Changes in Pulmonary Function and Exercise Endurance after Lung Resection

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Purposes : *The purposes of the study were to 1) compare the pulmonary function, respiratory muscle strength, and exercise endurance before and after lung resection; 2) compare the percentage of impairment in pulmonary function, respiratory muscle strength, and exercise endurance for patients with different extent of resection; and 3) investigate the determinants of hospital stay and the impairment in pulmonary function, respiratory muscle strength, and exercise endurance.* ***Methods:*** *Thirty-nine consecutive patients who had lung resection without major complications at the National Taiwan University Hospital served as the subjects of the study. Each of the subjects took a complete pulmonary function test (PFT) that includes measurements of VC, MVV, FVC, FEV_1, FEV_1 / FVC, PEF, maximal inspiratory and expiratory mouth pressure (MIP and MEP) before surgery and before discharge (13.2 ± 6.3 days after operation). In addition, 26 of them took walking tests for 3 minutes before and after surgery, respectively.* ***Results:*** *The results of the study demonstrated that the patients had significant reductions in lung volume, flow, respiratory muscle strength, and distance walked after thoracic surgery by the averages of 30-40%, 50%, 4-7%, and 26 %, respectively. Patients who underwent more than lobectomy had longer duration of chest tube drainage than patients who underwent less than lobectomy. However, patients who underwent less than lobectomy had higher percentage of impairment in PEF than the other patients. Significant correlations included the relationship of hospital stay with duration of chest tube drainage and impairment of PEF (r= 0.87 and 0.38, respectively), impairment of PEF with duration of chest tube drainage (r=0.32), while none of the changes in MIP, MEP, or walking distance were correlated. with other variables.* ***Conclusion****: After lung resection, patients still have significant impairments in PFT after using the extent of resection as the correction factor. Their MIP, MEP, and walking ability were also reduced. The length of hospital stay highly correlated with the duration of chest tube drainage.* 〈FJPT 2001; 26(1):1-8〉

Key words: Thoracic surgery, Pulmonary function, Respiratory muscle strength, Exercise endurance.

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Pulmonary function test has been used extensively for screening the risks of operation and postoperative complications.[1-3] Because of advances in anesthesiology, refinements in surgical technique, and improvements in postoperative care, the incidence of pulmonary complications following thoracic surgery has decreased.[4,5] However, relatively fewer researchers have discussed the changes in postoperative pulmonary function. Little work has been done on respiratory muscle strength that was reported to be important predictor of pulmonary complications after surgery.[6,7] Chest physical therapists work with patients after lung resection during hospitalization to maximize their ventilation and promote optimum body conditioning and function. Few studies have been performed that quantitatively evaluated the outcome of these patients at discharge, thus little work has been done concerning what can be done for the patients after discharge. The purposes of our study were to 1) compare the pulmonary function, respiratory muscle strength, and exercise endurance before and after lung resection; 2) compare the percentage of impairment in pulmonary function, respiratory muscle strength, and exercise endurance before patients were discharged according to their extent of resection; and 3) investigate the determinants of length of hospital stay and the impairment in pulmonary function, respiratory muscle strength, and exercise endurance.

METHODS

Thirty-nine consecutive patients who underwent lung resection without major complications at the National Taiwan University Hospital served as the subjects of the study. Twenty-four men and 15 women with ages ranging from 23 to 79 years (mean, 56.6 ± 14.4 years) participated in the study. Each subjects took a complete pulmonary function test (PFT) which included measurements of vital capacity (VC), maximal voluntary ventilation (MVV), forced vital capacity (FVC), forced expiratory volume at 1 second (FEV_1), FEV_1/FVC, peak expiratory flow (PEF), maximal inspiratory and expiratory mouth pressure (MIP and MEP) before the operation. They were tested again at an average of 13.2 ± 6.3 days after operation. At the second testing, they were all in stable condition and they were up walking ad lib. The parameters of pulmonary function tests were presented in actual values and percentage of normal predicted values. In addition, the postoperative pulmonary funtions were calculated according the formula: measured PFT / [the preoperative spirometric values x (residual segments/19)] and presented as percentage of corrected values.[8] Among the patients, only 26 took both pre and post-operative walking test for 3 minutes. The percentage of impairment of PFT was defined as the differences between the actual and the corrected postoperative PFT divided by the corrected post-operative values. A positive value in this ratio indicated there was no impairment, while the negative value indicated impairment. The percentage of impairment of MIP, MEP, or walking distance was the ratio of pre-and postoperative differences to the preoperative values.

Postoperative diagnosis in these patients included carcinoma (n=29), infection (TB etc, n=7), abscess, tumor, and bronchiectasis (one patient for each category in the last three diagnoses). Among them, seven underwent wedge resection or segmentectomy (less than lobectomy), 19 patients underwent lobectomy, 10 underwent lung resection more than a single lobectomy but less than pneumonectomy, and three underwent pneumonectomy. The extent of the resection averaged 3.9 ± 2.3 segments. Table 1 presents the general data of the subjects. Subjects were divided into three groups according to the extent of lung resection. The three divisions were less than lobectomy, lobectomy, and more than lobectomy. The average numbers of resected segments were 0.6 ± 0.8,

Table 1. General Data of the Subjects (n=39)

	Mean	S.D.	Range
Age (yr)	56.6	14.4	23 - 79
Body weight (kg)	58.3/ 56.9 *	9.2/8.8*	42.7 - 85.0/42.8-80.0*
Height (cm)	162.6	6.6	146.0 -179.0
Operation (hr)	3.3	0.8	1.75 - 5.08
Ventilator support (hr)	14.3	6.5	2.17 - 26.50
Chest tube drainage (d)	9.0	4.4	4 - 23
Length of hospital stay (d)	12.5	4.6	6 - 28

* indicates the postoperative body weight

3.8 ± 0.9, and 5.9 ± 2.2, respectively. During their stay in the hospital, all the patients received routine chest physical therapy that consisted of secretion mobilization, breathing exercises(diaphragmatic and regional breathing), incentive spirometer, shoulder and trunk mobility, and early ambulation with reconditioning.

Mean and standard deviation were used to present the data. Paired t-test was used to compare the measurements before and after surgery as well as the actual postoperative pulmonary functions and corrected predicted values.The differences among the three groups were tested using one way ANOVA and post hoc Bonferroni tests. The Pearson product moment correlation coefficient was used to investigate the determinants of hospital stay and the impairment in pulmonary function, respiratory muscle strength, and exercise endurance. P values less than 0.05 were considered significant.

RESULTS

The average length of operation was 3.3 ± 0.8 hours and the average intubation was 14.3 ±6.5 hours. The patients stayed in the hospital for an average of 12.5 ± 4.6 days and their chest tubes were removed at an average of 9.0 ± 4.4 days after surgery. Table 2 presents the test results of pulmonary function, MIP, MEP, and walking tests before and after surgery. Fewer reductions in PFT were noted after being corrected for the extent of resections. Greater reductions

Table 2. Measurements Before and After Surgery

	Before Surgery		After Surgery		
	Actual	% Normal Predicted	Actual	% Normal Predicted	% Corrected Values
VC (l)	2.84 ± 0.75	90.9 ± 20.7	1.72 ± 0.53*	54.7 ± 13.7*	72.4 ± 20.8[§]
FVC (l)	2.64 ± 0.65	79.1 ± 19.1	1.72 ± 0.52*	51.7 ± 12.7*	62.9 ± 18.1[§]
FEV_1 (l)	2.13 ± 0.59	80.9 ± 23.7	1.41 ± 0.45*	53.2 ± 13.8*	64.5 ± 21.3[§]
FEV_1/FVC (%)	79.9 ± 7.3		82.2 ± 7.3		
PEF (l/sec)	5.51 ± 2.24	66.3 ± 26.2	3.86 ± 1.72*	46.1 ± 19.1*	52.9 ± 21.4[§]
MVV (l/min)	83.8 ± 29.0	100.3 ± 32.5	58.0 ± 23.8*	69.1 ± 23.0*	80.3 ± 30.1[§]
MIP (cmH_2O)	42.2 ± 18.8		35.8 ± 17.5*		
MEP (cmH_2O)	39.2 ± 18.6		33.2 ± 16.5*		
Walking Dist. (M)	240.4 ± 44.4		176.1 ± 49.5*		

% Corrected Values = measured postoperative PFT / [the preoperative spirometric values x (residual segments/19)] x 100%
* $p<0.05$ when compared with the preoperative values; § $p<0.05$ when compared with the postoperative measured values

Table 3. General Data and % Impairments after Surgery in Three Patient Groups by the Extent of Lung Resection

	Less Than Lobectomy (n=7)	Lobectomy (n=19)	More Than Lobectomy (n=13)
Age (yr)	53.0 ± 14.4	62.4 ± 12.0 #	49.9 ± 15.2
Length of Intubation (hr)	13.9 ± 8.1	13.1 ± 6.4	16.2 ± 5.6
Duration of Chest Tube Drainage (d)	6.0 ± 2.4	8.7 ± 4.2	11.1 ± 4.7*
Length of Hospital Stay (d)	10.9 ± 5.0	11.7 ± 4.6	14.5 ± 3.9
VC (%)	-26.7 ± 16.0	-20.4 ± 17.5	-21.3 ± 18.8
FVC (%)	-20.9 ± 18.3	-9.2 ± 26.6	-16.5 ± 25.7
FEV_1 (%)	-24.9 ± 15.4	-9.0 ± 27.8	-10.1 ± 27.8
PEF (%)	-36.6 ± 11.5	-3.3 ± 26.6 ^	5.5 ± 38.5*
MVV (%)	-20.9 ± 35.2	-8.0 ± 26.8	2.3 ± 33.1
MIP (%)	-21.4 ± 32.8	-7.5 ± 44.1	-1.8 ± 36.5
MEP (%)	0.3 ± 52.9	-1.8 ± 35.0	-17.0 ± 34.3
Walking Distance (%)	-30.9 ± 17.5	-30.4 ± 14.8	-15.9 ± 30.0

* post-hoc significance level between group 3 and group 1; # between group 2 and 3; ^ between group 1 and 2

were found in parameters associated with lung volume and flow, followed by MVV and respiratory muscle strength. Table 3 presents the percentage of impairment after surgery in patients with different extents of lung resection. Only age, duration of chest tube drainage, and percentage of impairment in PEF were significantly different among the groups.

The results of the correlation analyses are in Table 4. Significant correlations occurred between the relationship of hospital stay with the duration of chest tube drainage and impairment of PEF, impairment of PEF with the duration of chest tube drainage, and the change in walking distance correlated with impairment of PEF. The percentage of impairment in PFT was not related to their preoperative values. While the postoperative changes in MIP and MEP correlated with their preoperative values (r= 0.41 and 0.44, p= 0.009 and 0.005, respectively).

DISCUSSION

In the present study, we investigated the changes in pulmonary function, respiratory muscle strength, and exercise endurance after lung resection. The postoperative PFT was corrected by the extent of lung resection using the equation proposed by Veneskoski and Sovijarvi and defined percentage of impairment as the ratio of difference to the corrected values.[8] Veneskoski and Sovijarvi demonstrated that FVC and FEV_1 that remained after lung resection could be predicted with sufficient accuracy using the results of the preoperative spirometry. No sophisticated regional lung function studies, such as radiospirometry

Table 4. Results of Correlation Analyses

Dependent Variable	Independent Variable	r	p
Hospital Stay	chest tube drainage	0.87	0.000
	% impairment in PEF	0.38	0.018
PEF Impairment	chest tube drainage	0.32	0.046
% Change in Walking Distance	% impairment in PEF	0.45	0.023

or radionuclide imaging, were required to predict their pulmonary functions. Using the percentage of corrected predictive values can eliminate the differences in extent of resection and detect the impairment promptly after operation.

Several researchers investigated pulmonary functions of patients after thoracotomy.[9-11] Bigler et al. reported a 40% decrease in FVC and FEV_1 after one month.[9] Landreneau et al. investigated patients after wedge resection or lobectomy and found FEV_1 was roughly half of the preoperative values at 21 days postoperative.[10] Hazerlrigg et al. studied patients after a variety of lung resections and found pulmonary functions returned toward preoperative values by one month regardless of the type of incision the patient underwent.[11] Gorlin et al. demonstrated that there was a decrease in VC during the first 2 weeks following thoracotomy, however, they returned to predicted normal values within 4 to 6 weeks.[12] The most striking decrease was seen in IC and followed by ERV. These authors contributed the reduction of PFT to the depressed end-expiratory position that might be due to the pleural pain after surgery. Cordiner et al. reported full recovery of lung functions in 3 to 4 months after thoracotomy.[13] Other researchers found that the decreases in functional residual capacity in addition to decreases in VC were predictive of postoperative pulmonary complications.[14]

Among the studies mentioned above, only Cordiner et al. used the corrected values. They found very few errors (1.6-2.0%) between the actual and corrected values in patients 3 to 4 months after surgery. Our results fall within the range of the previously reported values.[9-14] Considering that the postoperative period was shorter in our study than in other reports, the reduction in lung volume might be less than theirs due to the intervention of routine chest physical therapy. Only Pelletier et al.[15] mentioned that their patients were mobilized within 24 hours after surgery and discharged rapidly (12 ± 4 days) which was similar to our timeframe (Table 1). Our results for the duration of chest tube drainage and hospital stay were similar to other reports.[15-17]

Previous researchers have reported that pneumonectomy caused almost equal reduction in vital capacity and MVV.[18,19] Neuhaus et al. studied on 80 patients after pneumonectomy.[18] Their patients who underwent right pneumonectomy had 26 % reduction in MVV while the VC fell 35 % three months after surgery. Their patients who underwent left pneumonectomy decreased 25 % in MVV and 21 % in VC. An average of 25 months after operation, the mean increase in MVV was only 1.6%, and 2 % in VC. Gorlin et al. demonstrated that MVV decreased slightly in more than 50 % of the patients, while the other indices of pulmonary function test were seen in less than one quarter during the first 3 weeks.[12] They also found that abnormalities in breathing reserve and walking index occurred in less than one fourth of the patients during the period immediately following thoracotomy.[12] However, no degree of abnormality was reported. We found a reduction of 26.1 ± 21.4 % in walking distance after surgery in general. More than half of the patients(17/26) decreased their walking distance by more than one standard deviation of their preoperative walking distance. Pelletier et al. tested patients who underwent lobectomy and pneumonectomy 29-220 days after surgery and found a 10 to 20 % decrease in exercise capacity using normal predicted values.[15] They reported some patients barely changed their exercise capabilities even with 30 to 50 % loss in their ventilatory capacity and the patients had similar leg discomforts at maximal exercise no matter whether the underwent lobectomy or pneumonectomy. Thus, lack of conditioning was believed to result in the decrement in exercise capacity and exercise training was recommended for these patients. Further studies are needed to investigate whether training can really promote the recovery of pulmonary function and exercise capacity.

Our results showed a significant decreases in MIP and MEP after surgery that were different from those in

the study by Pelletier et al.[15] They also found MIP or MEP was not a possible factor for exercise intolerance.[15] Fratacci et al. found that thoracotomy and pulmonary resection produced a marked reduction of active diaphragmatic shortening that did not consistently correlate with the changes with transdiaphragmatic pressure.[21] Further studies in the role of ventilatory muscles in surgical patients are definitely needed.

In our study, we found that only the percentage of impairment in PEF was different among the groups of patients who underwent different degrees of lung resection. Khalil Ali et al. reported that after pneumonectomy patients had relatively stable pulmonary functions, while after lobectomy patients had disproportionate amount of early loss in FVC and FEV_1.[14] Since our study was conducted relatively soon after surgery, it might have contributed to the majority of the insignificant differences. We found that patients who underwent less resection had more impairments in PEF (Table 3). It has been hypothesized that with more resections there would be increased airway resistance at a given level of ventilation because of the reduction in total airway cross-sectional area.[20] However, our results were opposite. Whether these patients had more pain resulting in more impairment in PEF needs further study. The lack of investigation of the amount of pain experienced and the amount of pain medication received were the limitations of this study.

Our results also demonstrated a significant relationship between hospital stay with duration of chest tube drainage and impairment of PEF (r=0.87 and 0.38 respectively). It may indicate that length of chest tube drainage should be a criterion of evaluating the new surgical procedures. Impairment of PEF positively correlated with duration of chest tube drainage (r=0.32). This may be secondary to pain that was not measured and was a limitation of the study. The postoperative walking distance, MIP, and MEP were significantly reduced, however, these decreases did not correlate with any of patients' basic data.

In summary, patients had relatively decreased pulmonary functions that were corrected for the extent of resection. After receiving a thoracic surgery, the patients' MIP, MEP, and walking ability had also reduced before discharge. Patients receiving more than lobectomy had longer duration of chest tube drainage than patients with less than lobectomy, while patients receiving less than lobectomy had higher percentage of impairment in PEF than the other patients. Significant relationships between hospital stay with duration of chest tube drainage and impairment of PEF were found in this study.

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肺部手術後患者肺功能和運動耐力的改變

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目的： 1.比較肺部手術前後肺功能、呼吸肌肌力和運動耐力的差異；2.比較不同程度肺部切除手術後實際測量和依術前肺功能和切除大小校正後兩種肺功能值的差異；3.探討影響住院日數和術後肺功能、呼吸肌力和運動耐力的不足的因素。方法：受試者為39名在臺大醫院接受肺部手術後無重大併發症的病患，在術前和在術後13.2 ± 6.3天各接受一次肺功能和呼吸肌力的測量，其中26名患者還接受了3分鐘運動耐力的測試。結果：受試者在術後有30 -40% 明顯肺容積的下降、約50%氣流流速、4-7%呼吸肌肌力和26%運動耐力的下降。在小於肺葉切除、肺葉切除與大於肺葉切除三組病患間，只有胸管引流時間和最大呼氣流速的不足有明顯差異。病患住院日數與胸管引流時間、最大呼氣流速的不足成正相關（相關係數分別為 0.87 和 0.38 ），最大呼氣流速的不足和胸管引流時間也成正相關（相關係數=0.32），然而術後呼吸肌力和3分鐘運動耐力的差異和病人一般資料並無任何相關。結論：即使以切除肺部的程度做校正，病人在出院前的肺功能仍有明顯下降。此外，病患之呼吸肌肌力和三分鐘行走距離在術後也較術前有明顯下降。

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