A Computer Program for Calculation and Interpretation of Pulmonary Function Studies

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A computer program to calculate and interpret the standard pulmonary function tests has been developed on a programmable calculator system. The program computes both predicted and measured values for static and dynamic lung volumes, airways resistance and diffusing capacity. It then checks for differences between predicted and obtained values and interprets them according to a specific, clinically useful set of diagnostic criteria. By acquisition of a reliable and easy-to-use data processing system, a pulmonary function laboratory can significantly increase the efficiency and accuracy of its day-to-day work.

The calculation of pulmonary function tests is a tedious, repetitive, time-consuming task involving an extensive number of manipulations with corresponding risks of arithmetic errors. Interpretation of these tests, a job done by a physician, is usually quite monotonous, since it requires the application of a relatively few, well-defined rules. Occasional studies require a degree of judgment not available to a computer program, and the need for physician review is not eliminated. An automated procedure is strongly indicated both to calculate and interpret the standard pulmonary function tests. Such a system has been developed using a reliable programmable calculator.

**Method**

The program has been implemented on a small digital Wang 2200B-2 programmable calculator. This machine is a hybrid between a standard desktop calculator and a minicomputer. A programmable calculator is programmed directly through a keyboard, and the Wang 2200B is easily programmable in BASIC (Beginner's All-Purpose Symbolic Instruction Code). It has a large screen cathode ray tube (CRT) for convenient data display, a magnetic tape cassette for storage of programs and data, and an electric typewriter for output.

All the information is entered manually via the keyboard, and the program allows for human error by permitting corrections. The operator responds to a standard series of questions that are displayed on the CRT and he selects those tests actually performed on a particular patient. Pulmonary function tests performed routinely include the following as they appear on the CRT:

1. VC—slow vital capacity
2. ERV—expiratory reserve volume
3. FRC (he dil)—functional residual capacity (by helium dilution)
4. FRC (pleth)—functional residual capacity (by plethysmography)
5. FRC (N2 washout)—functional residual capacity (by nitrogen washout)
6. RA—airway resistance
7. FEV—forced expiratory volume (fast vital capacity)
8. FEV (1.0)—forced expiratory volume in one second
9. MEFR (.25—.75)—mid-expiratory flow rate between 25 percent and 75 percent FEV (also abbreviated MMFR)
10. DLco (SB)—diffusing capacity by single breath method
11. DLco (SS)—diffusing capacity by steady state method.

A similar choice of tests is given for studies following the inhalation of optional bronchodilators. Tests 1, 2, 7, 8, and 9 can be done on any standard spirometer. In this laboratory a Warren E. Collins modular lung analyzer is used so that these tests can be more easily combined with tests 3, 10, and 11. Tests 4 and 6 are performed with a constant volume plethysmograph and an Electronics for Medicine VRO recorder.

The predicted values for VC, FEV and TLC are calculated from regression equations utilizing sex, age and height. The FEV (1.0) and percent FEV expired in one second are predicted from the work of Boren, while the normal MEFR (.25—.75) values are taken from a table developed by Gaensler. The DLco (SB) is predicted from an age-specific formula, while the DLco (SS) is taken from Donevan et al. If the patient's hemoglobin level is known, the DLco is corrected accordingly. The predicted ERV is accepted as ½ VC, while predicted IC is ¾ VC. Predicted RV is TLC minus VC and FRC is RV plus ERV. Normal RA is considered less than 2.5 cm H2O per liter per second. All ventilation volumes are expressed at body temperature and pressure saturated with water vapor (BTPS).

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RESULTS

The printout can accommodate any standard form (Fig 1). The first tabulated portion gives values for both predicted and calculated pulmonary functions, the latter both before and after administration of bronchodilators, if they are done. The percentage of predicted values is also given, as well as two clinically important ratios, RV/TLC and percent expired in one second (FEV₁/FEV). Beneath the tabulated results, a tentative, computer-determined diagnosis appears.

The interpretative portions of the program are detailed in Figures 2, 3, and 4. The program checks for a decrease below predicted in the ratio FEV₁/FEV and, when present, is indicative of obstructive lung disease. It confirms this interpretation if RV and/or TLC are simultaneously higher than 120 percent predicted. With a normal FEV₁/FEV, a decrease in TLC and/or FEV less than 80 percent predicted indicates restrictive lung disease (portion 2). The isolated decrease in MMFR, with other data within normal limits, is suggestive of early small airways obstructive disease (portion 3). A decrease in DLCO below 80 percent predicted is noted on the printout. A moderate or marked decrease in DLCO, combined with moderate or severe airways obstruction, suggests emphysema contributing to the airways obstruction (portion 4). The program also checks for and prints out any significant changes in spirometric values and lung volumes occurring after inhalation of bronchodilators (portion 5).

Review of 200 abnormal results of studies was performed in blind fashion in order to compare physician and computer interpretation. Complete agreement between the two interpretations was pres-
Figure 2. Logic steps involved in computer evaluation of obstructive lung disease and restrictive lung disease without lung volumes. Diamond-shaped box represents decision point. Computer printout is presented in partial rectangle. Circles contain numbered portion of program to which program proceeds after decision has been made or printout is completed. If no obstruction is present, program proceeds to portion 2 (Fig 3).

Figure 3. Logic steps involved in computer evaluation of restrictive lung disease (portion 2) and small airways disease (portion 3). Symbols as in Figure 2.
ent in 184 (92 percent) of the studies. In those studies in which agreement was not complete, it was because of poor patient effort or cooperation, and qualifying comments were necessary. Also, comparison with previous studies was undertaken by the physician.

**DISCUSSION**

A program has been developed using a Wang 2200B programmable calculator both to calculate and interpret the standard pulmonary function tests. This has proved to be efficient and accurate. Online computerized spirometry analysis was designed by Dickman et al. and Earle. Similar work on processing flow-volume curves from forced expiratory maneuvers and online computer analysis of flow-volume loops followed, but all of these studies as well as other applications were accomplished by large expensive computer systems. A time-sharing system was described by Young. Routine clinical spirometry was analyzed by a desktop computer system (Wang model 700) as reported by Chiang. A recent editorial noted that general purpose, reprogrammable computers are essential to achieve the greatest return on one’s investment. The programmable calculator offers cost advantages over computers and are easier to install and operate. We feel that calculation and interpretation of the standard pulmonary function tests with a versatile programmable calculator is both economically practical and medically functional.

The computer-printed interpretation must be treated as a tentative suggestion to the physician, subject to his review and confirmation. It will save physician time, but does not relieve the physician of his responsibility to examine the record for the many helpful clues it contains.
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ANNOUNCEMENTS

Postgraduate Course: Pulmonary Disease for Clinicians

Boston University Medical Center will sponsor the Postgraduate Course on Pulmonary Disease for Clinicians, October 8-10 at Boston University School of Medicine. Further information may be obtained from Dr. Gordon L. Snider, University Hospital, 75 East Newton Street, Boston 02118.

Seminar on Respiratory Disease

The Nevada Lung Association and Sunrise Hospital will sponsor a Seminar in Respiratory Disease, October 1-3 at Caesar's Place Hotel, Las Vegas. For information, contact Mr. John Holck, Nevada Lung Association, 302 East Charleston Blvd, Las Vegas, Nevada 89104.