RESEARCH ARTICLE

Short-term in-hospital Pulmonary Rehabilitation versus perioperative Short-term in-hospital Chest Therapy before lung cancer resection: a randomized controlled trial

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Author Contributions

G.B. and L.P. conceived of the presented idea. A.D.I. and M.C. developed the theory and performed the computations. A.D.I. verified the analytical methods. V.L. encouraged C.D'A. to investigate and supervised the findings of this work. All authors discussed the results and contributed to the final manuscript.

Abstract

Objective: The aim of this study is to evaluate the effect of pulmonary resection and perioperative Short-term in-hospital Pulmonary Rehabilitation (SPR) versus perioperative Short-term in-hospital Chest Therapy (SCT) on the functional capacity and postoperative morbidity of patients with poor lung function.

Design: Single-blind randomized control trial.

Setting: Thoracic surgery department at "Santo Spirito" Civil Hospital – Pescara (Italy)

Participants: Patients undergoing elective lung cancer resection (N=30).

Interventions: Patients were randomly assigned to receive daily SPR (pulmonary rehabilitation, self-management and endurance training) versus daily SCT (breathing exercises). Both groups received early postoperative rehabilitation.

Outcome Measures: Pulmonary functional parameters assessed at baseline and prior to surgery (phase 1), hospital length of stay and pulmonary complications assessed after lung cancer resection (phase 2).

Results: Thirty patients were randomly assigned to the SPR arm (15) and SCT arm (15).

During phase 1 evaluation: Forced Vital Capacity (FVC) (p 0,0001); percentage of predicted FVC (p 0,0002); Forced Expiratory Volume in the first second (FEV1) (p 0,0001); percentage of predicted FEV1 (p 0,0001). Percentage of change from baseline to prior to surgery in two groups SPR: FVC (18%); percentage of predicted FVC (20%); FEV1 (29%); percentage of predicted FEV1 (25%). SCT: FVC (10%); percentage of predicted FVC (11%); FEV1 (9%); percentage of predicted FEV1 (9%).

Phase 2: the SPR group SPR group was in a favorable clinical condition compared with the SCT arm and the SPR group had a shorter length of postoperative stay (15 ± 5 vs 17 ±5, respectively).

Conclusions: Despite poor lung function, these findings suggest that a feasible perioperative SPR before lung cancer resection improves preoperative functional capacity and decreases the postoperative respiratory morbidity.

Key words: Lung cancer, Pulmonary Rehabilitation, Chest Therapy

1. Introduction

Lung cancer is the third most commonly diagnosed cancer and it is the leading cause of cancer death worldwide [1]. Non-small cell cancer (NSCLC) accounts for the majority of cases of lung cancer [2]. Despite improvements in the medical treatment over recent decades, the five-year lung cancer survival rate remains poor [1-2] . Surgical removal remains the best option for patients with Stage I and II of non-small cell lung cancer (NSCLC) and for selected patients with locally advanced disease (Stage IIIA) [3].These patients may display an increased risk of both immediate perioperative complications and long-term disability following surgical resection of lung disease. Cigarette smoking also predisposes these patients to other comorbid conditions which further increase perioperative risk. Consequently, in considering whether a patient should undergo curative surgical resection of lung cancer, the possible perioperative risk must be balanced. Identification of patients at an elevated risk by the preoperative assessment provides a basis for developing interventions to reduce the risk of perioperative complications and long-term disability. Spirometry, in particular FEV1 and predicted postoperative (PPO) FEV1, has traditionally represented the key test in the functional workup of surgical candidates with lung cancer. A reduced FEV1 or PPO FEV1 has been associated with increased respiratory morbidity and mortality rates. Berry et al [4] and Ferguson et al [5] found that FEV1 was an independent predictor of respiratory complications and cardiovascular complications. Besides, Licker et al [6] confirmed that the best cutoff value of FEV1 for predicting respiratory complications was 60% [7]. For patients who are candidates for surgery there is a high risk of developing postoperative pulmonary complications (PPCs) [8]. PPCs are common after abdominal, cardiac or thoracic surgery and they are associated with high rates of mortality, high hospital costs and prolonged length of hospital stay [9]. Furthermore, coexisting Chronic Obstructive Pulmonary Disease (COPD) is associated with increased postoperative morbidity and mortality [10-11]. Currently, there is no standardized definition for PPCs. Problems usually considered PPCs include: pneumonia, atelectasis, acute respiratory failure and need for reintubation, bronchospasm, pneumothorax and prolonged air leaks. To reduce the incidence of PPCs, several strategies and interventions have been developed such as screening for and modification of risk factors, optimization of preoperative status, patient's education and postoperative pulmonary care [12]. Furthermore, the incidence of PPCs is higher in patients treated with an open thoracotomy approach than minimally invasive Video-Assisted Thoracic Surgery (VATS) [13]. Process of enhancing in surgical technique and introduction of VATS has been associated with beneficial postoperative results. Endoh et al demonstrated that PPCs in lung function is lower in subjects undergoing VATS compared with subjects treated with an open surgical approach [14]. Indeed, one of the advantages of limited pulmonary resection is in part the ability to preserve a greater amount of lung volume and reducing the risk of physiological impairment after surgery [15]. Improvements in early diagnosis and surgical techniques have increased post-surgery survival rates [9]. Moreover, physiotherapy has been regularly utilized in both pre- and postoperative setting [7] with the aim of preventing or reducing PPCs [16] and it has recently been recommended by the European Respiratory Society, the European Society of Thoracic Surgeons and the American College of Chest Physicians for providing functional benefits [17]. The goals of physiotherapy include decreasing symptoms, maximizing exercise performance, promoting autonomy, increasing participation in daily activities and influencing long-term health-enhancing behavior change [18-19]. Indeed, a proposed but unproven benefit of rehabilitation in surgical patients include improved tolerance of the surgical procedure, increased ability to clear secretions and decreased work of breathing as a result of improvement in diaphragmatic functions [20]. In addition, patients receiving in-hospital physiotherapy showed increased level of physical activity during the first days after lung cancer surgery, compared to untreated in-hospital individuals. In this way, we want to emphasize the relevance of rehabilitation during the hospitalization by creating a short but feasible protocol for patients' candidate to thorax surgery [21]. Unfortunately, there have been few studies investigating the efficacy of physiotherapy and treatments [22] in lung cancer resection procedures and, thus, limited evidence on which to base treatment recommendations [23].

2. Materials and Methods

2.1 Patients

Of 220 pulmonary resections performed for lung cancer during this time, we identified 30 patients (14%) with FEV1 less than 60% [24] who underwent VATS pulmonary resection. All patients undergoing elective thoracic surgery due to suspected or confirmed lung cancer at the Department of Thoracic Surgery at "Santo Spirito" Civil Hospital – Pescara (Italy), during the time period January 2017 - December 2017, were eligible for the study. The patients had to be able to participate in required tests, and to read and understand the native language. Patients who had undergone previous thoracic surgery were not included. All the patients gave informed written consent to the procedure, which was in accordance with the latest revision of the Helsinki Declaration for Human Research and with the procedures concerning the privacy protection of subjects participating in biomedical research, as defined by ISO 9001 standards for research and experimentation.

2.2 Demographic and Clinical Data

Demographics, risk factors, smoking history, pulmonary function tests, and clinical course including respiratory and no respiratory complications were documented. A total of 30 patients during the study period fit the inclusion criteria for this study. The ages of the patients ranged from 62 to 88 years, with a mean of 71 years. The Demographic and Clinical Data scheme is depicted in table 1.

Table 1: Baseline characteristic of patients enrolled in the two study group: Short-term in-hospital Chest Therapy (SCT), and Short-term in-hospital Pulmonary Rehabilitation (SPR). Values were reported as mean±SD, and as number and percent.

	SCT	**SPR**	
	15	15	*p*-value
Age (yy)	69.27±1.74	68.20±3.92	0.81
Gender, (male)	9 (60.0)	10 (66.7)	0.71
Current smoker	12 (80.0)	9 (60.0)	0.43
Heart diseases	5 (33.3)	6 (40.0)	0.71
COPD	9 (60.0)	9 (60.0)	0.99
Histological cancer (adenocarcinoma)	8 (53.3)	7 (46.7)	0.72
FEV1 *	1.27±0.08	1.16±0.09	0.35
FEV1 (% of predicted)	52.13±1.41	49.00±1.79	0.18
FVC **	2.17±0.12	2.01±0.17	0.45
FVC (% of predicted)	69.07±3.11	65.00±3.02	0.36

* FEV1: forced expiratory volume in the first second;
** FVC: forced vital capacity;

2.3 Randomization

Single-blind randomized control trial was conducted. Patients were randomly allocated (according to hospital record number) to control or study group. Study Group (n.15) received daily perioperative Short-term in-hospital Pulmonary Rehabilitation (SPR) and Control Group (n.15) daily perioperative Short-term in-hospital Chest Therapy (SCT). The SPR protocol and the SCT protocol started on the day of admission in hospital. Both groups received a mean of one week of treatment and early postoperative rehabilitation. On the day of admission, a study-responsible physiotherapist informed patients about the study and asked them to participate.

2.4 Intervention

Inclusion criteria included diagnosis of early stage disease of NSCLC, VATS lung resection and patients with FEV1 less than 60% preoperatively which gives a high risk of perioperative mortality and respiratory morbidity [25 -26] (figure1). The advantages of limited pulmonary resection are in part the ability to preserve a greater amount of lung volume and reducing the risk of physiological impairment after surgery [15]. In addition, preparation to intervention for all patients included optimization of the pharmacological treatment and smoking cessation. The SPR group received brief individual preoperative physiotherapy information regarding SPR protocol and, during hospital stay, daily post-operative physiotherapy. The SPR protocol included: lower extremity endurance training by the patient on a treadmill one times a day, according to the patient's tolerance to exercise speed and time. The intensity of endurance training ranged from 50% to 60% of baseline heart rate. During the walking exercise a warm-up and cool-down were included. Oxygen saturation, heart rate and Borg scale of patients were monitored during exercise. The method for calculating heart rate (working heart rate) during exercise according to the "Karvonen method" is as follows: '0.65– 0.8 × [220-age (year)]' formula [27]. The duration was promoted up to 30 minutes during the timing of the program, with increments of 10 minutes each day. According to the patient's tolerance, walking was encouraged into the Thoracic ward throughout the day. Under the supervision of a physiotherapist, patients were educated to practice daily Yogic Breathing. Treatment consisted of inhalation by first expanding the abdomen and then the chest using one slow and uninterrupted movement and followed by a passively exhalation. Breathing cycle was timed to 12 seconds (s) and the timeline of breathing pattern was as follows: 4 s of inspiration, 4 s of air retention, and 8 s of expiration. The timing was increased based on the needs of the patients. The procedure was separated into three sets of 10 yoga breaths each, interspersed with 30–60 s pauses between each set [28]. Patients were trained to use volume-oriented respiratory device (Coach 2 ® Incentive Spirometer 4000 ml, Smiths Medical). In order to create an intensive but not stressful training, patients were coached to repeat throughout the day, the inhalation with respiratory device and yogic breathing 10 times every hour (from 9.00 am to 9.00 pm) that they should note in a specific diary gave by the physiotherapist. The SCT group received brief individual preoperative physiotherapy information regarding SCT protocol and, during hospital stay, daily post-operative physiotherapy. The protocol for the group receiving SCT consisted of instructions about the techniques for lung expansion: sustained maximal inspiration, fractional inspiration with or without a pause for inspiration hold, diaphragmatic movement and pursed lips. They were educated to use flow-based incentive spirometry device (Respiflo ™ Respiratory Exerciser, Covidien ™) without specific timing of repetition. All patients received, during hospital stay, daily postoperative physiotherapy treatment consisting of individually adapted mobilization and ambulation (day of surgery: sitting up in bed or in a chair; from the first postoperative day: progressive ambulation on the ward (approximately 100 m). Subsequently, the patients were instructed on coughing/huffing techniques and were motivated to walk as much as possible during the day, with or without a walking aid, according to their needs. Besides, they performed exercises for range of motion of shoulder due to the position during surgery. Both groups were treated the same way by the staff regarding pain management and nursing. All patients completed the protocol with any adverse events.

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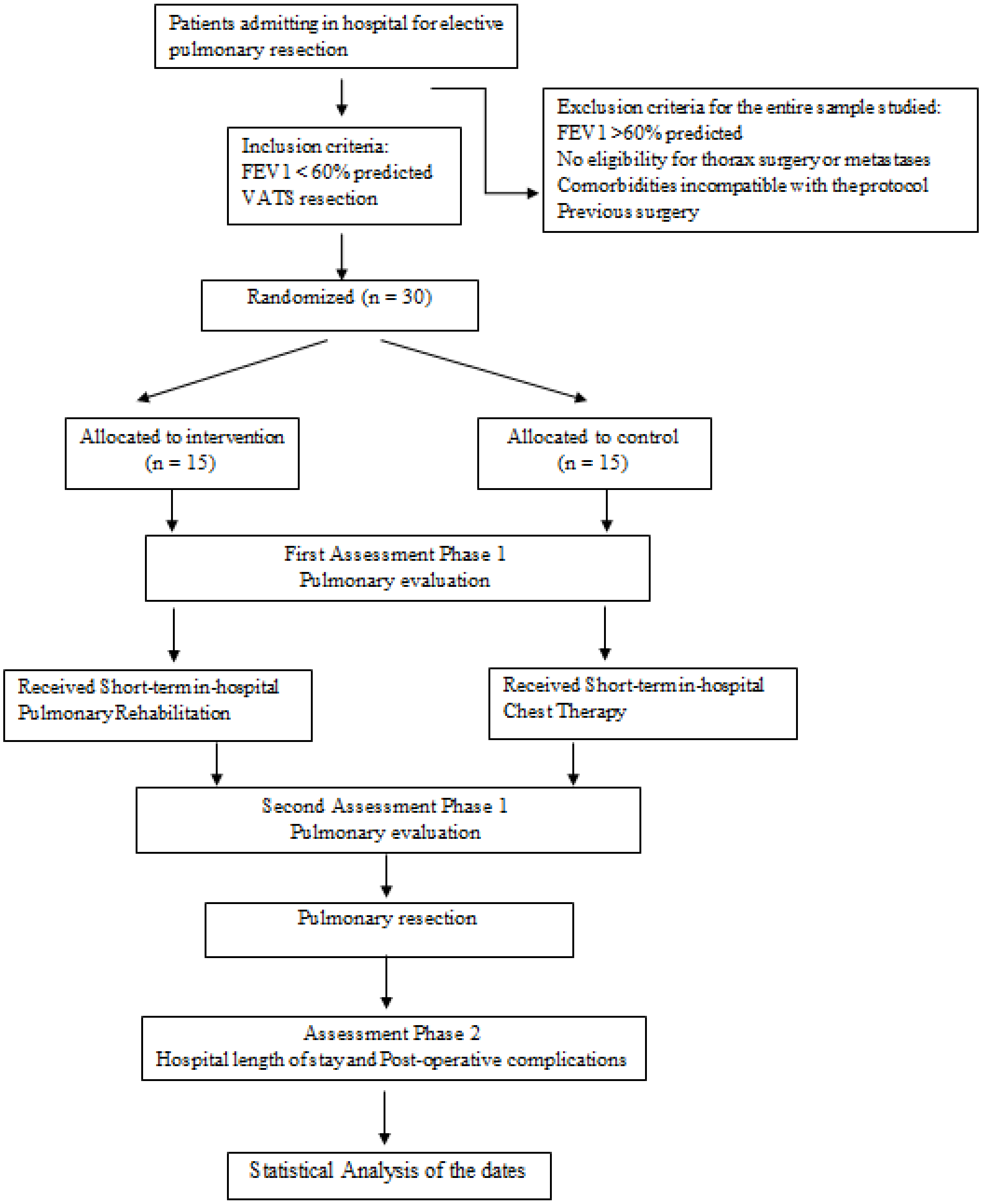

Figure 1: Design and flow of participants through the trial

2.5 Outcome measures

Endpoints of this study were evaluated in 2 phases: Pulmonary functional parameters assessed at baseline and prior to surgery (phase 1), and PPCs assessed after lung cancer resection (phase 2). Phase 1: Pulmonary function was tested using a Vyntus SPIRO (Care Fusion). The parameters taken into account were FVC – the maximum amount of air that can be exhaled when blowing out as fast as possible and FEV1 – the amount of air exhaled in 1 s. Prior to performing spirometry, the patient's identification should be checked, their height without shoes and weight measured. Then, their age, sex and race should be recorded. For FVC and FEV1, the patient takes a deep breath in, as deep as possible, and blows out as hard and as fast as possible and keeps going until there is no air left. A number of criteria for acceptable quality spirometry have been published. Guidelines from the American Thoracic Society (ATS)/European Respiratory Society (ERS) Task Force suggest that three acceptable maneuvers should be achieved and the best of the three should be considered [29]. All measurements were performed by a physiotherapist, blinded to group allocation.

Phase 2: Hospital length of stay and PPCs: pneumonia (new infiltrate plus either fever [temperature >38oC] and purulent secretions), severe atelectasis (confirmed by chest x-ray film, requiring chest physiotherapy or bronchoscopy), time of chest tubes in place (>4d), ventilation hours (>24 h), lengths of Intensive Unit Care stay (> 24h) and air leak (> 2 d). Postoperative outcomes were obtained from the medical records by a physical therapist blinded to the treatment assignment.

2.6 Statistical methods

Data analysis was performed using NCSS© for Windows statistical software package. Distribution of data at baseline was assessed with Shapiro-Wilks normality test. Categorical variables were tested using Fisher exact tests. Because of the majority of variables did not pass the normality test, nonparametric analysis was employed. Mean and Standard Deviation of each variable were calculated between the 2 treatment arms (SPR vs SCT) and were compared with the Mann-Whitney U test for two independent samples. Differences in the effectiveness of SPR and SCT were compared at two time points, at baseline (T0) and prior to surgery a (T1) with the Wilcoxon signed-rank test. For all analyses, a P-value <0.05 was considered statistically significant.

3. Results

Pulmonary functionality showed significant improvement in both groups from baseline to prior to surgery (table 2). Moreover, the percentage of change from baseline to prior to surgery in SPR group displayed a that pulmonary parameters changed more than SCT group. Thus, SPR values: FVC (18%); percentage of predicted FVC (20%); FEV1 (29%); percentage of predicted FEV1 (25%); SCT values : FVC (10%); percentage of predicted FVC (11%); FEV1 (9%); percentage of predicted FEV1 (9%). This could be related to the better performance in the respiratory pattern achieved with an intensive but not stressful training that improve the awareness of breathing and reduce fatigue with endurance training.

Table 2: Evaluation of pulmonary functional parameters assessed at baseline and prior to surgery (phase 1)						
Group	**SPR**			**SCT**		
Variabile	**Mean SD**	**Standard deviation**	***p* value**	**Mean SD**	**Standard deviation**	***p* value**
FEV1 (L) T0 FEV1 (L) T1	1.9 2.4	0.6 0.6	0.0001	1.2 1.3	0.3 0.3	0.003
FEV1 % T0 FEV1 % T1 (% predicted value)	63 79	11 13	0.00002	51 56	5.5 7.2	0.005
FVC (L) T0 FVC (L) T1	1.1 1.5	0.3 0.4	0.0001	2.1 2.4	0.4 0.5	0.01
FVC % T0 FVC % T1 (% predicted value)	48 63	6.1 8.7	0.00001	69 77	12.4 15.1	0.008
Abbreviations: FVC forced vital capacity, FEV1 forced expiratory volumes 1 s Wilcoxon signed-rank test						

In the Linear Mixed Model, variation of FEV1 (L), the 18.4% of the differences in FEV1 were linked to the differences between subjects; while 20.3% of within-person variations were linearly associated with the time. Finally, the effect of the different type of treatment during the study explains another 8% approximately (28.1%). Furthermore, FEV1 improves in the SPR group by about 0.327 (table 3).

Table 3: Linear Mixed Model, variation of FEV1 during the study period in the two groups of treatment.					
			Model A	Model B	Model C
Fixed Effect					
Initial Status	Intercept	γ_{00}	1.355±0.064	1.493±0.076	1.601±0.093
Rate of change	Time	γ_{10}		-0.277±0.082	-0.440±0.111
Treatment					
	SPR reference	γ_{20}			-0.217±0.110
	Interaction (γ_{10*}	γ_{30}			0.327±0.157
Variance Components					
Level 1	Within person	$\delta\ 2\varepsilon\ ^2{}_{\varepsilon}$	0.128±0.027	0.102±0.022	0.092±0.020

Level 2	In initial status	δ^2_0	0.029±0.023	0.035±0.023	0.037±0.023
		R^2_ε		0.203	0.281
Intraclass Correlation Coefficient		ρ	0.184		

In the Linear Mixed Model, variation of FEV1 ((% of predicted), the 98.5% of the differences in FEV1 were linked to the differences between subjects; while 37.4% of within-person variations are linearly associated with time. Finally, the effect of the different type of treatment during the study explains another 13% approximately (49.3%). Furthermore, FEV1% improves in the SPR group by about 11.3 (table 4).

Table 4: Linear Mixed Model, variation of FEV1 (% of predicted) during the study period in the two groups of treatment.

			Model A	Model B	Model C
Fixed Effect					
Initial Status	Intercept	γ_{00}	55.717±1.270	60.867±1.486	64.933±1.889
Rate of change	Time	γ_{10}		-10.300±1.951	-15.933±2.483
Treatment					
	SPR reference	γ_{20}			-8.133±2.483
	Interaction ($\gamma_{10*}\ \gamma_{20}$)	γ_{30}			11.267±3.512
Variance Components					
Level 1	Within person	δ^2_ε	91.194±19.494	57.100±12.178	46.253±10.093
Level 2	In initial status	δ^2_0	1.386±14.070	4.554±7.740	7.266±7.551
		R^2_ε		0.374	0.493
Intraclass Correlation Coefficient		ρ	0.985		

During phase 2 evaluation, to compare with SCT group, the results showed that the SPR group was in a favorable clinical condition to prevent PPCs. Indeed, the first one was hospitalized for a longer period, received more ventilation hours and had longer time of chest tubes in place. Our finding of shorter time of chest tubes in place in the SPR group may indicate a better lung re-expansion, a result that could be associated with the routine use of study protocol [30] (table 4). Thus, in comparison with SCT patients, SPR had lower incidence of prolonged length of Intensive Unit Care stay, a lower incidence of postoperative respiratory morbidity and a shorter number of patients requiring bronchoscopy for atelectasis. There wasn't recorded any case of pneumonia, n (%).

Table 4 Postoperative outcomes (phase 2) and surgical data according to type of intervention SPR vs CPT			
Parameters	SPR	SCT	P-value
Length of stay (days), mean (SD)	15 ± 5.3	17 ± 5.6	Ns
ICU stay, mean (SD)	29 ± 10	34 ± 12	Ns
Days with chest tubes, mean (SD)	6 ± 2.3	7 ± 4.3	Ns
Pneumonia, n (%)	0	0	Ns
Ventilation (h), mean (SD)	36 ± 12	38 ± 11	Ns
Respiratory morbidity	1 ± 0,7	2 ± 0,14	Ns
Air leak (d)	0.9 ± 1.9	0.8 ± 2.2	Ns
Atelectasis	0.07 ± 0.2	0.14 ± 0.3	Ns
Surgical data			
Lobectomy n (%)	6 (40%)	8 (53%)	
Bilobectomy n (%)	2 (13%)	2 (13%)	
Wedge resection n (%)	7 (47%)	5 (33%)	

Values are mean ±SD, or n (%).
Abbreviation: ICU, intensive care unit.
Mann-Whitney U test

4. Discussion

For lung cancer patients with or without underlying chronic respiratory disease, physical symptom burden, fatigue and performance status may have a negative effect on general function and poor postoperative outcomes [31-32]. Recent improvements in pain management and the increasing use of VATS changed the postoperative clinical pathways. However, the primary task of the preoperative assessment is to identify patients at an increased risk of both perioperative complications and long-term disability from lung cancer. In 2013, the American College of Chest Physicians provided a guideline to the preoperative assessment of patients being considered for surgical resection of lung cancer [24]. It has been recommended that patients must be assessed by a multidisciplinary team before operation and in the preoperative time. Optimal medical care (mainly for patients who have chronic respiratory disease) should include: smoking cessation, optimal pharmacologic and oxygen therapy when indicated. Firstly the aim of preoperative rehabilitation is to optimize the physical status and overall medical stability before surgery and secondly to reduce postoperative morbidity in operable patients. Some studies investigated the efficacy of interventions that started preoperatively and then continued after surgery [33-30]. The rehabilitation program includes incentive spirometry, breathing and coughing exercises, active cycle of breathing techniques, and shoulder/thoracic cage exercise. The authors found that pre-surgical interventions based on moderate-to-intense aerobic exercise in patients undergoing lung resection improved functional capacity and reduced postoperative morbidity, whereas interventions performed only during the postoperative period did not seem to reduce PPCs or hospital length of stay [34-35]. Cesario et al. [36] published a pilot trial comprising eight patients who underwent an inpatient preoperative rehabilitation program. It included five daily sessions of three hours each, every week, of supervised incremental exercise cycling and treadmill, breathing exercises, functional electrical stimulation of the abdominal muscles and educational sessions. Significant improvement was observed in lung functionality to demonstrate the physiological benefit of a structured preoperative exercise program. Bobbio et al. [37] performed a prospective observational study of patients with COPD that showed a significant improvement in maximum oxygen uptake consumption (VO2 max). Sekine et al. [38]proposed a rehabilitation protocol for two weeks which was continued in hospital admission and postoperatively until discharge. The results showed that perioperative pulmonary rehabilitation and chest physiotherapy tend to reduce risk of pulmonary complications and preserve pulmonary function in patients with COPD. Breathing is the only autonomic function that can be consciously controlled to bring the sympathetic and the parasympathetic nervous system into harmony [39]. Pranayama is an ancient yoga technique and it is one of type of yogic breathing exercise. The regular practice of Pranayama integrates the mind and the body. ShanKarappa V., showed that the pulmonary function values improved after short term pranayama practice. It could be linked to regular, slow and forceful inspiration and expiration for a longer duration during the pranayama practice which leads to strengthening of the respiratory muscles. Besides, Pranayama training causes improvement in the expiratory power and decreases the resistance to the air flow in the lungs [40].The practice of Pranayama is generally considered safe, and the training in yogic breathing is found to be an effective means of enhancing the pulmonary functions. Pranayama or yogic breathing practices were found to influence the neurocognitive abilities, autonomic and pulmonary functions as well as the biochemical and metabolic activities in the body. The studies in the clinical populations, show the effects of yogic breathing in a lot of physiological and psychological functions such as: relieving the symptoms and enhancing the pulmonary functions in bronchial asthma, to enhance mood for patients with drawing from cigarette smoking, to manage anxiety and stress, to modulate the pain perception, to reduce the cancer related symptoms and enhancing the antioxidant status of patients undergoing radiotherapy and chemotherapy for cancer [41]. In this study, the goal of promoting repetition of exercises during the day with and without supervision was to stimulate self-management of the patients. If correctly educated on how to perform the assignments, patients gained self confidence in their possibilities and with the techniques learned, they also became able to repeat them when needed in the postoperative phase without problems or pain. To obtain greater efficacy in the self-treatment, it is necessary for patients to learn properly their assignments, in order to enhance the confidence with different exercises and the awareness of their abilities. This allows fostering their autonomy during the rehabilitation process and in preparation for surgery. In this prospective, patient was encouraged to become an active participant in the preoperative setting. Anyway, the positive response we received from patients about the self-management, assessed by checking the rehabilitation diaries, supports the importance of their education. To achieve this goal of greater self-efficacy, we empowered patients to do what they were really confident to do, intending to foster their autonomy in their rehabilitation process and preparation for surgery. We believe that by targeting self-efficacy as one of the primary focus of all exercise training we introduced an innovative behavioral aspect in our SPR intervention. Self-efficacy has been identified as an important mediator for behavioral changes in patients with COPD and cancer [42-44] and its theory[45] is the foundation of many disease self-management programs [46-47]. Furthermore, a lot of evidences suggest that incentive spirometry may be appropriate for lung re-expansion following major thoracic surgery [48]. The update of Cochrane Library clinical practice guideline (2011) is the result of reviewing a total of 54 clinical trials and systematic reviews on incentive spirometry. To prevent PPCs, the following recommendations suggest that incentive spirometry alone is not recommended for routine use in both pre and postoperative setting. It is recommended that incentive spirometry be used with breath-cough technique, early mobilization, and optimal analgesia. It is suggested that a volume-oriented device can be selected as an incentive spirometry device [49]. Compare to flow-orientated devices, volume-orientated devices appear to give improved diaphragmatic activity and decreased work of breathing [48]. If using incentive spirometry postoperatively, volume-orientated devices are probably more suitable as there may be lower levels of imposed work of breathing, pain and fatigue, and subjects are more likely to achieve their best potential volume [50].

5. Conclusions

Despite poor lung function, these findings suggest that a feasible perioperative SPR before lung cancer resection improves preoperative functional capacity and decreases the postoperative respiratory morbidity. A short feasible protocol may have potential to improve surgical and may easily translate to practice. Moreover, our work may serve for a start in filling the knowledge gap on effective preoperative care including aspects that are not routinely used. Further studies are needed to better define the benefits and optimization of the intervention. We look forward to improving outcomes with the use of comprehensive pulmonary rehabilitation in lung cancer patients.

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Statement of Ethics

All participants signed the informed consent for the experimental procedure, which complies with the latest revision of the Helsinki Declaration and with the procedures defined by the ISO 9001-2015 standards for "Research and Experimentation"; this procedure also protects the privacy of subjects participating in biomedical research.

Disclosure Statement

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