Accuracy and precision of perfusion lung scintigraphy versus $^{133}$Xe-radiospirometry for preoperative pulmonary functional assessment of patients with lung cancer

Denis Mariano-Goulart¹, Eric Barbotte², Célia Basurko², F. Comte¹, Michel Rossi¹.

¹ Department of Nuclear Medicine, Montpellier University Hospital, Montpellier, France.

² Department of Statistics and Epidemiology, Montpellier University Hospital, Montpellier, France.

Communicating author:

Nam: Denis Mariano-Goulart

Address: Service Central de Médecine Nucléaire, CHU Lapeyronie, 371 avenue du Doyen Gaston Giraud, 34295 Montpellier Cedex 5, France

Telephone number: +33-467-338-598

Fax number: +33-467-338-465

E-mail: d-mariano_goulart@chu-montpellier.fr
Abstract. **Purpose:** This study sought to determine whether $^{133}$Xe-radiospirometry (XRS) successfully selects patients able to undergo lung resection without postoperative respiratory complication and whether perfusion lung scintigraphy (PLS) is likely to provide a similar selection of patients for certain stages of the tumor. **Methods:** Two hundred and eighty-four patients with resectable lung cancer underwent preoperative assessment of postoperative forced expiratory volume in one second ($\text{FEV}_1$) by XRS and PLS. Correlations, the Bland and Altman analysis and contingency tables were used to analyze the difference between the two predictive techniques. **Results:** One hundred and sixty patients underwent lung resection on the basis of XRS preoperative testing only. None of them developed respiratory insufficiency. Despite a close correlation, the limits of agreement between predicted $\text{FEV}_1$ by XRS and PLS exceeded $\pm 0.3 \text{ L/s}$. For tumor stages T1Nx and T2N0, PLS underestimated postoperative $\text{FEV}_1$ whereas it overestimated this parameter for stages III. **Conclusion:** The agreement between XRS and PLS is unacceptable, whereas XRS accurately selects patients able to undergo lung resection without postoperative pulmonary insufficiency. When only PLS is available, higher thresholds for patients with stage III cancers and lower thresholds for those with stage I cancers should be used to decide on operability.

**Key Words:** Radiospirometry – Xenon - perfusion – $99\text{mTc}$ albumin – Pulmonary resection – Lung cancer.
Introduction

When indicated, surgical resection offers the best chance for cure in patients with non-small cell lung carcinoma. However, the transitory increase in the dead space to tidal volume ratio during the postoperative period may be responsible for postoperative respiratory insufficiency in patients with impaired preoperative lung function [1]. This heightens the need for both efficient postoperative care and an accurate selection of patients who are likely to undergo lung resection without severe postoperative respiratory complications [2, 3]. Several studies have pointed out that global spirometric tests fail to detect the patients that are at high risk of postoperative complications, particularly among those with chronic obstructive pulmonary disease [1, 4]. Nevertheless, these tests are recommended by several guidelines before pulmonary resection [5, 6], and criteria for selecting patients who should be able to tolerate lung resection have been proposed on the basis of these tests [7, 8]. When these criteria are not fulfilled, assessment of regional lung function by quantitative imaging is required. Most studies and guidelines suggest that pulmonary resection is feasible in patients with a predicted postoperative FEV\textsubscript{1} of 30-40\% or more of the normal value [1, 3, 9, 10], or 1-1.2 L/s [11, 12]. Quantitative computed tomography scanning has shown promising results, but this method is not yet widely used [2, 3, 13, 14]. More usually, radionuclide techniques, including lung ventilation or perfusion scintigraphy, are employed for the assessment of postoperative pulmonary function [11, 15, 16].
Since the use of functional vital capacity (FVC) does not improve the accuracy of patient selection [18], the regional measurement of forced expiratory volume in the first second (FEV₁) is regarded as the most reliable spirometric index of pulmonary insufficiency and has been chosen by most investigators to assess operability. With the use of a spirometer and a large field-of-view gamma-camera, equilibrium ¹³³Xe-radiospirometry allows simultaneous measurements of the global FEV₁ and regional lung activities that are proportional to the volumes of the pulmonary lobes. Thus measurements of changes in regional activities in the first second of maximal forced expiration provide a direct assessment of regional FEV₁.

Along with bronchspirometry, which is invasive, ¹³³Xe-radiospirometry is considered as the method of first choice for the assessment of preoperative pulmonary function [18-27]. However, the widespread clinical use of this technique is impeded by the difficulties of performing a spirometric test with a gaseous isotope in routine clinical settings.

Alternatively, calculations based on measurements of regional activities on static ventilation radionuclide scans have been used to estimate preoperative FEV₁. However, Tc-99m aerosols or ultrafine carbon particles cannot be delivered to poorly ventilated peripheral respiratory bronchioles and the physical decay of ⁸¹m-krypton occurs before an equilibrium distribution can be attained. Thus the uptake of these static ventilation agents can only be regarded as an indirect means to assess regional FEV₁ measured during unforced breathing. Since airway hypoxia leads to vasoconstriction of peripheral pulmonary arteries, static ventilation and perfusion lung scintigraphies generally show a similar distribution of activity in patients
with no isolated perfusion defects. Previous studies have compared the capacity of static perfusion and ventilation studies for predicting postoperative lung function and reported no significant difference in accuracy, with a trend toward technetium-99m macroaggregated albumin (\(^{99m}\text{Tc-MAA}\)) perfusion scintigraphy as the most reliable method in routine settings \([1, 28, 29]\).

Using postoperative spirometric measurements as a gold standard, however, some authors have pointed out the high imprecision of perfusion lung scintigraphy in predicting postoperative residual pulmonary function for pneumectomies as well as for lobectomies \([10, 30-35]\). This method may be appropriate for measuring the precision of preoperative predictions, but it does not directly address the problem of preventing postoperative respiratory insufficiency. Since perfusion scintigraphy remains in routine use for the assessment of operability, these results illustrate the need to confirm the accuracy of this method for determining the risk of postoperative pulmonary insufficiency among patients scheduled for lung resection.

The goals of this study were therefore twofold. First, we sought to determine whether \(^{133}\text{Xe}\)-radiospirometry actually succeeds in selecting patients able to undergo lung resection safely. Second, we investigated whether the simpler perfusion lung scintigraphy is likely to provide a similar selection of patients for certain stages of cancer, which would justify its use in place of \(^{133}\text{Xe}\) radiospirometry.
Materials and methods

Patients

Two hundred and eighty-four patients (60 females and 224 males, mean age 64±10 years, range 38-84 years) referred for isotopic preoperative pulmonary functional assessment were prospectively included in the study. Ethical approval was obtained from the Ethics Committee of the School of Medicine. All patients were affected by squamous cell carcinoma or adenocarcinoma and scheduled for lobectomy or pneumectomy. The international system for staging lung cancer [36] was used to classify the anatomic extent of the disease. Mean T and N values were respectively 2.3±1 (range 1-4) and 0.9±1 (range 0-3). None of the patients presented known distant metastasis when the perfusion scintigraphy and the radiospirometry were performed (M=0). The number of patients included in the study with respect to T and N descriptors is shown in Table 1. Using the international stage grouping classification schema, this corresponds to 105 patients (37 %) with IA or IB, 54 patients (19 %) with IIA or IIB, 66 patients with IIIA (23 %) and 59 patients (21 %) with IIIB.

In the patient population, the primary tumor was located almost as often in the right lung (141 patients, 25% in the upper lobe, 20% in the lower lobe, 5 % in the middle lobe) as in the left lung (143 patients, 28 % in the upper lobe, 21 % in the lower lobe, 1 % in the lingular segments). Thirty-nine patients had a history of previous lung surgery regarding the right lung (12 upper lobectomies, 5 lower lobectomies, 1 middle lobectomy and 2 pneumectomies) or the left lung (8 upper lobectomies, 7 lower
lobectomies and 4 pneumectomies). Given the six patients with a history of pneumectomy, the results described for the whole study population were evaluated in a population of 278 patients only when the possibility of another pneumectomy was under consideration.

All patients underwent $^{133}$Xe-radiospirometry, immediately followed by a perfusion lung scintigraphy. The results from the perfusion scintigraphy were not used to decide whether the patients would undergo lung surgery. According to usual guidelines [3, 9], the decision to operate was based on $^{133}$Xe-radiospirometric assessment, when the predicted postoperative FEV$_1$ was above a threshold defined as 1 L/s or 35% of the normal FEV$_1$ evaluated with respect to the gender, height and age of the patient [37]. Postoperative complications were prospectively monitored and were defined as any cardiovascular or pulmonary trouble that required special treatment within 1 month of the operation. This included postoperative ventilation support > 24 h, reintubation for respiratory failure, acute carbon dioxide retention, pneumonia and atelectasis.

_scintigraphic assessment of regional pulmonary function_

Dynamic scintigraphic studies were recorded using a large field-of-view dual-head gamma camera (DST-XL, SMVi, Buc, France) with low-energy high-resolution parallel-hole collimators. All ventilation images were acquired in a 64x64 matrix. The patient was installed in the seated upright position in front of the radiospirometer. The two detectors of the gamma-camera were facing the back of the patient, in the left (LPO) and right posterior oblique (RPO) incidences. These incidences were chosen to
minimize the differential attenuation of the $^{133}$Xe signal from the different lobes. Next, 1110 MBq (30 mCi, that is 3mCi/L) of $^{133}$Xe gas was introduced into a closed rebreathing spirometer (Ventil-Con II; RadX, Houston, Texas) equipped with a CO$_2$ absorber and oxygen supply. After becoming accustomed to the mouthpiece and nose clip, the patient was instructed to breathe normally at the usual rate for at least 3 minutes to reach equilibrium. During this phase, FVC measurements were performed. Once equilibrium was reached, the FEV$_1$ measurements were recorded as planar dynamic LPO, and RPO scintigraphic data were acquired at five images/s for 20 seconds. This acquisition was followed by a washout phase during which the patient inspired room air. The expired mixture of $^{133}$Xe and room air was vented to a charcoal trap ventilation system. Washout images were recorded every 2 seconds for 2 minutes, but were not used for this study.

Last, with the subject still connected to the spirometer and the camera in the same position, 185 MBq (5 mCi) of $^{99m}$Tc-macroaggregated albumin were injected intravenously and static perfusion images were acquired in a 128x128 matrix.

Image treatment and analysis

First, the dynamic images recorded during FEV$_1$ measurement were summed and a threshold corresponding to 30% of the maximal pixel activity in the resulting image was used to set the background pixel values to zero. This image was used to define six regions of interest (ROI) corresponding to the upper lobes, the lower lobes, the middle lobe and the two lingular segments. To improve accuracy and reproducibility, the ROIs were defined
using the segmental reference chart proposed by Magnussen et al. [38]. The two images corresponding to this reference chart for left and right posterior oblique views were automatically translated and scaled to fit the summed images of the lung activity (Fig. 1).

![Figure 1](image)

Then, for each dynamic image corresponding to a time interval of 0.5 seconds, the values of the pixels belonging to a given ROI were summed to derive six time-activity curves (TAC). Because the images were acquired at equilibrium and the half-life of $^{133}$Xe is relatively long compared with the duration of the test ($T=5.24$ days), the activities measured in these TACs were proportional to the volumes of each pulmonary lobe. The coefficient of proportionality was computed by comparing the global FEV$_1$ and the corresponding variation of activity within the two lungs. Thus measurements of the variation of activity within a given ROI during 1 second of forced expiration following maximal inspiration provided a direct measurement of regional FEV$_1$, for each of the six lobes studied. These measurements of FEV$_1$ were termed radiospirometric measurements (RS-
FEV\textsubscript{1}). Similarly, the same ROIs were applied to the static left and right posterior oblique perfusion scintigraphic images. The relative function of each lobe was estimated by the ratio of the activity in the corresponding ROI to the total lung activity. Regional lung function was then estimated to be the product of the relative function of a given pulmonary lobe and the global FEV\textsubscript{1} measured during the radiospirometric test. These measurements of FEV\textsubscript{1} were termed perfusion measurements (P-FEV\textsubscript{1}) and compared with the radiospirometric measurements.

Statistical analysis

The mean value ± standard deviation (SD) and the range characterize the distributions of the parameters. Statistical significance was defined as p-value < 0.05. Continuous data were compared with a paired Student’s t-test or a paired Wilcoxon’s test, as appropriate. Agreements between predicted postoperative parameters provided by perfusion lung scintigraphy and \textsuperscript{133}Xe-radiospirometry were assessed using the Bland and Altman method. The limits of agreement of the two methods were defined as the mean difference ±1.96 standard deviation of the differences. The consequences of these limits of agreement were explored by computing positive and negative predictive values for the two methods with the previously defined threshold. A ROC curve analysis was performed to determine the threshold for lung perfusion scintigraphy that would prevent any lung resection that had been rejected using \textsuperscript{133}Xe-radiospirometry. Last, in order to investigate whether the (T, N) staging could explain the differences in FEV\textsubscript{1} assessments by the
two scintigraphic methods, these differences were divided into quartiles to perform a Pearson $\chi^2$ test and a Mantel-Haenszel $\chi^2$ test for trend.

**Results**

_Chi-squared test for trend and immediate outcome after surgery_

For the whole population, the mean global FVC and FEV$_1$ were respectively $3.13 \pm 0.72$ L (range: 1.21-5.28 L) and $2.02 \pm 0.59$ L/s (range: 0.88-4.51 L/s). One hundred and sixty patients (56%) of the 284 included had a predicted postoperative FEV$_1$ assessed by $^{133}$Xe-radiospirometry that was above the operability threshold; these patients underwent lung surgery within 1 month of the scintigraphic assessment of regional pulmonary function. The surgical resection included 82 right lobectomies (32 upper lobectomies, 19 lower lobectomies, 7 middle lobectomies and 24 pneumectomies) and 78 left lobectomies (34 upper lobectomies, 19 lower lobectomies and 25 pneumectomies). The patients who underwent pneumectomy had predicted RS-FEV$_1$ = $1.26 \pm 0.31$ (range 0.73 – 2.21) as assessed by radiospriomtry and P-FEV$_1$ = $1.26 \pm 0.29$ (range 0.72 – 2.14) as assessed by perfusion scintigraphy. For the patients who had a lobectomy, the predicted postoperative FEV$_1$ values were RS-FEV$_1$ = $1.81 \pm 0.53$ (range 0.74 – 3.45) and P-FEV$_1$ = $1.81 \pm 0.59$ (range 0.82 – 3.76), respectively. No patient developed respiratory insufficiency or required supplemental oxygen at the time of hospital discharge. The postoperative course was uneventful for 151 patients. Nine patients (5.6%) died within the first month of surgery. The
complications responsible for these fatal outcomes were postoperative septic shock (5 patients who benefited from neoadjuvant chemotherapy), cardiogenic shock (3 patients) and acute bleeding (1 patient).

Correlations in the whole population

In the whole population studied, the intraclass correlation coefficient between preoperative P-FEV\textsubscript{1} and RS-FEV\textsubscript{1} assessed for pneumectomy was 0.90 (95% confidence interval: 0.88-0.92), showing a very good global agreement between perfusion scintigraphy and \textsuperscript{133}Xe-radiospirometry (Fig. 2).

![Figure 2.](image)

The differences D\textsubscript{1} between P-FEV\textsubscript{1} and RS-FEV\textsubscript{1} assessed for pneumectomy ranged from –0.89 to 0.55 L/s (Fig. 3). The mean difference was 0.014 ± 0.17 L/s and the limits of agreement were –0.32 to 0.34 L/s. The Wilcoxon test showed that D\textsubscript{1} was significantly different from zero,
although this difference was relatively small ($p<0.03$; median difference = 0.015 L/s).

Figure 3.

Similar means and limits of agreement were found when $D_1$ was evaluated for the two subgroups corresponding to right and left pneumectomies.

When a lobectomy was scheduled, the intraclass correlation coefficient between P-FEV$_1$ and RS-FEV$_1$ was 0.94 (95% confidence interval: 0.92-0.95) for all the patients included in the study, confirming the very good global agreement between perfusion scintigraphy and $^{133}$Xe-radiospirometry (Fig. 4). The differences $D_2$ between P-FEV$_1$ and RS-FEV$_1$ assessed for lobectomy ranged from –0.85 to 0.72 L/s (Fig. 5). The mean difference was 0.011 ± 0.21 L/s and the limits of agreement were –0.39 to 0.41 L/s. The Wilcoxon test showed that $D_2$ was not significantly different
from zero, although this difference was relatively small ($p=0.06$; median difference $= 0.03 \text{ L/s}$).

Figure 4

Figure 5.
Similar means and limits of agreement were found when $D_2$ was evaluated for the subgroups corresponding to lower and upper lobectomies, as well as for the right and left lungs.

Tables 2 and 3 show the number of patients that would have been accepted or rejected for a lung resection using the previously defined threshold. According to the preoperative results provided by $^{133}$Xe-radiospirometry, 56% of the patients would have been accepted for pneumectomy and 91% for lobectomy. Of the 15 patients for whom radiospirometric analysis did not allow pneumectomy whereas perfusion scintigraphy did, nine underwent lobectomy without postoperative complication, and six were denied surgery. For those six patients, the difference $P$-FEV$_1$ – RS-FEV$_1$ averaged 0.31 ± 0.13 L/s (range: 0.16-0.55 L/s). To prevent any pneumectomy that would have been rejected using $^{133}$Xe-radiospirometry, the threshold for perfusion scintigraphy was 1.46 L/s. On the other hand, the only patient who was denied lobectomy, whereas $P$-FEV$_1$ was above the threshold, had similar predictive FEV$_1$ by the two methods (1.06 and 0.94 with perfusion scintigraphy and radiospirometry, respectively).

The positive predictive values for the perfusion lung scintigraphy were 90% for pneumectomy (95% confidence interval: 83-93) and 99.6 % for lobectomy (95% confidence interval: 96-99); the negative predictive values were 88% (95% confidence interval: 83-94) and 71% (95% confidence interval: 55-86), respectively.
Links with the anatomic extent of the lung cancer

Stage T, as well as the international stage grouping classification, was significantly linked with the difference in the assessment of FEV$_1$ by perfusion scintigraphy and $^{133}$Xe-radiospirometry ($p = 0.01$ and $p = 0.03$, respectively) when a pneumectomy was scheduled. For pneumectomies, perfusion scintigraphy underestimated postoperative FEV$_1$ when T=1 or for stages IA and IB. On the contrary, for T=4 and for stages IIIA or IIIB, perfusion scintigraphy overestimated postoperative FEV$_1$ in comparison with $^{133}$Xe-radiospirometry. All but one of the patients who were denied surgery with P-FEV$_1$ suggesting operability had IIIB tumors. The Mantel-Haenszel test showed evidence of a linear quantitative relationship between the differences and the grouped stages ($p = 0.01$). A similar tendency occurred when stage N was studied alone or when a simple lobectomy was scheduled. In these situations, however, no significant link between the difference in predicted FEV$_1$ and the staging could be proven by our data ($p = 0.07$-$0.09$ for T or grouped stages when a lobectomy was scheduled and $p = 0.22$-$0.52$ for N stages whatever the surgery).

Discussion

Using postoperative measurements of FEV$_1$ as a gold standard, most authors have reported an overall imprecision and inaccuracy of perfusion scintigraphy in the assessment of postlobectomy residual pulmonary function, with errors greater than 15% leading to significant postoperative mortality [12]. Some authors have reported significant overestimations of
postoperative FEV$_1$ [30,34], whereas others have pointed out several limitations including a systematic underestimation of postoperative FEV$_1$ [28, 11]. Thus, previous studies stated that a predictive preoperative FEV$_1$ of around 0.7-0.8 L/s should not be considered a total contraindication to surgery, whereas an operability threshold of predicted postoperative FEV$_1$ equal to 1.2-1.3 L/s should be chosen, especially for left pneumectomies or upper lobectomies where the margin of uncertainty is greater [11].

The key clinical point, however, is not so much to verify that perfusion lung scintigraphy can predict postoperative FEV$_1$ as it is to determine whether this technique is able to reliably identify the patients with an increased risk of pulmonary insufficiency during the postoperative period. Moreover, even if postoperative measurements of FEV$_1$ may be regarded as a gold standard, this parameter is often difficult to measure with high reproducibility when, as in the present work, the study population is living in a large geographic area. For this reason, the immediate postoperative outcome was used to determine whether scintigraphic methods can actually succeed in selecting patients able to undergo lung resection safely.

In the present study, operability was decided on using predicted postoperative FEV$_1$ assessed by $^{133}$Xe-radiospirometry only, with the threshold value that is generally used with lung perfusion scintigraphy [1,3,9,10,11]. None of the 160 patients who underwent lobectomy or pneumectomy developed postoperative respiratory insufficiency or a need for supplemental oxygen. This justifies the use of $^{133}$Xe-radiospirometry as a gold standard to evaluate the results provided by perfusion lung scintigraphy.
in the selection of patients scheduled for surgery, although the study design
did not allow us to draw conclusions about the seven patients (2.5% of the
population) who were denied pneumectomy or lobectomy on the basis of
radiospirometric measurements, whereas lung perfusion suggested
operability.

Perfusion lung scintigraphy can be regarded as accurate, as the mean
difference between predicted postoperative \( \text{FEV}_1 \) by this technique and by
\(^{133}\text{Xe}-\text{radiospirometry} \) remained small (for pneumectomies) or not
significantly different from zero (for lobectomies). But the limits of
agreement for predicted postoperative \( \text{FEV}_1 \) were greater than ± 0.3 L/s for
pneumectomies as well as for lobectomies. This agreement did not depend
on the lobe in which the tumor was located. Therefore, the differential
attenuation of the \(^{133}\text{Xe} \) signal from the different lobes does not significantly
alter the measurements when posterior oblique incidences are used. In the
population of this study, this poor agreement would have led to a high error
rate in rejecting patients for surgery (12% for pneumectomies and 29% for
lobectomies), mainly for patients with IA, IB and T1Nx lung tumors. These
results are consistent with those published by Giordano et al. [11]. On the
other hand, perfusion lung scintigraphies were found to overestimate
postoperative \( \text{FEV}_1 \) for patients with IIIA or IIIB lung tumors, possibly
because of a decrease in lung perfusion that is not due to the hypoxic
vasoconstriction reflex [41]. Further studies are required to check this
hypothesis, but our results indicate that if only lung perfusion scintigraphy
is available, operability thresholds equal to or possibly lower than 1L/s for
IA, IB and T1Nx lung tumors should be used. On the other hand, when a
pneumectomy is scheduled to cure IIIA or IIIB cancers, higher thresholds of up to 1.4-1.5 L/s are necessary to prevent any lung resection that would be rejected using $^{133}$Xe-radiospirometry.

**Conclusion**

The data presented in this study confirm that, whatever the lung surgery scheduled, $^{133}$Xe-radiospirometry reliably identifies those patients with no increased risk of pulmonary insufficiency during the postoperative period. In clinical centers where $^{133}$Xe-radiospirometry is unavailable, preoperative pulmonary function testing may be performed with perfusion lung scintigraphy, provided that higher thresholds are used to decide on operability in patients with advanced lung cancers. Last, as recently suggested [42], the results of this study point out the need for further research to determine whether it is possible to use lower thresholds for $^{133}$Xe-radiospirometry, in order not to deny surgery to patients who are able to tolerate it.
References


Figure legends

**Fig. 1.** Definition of the regions of interest and time-activity curves showing volumes of each pulmonary lobe versus time, during a $^{133}$Xe-radiospirometric test.

**Fig. 2.** Predicted postoperative FEV$_1$ for pneumectomy, assessed by perfusion scintigraphy (P-FEV$_1$) versus $^{133}$Xe-radiospirometry (RS-FEV$_1$).

**Fig. 3.** Plot of the predicted postoperative FEV$_1$ difference for pneumectomy (perfusion scintigraphy minus $^{133}$Xe-radiospirometry) against the mean obtained by the two methods. Solid lines represent the limits of agreement. The dashed line represents the mean difference.

**Fig. 4.** Predicted postoperative FEV$_1$ for lobectomy, assessed by perfusion scintigraphy (P-FEV$_1$) versus $^{133}$Xe-radiospirometry (RS-FEV$_1$).

**Fig. 5.** Plot of the predicted postoperative FEV$_1$ difference for lobectomy (perfusion scintigraphy minus $^{133}$Xe-radiospirometry) against the mean obtained by the two methods. Solid lines represent the limits of agreement. The dashed line represents the mean difference.
**Table 1.** Number of patients included in the study with respect to T and N stages

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>All T</th>
</tr>
</thead>
<tbody>
<tr>
<td>N0</td>
<td>68</td>
<td>37</td>
<td>17</td>
<td>18</td>
<td>140</td>
</tr>
<tr>
<td>N1</td>
<td>11</td>
<td>26</td>
<td>11</td>
<td>12</td>
<td>60</td>
</tr>
<tr>
<td>N2</td>
<td>4</td>
<td>34</td>
<td>17</td>
<td>16</td>
<td>71</td>
</tr>
<tr>
<td>N3</td>
<td>0</td>
<td>1</td>
<td>8</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>All N</td>
<td>83</td>
<td>98</td>
<td>53</td>
<td>50</td>
<td>284</td>
</tr>
</tbody>
</table>
Table 2. Number of patients with predictions of postoperative FEV$_1$ compatible or not with pneumectomy, using assessment by perfusion scintigraphy or by $^{133}$Xe-radiospirometry

<table>
<thead>
<tr>
<th>Pneumectomy</th>
<th>RS-FEV$<em>1$ &gt; FEV$</em>{LIM}$</th>
<th>RS-FEV$<em>1$ &lt; FEV$</em>{LIM}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-FEV$<em>1$ &gt; FEV$</em>{LIM}$</td>
<td>141</td>
<td>15</td>
</tr>
<tr>
<td>P-FEV$<em>1$ &lt; FEV$</em>{LIM}$</td>
<td>14</td>
<td>108</td>
</tr>
</tbody>
</table>

$P$ Perfusion lung scintigraphy, $RS$ $^{133}$Xe-radiospirometry

$FEV_1$ Forced expiratory volume in 1 second

$FEV_{LIM}$ 1 L/s or 35% of the normal global FEV$_1$ for the patient
Table 3. Number of patients with predictions of postoperative \( \text{FEV}_1 \) compatible or not with lobectomy, using assessment by perfusion scintigraphy or by \(^{133}\text{Xe}\)-radiospirometry

<table>
<thead>
<tr>
<th>Lobectomy</th>
<th>RS-FEV(<em>1 &gt; \text{FEV}</em>{\text{LIM}})</th>
<th>RS-FEV(<em>1 &lt; \text{FEV}</em>{\text{LIM}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-FEV(<em>1 &gt; \text{FEV}</em>{\text{LIM}})</td>
<td>249</td>
<td>1</td>
</tr>
<tr>
<td>P-FEV(<em>1 &lt; \text{FEV}</em>{\text{LIM}})</td>
<td>10</td>
<td>24</td>
</tr>
</tbody>
</table>

\( P \) Perfusion lung scintigraphy, \( RS \) \(^{133}\text{Xe}\)-radiospirometry

\( \text{FEV}_1 \) Forced expiratory volume in 1 second

\( \text{FEV}_{\text{LIM}} \) 1 L/s or 35% of the normal global \( \text{FEV}_1 \) for the patient