CALCULATION OF RESIDUAL VOLUME BY SPIROMETRIC DATA

R. HASHEMI, M.D., S.M. HOMAYOUNI, M.D., A.A. MEHRABIAN M.D., AND H. ZOJAJI, M.D.

From the Dept. of Internal Medicine, Shohada Medical & Educational Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

ABSTRACT

Background: The current practice to measure RV is either by BPG or helium dilution methods which may not be available in all clinics due to their cost.

Methods: This paper outlines a method for both direct and indirect calculation of RV via PFT with acceptable sensitivity (81%, 60%), specificity (71%, 94%) and validity (76%, 78%) for obstructive and restrictive lung disease respectively at a much lower cost.

Keywords: RV: Residual Volume, BPG: Body Plethysmography, PFT: Pulmonary Function Test, FRC: Functional Residual Capacity, ERV: Expiratory Reserve Volume.

INTRODUCTION

The measurement of FRC and TLC is dependent on the measurement of RV which is carried out by either BPG or helium dilution method. In the former a special chamber containing a spirometer is used where the subject is placed inside and is totally isolated from outside.

By measuring certain parameters FRC is calculated from the following formula (Boyle’s law):

\[ FRC = P_{v} \times (FRC + dv) \]

Having found FRC from the above and measuring ERV from the spirometric method, RV is then calculated by subtracting the two values.

In the helium dilution method, however, FRC is calculated from the following formula:

\[ V_{C_{2}} = FRC \times C_{2} \]

where \( C_{1} \) and \( C_{2} \) are the concentration of helium before and after inhalation and \( V \) is the initial volume of helium. As in the previous method RV is calculated from subtraction of FRC and ERV. Despite being the standard method, the above produces varied results under the same conditions.

MATERIAL AND METHODS

Theory

Principally RV is dependent on two parameters, namely vital capacity and degree of obstruction. Therefore it can be stated that:

\[ RV \text{ measured} = RV \text{ predicted} \times K \quad (F1) \]

Where \( K \) is an index defined as % vital capacity / % obstruction, i.e. RV measured is a fraction of RV predicted. It is possible to calculate percentages of vital capacity and obstruction by using the ratio of FVC measured / FVC predicted over mean obstruction of large and small airways, i.e. \( \frac{1}{2} \left( \% \text{FEV1 measured} / \% \text{FEF25-75 measured} \right) \) respectively. Therefore formula (1) can be expressed as:

\[ RV \text{ measured} = \frac{2 \times FVC \text{ measured}}{FVC \text{ predicted}} \quad (F2) \]

or

\[ RV \text{ predicted} = \frac{\% \text{FEV1 measured} + \% \text{FEF25-75 measured}}{FRC \times C_{2}} \quad (F3) \]

\[ RV \text{ measured} = \frac{2 \times FVC \text{ measured}}{FVC \text{ predicted}} \quad (F4) \]

\[ RV \text{ predicted} = \frac{\% \text{FEV1 measured} + \% \text{FEF25-75 predicted}}{FVC \text{ measured}} \quad (F5) \]

\[ RV \text{ measured} = \frac{2 \times FVC \text{ measured}}{FVC \text{ predicted}} \quad (F6) \]

\[ RV \text{ predicted} = \frac{\% \text{FEV1 measured} + \% \text{FEF25-75 predicted}}{FVC \text{ measured}} \quad (F7) \]

Correspondence: S.M. Homayouni, M.D., Dept. of Internal Medicine, Shohada Medical & Educational Center, Tajrish Square, Tehran, Iran, Tel. 009821-22718001.
Calculation of Residual Volume by Spirometric Data

Now RV predicted in males and females is calculated as follows:

Males RV predicted = 0.022Age + 1.98H - 0.013w - 1.54 ± 0.4 \ (F4)
Females RV predicted = 0.007Age + 2.66H - 3.42 ± 0.4 \ (F5)

It is therefore possible to easily calculate RV measured by having \(\% \text{FVCr/FVCp.} \% \text{FEV1m/FVCm, FEF25-75m/FEF25-75p}\) which are obtained by PFT.

RESULTS

A sample size of 110 cases who were referred to Sasan Hospital for BPG were considered over a period of 4 years. These patients were also tested for PFT at the same time.

Table I shows the results of RV obtained from BPG (gold standard) and that calculated from formula (2) suggested in this paper; then the two values were compared using paired t-test which was not significant (p > 0.5) with a correlation coefficient of \(r = 0.78\).

Using formula (3) \(RVm/RVp\) was also compared with that of RV measured/ RV predicted obtained from BPG in obstructive and restrictive lung disease. Tables II and III are the results of comparing data in obstructive and restrictive lung diseases respectively.

Table I. Results of calculated and measured RV by the two methods.

<table>
<thead>
<tr>
<th>No.</th>
<th>BPG RV</th>
<th>F2 RV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.5</td>
<td>1.3</td>
</tr>
<tr>
<td>2</td>
<td>2.5</td>
<td>1.9</td>
</tr>
<tr>
<td>3</td>
<td>2.8</td>
<td>2.5</td>
</tr>
<tr>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>Mean X</td>
<td>Mean Y</td>
<td></td>
</tr>
</tbody>
</table>

Table II. Comparing RV ratio in obstruction by the two methods.

<table>
<thead>
<tr>
<th>(BPG)</th>
<th>(% \text{RVm/RVp calculated})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\geq 120%) \hspace{1cm} &lt;120%</td>
</tr>
<tr>
<td>(\geq 120%)</td>
<td>44 \hspace{1cm} 10</td>
</tr>
<tr>
<td>(&lt;120%)</td>
<td>16 \hspace{1cm} 40</td>
</tr>
</tbody>
</table>

Obstruction

sensitivity = 81\% \hspace{0.5cm} \text{specificity} = 71\% \hspace{0.5cm} \text{validity} = 76\% \hspace{0.5cm} \text{PPV} = 73\% \hspace{0.5cm} \text{NPV} = 80\% \hspace{0.5cm} K \hspace{0.5cm} \text{agreement test (Cronbach)} = +0.53

Table III. Comparing RV Ratio in Restriction by the two methods.

<table>
<thead>
<tr>
<th>(BPG)</th>
<th>(% \text{RVm/RVp calculated})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(&lt;80%) \hspace{1cm} \geq 80%</td>
</tr>
<tr>
<td>&lt;80%</td>
<td>6 \hspace{1cm} 4</td>
</tr>
<tr>
<td>(\geq 80%)</td>
<td>6 \hspace{1cm} 94</td>
</tr>
</tbody>
</table>

Restriction

sensitivity = 60\% \hspace{0.5cm} \text{specificity} = 94\% \hspace{0.5cm} \text{validity} = 78\% \hspace{0.5cm} \text{PPV} = 50\% \hspace{0.5cm} \text{NPV} = 96\% \hspace{0.5cm} K \hspace{0.5cm} \text{agreement test (Cronbach)} = +0.47

DISCUSSION

Finding a spirometric method for calculation of RV (vs. measurement) not only improves the evaluation and analysis of PFT but also decreases the cost. Calculation of RV is dependent on two parameters, lung volume (vital capacity) and degree of large and small airway obstruction which is shown as \(\% \text{FEV1} \) and \(\% \text{FEV25-75}\) respectively. Thus RVm can be calculated as a fraction of RVp using formulas 2 and 3.

As indicated in formulas 4 and 5 and 95\% CI a range for RVp is obtained. Comparing the two values without using this range shows a correlation coefficient \(r = 0.78\) for the two methods, but using the range for RVp, RVm is within the range in 91\%.

Finally, clinical use of this method shows that calculation of RV by the method suggested in this paper using both formula 1 and 2 is an acceptable method for determining the presence of obstructive lung disease with a sensitivity of 81\% and specificity of 71\% and validity of 76\% and restrictive lung disease with a sensitivity of 60\%, specificity of 94\% and validity of 78\%.

REFERENCES
