cases previously considered unfit for surgery were rescued and underwent surgery successfully. However, these conclusions might be questionable because functional preoperative criteria in this investigation did not include exercise tests or DLCO; thus many of the patients might have been considered operable in other institutions.

Respiratory Physiotherapy in the Immediate Postoperative Period

The principles of atelectasis management require that retained secretions are removed from the airways and sufficient stretch is provided to the lung tissue for parenchymal re-expansion.\(^{55}\) The ideal deep breathing maneuver for recruiting collapsed alveoli was originally described by Bartlett et al,\(^{56}\) who found that a large inflating volume and transpulmonary pressure gradient should be maintained for several seconds. Both deep breathing exercises and sputum clearance techniques are important because sputum clearance decreases airway narrowing and improves lung re-expansion, and lung re-expansion aids secretion clearance via enhanced expiratory flow. To prevent PPCs, physiological reasoning indicates that postoperative physiotherapy regimens for patients undergoing major thoracic surgery should comprise a combination of deep breathing exercises and sputum clearance techniques as well as early mobilization and exercise. Postoperative physiotherapy is recommended in all thoracic surgical centers\(^8\) but might be of increasing importance because new European and British surgical guidelines\(^5,57\) have recently adopted more permissive inclusion criteria for the process of selecting patients for surgery (lower postoperative pulmonary function), and therefore it is possible that the incidence of PPC might increase in the future.

Widespread postoperative physiotherapy provision after open thoracotomy for lung surgery has been demonstrated in recent surveys of thoracic surgery centers in both the United Kingdom\(^58\) and Australia and New Zealand.\(^59\) Physiotherapy provision observed in the United Kingdom was in line with European recommendations,\(^5\) and postoperative treatments generally appear to include deep breathing exercises and early mobilization, but variability was observed in the use of adjuncts such as incentive
CHEST PHYSIOTHERAPY IN LUNG RESECTION PATIENTS

spirometry and positive expiratory pressure (PEP) devices.

A cross-sectional study with historical controls evaluated the cost-effectiveness of a physiotherapy regimen, including respiratory physiotherapy, early mobility, and exercise after lobectomy for lung cancer patients (n = 639). Overall incidence of atelectasis (1.7% versus 7.7%), length of stay (3.73 versus 8.33 days), and hospital costs were significantly lower in those receiving the intensive intervention (total cost saving of €89,523.50). The authors have since published a larger, quasi-experimental study (n = 784) (excluding video-assisted thoracic surgery cases) demonstrating with more robust methodology that implementing the intensive physiotherapy regimen previously described reduced overall pulmonary morbidity. A randomized clinical trial was not considered necessary because of previous atelectasis rate reduction. Frequency of pulmonary morbidity (pulmonary atelectasis and pneumonia) was 15.5% before the intensive physiotherapy program and 4.7% after (P = 0.000). Propensity scoring identified 359 pairs of patients and identified 55 cases with PPC before implementation of physiotherapy and only 15 after (P = 0.000). The logistic model demonstrated that physiotherapy had reduced risk of PPC (P = 0.000).

In a parallel single-blind randomized controlled trial (n = 76) targeted postoperative respiratory physiotherapy after thoracotomy and lung resection in addition to early mobilization, pain relief, and a standardized clinical pathway failed to demonstrate benefit, although frequency of PPC was generally very low; PPC only developed in 4.8% of intervention group subjects (n = 2) and 2.9% (n = 1) of control group subjects (P = 1.00). Because of the small patient numbers in this study, further studies were called for to clarify the necessity for targeted postoperative respiratory physiotherapy, especially in higher-risk patients, because a preoperative FEV1 <1.5 L or less (P = 0.005) and a history of COPD (P = 0.008) were associated with a greater number of positive PPC criteria.

In another study of patients after thoracotomy and lung resection (n = 53), the provision of postoperative exercise (a strength and mobility training program in addition to respiratory physiotherapy and mobilization) had no effect on frequency of postoperative complication, with 7.4% in the intervention group (n = 2) and 11.5% in the control group (n = 3), and there was no significant difference in mean length of stay, although this was lower by 2 days (8.9 versus 11.0 days) in the intervention group. In terms of physical recovery, the strength training prevented significant fall in quadriceps strength (P = 0.04); however, there was no benefit of treatment on QOL or 6-minute walking distance, which returned to baseline by 12 weeks after surgery regardless of intervention. In an additional randomized controlled trial (n = 18) examining physiotherapy and the recovery of exercise tolerance after lung resection, patients received preoperative instruction and early mobilization. Then from postoperative day 2 the mobilization distance of intervention group subjects was increased by an increment of 150% at every physiotherapy session, and exercise continued after hospital discharge. An improvement in exercise capacity and lung function was seen in all patients 4 weeks after surgery; however, patients who had received incremental physiotherapy demonstrated a significantly enhanced recovery (P < 0.001).

Literature review for incentive spirometry after thoracotomy reveals few studies with generally small numbers. When combined with inspiratory muscle training, incentive spirometry has been demonstrated to contribute to a faster postoperative recovery of lung function in patients undergoing lung resection, although there is no documented benefit of incentive spirometry in terms of reduction in PPC or length of stay in thoracic or other surgical populations. Similarly, evidence for PEP therapy is also lacking, with 2 older, comparative studies (which include patients after thoracotomy and pulmonary resection) of questionable methodology that reveal little benefit. In these studies, oscillating PEP (FLUTTER VRP1 Mucus Clearance Device; Scandipharm Inc, France) was compared with “chest physiotherapy,” and the effects of continuous positive airway pressure, PEP mask (Astra Meditech, Denmark), and PEP mask with additional inspiratory resistance were compared. Postoperative activity after thoracotomy and lung resection is very limited, with an observed mean daily count of 333 steps on postoperative days 2 and 3 and possibly adverse associated outcomes. Fast-track clinical pathways encouraging early mobilization and incorporating postoperative physical therapy have been shown to decrease the prevalence of adverse outcomes and hospital costs after thoracic surgery and are therefore a common component of postoperative care. Increased provision of physiotherapy and aggressive ambulation in high-risk thoracotomy patients prone to failing fast-tracking protocols (predicted FEV1 <45%) resulted in reduced length of stay from 6.2 to 4.3 days (P = 0.008).
Physiotherapists have had limited high-quality evidence on which to base postoperative treatment, although some more recently published evidence suggests that this type of therapy, as recommended in European guidelines, is beneficial. Personal experience has been cited as an influential factor in guiding postoperative practice in the recent United Kingdom survey, and because of the limited evidence available, this is unsurprising. Further research to identify exactly what interventions are most beneficial and in which patients (on the basis of risk) remains necessary. The study of high-risk individuals is of particular importance with the publication of recent guidelines, but a standardized definition of both PPC (treatable by physiotherapy) and “high risk” need consideration to improve quality of future research. Work has begun on this in 2 recent studies, with PPC recognition after thoracotomy and lung resection and independent factors for the development of PPC amenable to physiotherapy after thoracotomy and lung resection explored.

### Table 1. Recommended Physiotherapy for Lung Resection Patients in the Authors’ Settings

<table>
<thead>
<tr>
<th>Period</th>
<th>Patient Status</th>
<th>Recommendation*</th>
<th>Time and Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous to hospital admission</td>
<td>Normal healthy individual</td>
<td>No specific training needed. Information on postoperative expectations and exercises</td>
<td>Outpatient consultation</td>
</tr>
<tr>
<td></td>
<td>Mild to moderate COPD</td>
<td>Teaching inspiratory muscle training and incentive spirometry</td>
<td>1 wk before admission. Physiotherapy facilities</td>
</tr>
<tr>
<td></td>
<td>Decreased exercise capacity (\text{VO}_2\text{max}), High-risk patient</td>
<td>Teaching inspiratory muscle training and incentive spirometry Improving exercise capacity and motility.</td>
<td>4 wk. Physiotherapy facilities, no hospital admission recommended.</td>
</tr>
<tr>
<td></td>
<td>Moderate to severe hypersecretory patients</td>
<td>Add preoperative instruction for airway clearance to the above recommendations.</td>
<td>2 wk. Physiotherapy facilities, no hospital admission recommended.</td>
</tr>
<tr>
<td>Hospital admission for surgery</td>
<td>Normal healthy individual</td>
<td>Standard nursing care including early and progressive mobilization.</td>
<td>Starting postoperative day 1, up to discharge. Surgical ward.</td>
</tr>
<tr>
<td></td>
<td>Mild to moderate COPD</td>
<td>Addition of incentive spirometry by nursing staff under physiotherapist’s supervision</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decreased exercise capacity (\text{VO}_2\text{max}), High-risk patient</td>
<td>Mobilization, higher intensity exercise, and incentive spirometry by specifically trained respiratory therapists</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moderate to severe hypersecretory patients</td>
<td>Addition of airway clearance under physiotherapist’s supervision. Close monitoring of sputum retention.</td>
<td></td>
</tr>
<tr>
<td>After discharge</td>
<td>Normal healthy individual and lobectomy or sublobar resection</td>
<td>Written exercise planning</td>
<td>No specific consultation needed</td>
</tr>
<tr>
<td></td>
<td>Mild to moderate COPD</td>
<td>Inspiratory muscle training and improving exercise capacity and mobility</td>
<td>Physiotherapy facilities. 4-8 wk.</td>
</tr>
<tr>
<td></td>
<td>Decreased exercise capacity (\text{VO}_2\text{max}), High-risk or pneumonectomy patient</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moderate to severe hypersecretory patients</td>
<td>Instructions to maintain airway clearance</td>
<td>No specific consultation needed</td>
</tr>
</tbody>
</table>

*Recommendations are based on expert consensus because of lack of sound scientific evidence.

Postoperative Respiratory Rehabilitation After Lung Resection

Exercise intervention and pulmonary rehabilitation for patients with NSCLC also appear to be safe after surgery. Some small and preliminary studies have shown positive benefits on exercise capacity, symptoms, and some QOL domains, but there is also information on the increase of urinary measures of oxi-
dative stress caused by aerobic training in postsurgical NSCLC patients. Further research is required to establish the effect of exercise after hospital discharge in lung cancer patients, the optimum type of exercise training, and the optimum settings for the treatment.

**FUTURE PROSPECTS**

In times of economic crisis around the world and cost containment, the cost-effective balance of clinical practice has to be demonstrated. It has been published that chest physiotherapy is frequently inappropriately provided, and in a single institutional report, Selledy et al demonstrated that the basic respiratory care procedures delivered were not indicated in 1 of 5 patients, whereas patients were not receiving care that was indicated in almost 12% of cases.

To reduce the cost of inappropriately delivered respiratory care, measures have been advocated. The first is proper selection of cases via preoperative respiratory care assessment protocols that are based on widely accepted clinical practice guidelines. Implementing such guidelines has improved the appropriateness of chest physiotherapy prescription among hospitalized patients without impairing outcome. Most of the current recommendations on perioperative physiotherapy for patients undergoing lung resection lack scientific evidence and have to be considered as expert consensus. In Table 1 we present our current consensus on the basis of physiology and our previous experience.

Another suggestion to reduce the cost of chest physiotherapy, although not confirmed by all authors, is that therapists themselves are responsible for chest physiotherapy prescription and delivery instead of physician-directed respiratory care.

Work is still needed to design internationally valid respiratory physical therapy clinical practice guidelines for patients before and after thoracic surgery, where robust criteria can be found directing which patients require treatment and with which interventions.

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