PULMONARY FUNCTION TESTING IN OFFICE PRACTICE

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Pulmonary function tests (PFT) properly carried out in the office can help the pediatrician considerably in the diagnosis of respiratory diseases, in determining the severity and patterns of pulmonary dysfunction and in assessing response to therapy. Most children above 5 years of age can be taught to perform these tests(1). The reliability of the results are best when the technical personnel are well trained in testing children, when equipment best suited for children is selected and the child is patiently trained to perform the maneuvres(2,3).

Selection of Equipment

The peak flow meters and spirometers are recommended for office use.

Peak Flow Meter (PFM)

This is most inexpensive instrument for office use to determine peak expiratory flow rate (PEFR) and peak inspiratory flow rate (PIFR), which are useful in diagnosis and follow up of obstructive airway diseases(4). The Wright's PFMs for pediatric use are of two types: circular dial type and cylindrical type. The details of various PFMs available are given in *Table I.*

Spirometer

This is the most useful instrument for office use. The bell type wet spirometer introduced by Hutchinson is not now recommended for office use because of the problem of water movement during fast breathing maneuvre, spillage of water into the tubing system, bacterial growth and corrosion of the equipment by water. Hence, dry spirometers are recommended. Those having sensitivity at low volumes and flow rates are suitable for children. Essentially, it consists of accordian like bellows and mechanical or electronic recording system(1,5). The spirometers which give the visual liquid crystal display (LCD) and print out of the maneuvres are ideal but expensive. They have the advantage of judging the perfectness of various maneuvres carried out by the child. Second in order of preference are those which give

TABLE I—*Available Peak Flow Meters*

Name	Approx. cost (Rs.)	Remarks
1. Wright's (Mini)PFM P.K. Morgan Pvt. Ltd., England	1000/-	PEFR
2. PEM Vitallograph, U.K.	550/-	PEFR
3. Pink City Flowmeter Tirupati Scientific Instrument Company	200/-	PEFR and PIFR

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the digital print out of various pulmonary function parameters as well as the recording of volume time (VT) curves and flow volume (FV) loops from which the pulmonary function data are derived. Third in order of preference are those which give only the digital print out. The details of various spirometers available are given in *Table II*.

After recording the tidal breathing, the following maneuvres should be carried out by the child on the spirometers:

Inspiratory or Two Stage Vital Capacity (IVC/2 SVC) Maneuvre: In this, the patient is encouraged to exhale slowly to maximum extent and then inhale as deeply as possible(1). IVC maneuvres can give the following lung capacities, *i.e.,* IVC (2 SVC), ERV, IRV, IC and TV(7,8) (*Fig. 1*).

Forced Expiratory Vital Capacity (FVC) Maneuvre: The patient first breathes normally, following which, child is asked to breathe in as deeply as possible and hold his breath momentarily and then exhale as rapidly and completely as possible. FVC maneuvre will give the following parameters *viz.*, FVC, FEV_1, FEV_2, FEV_3, FEV_1/FVC ratio, FEF 25-75% and FEF 200-1200(6,7) (*Fig. 2*).

TABLE II—*Available Spirometers*

	Name	Approx. cost (Rs.)	Remarks
1.	Spirocheck portable spirometer. P.K. Morgan Pvt. Ltd., England	13,636	FVC, FEV, PEFR, portable.
2.	Morgan Flexiflow Pulmonary System with Dell Computer. P.K. Morgan Pvt. Ltd	1.68 lacs	
	or		
	Morgan Flexiflow Pulmonary system with Indian IBM compatible computer. England.	95,000	All lung capacities including TLC, FRC, RV, FV, loop, VT curve, Raw lung elasticity, constant, predicted and actual values and computer interpretation.
3.	Morgan TLC Test Automated lung volume spirometer with Dell computer. P.K. Morgan Pvt. Ltd., England.	5 lacs	Same as above with helium analyzer; *Not* portable.
4.	Spiroanalyzer, ST-90, Pulmonary Products, Fakuda Sanyo, Tokyo.	70,000	VC test, FVC test, FV test MVV test; portable.
5.	Spiroanalyzer, ST-300, Pulmonary Products, Fakuda Sanyo, Tokyo.	1.5 lacs	Same as above with actual and predicted values memory system and direct BTPS values.
6.	Spirometer by Jaeger, Erich Jaeger GMBH and Company, Germany.	2.5 lacs	Same as above with gas exchange (CO_2, VCO_2); *Not* portable.
7.	Pneumoscope, Erich Jaeger GMBH & Company, Germany.	60,000	Flow volume loop MVV, Raw, portable.
8.	Vitalograph. Vitalograph, UK.	90,000	VT curve, Flow volume, portable.

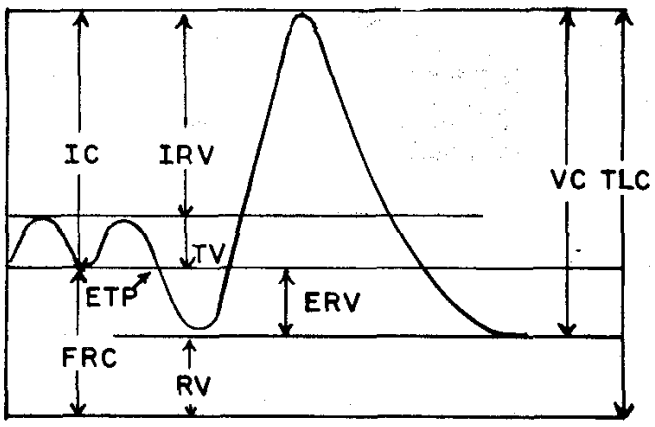

Fig. 1. Lung capacities in IVC (2 SVC) maneuvres.

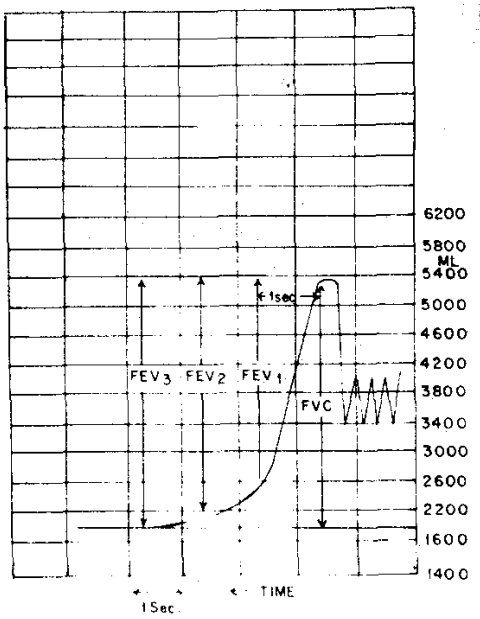

Fig. 2. Spirogram tracing showing measurements of FVC, FEV, FEV_2, FEV_3.

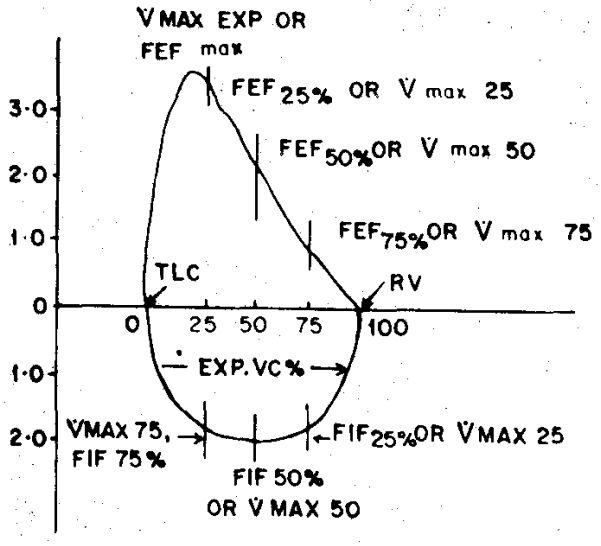

Fig. 3. Flow volume loop of a normal child.

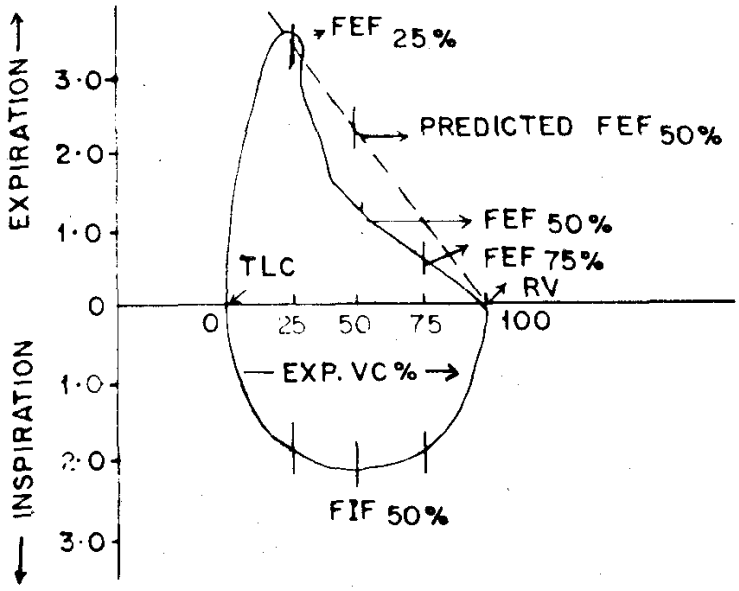

Fig. 4. Flow volume loop of a child with peripheral obstructive airway disease.

Flow Volume Loop Maneuvre: FVC maneuvre is followed by maximum inspiratory maneuvre to full inflation of the chest(1,6). The last three maneuvres may be repeated after inhalation of bronchodilators such as two puffs of salbutamol (asthalin) or terbutaline (brecanyl) from Metered Dose Inhaler (MDI). Flow volume loop maneuvre can give the following parameters, *i.e.,* FVC, MFEF (PEFR), FEF 25, 50 and 75%, FIF 50% and ratio of FEF 50% and FIF 50%(7,8) (*Figs. 3 & 4*).

Maximum Voluntary Ventilation (MVV) maneuvre: The measurement is made by having the child breathe air in and out maximally for 10-15 seconds. One then calculates the volume which would be exhaled or inhaled over a one minute period(1). MVV is the maximum volume of air that can be breathed in and out in one minute and can help in distinguishing obstructive and restrictive diseases. MVV is often normal in early obstructive airway disease but is reduced in moderate to severe impairment to air flow. Normal is considered to be equal to or greater than 80% of the predicted. A classic pattern for air trapping is often detected in significant obstructive airway disease(7,8) as shown in *Fig. 5.*

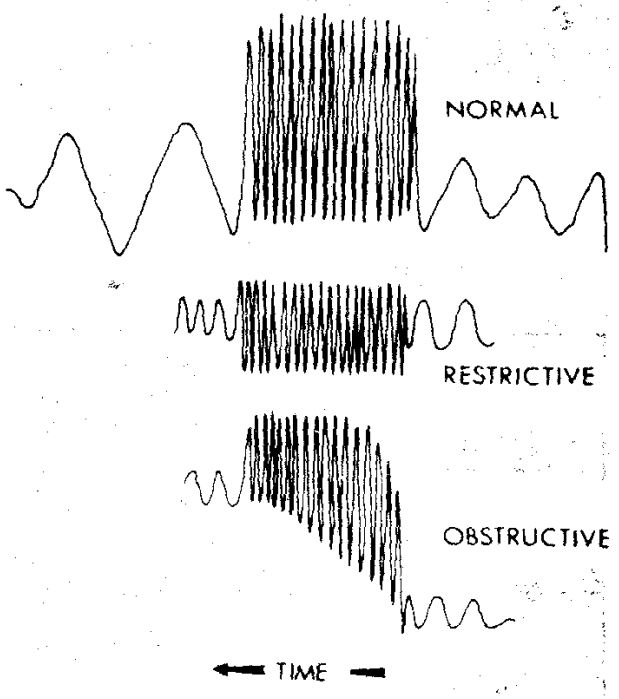

Fig. 5. Spirographic tracings showing maximal voluntary ventilation maneuvres. Normal is compared with obstructive and restrictive airway disease.

Calculation of Indices and Interpretation of Data Obtained from Clinical Spirometry

The spirometers which are computerized can give the print out of the above indices directly obviating the need for calculation. Some of these spirometers also give the predicted values for many of the indices for comparison with actual values obtained from the patient.

Pulmonary function tests are most useful in identifying the pattern of pulmonary function abnormalities as shown in *Table III.* It also can show the severity of the pulmonary dysfunction as shown in *Table IV.* The sensitivity of the various parameters for outlining the severity of the obstructive airway diseases varies. *Table V* lists the indices in order of increasing sensitivity to detect obstructive peripheral airway diseases.

When hyperreactive airway disorders such as bronchial asthma is suspected, VT, and FV curves obtained before and after inhalation of bronchodilators are very useful. Healthy children show an increase in FEV_1, by less than 5% and in maximal mid-expiratory flow rate (MMEF) by less than 20%, whereas children with hyperreactive airway disorders will show a much higher increase than values cited above. Similarly, VT and FV curves obtained before and after exercise challenge or inhalation of aerosolized antigen are useful in suspected cases of bronchial asthma. If

TABLE III—*Patterns of Pulmonary Function Abnormality*

Function	Normal*	Obstructive	Restrictive	Combined
FVC	≥80	N to ↓	↓	↓
FEV_1	≥80	N to ↓	↓	↓
$FEV_1/FVC \times 100$	≥75	↓	N to ↑	↓
$FEF_{25-75\%}$	≥80	↓	↑ N to ↓	↓
TLC	80 to 120	N to ↑	↓	↓
RV/TLC × 100	25 to 40	↑	N	↑

* Normal values represent the percentage of predicted values except for $FEV_1 \times 100/FVC$ and $RV \times 100/TLC$ which are absolute percentages.

TABLE IV—*The Staging of Severity of Restrictive Diseases and Obstructive Diseases*

FVC, % of predicted normal	Interpretation
≥80	No restriction
60-79	Mild restriction
50-60	Moderate restriction
<50	Severe restriction

FEV_1/FVC Percentage of normal	Interpretation
≥80	No obstruction
60-79	Mild obstruction
40-59	Moderate obstruction
<40	Severe obstruction

Adapted from Tisi GM(5).

TABLE V—*PFT Related to Severity of Obstructive Airway Disease*

Function	Mild	Moderate	Severe
PEF or FEF_{max}			
FVC			
FEV_1/FVC			
$FEF_{25-75\%}$			
$FEF_{50\%}$			
$FEF_{75\%}$			
$He\text{-}O_2$/air $FEF_{50\%}$			
$He\text{-}O_2$/air $FEF_{75\%}$			
PIF			

$He\text{-}O_2$/air FEF 50 and 75%—The ratio of flows achieved while breathing He/O_2 and air at 50 and 75% of expired vital capacity.
PIF—Point of identical flow.
Adopted from Lemen RJ(1).

exercise challenge produces a reduction of FEV_1 greater than 10%, it supports the diagnosis of Extrinsic Bronchial Asthma (EBA).

The spirometric data should be evaluated by comparing them with predicted normal. The normal values for Indian children have been reported(7-11). Regression equations are available to predict normal values and many of the computerized spirometers give print out of normal values based on such regression equations(12).

Another point of importance which should be taken into account in interpreting parameters of lung function is that some functions are effort dependent while others are effort independent. The effort dependent parameters are those that are measured during the expiration of first 25% of vital capacity such as PEFR or FEF

TABLE VI–*Predicted Normal Values*

Height	Males			Females		
	VC	FRC	TLC	VC	FRC	TLC
	(Lung volumes in litres)					
92	0.68	0.38	0.88	0.66	0.41	0.88
96	0.77	0.43	1.00	0.74	0.47	0.99
100	0.87	0.49	1.14	0.84	0.54	1.12
104	0.98	0.56	1.28	0.94	0.61	1.25
108	1.10	0.64	1.44	1.05	0.68	1.40
112	1.23	0.72	1.60	1.17	0.76	1.55
116	1.37	0.81	1.78	1.29	0.85	1.72
120	1.52	0.90	1.98	1.43	0.95	1.90
124	1.67	1.01	2.19	1.57	1.05	2.09
128	1.84	1.12	2.41	1.73	1.16	2.29
132	2.02	1.24	2.64	1.89	1.28	2.50
136	2.21	1.36	2.89	2.06	1.40	2.73
140	2.42	1.50	3.16	2.24	1.54	2.97
144	2.63	1.65	3.44	2.43	1.68	3.23
148	2.86	1.80	3.74	2.64	1.83	3.49
152	3.10	1.97	4.06	2.85	1.99	3.78
156	3.35	2.14	4.39	3.07	2.16	4.07
160	3.62	2.33	4.74	3.31	2.34	4.38
164	3.9	2.53	5.11	3.56	2.53	4.71
168	4.2	2.74	5.50	3.82	2.72	5.05
172	4.51	2.96	5.91	4.09	2.93	5.41
176	4.83	3.19	6.34	4.37	3.15	5.78
180	5.17	3.44	6.78	4.67	3.30	6.17

Adopted from Cook and Hamann–J Pediatr 1961, 59: 710.

25% (V max 25); during inspiratory effort such as FIF 25, 50 and 75%. The effort independent parameters are those that are measured during the expiration of last 75% of VC such as FEF 50-75% and FEF 200-1200 ml. Obstruction of central airways, *i.e.*, larynx, trachea and main stem bronchi will reduce the effort dependent parameters whereas obstruction of peripheral airways will reduce the effort independent parameters(1) (*Fig. 4*).

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EMERGENCY TIPS

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Persistent Purulent Nasal Discharge

Purulent nasal discharge is a common clinical symptom in children. Wald(1) reviews the differential diagnosis, evaluation and management of this most common problem.

Viral Infection: The most likely diagnosis with acute onset purulent nasal discharge is viral infection. The discharge is usually clear and watery and the condition does not require specific antimicrobial intervention.

Sinusitis: Thick and colored nasal discharge persists for more than ten days. The symptoms include: day time cough, malodorous breath, and fever. In children older than one year, sinus radiographs show either complete opacification or mucosal swelling of at least 4 mm; air fluids levels are rarely seen. In infants, the diagnosis is difficult and radiographs show diffuse opacification.

Streptococcosis: In young children (under 3 years) Group A streptococcus causes a more indolent and less localized illness characterized by low grade fever, purulent nasal discharge and cervical adenopathy. Sore throat is not a common complaint nor is pharyngitis a typical finding. The diagnosis is confirmed by isolation of Group A streptococci from the nasopharynx or throat. *Staph. aureus, Strep. pneumoniae,* nontypical *H. influenzae* and *N. catarrhalis* are often recovered from the noses and throats of asymptomatic children and constitute normal flora of the upper respiratory tract.

Adenoiditis: Another potential cause of purulent nasal discharge; an enlarged adenoid shadow is demonstrated on a lateral neck radiograph. Most children require

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