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The use of SPECT in preoperative assessment of patients with lung cancer

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The use of SPECT in preoperative assessment of patients with lung cancer. D.B. Piai, R. Quagliatto Jr, I. Toro, C. Cunha Neto, E. Etchbehere, E. Camargo. ©ERS Journals Ltd 2004.

ABSTRACT: Perfusion scintigraphy is the most frequently used method for the regional assessment of pulmonary function in candidates for pulmonary resection with borderline respiratory function. This method provides two-dimensional images, and it considers all the segments of the pulmonary lobes as having the same volume and function, without considering the spatial overlapping of pulmonary areas with different function. As single-photon emission computed tomography (SPECT) provides tomographic imaging, this could be a more precise method for regional assessment.

In this study, the postoperative predicted forced expiratory volume in one second (FEV_1) ($FEV_{1,ppo}$) was calculated in 26 patients with lung cancer using FEV_1, quantitative lung perfusion scan with planar acquisition (PA) and quantitative lung perfusion scan with tomographic imaging (SPECT).

The estimated $FEV_{1,ppo}$ values obtained using both methods were compared with FEV_1 values measured after surgery (mean: 48±44 days; range: 15–180 days; median: 32 days). The Pearson's linear correlation coefficient was 0.8840 for $FEV_{1,ppo}$ estimated by PA and 0.8791 for $FEV_{1,ppo}$ estimated by SPECT. The linear correlation coefficient for lobectomy was greater than the coefficient for pneumonectomy using both methods.

In conclusion, both methods show good correlation for real postoperative pulmonary function without demonstrating single-photon emission computed tomography superiority over planar acquisition, and both methods were more effective for estimating postoperative predicted forced expiratory volume in one second in lobectomies than in pneumonectomies.

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Surgical resection is the treatment of choice for nonsmall cell lung cancer, and this therapy should be encouraged, as the prognosis worsens for patients who are not operated on. However, the removal of the lung parenchyma in patients, the majority of whom are smokers, and who have compromised cardiovascular and lung conditions, may cause deterioration in ventilatory function and lead to cardiopulmonary failure or death. Therefore, in these patients, a preoperative assessment is extremely important before the appropriate therapy is chosen [1–4].

Pneumonectomy is well tolerated by the patient if: the forced expiratory volume in one second (FEV_1) is either $\geqslant$2 L or >60% FEV_1 predicted; the maximal voluntary ventilation (MVV) is >50% pred; the residual volume/total lung capacity ratio is either <0.5 or the carbon monoxide diffusion capacity of the lung is >60%. Lobectomy is well tolerated by the patient if: the FEV_1 is $\geqslant$1 L and if the MVV is $\geqslant$40% pred. Nevertheless, many patients who could benefit from resection surgery show poor functional values that go against an indication for this surgery. In these cases other assessments are needed, such as perfusion or ventilation pulmonary scintigraphy, which are the most frequently used methods, as they provide a regional assessment of lung function and can be used to estimate postoperative pulmonary function, using the predicted postoperative FEV_1 ($FEV_{1,ppo}$) [5–13]. Operative risks in patients with $FEV_{1,ppo}$ 0.8–1.0 L or >40% FEV_1 pred are acceptable for indicating lung resection for both pneumonectomy and lobectomy [14–16].

Pulmonary scintigraphy with planar acquisition (PA) provides two-dimensional pulmonary images, and the estimated $FEV_{1,ppo}$ considers all the segments of the lung lobes as having the same volume and function, without considering the spatial overlapping of pulmonary areas with different functions, which could diminish the precision of the method. Conversely, single-photon emission computed tomography (SPECT) provides images that could help detect radioactivity in each pulmonary lobe, avoiding spatial overlapping, thus making the method of regional pulmonary function assessment more precise. In some hospitals, this method has been used to plan radiotherapy for lung application and also to monitor regional alterations of pulmonary function after radiotherapy in patients with extrapulmonary diseases [17–19].

The aim of the current study was to compare the effectiveness of both the PA and SPECT methods for estimating $FEV_{1,ppo}$ in patients with lung cancer during the preoperative period.

Methods

Patients

A prospective study was conducted on 26 patients with lung cancer, who underwent lung resection. The sample consisted of 23 males and three females; mean age 63±8.97 yrs (table 1). This sample represented 70% of the patients who underwent this surgery during the period November 1998 to April 2001, at the Hospital de Clinicas (State University of Campinas, São Paulo, Brazil). All the patients were informed about the research protocol, which had received the approval of the hospital's Commission for Ethics in Research. All the patients underwent a pulmonary function test with measurements of the forced vital capacity (FVC) and FEV1 according to the norms of the American Thoracic Society [20]. They also underwent the PA and SPECT. After surgery, the pulmonary function test was repeated (48±44 days; median: 32 days).

Lung perfusion scintigraphy protocol

Injection and acquisition. All the patients were submitted to a lung perfusion scintigraphy, which did not require prior preparation. The patients received an intravenous injection of 185 MBq (5 mCi) macroaggregated albumin labelled with technetium-99 in the supine position. Five minutes after radiotracer injection, static images of the lungs with 500,000 counts were obtained in the anterior, posterior, oblique posterior and lateral projections. Only anterior and posterior projections were used for PA estimation of FEV1,ppo. This procedure was followed by 360° tomographic imaging, taking one image in every 6° for SPECT images.

Processing and analysis. Semi-quantitative analyses of planar and tomographic images were performed.

In the PA, regions of interest (ROI) were drawn in the anterior and posterior projections around the entire lung and also adjacent to the lungs, in order to subtract the background radiation. The percentage of the function of each lung was calculated by the geometric mean.

The SPECT images were normalised and reconstructed in sagittal planes. Ten sagittal images were generated for each lung. ROI were drawn, in each sagittal image, around the pulmonary lobes, according to their anatomical shape. The perfusion of each lobe was determined by the sum of the 10 ROI in the sagittal images. The per cent perfusion of each lobe was determined in relation to the perfusion of both lungs.

Estimation of postoperative pulmonary function

The FEV1,ppo values for each patient were estimated based on the preoperative FEV1 values, as well as the PA and SPECT pulmonary values. The values estimated by both methods were compared with the postoperative FEV1 values.

In PA, FEV1,ppo was estimated using different formulas for pneumonectomy and lobectomy. For pneumonectomy the formula below was used:

$$FEV_{1,ppo} = FEV_1 - \left(FEV_1 \times \frac{\%\,\text{perfusion of affected lung}}{100} \right) \quad (1)$$

where % perfusion of affected lung is the percentage of perfusion of lung with tumour. For lobectomy the FEV1,ppo was estimated using the formula described by ALI *et al.* [21]:

$$FEV_{1,ppo} = FEV_1 - \left(FEV_1 \times \frac{\%\,\text{perfusion of affected lung}}{100} \times \frac{\text{segments of affected lobe(s)}}{\text{segments of lung}} \right) \quad (2)$$

where segments of affected lobe(s) is the number of segments

Table 1. – Clinical and functional characteristics

Subject no.	Age yrs	Sex	Race	Histological type	Karnofsky %	FVC L	FVC %	FEV1 L	FEV1 %	FEV1/ FVC	P_{O_2} mmHg	P_{CO_2} mmHg
1	63	M	NC	Epidermoid	90	3.92	113	2.80	114	0.71	73.3	32.3
2	68	M	C	Adenocarcinoma	100	3.53	105	2.31	99	0.66	75.3	31.8
3	46	M	NC	Large cells	90	3.22	90	2.36	86	0.73	84.3	30.8
4	60	M	NC	Epidermoid	90	3.21	99	2.58	110	0.80	87.8	29.7
5	67	M	C	Adenocarcinoma	90	3.83	84	2.82	90	0.73	80.3	38.9
6	69	M	C	Adenocarcinoma	100	3.34	96	2.69	112	0.86	89.3	33.2
7	72	M	C	Epidermoid	100	2.97	75	2.69	101	0.90	66.1	37.5
8	67	M	C	Large cells	100	2.51	72	2.06	84	0.82	72.5	41.9
9	77	M	C	Epidermoid	100	3.68	96	2.78	111	0.75	73.7	41.2
10	79	M	C	Epidermoid	80	2.86	98	1.89	66	0.66	77.8	36.9
11	59	M	C	Epidermoid	100	2.53	70	2.03	76	0.80	78.6	37.5
12	60	M	C	Epidermoid	90	3.29	85	2.26	81	0.79	83.5	34.5
13	61	M	C	Epidermoid	90	2.67	69	1.71	62	0.64	75.4	42.9
14	66	M	C	Adenocarcinoma	100	3.13	83	2.49	94	0.80	67.7	37.2
15	68	M	C	Epidermoid	90	1.86	61	1.23	57	0.66	63.4	32.5
16	53	F	C	Adenocarcinoma	100	2.65	87	2.40	105	0.90	75.4	38.0
17	67	F	C	Adenocarcinoma	100	2.39	71	1.62	70	0.70	80.0	33.0
18	50	M	C	Adenocarcinoma	90	4.00	84	3.28	93	0.82	83.3	38.3
19	69	M	C	Nonsmall cells	100	3.28	136	2.06	108	0.63	73.5	42.0
20	70	M	C	Nonsmall cells	100	4.80	107	3.01	85	0.63	77.5	36.1
21	60	M	C	Epidermoid	90	3.82	117	2.01	76	0.53	62.4	37.0
22	73	M	C	Nonsmall cells	90	2.37	85	0.99	45	0.45	69.0	34.6
23	43	F	C	Large cells	80	2.30	84	1.93	82	0.84	NA	NA
24	69	M	C	Nonsmall cells	80	2.81	73	2.69	87	0.93	74.4	34.0
25	70	M	C	Epidermoid	80	2.67	87	2.13	88	0.80	54.2	43.9
26	54	M	C	Epidermoid	70	1.87	45	1.07	32	0.57	74.6	34.6
Mean	63.8				92	3.06	80,2	2.26	85.1	0.74	74.9	36.4
SD	8.97				0.08	0.70	30.5	0.58	20.2	0.12	8.1	3.9

FVC: forced vital capacity; FEV1: forced expiratory volume in one second; P_{O_2}: partial pressure of oxygen ; P_{CO_2}: partial pressure of carbon dioxide; M: male; F: female; C: Caucasian; NC: non-Caucasian; NA: not available. kPa×0.133=mmHg.

in pulmonary lobe(s) to be resected and segments of lung is the whole number of segments of affected lung.

In SPECT, the same formula was used for the calculation of $FEV_{1,ppo}$ in pneumonectomy and lobectomy:

$$FEV_{1,ppo} = FEV_1 - (FEV_1 \times \%\,\text{perfusion of resected lobe(s)}) \quad (3)$$

where % perfusion of resected lobe(s) is the percentage of perfusion of lobe(s) to be resected with regard to total radiation of both lungs.

Statistical analysis

The Pearson or the Spearman correlation coefficient was applied, according to its need to verify the concordance between two measures. Values approximately equal to 1 indicated concordance [22, 23].

Results

The study consisted of 26 patients with lung cancer, 13 of these patients (50%) underwent lobectomy and 13 patients (50%) underwent pneumonectomy. The study on six patients was not completed because one patient missed the follow-up and five patients died within 54 days of surgery (two of pneumonia, one of septic shock, one of acute myocardial infarct and one of stroke).

The mean PA-estimated $FEV_{1,ppo}$ was 1.73±0.55 L and the Pearson linear correlation coefficient of the postoperative FEV_1 was 0.8840 ($p<0.0001$). The mean SPECT-estimated value of $FEV_{1,ppo}$ was 1.73±0.53 L and the Pearson linear correlation coefficient of the postoperative FEV_1 was 0.8791, as shown in tables 2 and 3. There was no significant difference between $FEV_{1,ppo}$ values estimated by PA and $FEV_{1,ppo}$ values estimated by SPECT (table 3).

Table 3. – Pearson's linear correlation coefficient for the variables below

Variables	Coefficient	p-value
$FEV_{1,ppo}$ PA×postoperative FEV_1	0.8840	<0.0001
$FEV_{1,ppo}$ SPECT×postoperative FEV_1	0.8791	<0.0001
$FEV_{1,ppo}$ PA×$FEV_{1,ppo}$ SPECT	0.9751	<0.0001

$FEV_{1,ppo}$: postoperative predicted forced expiratory volume in one second; FEV_1: forced expiratory volume in one second; PA: planar acquisition; SPECT: quantitative lung perfusion scan with tomographic imaging.

With regard to the type of surgery performed, the PA-estimated $FEV_{1,ppo}$ in relation to postoperative FEV_1 presented a linear correlation coefficient of 0.8818 ($p=0.0003$) for lobectomies and 0.6444 ($p=0.0610$) for pneumonectomies. The SPECT-estimated $FEV_{1,ppo}$ in relation to postoperative FEV_1, presented a linear correlation coefficient of 0.8182 ($p=0.0021$) for lobectomies and 0.5021 ($p=0.1684$) for pneumonectomies (table 4).

Discussion

Predicted postoperative pulmonary function improves with the use of perfusion-ventilation lung scintigraphy. It shows a

Table 2. – Predicted and real postoperative pulmonary function

Subject no.	Surgery performed	$FEV_{1,ppo}$ L		Postoperative FEV_1 L
		PA	SPECT	
1	Lobectomy	2.45	2.42	1.78
2	Lobectomy	2.14	1.85	1.91
3	Lobectomy	2.00	2.22	Death
4	Pneumonectomy	1.58	1.67	1.00
5	Lobectomy	2.51	2.41	2.39
6	Lobectomy	2.59	2.57	2.1
7	Pneumonectomy	2.42	2.26	Death
8	Pneumonectomy	1.36	1.36	1.14
9	Lobectomy	2.39	2.37	1.96
10	Lobectomy	1.61	1.54	1.26
11	Lobectomy	1.32	1.29	1.44
12	Pneumonectomy	1.44	1.64	1.51
13	Lobectomy	1.43	1.41	Death
14	Lobectomy	1.93	2.09	1.85
15	Pneumonectomy	1.15	1.22	0.98
16	Pneumonectomy	1.68	1.65	1.46
17	Pneumonectomy	0.97	0.91	Death
18	Lobectomy	2.77	2.67	2.24
19	Lobectomy	1.80	1.66	1.22
20	Pneumonectomy	1.62	1.62	Death
21	Pneumonectomy	1.27	1.25	1.38
22	Lobectomy	0.81	0.72	0.85
23	Pneumonectomy	1.04	1.08	0.98
24	Pneumonectomy	1.69	1.83	NA
25	Pneumonectomy	1.87	2.09	1.83
26	Pneumonectomy	1.18	1.18	1.47
Mean		1.73	1.73	1.54
SD		0.55	0.53	0.45

$FEV_{1,ppo}$: postoperative predicted forced expiratory volume in one second; FEV_1: forced expiratory volume in one second; PA: planar acquisition; SPECT: quantitative lung perfusion scan with tomographic imaging; NA: not available.

Table 4. – Spearman's linear correlation coefficient for the variables according to the type of surgery

Variables	Coefficient (p-value)	
	Lobectomy	Pneumonectomy
$FEV_{1,ppo}$ PA×postoperative FEV_1	0.8818 (0.0003)	0.6444 (0.0610)
$FEV_{1,ppo}$ SPECT×postoperative FEV_1	0.8182 (0.0021)	0.5021 (0.1684)
$FEV_{1,ppo}$ PA×$FEV_{1,ppo}$ SPECT	0.9780 (<0.0001)	0.9670 (<0.0001)

$FEV_{1,ppo}$: postoperative predicted forced expiratory volume in one second; FEV_1: forced expiratory volume in one second; PA: planar acquisition; SPECT: quantitative lung perfusion scan with tomographic imaging.

good degree of accuracy, it is noninvasive and accessible. Patients with spirometric results that indicate intermediate or high risk for surgery should have their regional lung function assessed by this method. In these cases, the $FEV_{1,ppo}$ is estimated by a significant linear correlation [6, 9, 11, 13]. This method could be made more precise by incorporating tomographic imaging.

This study demonstrates a good correlation between $FEV_{1,ppo}$ estimated for both PA as well as SPECT and the real postoperative FEV_1. Both methods were more precise in predicting postoperative pulmonary function for lobectomies than for pneumonectomies (table 4).

The $FEV_{1,ppo}$ estimated by SPECT has been used in the preoperative assessment of patients with lung cancer and the results obtained have been similar to those obtained in this study. IMAEDA *et al.* [24] conducted a study on 33 patients and analysed the precision of SPECT with perfusion-inhalation in the prediction of postoperative pulmonary function. The SPECT sections were correlated with the computerised tomographic images of the thorax for better delimitation of the lobes to be resected. After a postoperative period of 3–6 months, the correlation between $FEV_{1,ppo}$ and FEV_1 was found to be good, with a linear correlation coefficient of 0.80–0.87, respectively [24].

In the PA-estimated $FEV_{1,ppo}$, the calculation of the pulmonary function of each lobe is obtained using an antero-posterior projection on a two-dimensional image. It does not take into consideration the spatial overlapping of the pulmonary lobes and the differences in their size or perfusion. Conversely, in the case of the SPECT-estimated $FEV_{1,ppo}$, these problems can be resolved by measuring the perfusion for each pulmonary lobe, hoping for a better correlation between $FEV_{1,ppo}$ and real postoperative FEV_1. Although the SPECT estimate of $FEV_{1,ppo}$ utilises more sophisticated technological resources, this method was not superior to the PA estimate of $FEV_{1,ppo}$ in this study (linear correlation coefficient: 0.9751; $p<0.0001$). Perhaps the SPECT estimate of $FEV_{1,ppo}$ could be improved by combining these images with computerised tomography, which does not provide functional images of the lung, but provides precise anatomic information that could diminish the anatomic imprecision of the SPECT images [17–19].

In conclusion, the postoperative predicted forced expiratory volume in one second estimated by both methods, planar acquisition and single-photon emission computed tomography, has a good correlation with the real forced expiratory volume in one second, but it did not verify the superiority of single-photon emission computed tomography over planar acquisition. Both methods were more precise in patients who underwent a lobectomy than in those who underwent a pneumonectomy.

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