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DEVELOPMENT OF SOFTWARE FOR COMPUTER-ASSISTED INTERPRETATION OF PULMONARY FUNCTION TESTS

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Abstract : This paper describes the need for the development of software for computer interpretation of Pulmonary Function Tests based on equations derived from Indian populations, and the development strategies adopted. The decision flowcharts are given. The present limitations and areas of ongoing refinement of the program are discussed.

Key words : pulmonary functions computer-assistance interpretation software

INTRODUCTION

Almost all pulmonary function test (PFT) equipment is now micro-processor based, and provides data on a very large number of parameters. Computer assisted interpretation of these tests is gaining widespread popularity, possibly because it ensures that not even the minutest deviation from normal is missed out, especially in a complex data environment where most parameters are inter-related.

Unfortunately, all the systems which now provide computer-assisted interpretation of PFTs are programmed in such a way that they base their calculations on equations derived from western data, and totally unsuitable for our country. Though prediction equations for our country have been available for a long time, there is usually no provision to incorporate our constants into the equations used by the interpretation programs.

Against this background, the need arises to develop our own programs for computer-assisted interpretation of PFTs. These programs could be modified by different user institutions to suit their available equipment, and if prediction equations are available, to fit that specific population.

METHODS

The original programs were written in BASIC language, but are presented here in flow-chart form, so as to make them "language-free", and facilitate transportation to other operating systems or languages.

Prediction equations for the spirometry parameters were taken from equations derived at our Centre (1) from the data of 2264 male, healthy, non-smoking, predominantly South-Indian industrial worker population of age 35.1 ± 3.86 years (mean ± SD), height 162.9 ± 6.06 cms, and weight 59.7 ± 8:37 kg; using VITALOGRAPH-S dry spirometer with function analyser, and Jaeger whole-body plethysmograph (pneumotachography and spirometry programs). The equations used are:

VC (1) = 0.73106 — 0.04153 * AGE (y) + 0.02524 * HT (cm)

FVC (1) = 0.028029 — 0.03631 * AGE (Y) + 0.02697 * HT (cm)

FEV1 (1) = 0.97961 — 0.03631 * AGE (Y) + 0.01962 * HT (cm)

Miller's Quadrant (2) formed the starting point for the spirometry interpretation logic, but the obstructive defect portion of the quadrant was further sub-divided into 'mild' (FEV1% > 60%)' 'Moderate' (60% FEV1% > 40%), and 'Severe' (FEV1% < 40%) to enhance the sensitivity of the staging.

Curve Analysis of the Forced Maximal Expiration Manoeuver

Curve analysis of the forced maximal expiration flow-volume curve to residual volume is based on the observation that people with airway disorders produce reproducible changes in curve shape compared with healthy persons.

Lack of cooperation and effort will have greater effect on flow-rates at higher lung volumes than at lower lung volumes, because the former are effort-dependent. Flow at lung volumes below about two-thirds of maximal expiration are limited mainly by physical factors of the lower airways and lung parenchyma (3).

In order to evaluate amplitude changes in the expiratory flow axis, the volume axis is divided into three parts:

1. *PEFR to MEF 75* (TLC — 75% FVC remaining in the lungs) : This part is dependent on subject cooperation, so that any evaluation is relatively unreliable.

2. *MEF 75 to MEF 25* : This part only depends slightly on subject cooperation and is characterised by the value MEF 50 which allows assessment of the airflow which is effort-independent. The flow at 50% FVC (ie — MEF 50 in 1/sec) is about numerically equal to the predicted VC (1) (4).
   upper limit : 0.8 * predicted VC
   lower limit : 1.4 * predicted VC

3. *MEF 25 to Residual Volume* : The flow curve below breathing baseline is independent of subject cooperation as long as the subject is still actively exhaling maximally.

The flow at this point depends on lung elasticity and recoil. It is concave in older persons, smokers, and very concave in those with poor lung recoil (emphysema). The concavity is characterised by the ratio MEF 25/MEF 50 which is normally about 0.4.

RESULTS

Fig. 1 presents the master program block-diagram, consisting of data input, prediction, interpre-

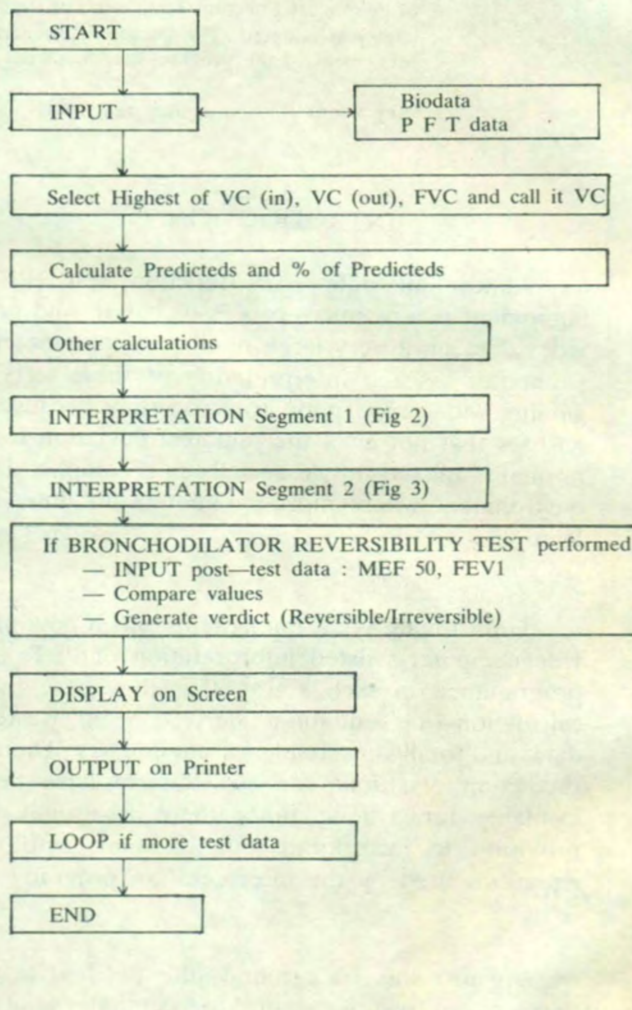


Fig. 1 : Block Diagram of Main Program

tation and output functions. For simplification, some stages have been omitted. These include segments such as minor calculations (eg — FEV1% from FEV1 and FVC), string assignments (the actual texts to be printed in different situations), and input/output control functions (eg — number of copies, disk storage or printer output, etc).

If the reversibility of airway obstruction is to be assessed by measuring the changes with bronchodilator administration, the post-bronchodilator results are compared with the pre-treatment values, and a verdict on reversibility is given [as per standardised criteria (5)]. The Pre/Post tests may be arranged to compare the Post-test flow with the flow value at the Pre-test expired volume, because the FVC also changes Pre/Post and may otherwise partly compensate for the change in flow (4).

Fig. 2 presents the decision flow-chart for the Capacities and Volumes. Fig. 3 presents the decision flow-chart for the Maximum Expiratory Flow Rates (MEFR). It may be clarified that an intermediate

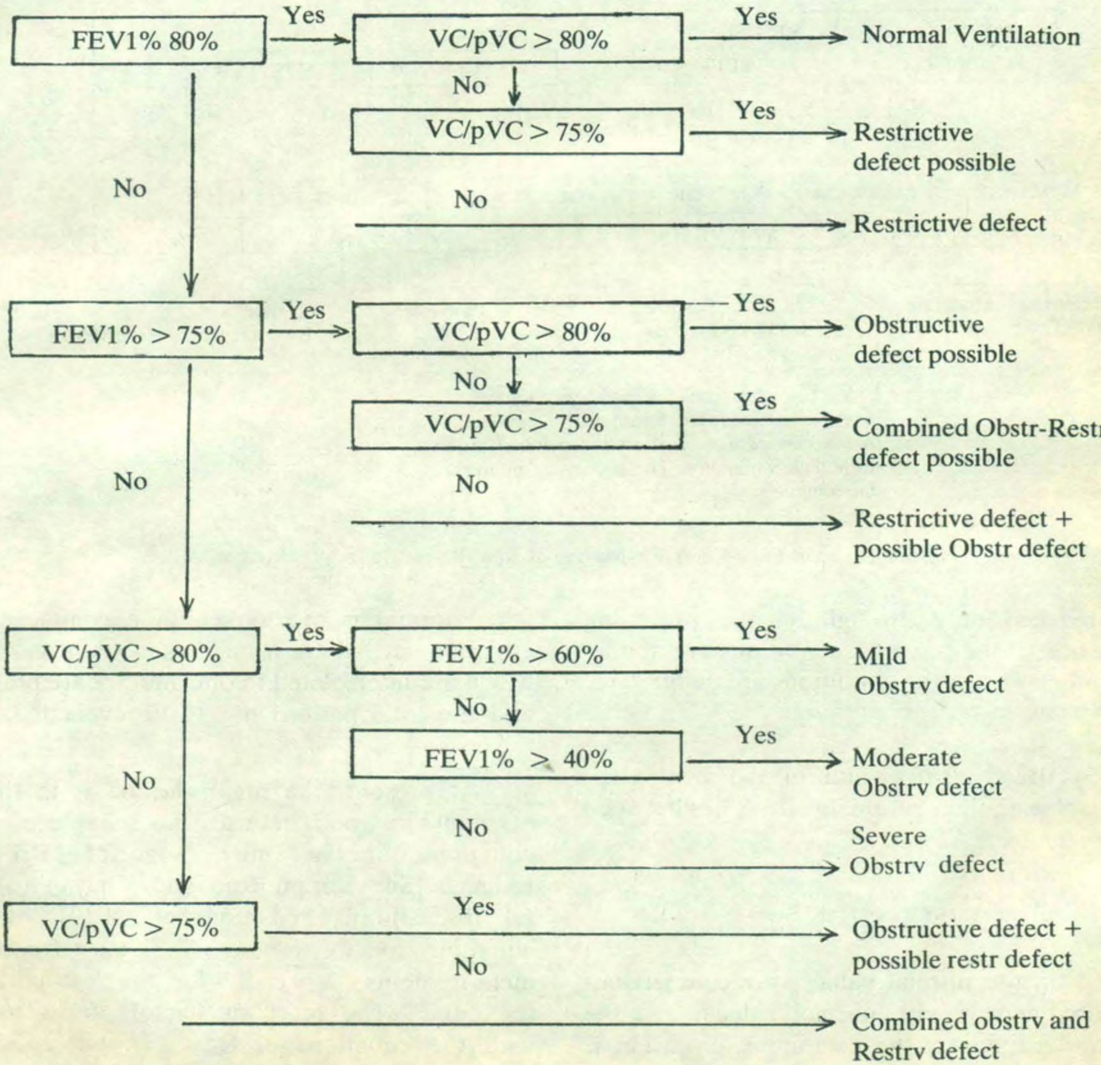
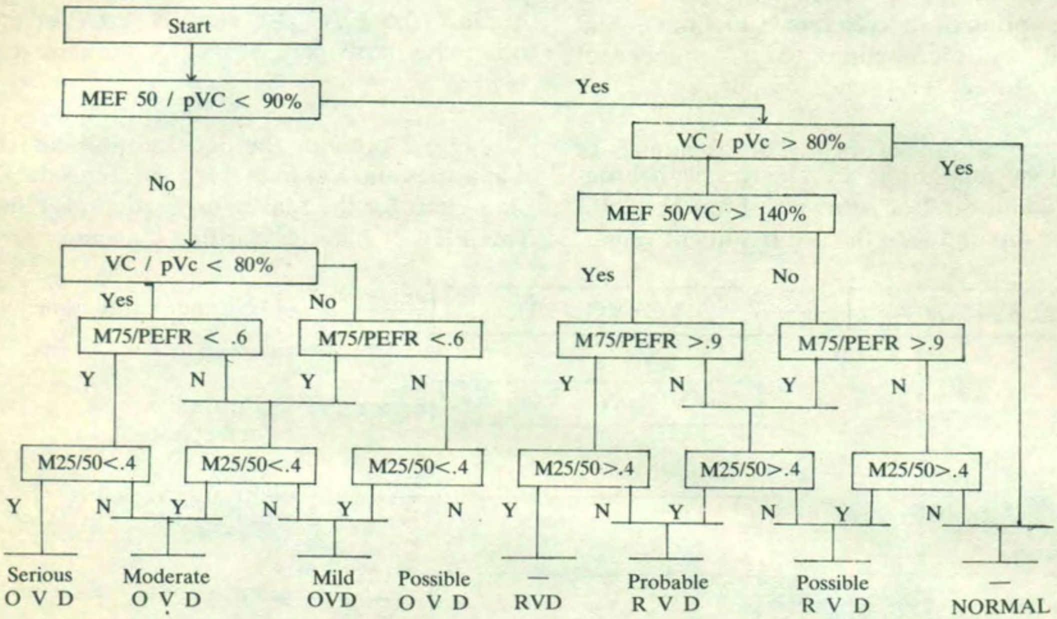


Fig. 2 : Decision Flow-Chart for Capacities and Volumes. (p = predicted value)

M75/PEFR = MEF 75% / PEFR
M25/50 = MEF 25% / MEF 50%



O V D = Obstructive Ventilatory Disease
R V D = Restrictive Ventilatory Disease
Note: In the best of hands, effort independent airflows show high variability. The user must interpret the computer aided diagnosis with this in mind.

Fig. 3 : Decision Flow-Chart for Maximum flow Rates. (p = predicted value)

step is reached only through all the preceding steps. Hence all the previous conditions are applicable. In other words, the conditions are *cumulative,* not *discrete*.

If "A>B" is 'true', and in the next step, "A>C" is 'false', then automatically A lies between B and C, or "C>A>B".

DISCUSSION

Based on the normal values, the comparisons of measured values with normal values, and the preliminary diagnoses, the examining physician is 'computer assisted' in arriving at the final diagnosis. The computer assistance ensures that no deviation from normal is overlooked in a complex hi-tech environment, where a large number of parameters which are interrelated to one another are presented, and the total pattern has to be evaluated.

At present, the major lacuna is in the area of small-airways. There are no reliable prediction equations for the entire range of MEFRs for Indians. [See Kuppu Rao and Vijayan (6) for a full discussion]. Predictions of MEFRs based on equations for westerners (7, 8) vary from actual measurements, especially for the last portion of the curve. The most satisfactory fit is obtained with the equations of Bass (3), but MEF 50% tends to get under-estimated. The programs described in this paper, however, relate the MEF values to the predicted VC, for which the prediction equations are derived from the same population.

Refinement of the program is in progress, and the major thrust-areas are small-airway ventilation, retraction loss, the inspiratory flow rates and inclusion of plethysmography parameters like Intra-Thoracic Gas Volume (ITGV), Residual Volume (RV) and Total Lung Capacity (TLC).

Abnormalities detected by the program have been correlated with results of other investigations and confirmed with clinical findings. Two clinical cases are presented in Appendix A. The program will be most useful only when the operator ensures that the subject/patient in fact makes the maximal forced expiratory effort from TLC to residual volume.

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APPENDIX — A : CLINICAL CASES

	Case No. 1	Case No. 2
Ht	: 179.0 Cms	152.5 cms
Wt	: 69.0 kg	65.0 kg
Age	: 33 yrs	49 yrs
Sex	: Male	Female
Diag	: Allergic Bronchitis	Interstitial Fibrosis

Pulmonary Functions & Computer Interpertations

Parameter	*Unit*	*Meas*	*Pred*	*% Pred*	*Meas*	*Pred*	*% Pred*
SPIROMETRY							
TV	(1)	0.86			0.48		
ERV	(1)	0.62			0.77		
VC	(1)	3.14	3.88	80.9	1.57	2.28	68.9
FVC	(1)	2.85	3.66	77.9	1.38	2.25	61.3
FEV1	(1)	1.54	3.29	46.8	1.37	2.08	65.9
FEV%	(1)	54.1	90.0	60.1	99.3	92.4	107.5
IMPRESSION : Moderate obstructive ventilatory defect					Restrictive ventilatory defect		
FLOW-VOLUME CURVE							
PEFR	(1/sec)	4.20	8.61	48.8	5.00	5.88	85.0
MEF 75%	(1/sec)	2.40	8.22	29.2	4.80	4.82	99.5
MEF 50%	(1/sec)	1.10	5.44	20.2	3.20	3.95	81.0
MEF 25%	(1/sec)	0.40	2.07	19.4	1.20	1.46	82.2
IMPRESSION : Moderate obstructive ventilatory defect					Probable restrictive ventilatory defect		

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