



The Respiratory System at a Glance

Fourth Edition

**Jeremy P. T. Ward
Jane Ward
Richard M. Leach**



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The Respiratory System at a Glance

Fourth edition

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Preface to fourth edition

The medical curriculum is constantly being reviewed, but all modern curricula interleave basic and clinical science, physiology and pathophysiology. Clinical examples and cases provide relevance to and assist understanding of the underlying basic science, and basic science concepts help in the understanding of the pathophysiology and treatment of disease. *The Respiratory System at a Glance* is designed to support students following all programmes of study that integrate core aspects of basic science, pathophysiology and clinical medicine, including treatment. As such, it should be useful to medical students throughout their training, and also to other healthcare professions, including nursing.

As with other volumes in the *At a Glance* series, it is based around a two-page spread for each main topic, with figures and text complementing each other to give an overview at a glance. Case studies based on some of the most commonly encountered conditions are also provided on the companion website, and can be used for both basic science and clinical study. Although primarily designed for revision, the book covers all the core elements of the respiratory system and its major diseases, and as such could be used as a main text in the first couple of years of the course. It is advised, however, that additional reference to more detailed textbooks will aid deeper and wider understanding of the subject. This is particularly the case for the pathophysiological chapters, as a book this concise cannot hope to provide a complete guide to clinical practice.

In this fourth edition we have significantly revised the majority of chapters and improved or replaced figures to aid comprehension. In response to requests from readers,

we now provide separate chapters on lung defence mechanisms and immunology, in keeping with their importance for most respiratory diseases, and there are now two chapters covering regulation of acid-base balance and acid-base disorders, an area that many find difficult. There are several additional case studies and self-assessment MCQs, now to be found on the companion website. We have hopefully corrected all errors in the last edition. We have been greatly assisted by our many colleagues and students who have kindly advised us and commented on the contents, but any errors and omissions are entirely our responsibility. We also thank the staff at Wiley, without whom we would not have been able to produce this edition.

Jeremy P.T. Ward
Jane Ward
Richard M. Leach

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Units and symbols

Units

The medical profession and scientific community generally use SI (Système International) units.

Pressure conversion: SI unit of pressure: 1 pascal (Pa) = 1 N/m^2 . As this is small, in medicine the kPa ($=10^3$ Pa) is more commonly used. Note that millimetres of mercury (mmHg) are still the most common unit for expressing arterial and venous blood pressures, and low pressures - e.g. central venous pressure and intrapleural pressure - are sometimes expressed as centimetres of H_2O (cmH₂O).

Blood gas partial pressures are reported by some laboratories in kPa and by some in mmHg, so you need to be familiar with both systems.

$$1\text{ kPa} = 7.5\text{ mmHg} = 10.2\text{ cmH}_2\text{O}$$

$$1\text{ mmHg} = 1\text{ torr} = 0.133\text{ kPa} = 1.36\text{ cmH}_2\text{O}$$

$$1\text{ cmH}_2\text{O} = 0.098\text{ kPa} = 0.74\text{ mmHg}$$

$$1\text{ standard atmosphere} (\approx 1\text{ bar}) = 101.3\text{ kPa} = 760\text{ mmHg} = 1033\text{ cmH}_2\text{O}$$

Contents are often expressed per 100 mL (dL), and these need to be multiplied by 10 to give the standard SI unit per litre. Contents are also increasingly being expressed as mmol/L. For haemoglobin: $1\text{ g/dL} = 10\text{ g/L} = 0.062\text{ mmol/L}$. For ideal gases (including oxygen and nitrogen): $1\text{ mmol} = 22.4\text{ mL}$ standard temperature and pressure dry (STPD; see Chapter 4). For non-ideal gases, such as nitrous oxide and carbon dioxide: $1\text{ mmol} = 22.25\text{ mL STPD}$. Technically, concentrations of ions in solution (e.g. $[\text{H}^+]$, $[\text{K}^+]$) should be

expressed as mole equivalents (e.g. mEq), but as there is no difference either numerically or in meaning we have mostly followed the convention of using molar concentrations.

Standard symbols

Primary symbols

F = Fractional concentration of gas

C = Content of a gas in blood

V = Volume of a gas

P = Pressure of partial pressure

S = Saturation of haemoglobin with oxygen

Q = Volume of blood

A dot over a letter means a time derivative, e.g. \dot{v} = ventilation (L/min); \dot{Q} = blood flow (L/min)

Secondary symbols

Gas: I = Inspired gas

E = Expired gas

A = Alveolar gas

D = Dead-space gas

T = Tidal

B = Barometric

ET = End-tidal

Blood: a = Arterial

v = Venous

c = Capillary

A dash means mixed or mean

e.g. \bar{v} = Mixed venous

A' after a symbol means end

e.g. c' = End-capillary

Tertiary symbols

O_2 = Oxygen

CO_2 = Carbon dioxide

CO = Carbon monoxide

Examples

$\dot{V}O_2$ = Oxygen consumption

P_ACO_2 = Alveolar partial pressure of carbon dioxide

Typical values

Typical inspired, alveolar and blood gas values in healthy young adults are shown in the table below. Ranges are given for arterial blood gas values. Mean arterial PO_2 falls with age, and by 60 years is about 11 kPa/82 mmHg. Typical values for lung volumes and other lung function tests are given in the appropriate chapters. Ranges for many values are affected by age, sex and height, as well as by the method of measurement, and hence it is necessary to refer to appropriate nomograms.

Inspired PO_2 (dry, sea level)	21 kPa	159 mmHg
	13.3 kPa	100 mmHg

Alveolar P_{O_2}		
Arterial P_{O_2}	12.5 (11.2–13.9) kPa	94 (84–104) mmHg
A-a P_{O_2} gradient	<2kPa	<15 mmHg (greater in elderly)
Arterial oxygen saturation	>97%	
Arterial oxygen content	200 mL/L	20 mL/dL
Inspired P_{CO_2}	0.03 kPa	0.2 mmHg
Alveolar P_{CO_2}	5.3 (4.7–6.1) kPa	40 (35–45) mmHg
Arterial P_{CO_2}	5.3 (4.7–6.1) kPa	40 (35–45) mmHg
Arterial CO_2 content	480 mL/L	48 mL/dL
Arterial $[H^+]$ /pH	35–45 nmol/L	7.45–7.35
Resting mixed venous P_{O_2}	5.3 kPa	40 mmHg
Resting mixed venous O_2 content	150 mL/L	15 mL/dL
Resting mixed venous	75%	

O ₂ saturation		
Resting mixed venous <i>P</i> co ₂	6.1 kPa	46 mmHg
Resting mixed venous CO ₂ content	520 mL/L	52 mL/dL
Arterial [HCO_3^-]	24 (21-27) mmol/L	

List of abbreviations

A-a gradient

(A-a P_{O_2}) gradient, the difference between ideal alveolar and arterial P_{O_2}

AAT

α_1 -antitrypsin

AHI

apnoea plus hypopnoea index

AIDS

acquired immune deficiency syndrome

AIP

acute interstitial pneumonia/pneumonitis (Hamman-Rich syndrome)

ALI

acute lung injury

ANA

anti-nuclear antibody

ANCA

anti-neutrophil cytoplasmic antibody

AP

anterior-posterior

ARDS

acute (formerly adult) respiratory distress syndrome

ATPS

ambient temperature and pressure saturated

ATS

American Thoracic Society (guidelines)

BAL

bronchoalveolar lavage

BALT

bronchus-associated lymphoid tissue

BCG

bacille Calmette-Guérin

BiPAP

bilevel positive airway pressure, biphasic positive airway pressure

BP

blood pressure

BTPS

body temperature and pressure saturated

BTS

British Thoracic Society (guidelines)

CA

carbonic anhydrase

cAMP

cyclic adenosine monophosphate

CAP

community-acquired pneumonia

CCF

congestive cardiac failure

CF

cystic fibrosis

CFA

cryptogenic fibrosing alveolitis

CFTR

cystic fibrosis transmembrane conductance regulator

C_L

lung compliance = $\Delta V / \Delta P$, where P = alveolar - intrapleural pressure

CMV

controlled mechanical ventilation

CMV

cytomegalovirus

CNS

central nervous system

COAD

chronic obstructive airway disease (synonymous with COPD, COLD)

COLD

chronic obstructive lung disease (synonymous with COAD, COPD)

COPD

chronic obstructive pulmonary disease (synonymous with COAD, COLD)

COX

cyclooxygenase

CPAP

continuous positive airway pressure

CREST

calcinosis, Raynaud's phenomenon, esophageal involvement, sclerodactyly and telangiectasia

CSA

central sleep apnoea

CSF

cerebrospinal fluid

CT

computed tomography

CTPA

computed tomography pulmonary angiogram

CWP

coal worker's pneumoconiosis

CXR

chest X-ray

DIP

desquamative interstitial pneumonia

 D_{LCO}

diffusing capacity of the lungs for carbon monoxide

 D_{Lg}

diffusing capacity of the lungs for gas

 D_{LO_2}

diffusing capacity of the lungs for oxygen

DRG

dorsal respiratory group

DVT

deep venous thrombosis

EBV

Epstein-Barr virus

ECG

electrocardiogram

ECMO

extracorporeal membrane oxygenation

ECP

eosinophil cationic protein

EEG

electroencephalogram

EGF

epidermal growth factor

ELISA

enzyme-linked immunoassay

EMG

electromyogram

EOG

electrooculogram

ERV

expiratory reserve volume

ESR

erythrocyte sedimentation rate

FDG

fuorodeoxyglucose

FDG PET

fuorodeoxyglucose positron emission tomography

FEF₂₅₋₇₅

mean forced expiratory flow over middle 50% of forced vital capacity

FER

forced expiratory ratio

FEV₁

forced expiratory volume in 1 second

FEV₁/FVC

FEV₁ expressed as a fraction, or more usually a percentage of FVC (= FER)

FGF

fbroblast growth factor

FRC

functional residual capacity

FVC

forced vital capacity

GBM

glomerular basement membrane

GM-CSF

granulocyte macrophage colony-stimulating factor

GU

genitourinary

HAART

highly active antiretroviral therapy

HAP

hospital acquired pneumonia

HCAP

healthcare-associated pneumonia

HIV

human immunodeficiency virus

HR

heart rate

HRCT

high-resolution computed tomography

ICU

intensive care unit

IFN- γ

interferon- γ

Ig

immunoglobulin, e.g. IgA, IgE, IgG and IgM

IL

interleukin, e.g. IL-10

ILD

interstitial lung disease

INPV

intermittent negative pressure ventilation

IPF

idiopathic pulmonary fibrosis (synonymous with CFA)

IPPV

intermittent positive pressure breathing

IRV

inspiratory reserve volume

IVC

inferior vena cava

JVP

jugular venous pressure