Clinical Respiratory Physiology

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PREFACE

The purpose of this short text is to try to clear up some of the difficulties which a succession of Housemen and Registrars have asked me to explain. I have therefore stressed the practical aspects of applied respiratory physiology together with those theoretical concepts that I feel are necessary for proper understanding. The book will, I hope, meet the basic requirements of junior doctors working in respiratory units and those studying for higher qualifications. It should be of value to technicians in respiratory laboratories, and to General Physicians wishing for a brief review of the subject. It may even stimulate an interest in senior medical students, whose knowledge of respiratory physiology is regrettably often precarious.

I have deliberately refrained from cluttering up the text with references. Indeed to quote them all would at least double the size of the book. Instead I have included a bibliography at the end. The books listed have been of great value to me over the years and contain many hundreds of references. The really interested reader of my little book will undoubtedly wish to turn to them.

L.H.

November 1974

TO MY WIFE AND CHILDREN
IN GRATITUDE FOR THEIR ENCOURAGEMENT

SYMBOLS AND ABBREVIATIONS

Ventilatory

PRIMARY

V = volume
$\dot{V}$ = volume/unit time
P = pressure
F = fractional concentration
R = respiratory exchange ratio (without subscript) and also resistance (with subscript)
T_L = transfer factor
G = conductance
C = compliance
S = specific
D = diffusing capacity

SECONDARY

I = inspired
E = expired
A = alveolar
T = tidal
D = dead space
B = barometric
L = lung
AW = airway
M = membrane

LUNG VOLUMES

IRV = inspiratory reserve volume
TV = tidal volume (normal quiet breathing)
VC = vital capacity
FVC = forced (or fast) vital capacity

FEV = forced expiratory volume (with subscript for time, e.g. 0·75, 1·0, 3·0)
ERV = expiratory reserve volume
FRC = functional residual capacity
RV = residual volume
TLC = total lung capacity
MBC or MVV = maximum breathing capacity or maximum voluntary ventilation
MEFR = maximum expiratory flow rate
MIFR = maximum inspiratory flow rate
PEFR = peak expiratory flow rate
FMF or MMF = maximum mid-expiratory flow rate (with subscript for portion measured, e.g. 25–75%, 200–1, 200 ml.)

OTHER
f = respiratory frequency
kCO = diffusion coefficient

Blood

PRIMARY
$\dot{Q}$ = volume per unit time
C = gas concentration (content)
S = saturation
P = pressure
D = pressure difference

SECONDARY
a = arterial
v = venous
$\bar{v}$ = mixed venous
c = capillary
s = shunt
t = total

NB: The 'p' in 'pH' does *not* stand for pressure but is a conventional symbol for negative logarithm. A capital italic '*P*' should always be used for pressure, e.g. P_{CO_2} (*see* Chapter 11).

Chapter One

Ventilatory Capacity (Timed Spirometry)

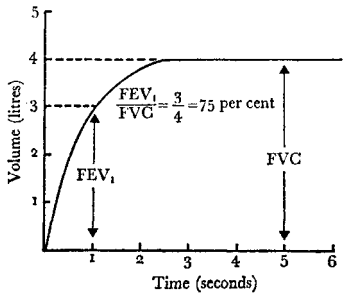
Expiratory Measurements

A number of measurements can be made from a fast (or forced) expiratory trace, and each may be used as an index of expiratory airways obstruction (provided that restriction of ventilation can be excluded).

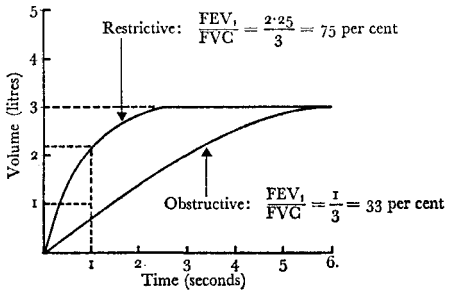
FEV_1 = forced expiratory volume in the first second (other FEV times are sometimes used, e.g. 0·75 sec, 3 sec, but FEV_1 has become the accepted standard in general).

FVC = forced vital capacity (this may be less than the vital capacity (VC) performed slowly, especially if there is premature collapse of larger airways).

$(FEV_1/FVC) \times 100$ (sometimes expressed as FEV per cent) distinguishes between obstructive and restrictive conditions. The normal ratio is >80 per cent at age 20, >75 per cent at age 40, >70 per cent at age 60. In obstructive airways diseases FEV_1/FVC is reduced. In restrictive conditions the ratio is normal, even though FEV_1 and FVC are individually reduced.



This is a normal trace (as obtained on the popular type of dry spirometer) for a 40-year-old man, 1·82 m in height.



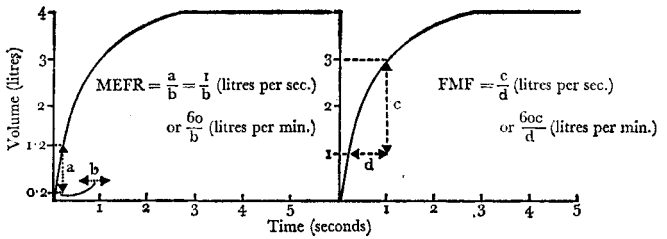
These traces (for men of same age and height as above) indicate the distinction between obstructive and restrictive patterns.

The usual method of obtaining the forced expiratory tracing is to ask the subject to take in the biggest breath he can and then breathe out into the machine as hard and fast as he can, i.e. maximum inspiration followed by recording maximum rapid expiration.

Other indices which can be obtained from the trace offer doubtful advantage over a carefully performed FEV_1 and FVC, although some workers claim that they are more sensitive, as they are less dependent on the initial part of expiration which is influenced by subject co-operation.

MEFR = maximum expiratory flow rate measured in litres per min. over 1 litre after expiration of the first 0·2 litres (i.e. from 0·2 to 1·2 litres).

FMF (or MMF) = maximum mid-expiratory flow measured in litres per min. over the middle 50 per cent of the FVC.



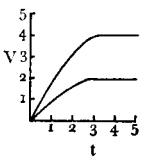
PEFR = peak expiratory flow rate, is a widely used measurement, being read from the dial of a peak flow meter. It does not distinguish between obstruction and restriction.

MVV = maximum voluntary ventilation, which is obtained by measuring the volume expired with the subject making the greatest possible respiratory effort for 15 seconds and then multiplied by 4 to give the rate in litres per min. This has largely been abandoned in favour of the other methods already described.

Reversibility of expiratory airways obstruction can be assessed by measuring FEV_1 before and after administration of a bronchodilator (Note: FEV_1 and FVC may change proportionately or disproportionately either way, therefore change in FEV/FVC per cent does *not* measure reversibility). Expiratory airways obstruction should not be labelled irreversible until it has been shown that there is a lack of response to—

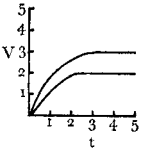
1. A sympathomimetic β_2-adrenergic stimulator,
   e.g. isoprenaline, salbutamol etc.
2. A compound of theophylline,
   e.g. proxyphylline, aminophylline, etc.
3. A corticosteroid or corticotrophin.

A clinically significant response is a 20 per cent increase in FEV_1 over the resting value (although some workers accept 15 per cent).



Post-bronchodilator: FEV_1 2·0; FVC 4·0; FEV per cent 50 per cent. FEV_1 increase $\frac{(2-1)}{1} \times 100 = 100$ per cent.

Pre-bronchodilator: FEV_1 1·0 L; FVC 2·0 L; FEV per cent 50 per cent. FEV per cent. No change

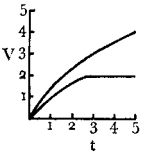


Post: FEV_1 2·0 L; FVC 3·0 L; FEV per cent 67 per cent

Pre: FEV_1 1·0 L; FVC 2·0 L; FEV per cent 50 per cent

FEV_1 increase $\frac{(2-1)}{1} \times 100 = 100$ per cent

FEV per cent increased



Post: FEV_1 1·5 L; FVC 4·0 L; FEV per cent 37·5 per cent

Pre: FEV_1 1·0 L; FVC 2·0 L; FEV per cent 50 per cent

FEV_1 increase $\frac{(1{\cdot}5-1)}{1} \times 100 = 50$ per cent

FEV per cent decreased

Inspiratory Measurements

The equivalent of the forced expiratory measurements may be made during inspiration also viz:

FIV = forced inspiratory volume
MIFR = maximum inspiratory flow rate
PIFR = peak inspiratory flow rate

FIV and MIFR can be obtained with a fast moving drum water-filled spirometer, but not from the commonly used dry spirometer. PIFR requires a specially modified peak flow instrument.

Some workers consider that impaired inspiratory flow rates reflect restrictive disorders. It has also been suggested that comparison of inspiratory and expiratory flow rates e.g. FIV_1/FEV_1 or MIFR/MEFR or PIFR/PEFR may help to distinguish between asthma and emphysema (on the grounds that the ratio is high in asthma, but normal in emphysema) and restrictive conditions (low ratio).

E.g. Normal young man

MIFR 300 litres per min
MEFR 400 litres per min
} ratio 0·75

Asthmatic

MIFR 250 litres per min
MEFR 200 litres per min
} ratio 1·25

Emphysematous

MIFR 150 litres per min
MEFR 200 litres per min
} ratio 0·75

Diffuse fibrosis

MIFR 200 litres per min
MEFR 400 litres per min
} ratio 0·5

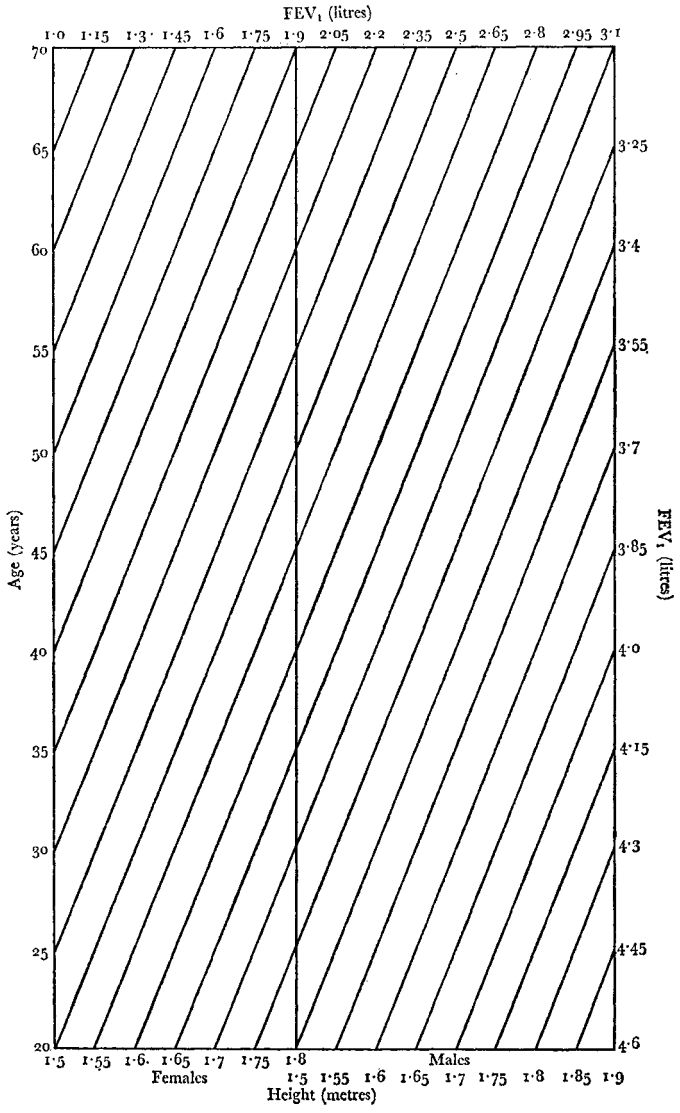
It has further been suggested that the FVC correlates best with the inspiratory indices.

In practice they are seldom used because the FEV_1, FVC and FEV per cent ± bronchodilator usually give sufficient information for clinical purposes.

Predicted values for FEV_1 based on Age, Height and Sex

Values ± 0·45 litres of predicted value may be considered as being within normal range, i.e. within 3 diagonal grid lines on either side of predicted.

(*See* next page)


FEV1 (litres)
1·0 1·15 1·3 1·45 1·6 1·75 1·9 2·05 2·2 2·35 2·5 2·65 2·8 2·95 3·1
70
65
60
55
50
45
40
35
30
25
20
Age (years)
3·25
3·4
3·55
3·7
3·85
4·0
4·15
4·3
4·45
4·6
FEV1 (litres)
1·5 1·55 1·6 1·65 1·7 1·75 1·8
Females
1·5 1·55 1·6 1·65 1·7 1·75 1·8 1·85 1·9
Males
Height (metres)