A Simplified Computer Report*  
Towards an Understandable Pulmonary Function Test  

Joseph J. Cottrell, M.D.;† Bernard E. Pennock, Ph.D.;‡ and  
Robert M. Rogers, M.D., F.C.C.P.§

We have developed a graphic format for the display of pulmonary function test results. Patient test results appear as a series of horizontal bar graphs. Each bar length is proportional to the test result and is printed over the normal ranges. This format allows rapid recognition of individually abnormal values. We have also grouped bars to create distinctive patterns characteristic of obstructive or restrictive lung disease. A computer program generates a custom form for each patient, displaying the results and ranges only for the specific test performed on that individual. No preprinting of forms is required. Written in the BASIC computer language, this program was designed to be flexible. A change of program parameters requires only minor program modification. In addition, because of its simplicity, our program can be implemented on almost any computer printer.

A modern pulmonary function laboratory is capable of generating a large amount of numerical data for each patient. Unfortunately, this generation of data has not been coupled to improvements in data display and presentation. Many pulmonary function reports are confusing to nonpulmonary physicians. We have developed a new pulmonary function test report which, we feel, offers significant advantages over the report forms that are currently in use. Although simpler to read and understand, it sacrifices no clinically useful information.

To develop our new test report we decided to prioritize information that seemed most useful to clinical practice and interpretation. Display of patient information (name, age, height, diagnosis, etc), absolute test results, the relationship to a predicted normal, and a normal range had highest priority.

Although many different pulmonary function tests are available, they may generally be categorized into one of three groups, spirometric indices, lung volumes, or diffusing capacities. We decided to display results in that order. Our final design goal was to develop a system that could be implemented inexpensively on a wide variety of computers, from the smallest micro to the largest mainframe.

Every attempt was made to minimize costs and maintain simplicity. We decided that for maximum flexibility the form should not require preprinting, and that the report should not exceed standard chart size

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*From the Division of Pulmonary Medicine, University of Pittsburgh School of Medicine, and Oakland Veterans Administration Hospital, Pittsburgh. Supported in part by funds from the Christmas Seel League of Southwestern Pennsylvania.
†Assistant Professor of Medicine.
‡Associate Professor of Medicine.
§Professor of Medicine and Anesthesiology.
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Reprint requests: Dr. Cottrell, 440 Scaife Hall, University of Pittsburgh, Pittsburgh 15261

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**Figure 1.** Simple spirometry report demonstrating "obstructive pattern."
Figure 2. An extended study revealing “restrictive pattern.”

(8½” x 11”). We decided that to display the large amount of data obtained from pulmonary function testing in a numerical only fashion was futile. We elected to use a graphic display with patient results displayed in relation to a “normal range.” We elected to use a horizontal format rather than a vertical one, because of the ease with which it can be implemented on even the most inexpensive printer. Additionally, the patterns associated with disease conditions were more easily recognizable in the horizontal format than they
were in a vertical form. Lastly, we desired our report to be as uncluttered as possible. To achieve this, we decided to print ranges and results for only the tests performed on a particular patient. Our final form (Fig 1, 2, 3, © Cottrell, Pennock, Rogers) meets all of the above design criteria.

Our program was written in BASIC, so that it can be implemented on almost any computer system. It was initially developed on a PDP-11/34 minicomputer (Digital Equipment Corp, Maynard, MA) and has been modified to run on an Apple II plus microcomputer (Apple Computer, Cupertino, CA). The program is compact, requiring approximately 5K of memory. The time to generate the report varies with both the type of printer used, as well as the number of tests performed on the patient. In general, however, a report is generated in approximately 45 seconds. The program can be easily modified. Although we chose to use the Intermountain Thoracic Society criteria as a source for our regression equations, other equations can be substituted with ease. Similarly, although we use the homoscedastic model for the description of the normal range, the program can be easily modified to display the ranges described by the homoscedastic model. In a heteroscedastic mode, the range of normal is a fixed percentage of the predicted mean. The generated reports display a fixed band of normal, expressed in percentage. In the homoscedastic model, the normal range is defined by a fixed number above and/or below the predicted value. When this range is used, the band of normal, again expressed in percentage, varies individually for each patient. Indeed, the report allows the display of normal ranges for all systems that have been described.

We chose dots for display of the normal range and lines for the representation of the measured values after evaluating over 100 other combinations of symbols and letters. This combination offers a clear separation of the measured value from the normal band and is available on all printers. A legend, explaining these symbols, is placed on each report.

If a value is outside the graphic range, a "<" or ">") is printed at the lower or upper limit of the graphic field. In addition, the patient's value can be displayed as a "•", an "X", or any character desired.

Superior separation can be obtained with specialized characters available on expensive printers. Again, the program allows for easy change. We have, for example, obtained better separation using a low-cost (<$2,000) color printer (Prism, Integral Data Systems, Milford, NH). This printer also permits individual sheets or fanfold paper to be used. Individual sheets can be used to record a flow-volume loop and the reverse side then used for report generation.

The program is currently written as a "stand alone," but it can be easily interfaced for direct data acquisition. It is copyrighted, but listings or Apple II discs are available from the authors for noncommercial use.

This report form is, we believe, a practical and informative display of pulmonary function test results. Its extreme flexibility allows it to be implemented on almost any computer, use any set of normal values or ranges, and display the information clearly.

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