Evaluation of the turbine pocket spirometer

K A GUNAWARDENA, K HOUSTON, A P SMITH

From Riyadh Military Hospital, Riyadh, Saudi Arabia, and Llandough Hospital, Penarth, South Glamorgan

ABSTRACT: A compact electronic spirometer, the turbine pocket spirometer, which measures the FEV₁, forced vital capacity (FVC), and peak expiratory flow (PEF) in a single expiration, was compared with the Vitalograph and the Wright peak flow meter in 99 subjects (FEV₁ range 0–40–5–50 litres; FVC 0.58–6.48 l; PEF 40–650 l min⁻¹). The mean differences between the machines were small—0.05 l for FEV₁, 0.05 l for FVC, and 11.61 min⁻¹ for PEF, with the limits of agreement at ±0.25 l, ±0.48 l, and ±52.2 l min⁻¹ respectively. The wide limits of agreement for the PEF comparison were probably because of the difference in the technique of blowing: a fast, long blow was used for the pocket spirometer and a short, sharp one for the Wright peak flow meter. The FEV₁ and FVC showed a proportional bias of around 4–5% in favour of the Vitalograph. The repeatability coefficient for the pocket spirometer FEV₁ was 0.18 l, for FVC 0.22 l, and for PEF 31 l min⁻¹. These compared well with the repeatability coefficients of the Vitalograph and the Wright peak flow meter, which gave values of 0.18 l, 0.28 l, and 27 l min⁻¹ respectively. At flow rates of over 600 l min⁻¹ the resistance of the pocket spirometer marginally exceeded the American Thoracic Society recommendations. The machine is easy to operate and portable, and less expensive than the Vitalograph and Wright peak flow meter combined. It can be recommended for general use.

Simple measurements of pulmonary function, such as FEV₁, forced vital capacity (FVC), and peak expiratory flow (PEF) are now widely used in the monitoring of patients with airflow limitation both in hospital and at home. In occupational medicine and clinical trials repetitive measurements of these indices may be needed in large numbers of subjects. Inexpensive, portable devices for measuring the PEF have been available for clinical use for many years.¹⁻³ Instruments for measuring FEV₁ and FVC, however, are often expensive and bulky. In 1982 Chowienczyk and Lawson⁴ described a pocket sized device for measuring the FEV₁, and FVC. This instrument gave measurements that agreed well with those of the Ohio spirometer (Ohio Inc, Houston, Texas) when they were connected in series. The device, which the authors called the turbine spirometer, has now been developed further to measure the PEF. The object of the present study was to evaluate this new device in a clinical setting by comparing its performance with that of the Vitalograph (Vitalograph Ltd, Maids Moreton House, Buckingham) and the Wright peak flow meter (Aired, Clement Clarke International Ltd, Harlow, Essex), which are widely used and whose reliability has been established.⁵⁻⁹

Methods

A turbine pocket spirometer loaned by the manufacturers (Micro Medical Instruments, PO Box 6, Rochester, Kent) was compared with a model S Vitalograph and a standard Wright peak flow meter that were in routine use in the lung function laboratory. The turbine pocket spirometer (fig 1) weighs 400 g and is powered by a single 9 V (PP3) battery. The unit consists of a fixed turbine, which generates a rotational flow that drives a low inertia vane. The rotation of the vane is converted into electrical pulses by means of an infrared light emitting diode and a photodiode sensor enclosed in the turbine housing. These electrical pulses are converted into FEV₁, FVC, and PEF measurements by means of a microprocessor in the control unit and are displayed digitally. The pocket spirometer is very easy to operate. When the instrument is switched on no warm up time is necessary, and when the “reset” button is pressed all the readings are converted to zero. The subject is then instructed to perform a forced vital capacity manoeuvre into the mouthpiece. The FVC, FEV₁, and PEF readings can be read directly off the

Address for reprint requests: Dr K A Gunawardena, Riyadh Military Hospital, PO Box 7897, Riyadh 11159, Saudi Arabia.

Accepted 13 January 1987
display by means of the selector switch provided. The readings are stored indefinitely until the reset button is pressed again. The unit at present costs £340.

Volume calibration was effected with a 1-0 litre syringe so that the volume displayed on the pocket spirometer agreed with the volume indicated on the ATPS scale of the Vitalograph. The linearity of the Vitalograph was checked further with increments of 1-0 litre up to 6-0 litres. The percentage error was zero for 1-0 l, but increased slightly at higher volumes, the error at 5-0 l being +2.6%. The calibration of the Wright peak flow meter was checked against a Fisher Controls rotameter (Fisher Controls Ltd, Rotameter Works, Croydon, Surrey) as described by Cotes, but with correction of the observed rotameter flow for both the temperature and the back pressure. The observed meter readings were all within 10% of the expected readings, the percentage error being +5.9% at 200 l min⁻¹ and −8.3% at 800 l min⁻¹, indicating a tendency for the Wright peak flow meter to overread at low values and underread at high values.

Ninety nine subjects took part in the main study. They were drawn from the staff and the patients attending the outpatient chest clinics at the Llandough Hospital. Most subjects were regular attenders at the chest clinics and were familiar with the forced expiratory manoeuvre. The nature and purpose of the study were explained, and after the subject had become familiar with the instruments each provided three technically satisfactory readings with the pocket spirometer, three with the Vitalograph, and three with the Wright peak flow meter. In the case of the pocket spirometer as well as the Wright peak flow meter the assessment of the adequacy of effort could be made only by observing the subject. The instrument to be blown into first was varied systematically, so that the results would not be biased by the effects of training or fatigue. For each comparison the best of the three readings was used. For FEV₁ and FVC the volumes indicated on the BTPS scale of the Vitalograph were compared with the direct digital readout from the pocket spirometer.

Since patients are normally instructed to produce a short, sharp blow into the Wright peak flow meter but a prolonged fast blow for measurement of the FVC and FEV₁, a further study was carried out to compare the PEF readings obtained by a short, sharp blow with the PEF obtained by a prolonged fast blow. Data for short, sharp versus prolonged blows on the Wright peak flow meter were obtained from 44 subjects and similar data for the pocket spirometer were obtained from 41 subjects.

The resistance of the pocket spirometer was measured as described by Cotes. The results were analysed by the statistical methods described by Bland and Altman.

**Results**

**Comparison of the instruments**

In the 99 subjects tested, FEV₁ ranged from 0.40 to 5.50 litres, FVC from 0.58 to 6.48 litres, and PEFR from 40 to 650 l/min. Figure 2 shows the difference between measurements obtained from the two machines plotted against the average of the two readings. The mean difference for the FEV₁ readings was 0.05 l (SD 0.13), for FVC 0.05 l (SD 0.24) and for PEFR 11.6 l min⁻¹ (SD 26). Table 1 gives the 95% confidence limits for the estimates of the mean difference, and the "limits of agreement."¹¹

The differences were negatively correlated with the average reading of FEV₁ (r = −0.39, t = 4.18, df = 97; p < 0.001), and weakly negatively correlated with average FVC (r = −0.198, t = 1.99, df = 97; p < 0.05); but there was no correlation in the case of PEF. The slopes of the regressions for difference versus average were −0.051 for FEV₁ (95% limits −0.075 to −0.027) and −0.041 for FVC (95% limits −0.083 to 0.000). There was thus a significant proportional bias for FEV₁, with the Vitalograph giving the higher readings at higher values of FEV₁.
Evaluation of the turbine pocket spirometer

Fig 2. Comparisons of (a) FEV₁, (b) forced vital capacity (FVC), and (c) peak expiratory flow (PEF) readings of the pocket spirometer with those of the Vitalograph and the Wright peak flow meter: difference between the machines plotted against the average. —— mean; ——— limits of agreement.

This proportional bias would somewhat overestimate the mean and the SD of the differences for FEV₁ and FVC. Logarithmic transformation of the data to remove this relationship was not helpful, as it tended to disproportionately increase the scatter at low readings.

Table 1. Confidence limits for the estimates of mean difference (pocket spirometer – Vitalograph/Wright peak flow meter) and limits of agreement.

<table>
<thead>
<tr>
<th>Estimate</th>
<th>95% limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV₁ (l)</td>
<td></td>
</tr>
<tr>
<td>d̄</td>
<td>-0.05</td>
</tr>
<tr>
<td>SD</td>
<td>0.13</td>
</tr>
<tr>
<td>d̄ - 2SD</td>
<td>-0.30</td>
</tr>
<tr>
<td>d̄ + 2SD</td>
<td>0.20</td>
</tr>
<tr>
<td>FVC (l)</td>
<td></td>
</tr>
<tr>
<td>d̄</td>
<td>-0.05</td>
</tr>
<tr>
<td>SD</td>
<td>0.24</td>
</tr>
<tr>
<td>d̄ - 2SD</td>
<td>-0.53</td>
</tr>
<tr>
<td>d̄ + 2SD</td>
<td>0.43</td>
</tr>
<tr>
<td>PEF (l min⁻¹)</td>
<td></td>
</tr>
<tr>
<td>d̄</td>
<td>-11.6</td>
</tr>
<tr>
<td>SD</td>
<td>26.1</td>
</tr>
<tr>
<td>d̄ - 2SD</td>
<td>-63.6</td>
</tr>
<tr>
<td>d̄ + 2SD</td>
<td>40.4</td>
</tr>
</tbody>
</table>

FVC—forced vital capacity; PEF—peak expiratory flow; d̄—mean difference; SD—standard deviation; d̄ - 2SD = lower limit of agreement; d̄ + 2SD = upper limit of agreement.

SHORT VERSUS LONG BLOWS
The results of the comparisons of the short sharp blows versus the prolonged fast blows are shown in figure 3. For the Wright peak flow meter the mean

Fig 3. Comparisons of short, sharp blows with prolonged fast blows for the measurement of peak expiratory flow on (a) the Wright peak flow meter and (b) the pocket spirometer. —— mean; ——— limits of agreement.
The back pressure generated by the pocket spirometer at various flow rates and resistance of the instrument are shown in table 3.

**Table 2  Confidence limits for the estimates of the mean differences (short blow—long blow)**

<table>
<thead>
<tr>
<th>Method</th>
<th>Estimate (l min⁻¹)</th>
<th>95% limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wright peak flow meter</td>
<td>d</td>
<td>6.25 to 21.93</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>25.8</td>
</tr>
<tr>
<td></td>
<td>d − 2 SD</td>
<td>-37.5</td>
</tr>
<tr>
<td></td>
<td>d + 2 SD</td>
<td>32.0</td>
</tr>
<tr>
<td>Pocket spirometer</td>
<td>d</td>
<td>21.21 to 57.79</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>19.7</td>
</tr>
<tr>
<td></td>
<td>d − 2 SD</td>
<td>-32.0</td>
</tr>
<tr>
<td></td>
<td>d + 2 SD</td>
<td>36.21 to 57.79</td>
</tr>
</tbody>
</table>

Abbreviations as in table 1.

The repeatability for each of the measurements on the series of 99 subjects was assessed by calculating the standard deviation of the difference between the two closest values. The defined repeatability coefficients are twice these standard deviations. This would indicate the 95% probability limit within which the best two out of the three readings would lie. For the Vitalograph FEV1, the repeatability coefficient was 0.18 l, for FVC 0.28 l, and for the Wright machine's PEFR 0.07 l min⁻¹. The corresponding values for the pocket spirometer were: FEV1 0.18 l, FVC 0.22 l, and for PEFR 0.01 l min⁻¹. Thus the repeatability of the readings on the pocket spirometer appeared to be as good as those for the Vitalograph and the Wright peak flow meter.

**Table 3  Resistance of the pocket spirometer at different flow rates (actual flow rates calculated by correcting the observed flow rate for both the temperature and the back pressure)**

<table>
<thead>
<tr>
<th>Observed rotameter flow (l min⁻¹)</th>
<th>Actual flow (l min⁻¹)</th>
<th>Back pressure (mm H₂O)</th>
<th>Resistance (mm H₂O l s⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>98</td>
<td>6.2</td>
<td>3.8</td>
</tr>
<tr>
<td>150</td>
<td>148</td>
<td>13.0</td>
<td>5.3</td>
</tr>
<tr>
<td>200</td>
<td>198</td>
<td>20.2</td>
<td>6.1</td>
</tr>
<tr>
<td>250</td>
<td>249</td>
<td>29.0</td>
<td>7.0</td>
</tr>
<tr>
<td>300</td>
<td>300</td>
<td>43.2</td>
<td>8.6</td>
</tr>
<tr>
<td>350</td>
<td>352</td>
<td>59.4</td>
<td>10.1</td>
</tr>
<tr>
<td>400</td>
<td>405</td>
<td>74.0</td>
<td>11.0</td>
</tr>
<tr>
<td>450</td>
<td>459</td>
<td>94.4</td>
<td>12.3</td>
</tr>
<tr>
<td>500</td>
<td>514</td>
<td>114.4</td>
<td>13.3</td>
</tr>
<tr>
<td>550</td>
<td>570</td>
<td>135.1</td>
<td>14.2</td>
</tr>
<tr>
<td>600</td>
<td>627</td>
<td>160.2</td>
<td>15.3</td>
</tr>
<tr>
<td>650</td>
<td>687</td>
<td>188.9</td>
<td>16.5</td>
</tr>
</tbody>
</table>
Evaluation of the turbine pocket spirometer

limits of agreement should not be too large in relation to
the repeatability coefficient for the established
method.

For the FEV₁ comparison (disregarding the
proportional bias), the limits of agreement of ±0·25 l
seem quite acceptable, considering that the
repeatability coefficient of the FEV₁ for the
Vitalograph is of the order of 0·18 l. For the FVC,
however, with a repeatability coefficient of 0·28 l, the
limits of agreement of ±0·48 l, even though not
excessive, appear less than ideal. The lack of a
comparable endpoint to the expiratory manoeuvre
may explain part of the variation between the
machines. The pocket spirometer does not provide a
visual display of the spiographic curve, and therefore
the adequacy of effort and the end of expiration are
more difficult to judge than with the Vitalograph,
especially in patients with severe airflow obstruction.
Despite this, the repeatability coefficient of 0·22 l for
the FVC on the pocket spirometer was marginally
better than with the Vitalograph.

For PEF, the coefficients of repeatability for the
Wright peak flow meter and for the pocket spirometer
were broadly similar, and the mean difference in the
readings negligible. The limits of agreement of ±52·21/min were, however, wide, but were of the
order that would be expected from comparison of the
readings obtained with a short, sharp blow with the
readings obtained with a prolonged blow on the
Wright peak flow meter. Perhaps the wide limits of
agreement between the two machines could be
explained by the fact that we used a prolonged blow
for the pocket spirometer and a short, sharp one for
the Wright peak flow meter. Possibly better
agreement would have been obtained if we had used
similar type of blows for the two machines.

The minimal spirometry standards laid down by
the American Thoracic Society require the
resistance of a spirometer used for measuring the
FEV₁ to be less than 1·5 cm of water 1 s⁻¹ at a flow
rate of 12 l s⁻¹. With the pocket spirometer the
resistance exceeds 1·5 cm of water 1 s⁻¹ at a flow
rate of around 10 l s⁻¹ (table 3). This, however,
should not be a serious drawback to the clinical use of
the instrument.

The major disadvantage of the pocket spirometer is
the lack of a visual display of the spiographic curve.
Despite this, its overall performance was impressive.
It is eminently portable and easy to use, and gives
accurate and reliable readings if the tests are
performed with sufficient care. The tests can be
performed rapidly with a lesser number of efforts on
the part of the patient to obtain the three most
commonly used parameters of ventilatory function.
At £340 it is considerably cheaper than the combined
cost of a model-S Vitalograph and a standard Wright
peak flow meter (about £820 + £180). The pocket
spirometer should therefore prove to be a useful tool
in a busy respiratory laboratory as well as in the
doctor’s surgery or in clinical and epidemiological
research.

We thank Mrs G Collins, Mrs A Donkin, Mr G
Hawkins, Mr J M Lucas, Mr D H Richards, Mr M J
Saunders, Mr P Thomas, Miss S Tutt, and Miss F
Williams of the lung function laboratory, Llandough
Hospital, Penarth, for their assistance.

References

1 Wright WB, McKerrow CB. Maximum forced
expiratory flow rate as a measure of ventilatory
2 Wright BM. A miniature Wright peak flow meter. Br
3 Perks WH, Cole M, Steventon RD, Tams IP, Prowse K.
An evaluation of the Vitalograph pulmonary monitor.
4 Chowienczyk PJ, Lawson CP. Pocket-sized device for
measuring forced expiratory volume in one second
5 Drew CDM, Hughes DTD. Characteristics of the
6 Wever AMJ, Britton MG, Hughes DTD. Evaluation of
two spirometers. A comparative study of the
Stead- Wells and the Vitalograph spirometers. Chest
1976;70:244–50.
7 Wever AMJ, Britton MG, Hughes DTD, Van der Plas
KH, Wever-Hess J. Clinical evaluation of five
spirometers: Monaghan M403, Pneumoscreen,
Spiroraph, Vicatest and Vitalograph. Eur J Respir Dis
8 Lockhart W, Smith DH, Mair A, Wilson WA. Practical
experience with the peak flow meter. Br Med J
1960;i:37.
9 Shephard RJ. Some observation on peak expiratory
10 Cotes JE. Lung function: assessment and application in
11 Bland JM, Altman DG. Statistical methods for assessing
agreement between two methods of clinical
12 Altman DG, Bland JM. Measurement in medicine: the
analysis of method comparison studies. Statistician
13 Fitzgerald MX, Smith AA, Gaensler EA. Evaluation of
14 Shanks DE, Morris JF. Clinical comparison of two
electronic spirometers with a water-sealed spirometer.
15 Gunawardena KA, Smith AP. An evaluation of the LA3
16 Westgard JO, Hunt MR. Use and interpretation of
common statistical tests in method-comparison
17 Gardner RM, Hankinson JL, West BJ. Evaluating
commercially available spirometers. Am Rev Respir
Dis 1980;121:73–82.
18 American Thoracic Society. Snowbird workshop on
standardization of spirometry. Am Rev Respir Dis
Evaluation of the turbine pocket spirometer.

K A Gunawardena, K Houston and A P Smith

Thorax 1987 42: 689-693
doi: 10.1136/thx.42.9.689

Updated information and services can be found at:
http://thorax.bmj.com/content/42/9/689

These include:

Email alerting service

Receive free email alerts when new articles cite this article. Sign up in the box at the top right corner of the online article.

Notes

To request permissions go to:
http://group.bmj.com/group/rights-licensing/permissions

To order reprints go to:
http://journals.bmj.com/cgi/reprintform

To subscribe to BMJ go to:
http://group.bmj.com/subscribe/