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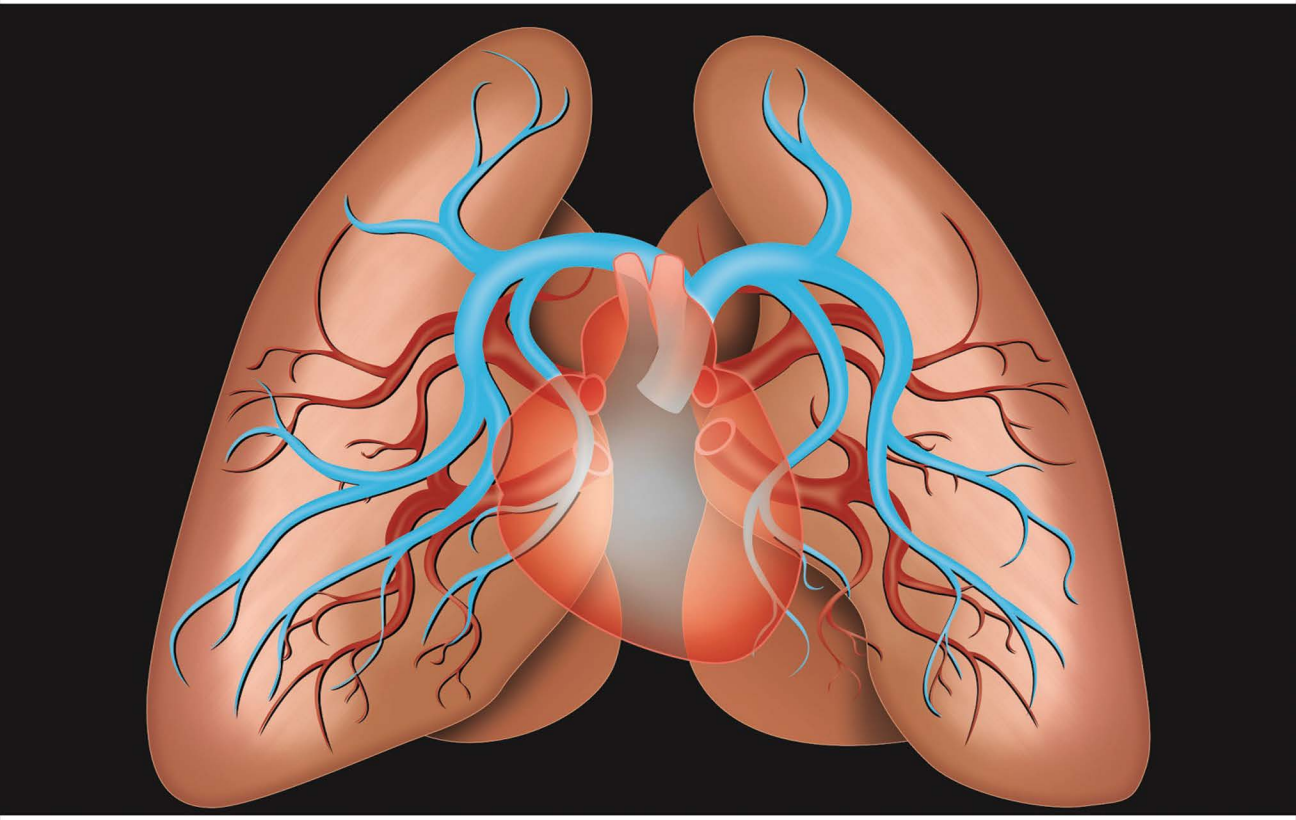
KNV's Manual of Cardiorespiratory Disorders



Editor
K Neelakantan Viswanathan

Deputy Editor
Sowmya Gopalan

Forewords
JSN Murthy
RS Hariharan

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12 CHAPTER

Pulmonary Function Tests

Han Ni, Marwan Nazaruddin

INTRODUCTION

Pulmonary function tests (PFTs) are used to measure the function of lungs including the lung volumes. It can identify and differentiate restrictive or obstructive lung disease. **Table 1** shows the differences between peak flow meter and spirometry.

PEAK EXPIRATORY FLOW RATE

Peak expiratory flow rate (PEFR) is the maximum airflow rate attained during forced expiration (in L/min). It is used to diagnose and monitor treatment response in asthma. The normal PEFR varies from person to person and depends on height, gender, and age. PEFR is higher in taller persons and males.

Indications

It is used to diagnose asthma and to assess severity of an exacerbation and monitor patient's response postnebulization.

TABLE 1: Differences between peak flow meter and spirometry.

Peak flow meter	***Spirometry***
Measures the ability to exhale	Measures the flow and capacity simultaneously
Will vary with lung capacity	
Measures the degree of airway obstruction	Gold standard for diagnosis of obstructive and restrictive lung disease
May underestimate disease severity in chronic obstructive pulmonary disease (COPD)	Cost more than peak flow meters
	

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Contraindication

When a patient is unable to breathe fully and severe respiratory distress.

SPIROMETRY

Forced expiratory volume in 1 second (FEV1) refers to the maximum volume of air that can be forcefully expired within the first second after maximal inspiration.

Forced vital capacity (FVC) refers to the maximum volume of air that can be forcefully expired after maximal inspiration. Both are subjected to height, age, sex, and ethnicity.

The normal FEV1:FVC ratio is ≥70%. The differences between obstructive and restrictive lung diseases are shown in **Table 2**.

FLOW-VOLUME LOOPS

A flow-volume loop is a graphical representation of spirometry testing. It plots inspiratory and expiratory flow on the *y*-axis (L/s) against lung volume on the *x*-axis. A normal flow-volume loop is seen as a "triangle sitting on a semicircle" **(Fig. 1)**.

Figures 2A to G depict flow volume loops in diseased states compared to normal.

TABLE 2: Differences between obstructive and restrictive lung diseases.

Obstructive	***Restrictive***
FEV1: decreased	FEV1: decreased
FVC: normal	FVC: decreased
FEV1/FVC ratio: <70%	FEV1/FVC ratio: normal or increased
• Asthma • COPD • Bronchiectasis • Cystic fibrosis	• Pulmonary fibrosis • Pleural diseases • Neuromuscular disorders • Obesity

(COPD: chronic obstructive pulmonary disease; FVC: forced vital capacity; FEV1: forced expiratory volume in 1 second)

Figures 2A, B, D, E, and H depict FEV1/FVC in chronic obstructive pulmonary disease (COPD) and fibrosis as opposed to normal.

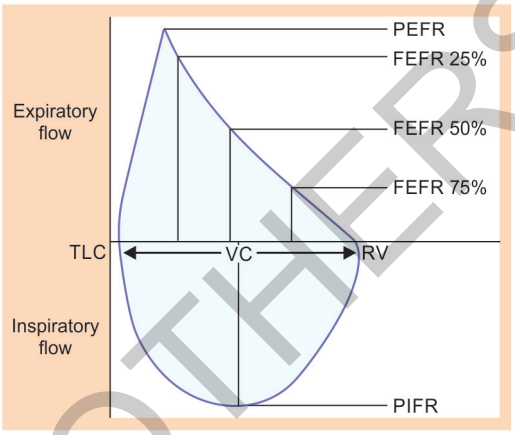

Fig. 1: Normal flow-volume loop. (TLC: total lung capacity; VC: vital capacity; RV: residual volume; PIFR: peak inspiratory flow rate; PEFR: peak expiratory flow rate; FEFR: forced expiratory flow rate).

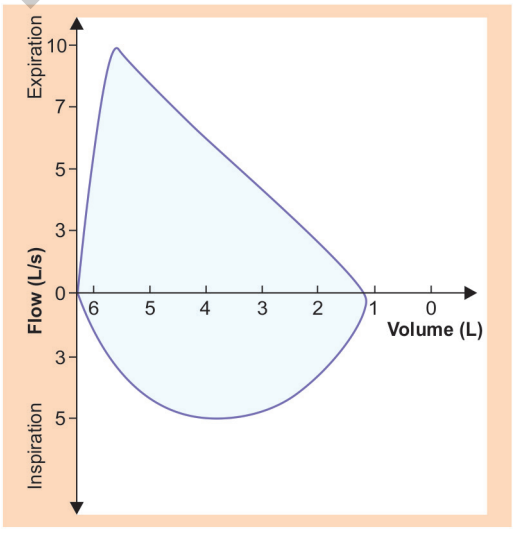

Fig. 2A: *Normal (also Fig. 1):* The patient has breathed to a total lung capacity of approximately 6.25 L at the start of the test, and there is no flow. As the patient exhales forcefully, the flow immediately reaches a peak of around 10 L/s (normal adult range: 6–12.5 L/s) and then decreases almost linearly until flow is nil at a residual volume of little more than 1 L.

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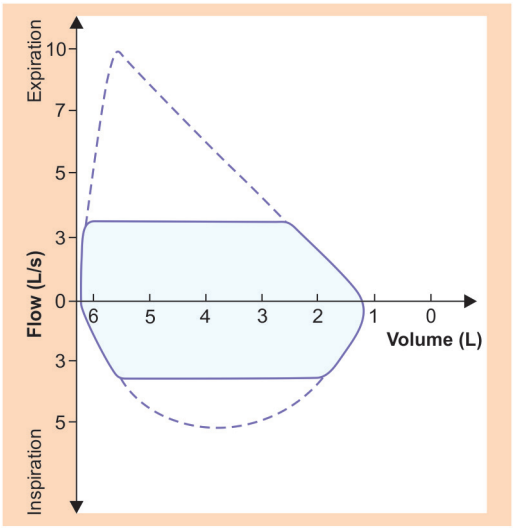

Fig. 2B: Fixed upper airway obstruction: As a result of the fixed blockage, both expiratory and inspiratory flows flatten and decrease.

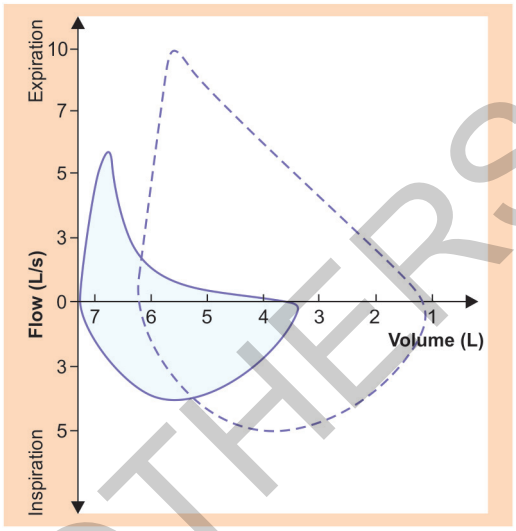

Fig. 2D: *Emphysema:* The collapse of small airways obstructs the passage of exhalation. As a result, the peak expiratory flow rate is lower than normal, and the curve toward the residual volume is concave (scooped). Because of the lung's greater compliance, reduced recoil, and air trapping, the residual volume and total lung capacity are abnormally raised.

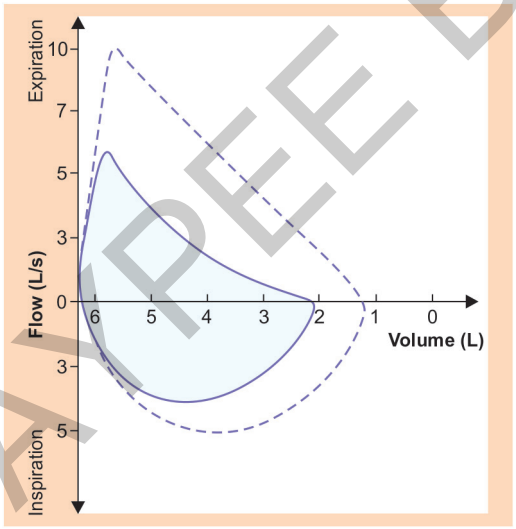

Fig. 2C: *Acute asthma:* Narrowed airways hinder exhalation flow. As a result, the maximum expiratory flow rate is lower than usual, with a slightly concave (scooped) slope toward the residual volume. The residual volume is exceptionally high because the constricted airways prevented complete expiration.

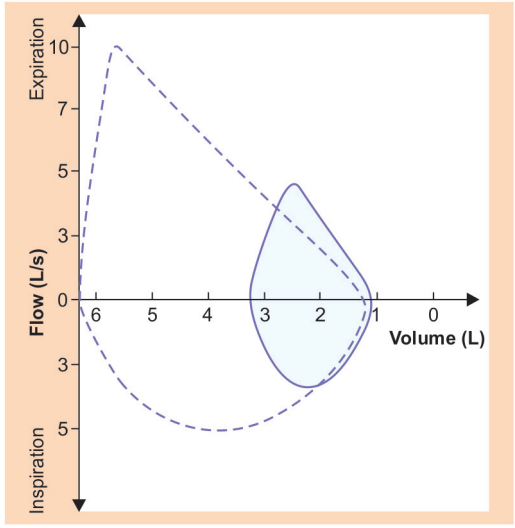

Fig. 2E: *Fibrosis:* Because of the lung's lower compliance, total lung capacity peak expiratory and inspiratory flows are significantly reduced. Expiratory flow is not reduced as much as lung volume due to the increased elastic rebound of fibrotic lung parenchyma.

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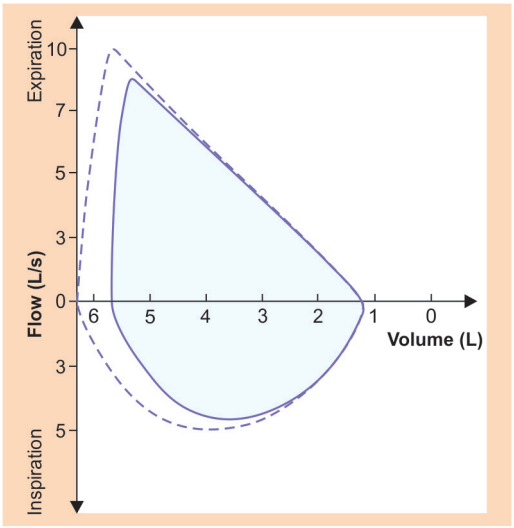

Fig. 2F: *Obesity:* Expiratory and inspiratory fluxes, as well as total lung capacity, are lowered due to the obese chest wall's mechanical constraint to expand to full capacity.

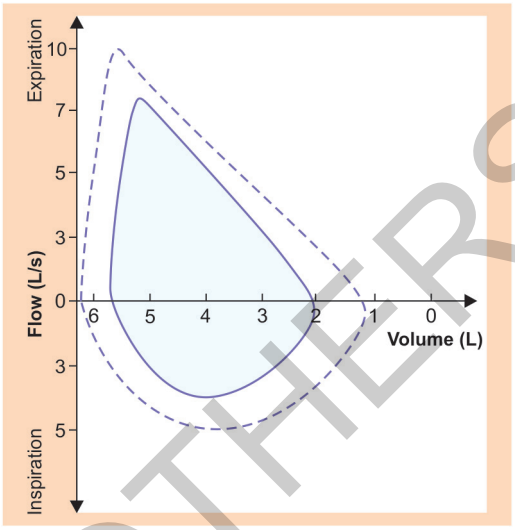

Fig. 2G: *Neuromuscular weakness:* Respiratory muscle weakness reduces expiratory and inspiratory flows, as well as total lung capacity and residual volume.

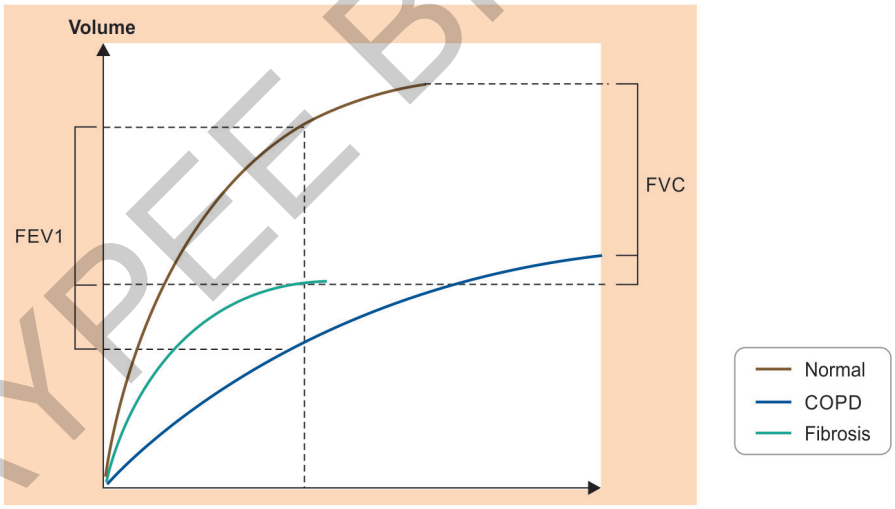

Fig. 2H: Volume/time traces in forced expiration. Volume/time traces from forced expiration in a normal subject, in COPD and fibrosis. COPD causes slow, prolonged and limited exhalation. In fibrosis, forced expiration results in rapid expulsion of a reduced forced vital capacity (FVC). Forced expiratory volume (FEV1) is reduced in both diseases but is disproportionately reduced, compared to FVC, in COPD. (COPD: chronic obstructive pulmonary disease)

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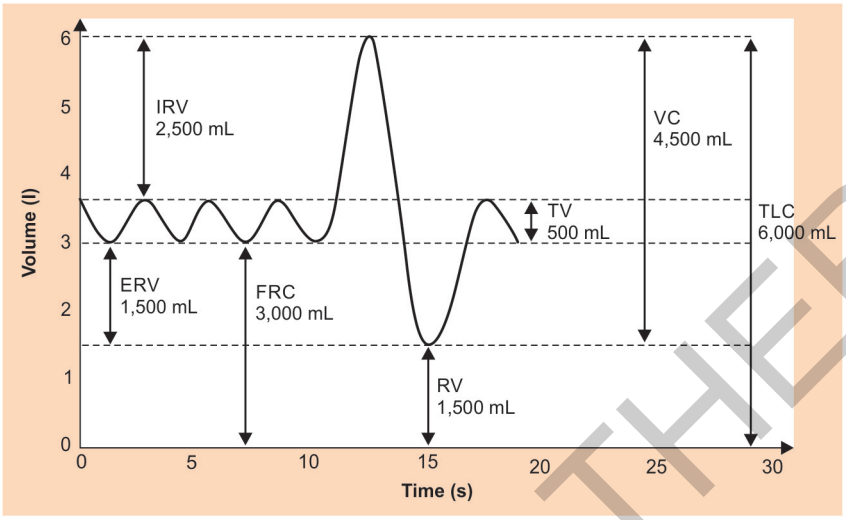

Fig. 3: Lung volumes. (ERV: expiratory reserve volume; FRC: functional residual capacity; IRV: inspiratory reserve volume; RV: residual volume; TLC: total lung capacity; TV: tidal volume; VC: vital capacity)

TABLE 2: Definitions and normal range of pulmonary function tests.

Total lung capacity (TLC)	Volume of air in the lungs after maximal inhalation	6–6.5 L
Vital capacity (VC)	Difference in lung volume between maximal exhalation and maximal inhalation	4.5–5 L
Residual volume (RV)	Volume of air that remains in the lungs after maximal exhalation	1–1.5 L
Tidal volume (TV)	Volume of air that is inhaled and exhaled in a normal breath at rest	~500 mL or 7 mL/kg
Inspiratory reserve volume (IRV)	Maximum volume of air that can still be forcibly inhaled following the inhalation of a normal TV	3–3.5 L
Inspiratory capacity (IC)	Maximum volume of air that can be inhaled after the exhalation of a normal TV	3.5–4 L
Expiratory reserve volume (ERV)	Maximum volume of air that can still be forcibly exhaled after the exhalation of a normal TV	1.5 L
Expiratory capacity (EC)	Maximum volume of air that can be exhaled after the inspiration of a normal TV	2 L
Functional residual capacity (FRC)	Volume of air that remains in the lungs after the exhalation of a normal TV	2.5–3 L

Lung volumes are shown in **Figure 3**.

Definitions and normal range of PETs are shown in **Table 2**.

TRANSFER FACTOR

In healthy lungs, the transfer factor, which is influenced by the thickness of the

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alveolar-capillary membrane, properly represents how effectively oxygen diffuses from alveolar air into blood. Because carbon monoxide has a comparable diffusion rate to oxygen, it is employed as a substitute marker to detect this. A single breath-hold or a steady-state method is used and reported as total gas transfer corrected for lung volume transfer (diffusing capacity or DLCO) or gas transfer corrected for lung volume (transfer coefficient or KCO).

$$KCO = DLCO/VA$$

where VA is alveolar volume.

Gas transfer is decreased in emphysema, fibrosis, heart failure, and anemia. In pulmonary hemorrhage, the KCO rises.

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KNV's Manual of Cardiorespiratory Disorders

KNV's Manual of Cardiorespiratory Disorders is the second of this kind following the earlier publication of the Neurology manual by the same author. It is brought out with the intention of serving the needs of the postgraduates in Internal Medicine though certain sections would be useful and appealing to the undergraduates. Exam-oriented topics are selected and dealt with in the chapters starting from the basics and going on to cover the advanced materials and rare syndromes which fall under the "nice to know" category, thus ensuring their completeness. The basis of interpretation of each clinical sign is explained in detail. Illustrations are an added attraction. Mnemonics in the book help in the joyful reading and easy assimilation of the facts and moreover the important statements are stressed by underlining them or printing them in italics. Recent advances in the relevant chapters and investigations both interventional and non-interventional have been briefly incorporated.

K Neelakantan Viswanathan MBBS (JIPMER) DNB (Med) FRCP (London) FRCP (Glasgow) FACTM AB (US) FACP (US) FCCP FIACM is a Senior Professor of Medicine at Sri Manakula Vinayagar Medical College and Hospital, Puducherry, India. He had a brilliant academic career during his student days and has worked in premier institutions like JIPMER, NIMHANS, SRMC & RI and Madras Medical College with a short stint overseas. He is an excellent teacher with an immaculate clinical acumen and has guided several postgraduates in their thesis work. He has contributed to several chapters in *Kumar and Clark's Clinical Medicine* and is an International Advisory Board Member for the same book and *Davidson's Principles and Practice of Medicine.* He has contributed to chapters in *Conn's Current Therapy* and *Bates' Guide to Physical Diagnosis and History Taking* and has published more than 50 scientific/research articles in various national and international journals. He is an examiner for more than 100 MBBS and 150 MD exams of several universities. He also contributes to chapters in *Medicine Update* yearly. He is an invited speaker at conferences in India and abroad. He has received the EMINENT PHYSICIAN award from the API City Physicians Association, Chennai, for the outstanding contribution in expanding the frontiers of Medical Education. He plays an important role in shaping the cutting-edge postgraduate teaching programs in Internal Medicine.

Sowmya Gopalan MD (General Med) MRCP (UK) is a Professor of Medicine at Sri Ramachandra Institute of Higher Education and Research, Chennai, Tamil Nadu, India. She completed her undergraduate and postgraduate studies from the Christian Medical College, Vellore where she won multiple awards and was the best outgoing postgraduate student. Following a short stint in Delhi, she joined SRIHER where she has guided many UG and PG students. She has published more than 30 articles in various international journals mainly in the field of infectious diseases. She believes in the power of education and stimulating young doctors towards a lifelong love for learning.

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