

PREOPERATIVE PREDICTION OF LUNG FUNCTION IN PNEUMONECTOMY BY SPIROMETRY AND LUNG PERFUSION SCINTIGRAPHY

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ABSTRACT

Introduction: Nowadays an increasing number of lung resections are being done because of the rising prevalence of lung cancer that occurs mainly in patients with limited lung function, what is caused by common etiologic factor - smoking cigarettes. Loss of lung tissue in such patients can worsen much the postoperative pulmonary function. So it is necessary to assess the postoperative pulmonary function especially after maximal resection, i.e. pneumonectomy. **Objective:** To check over the accuracy of preoperative prognosis of postoperative lung function

after pneumonectomy using spirometry and lung perfusion scintigraphy. **Material and methods:** The study was done on 17 patients operated at the Clinic for thoracic surgery, who were treated previously at the Clinic for Pulmonary Diseases "Podhrastovi" in the period from 01. 12. 2008. to 01. 06. 2011. Postoperative pulmonary function expressed as ppoFEV1 [predicted postoperative forced expiratory volume in one second] was prognosticated preoperatively using spirometry, i.e. simple calculation according to the number of the pulmonary segments to be removed and perfusion lung scintigraphy. **Results:** There is no significant deviation of postoperative

achieved values of FEV1 from predicted ones obtained by both methods, and there is no significant differences between predicted values (ppoFEV1) obtained by spirometry and perfusion scintigraphy. **Conclusion:** it is necessary to assess the postoperative pulmonary function before lung resection to avoid postoperative respiratory failure and other cardiopulmonary complications. It is absolutely necessary for pneumonectomy, i.e. maximal pulmonary resection. It can be done with great possibility using spirometry or perfusion lung scintigraphy.

Key words: pneumonectomy, spirometry, perfusion lung scintigraphy.

1. INTRODUCTION

In recent years there has been increase in the number of patients who need thoracic surgery, first of all different types of pulmonary resection for primary bronchial cancer, particularly among patients whose lung function is impaired due to the different degrees of bronchial obstruction. In all these patients it is necessary to assess functional status after lung surgery performed, although in these patients we may ask - what is the risk of postoperative complications in relation to disease that certainly has fatal outcome if not treated surgically?

This problem is differently treated in the literature. Various methods are recommended for evaluation of postoperative lung function. Some authors recommend measuring only FEV1 (forced expiratory volume in one second) (1, 2, 3, 4, 5, 6, 7, 8, 9),

and some recommend that in addition to FEV1, in cases where there are diffuse interstitial changes of lung and DLCo (transfer factor for CO) should be determined (2, 3, 4). Other authors consider that there is the need for complete spirometry processing: (FEV1), vital capacity (VC), forced vital capacity (FVC), flow-volume curve, pulmonary resistance (Rt), residual lung volume (RV), bronchodilator test, maximum voluntary minute ventilation (MMV) and total lung capacity (TLC) (10, 11, 12, 13), but all require to do the analysis of gases in the blood. If there is hypercapnia, i.e. high partial pressure of carbon dioxide in arterial blood (Pa CO_2) >45 mm Hg (6 kPa) it does not give the approval for the surgery. If there is hypoxemia i.e. decreased partial pressure of oxygen in arterial blood (PaO_2) <60 mmHg (8 kPa) or arterial oxygen saturation

(SaO_2) below 90% it does not give the approval for the surgery (1, 3, 10, 14, 15, 16, 17). Many authors require to be done and ventilation-perfusion or a perfusion lung scintigraphy especially for planned pneumonectomy (2, 3, 19, 20, 21, 22).

2. OBJECTIVE

To check over the accuracy of preoperative prognosis of postoperative lung function in pneumonectomy using spirometry and lung perfusion scintigraphy and to compare the results of preoperative prediction obtained by these two methods.

3. MATERIAL AND METHODS

The study was done on 17 patients surgically treated at the Clinic for thoracic surgery, KCU Sarajevo, who were treated previously at the Clinic for Pulmonary Diseases "Podhrastovi" in the period from 01.

12. 2008. to 01. 06. 2011. All of them had some form of bronchial cancer. Left or right pneumonectomy was made.

The control group consisted of the same patients whose predicted values of the parameters of postoperative lung function were compared with the actual values of these parameters after pneumonectomy that is planned in a multidisciplinary meeting (thoracic surgeon, pulmonologist and radiologist).

Lung function tests were done when the patient was clinically stable and after taking the complete bronchodilator treatment, if it was needed.

All patients were undergone to complete spirometry processing as follows: FVC, FEV₁, flow-volume curve, RT including bronchodilator test, RV and TLC. Arterial blood gas analysis was also performed.

- If there was a disturbance in blood gases: hypoxemia i.e. PaO₂ below 60 mm Hg (8kPa) or SaO₂ below 90%, with or without hypercapnia i.e. PaCO₂ above 45 mmHg (6kPa) approval for operation was not given. We tried with bronchodilator therapy and with oxygen therapy, to achieve the normalization gases in blood. If the blood gases normalized patients were given the approval for the surgery.
- If there was bronchospasm it also did not give the approval for surgery because bronchospasm is accompanied with vasospasm and a significant increase in pulmonary vascular resistance and that is a big surgical risk. If bronchospasm is relieved by appropriate bronchodilator therapy patients were given the approval for the surgery.
- If there was hyperinflation of lung parenchyma in great degree i.e. the RV greater than 300% of normal values, which indicating a distinct bronchial obstruction, we did not give permission for operation. If the appropriate bronchodilator therapy decreased RV to values below 300% of standard values patients were given the approval for the sur-

gery.

The degree of damage of the lung function is primarily determined based on the FEV₁ because it is the most objective parameter of lung function which indicates the obstructive and restrictive disorders of lung function and indicates the type and degree of damage of ventilatory lung function.

In all patients on the basis of measured preoperative lung functional parameters, we predicted postoperative lung function.

In all patients the residual pulmonary function was predicted as follows: it is assumed that each segment of the lung, and there are total 19 of them (upper right lobe - 3, right middle lobe - 2, right lower lobe - 5; upper left lobe - 3, lingula - 2, lower left lobe - 4 segments) in the healthy lung contributes equally to ventilation that is 1/19 (nineteenth part) or 5.26% of total lung ventilation (100%).

Predicted postoperative FEV₁ (ppo FEV₁) in absolute values (l-L) is calculated as follows:

- $Ppo\ FEV_1 = preoperative\ FEV_1 \times (19\ segments - \text{number of segments to be removed}) \div 19$ or by the formula.
- $Ppo\ FEV_1 = preoperative\ FEV_1 \times (1 - (S \times 5.26)) \div 100$.
(S = number of segments to be removed).

Both formulas provide the same result. If there was bronchoscopic evidence of stricture or obstruction of segmental bronchi of the parts of lungs in particular which have not been planned for resection then we used the following formula:

- $ppoFEV_1 = preoperative\ FEV_1 \times \frac{(19-a)-b}{(19-a)}$, where a = number of obstructed segments, b = number of no obstructed segments to be resected.

Then the predicted postoperative FEV₁ was expressed as a percentage (%) of normal values for the patient's FEV₁ (ppoFEV₁%) and was calculated by the following formula:

- $\% ppoFEV_1 = \{ppo\ FEV_1\ (in\ Liters) \times 100\} \div \text{normal}\ FEV_1\ (L)\ \text{for}\ \text{this}\ \text{patient}$.

For normal spirometric parameters are taken "European standards" or CECA norms that are established

under the auspices of the European Community for Coal and Steel, which was the forerunner of today's European union, and taking into account height, weight, age and sex of the patient and which are entered into the computer of every spirometry apparatus.

In 10 patients residual pulmonary functional reserve was calculated, not only by spirometry, but also on the basis of findings of perfusion lung scintigraphy according to the formula:

- $ppo\ FEV_1 = preoperative\ FEV_1 \times (1 - \text{fraction of total perfusion of removed lung})$.

In these 10 patients we compared the ppo FEV₁ values obtained by calculation based on the number of segments to be removed and the values obtained from a lung scintigraphy.

Complete spirometry processing was done on the apparatus MasterLab-Jaeger, and determination of blood gases on the Radiometer ABL 505 apparatus in the Laboratory for Clinical Respiratory Physiology at the Clinic "Podhrastovi" and perfusion lung scintigraphy by gamma camera was done at the Institute of Nuclear Medicine of Clinical center of University of Sarajevo.

Lung function tests were done within 7-10 days before surgery and were performed after the patient took a bronchodilator (if it was needed) and after 2 months after surgery when it is considered that the stabilization of the functional lung status was achieved. If it was done more than one testing, for preoperative calculation was taken the highest value achieved. We compared the predicted and the realized values of postoperative FEV₁ and compared predicted values obtained by both methods. Results were statistically analyzed by SPSS and Microsoft Office Excel. Statistical significance was determined at an interval of 95%.

4. RESULTS

Results obtained by spirometric calculation are presented in the four tables.

In 9 males with left pneumonectomy there was no significant

LEFT PNEUMONECTOMY											
Sex :	M	Number of cases :	9	Average age : (years)	64,55						
Preoperative FEV1		Predicted values			Postoperative FEV1					Is there significant deviation ?	
Normal (L)	Realized (L)	% of normal	ppoFEV1 (L)	% ppo FEV1	Realized		Deviation from prognosis in:				
					L	% of normal	L	% of prognosis in L	% of normal		
3,21	2,67	83,18	1,51	47,04	1,69	52,65	+0,18	+11,92	+5,61	NO (p=0.158)	

Table 1. The ratio between predicted and realised values of FEV1- left pneumonectomy -males

LEFT PNEUMONECTOMY											
Sex :	F	Number of cases :	2	Average age : (years)	47						
Preoperative FEV1		Predicted values			Postoperative FEV1					Is there significant deviation ?	
Normal (L)	Realized (L)	% of normal	ppoFEV1 (L)	% ppo FEV1	L	% of normal	L	% of prognosis in L	% of normal		
2,83	2,04	72,08	1,05	37,10	1,14	40,28	+0,09	+8,57	+3,18	NO (p=0.212)	

Table 2. The ratio between predicted and realised values of FEV1 - left pneumonectomy -females

differences between predicted and achieved values. Higher values of prognosis were achieved-realized in 6 patients but with no significant differences to predicted ones (table 1).

Smaller values of prognosis were achieved in 2 patients but with no significant differences to predicted ones. In 2 females with left pneumonectomy there was no significant differences between predicted and achieved values. Higher value of prognosis was achieved in 1 patient but with no significant difference to predicted one. Smaller value of prognosis was achieved in 1 patient but with no significant difference to predicted one. In 5 males with right pneumonectomy there was no significant differences between predicted and achieved values. Higher values of prognosis were achieved in 4 patients but with no significant differences to predicted ones. Smaller value of prognosis was achieved in 1 patient but with no significant differences to predicted one. In 1 female with right pneumonectomy there was no significant differences between predicted and achieved value Smaller value of prognosis was achieved. (table 2, 3).

In 10 patients residual pulmonary functional reserve i.e. postoperative FEV1 was prognosticated not only by spirometry but also by perfusion lung scintigraphy. On the Figure 1. there is the presentation of perfusion

RIGHT PNEUMONECTOMY											
Sex:	M	Number of cases:	5	Average age : (years):	54,4						
Preoperative FEV1		Predicted values			Postoperative FEV1					Is there significant deviation ?	
Normal (L)	Realized (L)	% of normal	ppoFEV1 (L)	% ppo FEV1	Realized		Deviation from prognosis in:				
					L	% of normal	L	% of prognosis in L	% of normal		
3,77	3,15	83,55	1,48	39,26	1,77	46,95	+0,29	+19,59	+7,69	NO (p=0.110)	

Table 3. The ratio between predicted and realised values of FEV1 -right pneumonectomy -males

RIGHT PNEUMONECTOMY											
Sex	F	Number of cases:	1	Age (years):	55						
Preoperative FEV1		Predicted values			Postoperative FEV1					Is there significant deviation ?	
Normal (L)	Realized (L)	% of normal	ppoFEV1 (L)	% ppo FEV1	Realized		Deviation from prognosis in:				
					L	% of normal	L	% of prognosis in L	% of normal		
2,47	1,55	62,75	0,75	30,36	1,01	40,90	+0,26	+34,67	+10,54	-	

Table 4. The ratio between predicted and realised values of FEV1 - right pneumonectomy-females

scintigraphy done in one of them. In all of patients we performed ventilation/perfusion scintigraphy but only the results of perfusion scintigraphy we took into consideration. There were no statistically significant differences between the % ppo FEV1 obtained by spirometry and lung perfusion scintigraphy ($p > 0.05$).

The maximum deviation was in one patient with left pneumonectomy where the %ppoFEV1 calculated by scintigraphy was for 11% higher than the value calculated by spirometry. (table 4.)

From the results above it is seen that the postoperative lung function

after pneumonectomy can be predicted with a great per cent of confidence according to preoperative values and that there are no significant differences between these two methods: spirometry and perfusion lung scintigraphy.

5. DISCUSSION

For many patients with lung diseases, including lung cancer presented as localized disease, surgical resection is the only potentially curative option that provides the best perspective for long-term survival (14). However, high levels of coexisting illnesses make it difficult to undergo these patients to surgery. Smoking cigarettes, which is a major cause of cancer, causes chronic obstructive pulmonary disease (COPD), as well as atheroscle-

rotic vascular disease, all of which reduces the ability of the patient for resection surgery (1). Decision to operate in such patients is much more difficult due to the lack of respiratory reserve which is the main determinant of postoperative morbidity and mortality (15, 23, 24). Patients with airway obstruction are limited in their daily life before the surgery, and an additional loss of lung tissue due to resection contributes to their inability. Loss of lung tissue in such patients can worsen much the postoperative pulmonary ventilatory function which can lead to respiratory failure and various cardiopul-

	sex	Age (years)	% ppo FEV1 (spirometry)	Postoperative FEV1 in % of normal	% ppo FEV1 (perfusion scintigraphy)	Difference in % ppo FEV1
Left pneumonectomy	m	60	50%	58%	52%	+2%
	m	61	45%	37%	56%	+11%
	m	57	33%	48%	35%	+2%
	m	70	52%	56%	54%	+2%
	m	68	50%	50%	54%	+4%
	m	67	40%	49%	44%	+4%
Right pneumonectomy	m	70	33%	34%	38%	+5%
	m	53	34%	24%	36%	+2%
	m	48	51%	68%	50%	-1%
	m	47	36%	49%	38%	+2%

Table 5. Comparison of % ppo FEV1 values obtained by spirometry and perfusion lung scintigraphy

monary complications, including death. The aim of the surgeon performing the operation of resection, especially in high-risk patients with already impaired preoperative pulmonary function, should be curative resection with preservation of the maximum amount of functional lung tissue. In all patients, especially ones with compromised pulmonary function, it is necessary to predict the probably post-resection lung function and identify possible steps to prevent complications during and after surgery and chronic pulmonary insufficiency.

Advances in surgery and anesthesiology made the operations possible and in patients with severe associated cardiopulmonary diseases who previously were not given an approval for surgery (25). Two issues are raised during the preoperative functional assessment and so: a) whether the cardiopulmonary reserve is sufficient to enable the patient to survive the operation, and b) whether the patient be chronically incapable for daily life due to insufficient pulmonary function (26). The potential benefits of the surgery – pulmonary resection should be balanced in relation to postoperative morbidity and mortality. Nowadays the most common diseases that require resection of lung are malignant. But

preoperative evaluation of postoperative lung function. One of them is the simple calculation according to the number of lung segments planned to be resected, and one is the calculation from lung perfusion scintigraphy. Different authors give the different recommendations but great number of them recommend both methods to be done in planned pneumonectomy.

Prediction of postoperative pulmonary function can be done in different ways: the use of ventilation scintigraphy (10, 19, 20), perfusion scintigraphy (1, 2, 3, 10, 19, 20, 21, 22), quantitative CT (computed tomography) (19) and a simple calculation according to the number of lung segments planned to be removed (1, 3, 5, 22, 27, 28). All these methods provide similar quantitative estimates of the value of postoperative lung function (1, 2, 3, 16, 22,

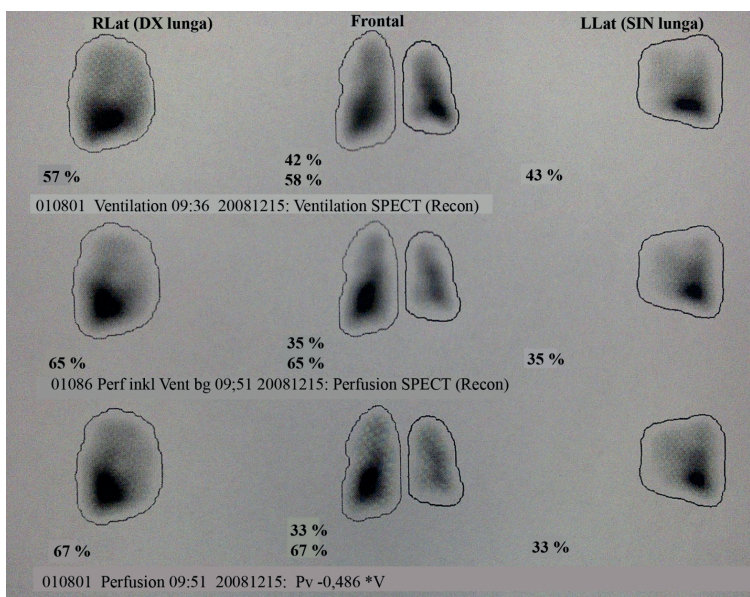


Figure 1. Example of Ventilation /perfusion scintigraphy done in one patient

the question, asked already by Gass GD and Olsen GN in 1986th, stayed open – “what is the acceptable surgical mortality for the disease that is 100% fatal if not operated?” (25). All patients planned for lung surgical resection should be assessed preoperatively whether they can endure the maximal resection i.e. pneumonectomy if during the operation it is seen that planned lower resections i.e. lobectomy or bilobectomy will not give the satisfactory result. Various methods are recommended for

24, 27, 29, 30, 31, 32).

All patients according to BTS and ACCP (2, 3) guides should have full lung function tests, and quantitative isotope perfusion scan if pneumonectomy is considered. Perfusion lung scintigraphy is an easy, available efficient test for prediction of postoperative lung function. The predicted postoperative FEV1 is in good correlation with actual values. In this test radionucleotid emission detected in any part of the lung can be expressed as a percentage of the

total emission detected by gamma cameras that are placed over each hemi thorax (11). Perfusion, so and ventilation scintigraphy may be used to assess the residual lung function (20, 30, 31) as non-invasive methods to evaluate the contribution of each lung to the total ventilation and perfusion. Ventilation/perfusion studies have shown that the loss of function after pneumonectomy is approximately proportional to the percentage of the contribution of each lung to the total lung function. In our study in 10 patients planned for pneumonectomy we did ventilation-perfusion scintigraphy but took into consideration only the result of perfusion.

In our study in 10 patients scheduled for pneumonectomy predicted postoperative pulmonary function is calculated not only by formula based on the number of segments to be removed but also by perfusion lung scintigraphy in order to compare the predictive value of these two methods. It was found that the ppoFEV1 values calculated by the two methods did not differ significantly and in both methods we did not find the significant differences between predicted and achieved values. The biggest difference was found in one patient with left pneumonectomy where the calculated % ppoFEV1 by perfusion scintigraphy was 11% higher than that calculated by spirometry.

6. CONCLUSION

For many patients with lung diseases, including lung cancer present as localized disease, surgical resection is the only potentially curative option that provides the best perspective for long-term survival. It is necessary to predict the probably post-resection lung function to prevent complications during and after surgery and chronic pulmonary insufficiency. The potential benefits of the surgery-pulmonary resection should be balanced in relation to postoperative morbidity and mortality.

All patients planned for lung surgical resection, whether pneumonectomy is planned or not, should be assessed preoperatively whether

they can endure the maximal resection, i.e. pneumonectomy if during the operation it is seen that planned lower resections will not give the satisfactory result.

Postoperative pulmonary function after pneumonectomy can be predicted by use of simple calculation according to the number of lung segments planned to be removed or by perfusion scintigraphy.

Predicted – prognosticated values of postoperative pulmonary function obtained by these two methods do not differ significantly, and there are no significant differences between predicted and achieved values in both methods.

Conflict of interest: none declared.

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