The Respiratory System at a Glance

Fourth Edition

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This edition first published 2015 © 2015 by John Wiley & Sons Ltd.
Previous editions 2002, 2006, 2010 by J.P.T. Ward, J. Ward, R.M. Leach

Registered office:
John Wiley & Sons, Ltd, The Atrium, Southern Gate, Chichester,
West Sussex, PO19 8SQ, UK

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Library of Congress Cataloging-in-Publication Data

Ward, Jeremy P. T., author.
The respiratory system at a glance / Jeremy P.T. Ward, Jane Ward, Richard M. Leach. — Fourth edition.
p. ; cm. — (At a glance series)
Includes index.
ISBN 978-1-118-76107-6 (pbk.)
I. Ward, Jane, 1952– , author. II. Leach, Richard M. (Haematologist), author. III. Title. IV. Series: At a glance series (Oxford, England)
[DNLM: 1. Respiratory Physiological Phenomena. 2. Respiratory System – physiopathology. 3. Respiratory Tract Diseases. WF 102]
RC731
616.2—dc23
2015004640

A catalogue record for this book is available from the British Library.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Cover image: istock © Nerthuz

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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

Acknowledgement

We would like to thank Charles M. Wiener, Professor of Medicine and Physiology at John Hopkins School of Medicine, Baltimore, USA, for his contribution to the original concept and the first and second editions of this book.

Units and symbols

Units

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

Pressure conversion: SI unit of pressure: 1 pascal (Pa) = $1N/m^2$. 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 (cmH_2O).

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 kPa = 7.5 mmHg = 10.2 cmH_2O

1 mmHg = 1 torr = 0.133 kPa = 1.36 cmH_2O

1 cmH_2O = 0.098 kPa = 0.74 mmHg

1 standard atmosphere ($\simeq$1 bar) = 101.3 kPa = 760 mmHg =1033 cmH_2O

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 g/dL = 10 g/L = 0.062 mmol/L. For ideal gases (including oxygen and nitrogen): 1 mmol = 22.4 mL standard temperature and pressure dry (STPD; see Chapter 4). For non-ideal gases, such as nitrous oxide and carbon dioxide: 1 mmol = 22.25 mL STPD. Technically, concentrations of ions in solution (e.g. $[H^+]$, $[K^+]$) 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 Po_2		
Arterial Po_2	12.5 (11.2–13.9) kPa	94 (84–104) mmHg
A–a Po_2 gradient	<2kPa	<15 mmHg (greater in elderly)
Arterial oxygen saturation	>97%	
Arterial oxygen content	200 mL/L	20 mL/dL
Inspired Pco_2	0.03 kPa	0.2 mmHg
Alveolar Pco_2	5.3 (4.7–6.1) kPa	40 (35–45) mmHg
Arterial Pco_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 Po_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 Pco_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 defciency 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 fbrosis

CFA
cryptogenic fbrosing alveolitis

CFTR
cystic fbrosis 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 fuid

CT
computed tomography

CTPA
computed tomography pulmonary angiogram

CWP
coal worker's pneumoconiosis

CXR
chest X-ray

DIP
desquamative interstitial pneumonia

$D_L$co
diffusing capacity of the lungs for carbon monoxide

D_Lg
diffusing capacity of the lungs for gas

$D_L O_2$
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

FEF_{25-75}
mean forced expiratory fow over middle 50% of forced vital capacity

FER
forced expiratory ratio

FEV_1
forced expiratory volume in 1 second

FEV_1/FVC
FEV_1 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 immunodefciency virus

HR
heart rate

HRCT
high-resolution computed tomography

ICU
intensive care unit

IFN-γ
interferon-γ

lg
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 fbrosis (synonymous with CFA)

IPPV
intermittent positive pressure breathing

IRV
inspiratory reserve volume

IVC
inferior vena cava

JVP
jugular venous pressure