

Cambridge University Press
978-1-108-41938-3 — Core Topics in Cardiac Anaesthesia
Edited by Joseph Arrowsmith , Andrew Roscoe , Jonathan Mackay
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Third Edition

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For J-P

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Reviews of the First Edition

“The book has set itself clear objectives and very largely achieves them. Whilst trying not to be all-encompassing nor the only reference book required for this burgeoning field, it covers all the necessary and relevant areas to provide a sound basis and grounding in good clinical practice.”

“The extensive list of abbreviations . . . reduces confusion and enhances the flow of the text”

“There is little cross-over between chapters and each chapter covers the topic in sufficient detail to make it useful as a stand-alone reference text.”

“ . . . a thoughtfully produced and well-written book.”

Jonathan J Ross, Sheffield, UK.

British Journal of Anaesthesia 2005; 94(6): 868

“the book relies heavily on tables and figures, which makes it an effective didactic teaching tool.”

“The pharmacology section includes a succinct summary of the drugs used every day in the cardiac operating rooms.”

“ . . . the chapter on signs and symptoms of cardiac disease is one of the best this reviewer has seen.”

“ . . . an excellent introductory text book for the trainee in cardiac anaesthesia”

“ . . . likely to become a classic in the resident or fellow library.”

Pablo Motta MD, Cleveland Clinic Foundation, USA.

Anesthesia & Analgesia 2006; 102(2): 657

“ . . . the ubiquitous use of well-labeled diagrams, photographs and clinical tracings adds understanding at every level . . . a delight to use as a teaching device.”

“ . . . a rare text that is without institutional bias or personal beliefs.”

“ . . . I would advise curious learners to save their time and money until they have absorbed all that this book has to offer!”

J Cousins, London, UK

Perfusion 2006; 21(3): 193

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Preface to the Third Edition

In the words of one of our contributors (Sam Nashef*), “There is no such thing as a good cardiac anaesthetist”. Recently published** evidence, however, suggests that the variability in cardiac anaesthetists’ performance is much lower than that of cardiac surgeons. This may reflect widespread uniformity in training and standardised clinical practice.

As with many textbooks, it was inevitable that the second edition was fatter and heavier than the first as we sought to cover more topics in greater detail. In considering a third edition, the consistent feedback (sometimes blunt) was to delete less frequently read chapters and return to the original remit – a small, concise, portable reference focusing on key points for trainees in the first 6 months of subspecialty training.

We warmly welcome Andy Roscoe, a recognized international authority on transoesophageal echocardiography, as an editor. Under Andy’s stewardship, we are confident that future editions of this book will be in safe hands.

In the third edition, we cover many of changes that have occurred since publication of the second edition – a huge expansion in ECMO (a *four-letter word* in many centres), increased numbers of cardiology procedures undertaken in cardiac catheter laboratory and hybrid operating theatre, and the tentative return of aprotinin into clinical practice.

In larger cardiac surgical centres there has been a gradual separation of cardiothoracic anaesthesia from critical care, with the latter becoming a specialty in its own right. Many intensive topics are well covered in a sister publication, *Core Topics in Cardiothoracic Critical Care, Second Edition* and these are referenced in the text.

We are extremely grateful to our contributors for their forbearance and to Cambridge University Press for their seemingly endless patience.

Joe Arrowsmith
Jon Mackay
December 2018

* Nashef S. *The Naked Surgeon: The Power and Peril of Transparency in Medicine*. London: Scribe; 2016.

** Papachristofi O, *et al*. The contribution of the anaesthetist to risk-adjusted mortality after cardiac surgery. *Anaesthesia* 2016; 71(2): 138–46.

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Preface to the First Edition

This book is primarily aimed at anaesthetic trainees in the first 3–6 months of subspecialty training in cardiac anaesthesia and critical care. It is our response to the many trainees who have regularly asked us to recommend a small textbook on cardiac anaesthesia.

We realize that it is impossible to produce a truly comprehensive review of cardiac anaesthesia in ~120,000 words but hope that this book provides a sound grounding in all of the core topics. The content of this book has been very much guided by The Royal College of Anaesthetists' *CCST in Anaesthesia* manual, The Society of Cardiovascular Anesthesiologists' *Program Requirements for Resident Education*, and recent examination papers from the United Kingdom, North America and Australasia.

Our instructions to contributing authors and editorial aims were simple; produce a concise yet comprehensive overview of the subject emphasizing pathophysiology, basic scientific principles and the key elements of practice. We hope that the use of a presentation format that relies on figures and tables in preference to text will aid comprehension and recall.

We have endeavoured to avoid repetition of information, long lists of references and institutional bias. We trust that the curious trainee will turn to the larger textbooks and the Internet for more detailed discussions and exhaustive literature reviews. Finally, we hope that many sections of this book will also appeal to those preparing trainees for examinations and to clinical nurse specialists working in the field of cardiothoracic intensive care.

We would like to thank all of those who have made the publication of this volume possible; our international panel of contributors for taking the time to share their knowledge and expertise; Gill Clark and Gavin Smith of Greenwich Medical Media for their encouragement, advice and patience; and our Specialist Registrars for their advice and proof reading. Last, we wish to thank our families for their willing, and occasionally unwilling, support during this enterprise.

Jon Mackay
Joe Arrowsmith
January 2004

Foreword to the First Edition

Cardiac anaesthesia brings many divergent disciplines into one unifying practice, making it one of the most complex anaesthetic subspecialties. It requires an understanding of pathology, physiology, pharmacology, internal medicine, cardiology, cardiac surgery and intensive care. The ever-expanding nature of the specialty presents considerable challenges for both the everyday practitioner and the trainee – for whom this text is particularly targeted.

In this day and age, when a vast amount of information is already available both in print and on-line, one may be forgiven for questioning the need for yet another printed textbook. By way of an answer, the Editors (both of whom have worked in the UK and the USA) have produced a textbook (rather than a *cookbook*) that addresses a relatively unfulfilled need—a source that is specifically directed towards those who represent the future of our specialty. By incorporating contributions from authors from many countries, the Editors have largely avoided national and institutional bias.

Today's anaesthetic trainees are confronted with the seemingly impossible task of assimilating,

understanding and memorizing an almost infinite body of information. Those who succeed in this task are invariably those who can confidently identify core principles without getting distracted by minute details. The Editors never intended to produce an exhaustive reference and the need to consult other sources of detailed information has, therefore, not been completely eliminated. This book does, however, provide the trainee with a very convenient framework onto which further knowledge can be added as it is acquired. The manner in which the authors have organized and presented information in this book should help the reader to more quickly see the 'bigger picture' and appreciate the subtleties of cardiac anaesthesia.

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Abbreviations

A

2D two-dimensional
3D three-dimensional
 A₂ aortic valve component of second heart sound
AAA abdominal aortic aneurysm
AAGBI Association of Anaesthetists of Great Britain and Ireland
AATS American Association for Thoracic Surgery
ABG arterial blood gas
 ACA anterior cerebral artery
ACC American College of Cardiologists
ACCF American College of Cardiology Foundation
ACE angiotensin converting enzyme
 ACHD adult congenital heart disease
 ACoA anterior communicating (cerebral) artery
 ACP American College of Physicians
ACS acute coronary syndrome(s)
ACT activated clotting time
 ADH antidiuretic hormone
 ADP adenosine diphosphate
 AE air embolism
 AECC American-European Consensus Conference
 AEP auditory evoked potential
AF atrial fibrillation
 AHA American Heart Association
 AKI acute kidney injury
 ALI acute lung injury
 ALS advanced life support
 AMVL anterior mitral valve leaflet
 AP action potential
APTT activated partial thromboplastin time
AR aortic regurgitation (incompetence)
ARDS acute respiratory distress syndrome
ARF acute renal failure
 ARVC arrhythmogenic right ventricular cardiomyopathy
AS aortic stenosis
ASA American Society of Anesthesiologists
ASD atrial septal defect
 AT antithrombin
 ATP adenosine triphosphate
AV aortic valve
 A-V atrioventricular
 AVA aortic valve (orifice) area
AVR aortic valve replacement
 AVSD atrioventricular septal defect
AXC aortic cross-clamp

B

BA basilar artery
 BAER brainstem auditory evoked response
 BAS balloon atrial septostomy
 BCPS bidirection cavopulmonary shunt
 BIS bispectral (index)
 BIVAD biventricular assist device
BP blood pressure
 BPEG British Pacing and Electrophysiology Group
bpm beats (breaths) per minute
 B-T Blalock-Taussig (shunt)
 BTT bridge to transplantation

C

CABG coronary artery bypass graft
 CAD coronary artery disease
 CAJ cavo-atrial junction
 CBF cerebral blood flow
CCS Canadian Cardiovascular Society
CFD colour-flow Doppler (sonography)
 CHARGE coloboma, heart, atresia, retardation, genital, ear
 CHD congenital heart disease
CI cardiac index
 CK-MB creatinine kinase MB (isoenzyme)
 CMR cardiac magnetic resonance imaging
CMRO₂ cerebral metabolic rate (for oxygen)
CNS central nervous system
CO cardiac output
 CoA coarctation of the aorta
 CP cavopulmonary (shunt)
 CPAP continuous positive airway pressure
CPB cardiopulmonary bypass
CPR cardiopulmonary resuscitation
 CRA chronic refractory angina
 CRT cardiac resynchronization therapy
CSF cerebrospinal fluid
CT computed tomogram/tomography
 CTA CT angiography
 CTEPH chronic thromboembolic pulmonary hypertension
CVA cerebrovascular accident
CVP central venous pressure
 CVVHF continuous veno-venous haemofiltration
CWD continuous-wave Doppler (sonography)
CXR chest X-ray/radiograph

Abbreviations

D

DA ductus arteriosus
 DASI Duke Activity Status Index
 DBD donation after brain death
DC direct current
 DCCV direct current cardioversion
 DCD donation after circulatory-determined death
 DCM dilated cardiomyopathy
 DDAVP desmopressin (1-desamino-8-d-arginine vasopressin)
 DFT defibrillation (energy) threshold
 DHCA deep hypothermic circulatory arrest
 DH dorsal horn
 DI dimensionless index
DIC disseminated intravascular coagulation
DM diabetes mellitus
DNA deoxyribonucleic acid
 DNAR do not attempt resuscitation
DO₂ oxygen delivery
 DOA depth of anaesthesia
 DOAC direct-acting oral anticoagulant
 DSCT dual-source computed tomography
 DVT deep vein thrombosis

E

EBCT electron-beam CT
 ECC extracorporeal circulation
ECG electrocardiograph
 ECLS extracorporeal life support
ECMO extracorporeal membrane oxygenation
 EDM early diastolic murmur
 EDV end-diastolic volume
 EECG exercise ECG
 EEG electroencephalograph
 EMI electromagnetic interference
 ESC European Society of Cardiology
 ESPVR end-systolic pressure–volume relationship
 ET endothelin
 EuroSCORE European System for Cardiac Operative Risk Evaluation

F

FAC fractional area change
FBC full blood count
FDA Food and Drug Administration (USA)
 FDG fluorodeoxyglucose
 FDPs fibrin(ogen) degradation products
FFP fresh-frozen plasma
 FFR fractional flow reserve
FiO₂ fraction of inspired oxygen
 FS fractional shortening

G

Gd-DTPA gadolinium diethylene triamine pentaacetic acid
GFR glomerular filtration rate

GI gastrointestinal
 GP glycoprotein
GTN glyceryl trinitrate

H

Hb haemoglobin
 Hb-SS haemoglobin-SS (homozygous sickle)
HFSA Heart Failure Society of America
 5-HIAA 5-hydroxyindoleacetic acid
 HIT heparin-induced thrombocytopenia
 HITTS heparin-induced thrombotic thrombocytopenic syndrome
 HLHS hypoplastic left heart syndrome
 HOCM hypertrophic obstructive cardiomyopathy
HR heart rate

I

IABP intra-aortic balloon pump
 ICA internal carotid artery
ICD implantable cardiofibrillator
 ICM implantable cardiac monitoring
ICU intensive care unit
 Ig immunoglobulin
IHD ischaemic heart disease
 IJV internal jugular vein
 IMA internal mammary artery
INR international normalized ratio
 INTERMACS Interagency Registry for Mechanically Assisted Circulatory Support
 IPC ischaemic preconditioning
 IPPV intermittent positive-pressure ventilation
 IRI ischaemia reperfusion injury
 ITP intrathecal pressure
IV intravenous
IVC inferior vena cava
 IVS interventricular septum
 IVUS intravascular ultrasound

J

JET junctional ectopic tachycardia

L

LA left atrium/atrial
 LAA left atrial appendage
LAD left anterior descending (coronary artery)
 LAP left atrial pressure
 LAX long axis
LBBB left bundle branch block
 LCOS low cardiac output state
 LDM late diastolic murmur
 LHB left heart bypass
 LHC left heart catheterization
 LIMA left internal mammary artery
 LLSE left lower sternal edge
 LMS left main stem (coronary artery)
 LMWH low-molecular-weight heparin

LPA left pulmonary artery
 LSM late systolic murmur
 LSV long saphenous vein
 LUSE left upper sternal edge
LV left ventricle/ventricular
 LVAD left ventricular assist device
LVEDP left ventricular end-diastolic pressure
 LVEDV left ventricular end-diastolic volume
 LVEF left ventricular ejection fraction
 LVESV left ventricular end-systolic volume
 LVID left ventricular internal diameter
LVH left ventricular hypertrophy
 LVOT left ventricular outflow tract

M

MAC minimal alveolar concentration
 MAO monoamine oxidase
MAP mean arterial pressure
 MAPCAs major aorta pulmonary collateral arteries
 MCA middle cerebral artery
 MCS mechanical circulatory support
 MDCT multidetector row CT
 MDM mid diastolic murmur
 ME mid-oesophageal
 MEP motor evoked potential
MI myocardial infarction
 MICS minimally invasive cardiac surgery
 MIDCAB minimally invasive direct coronary artery bypass
 MPA main pulmonary artery
 mPAP mean pulmonary artery pressure
MR mitral regurgitation (incompetence)
 MRA magnetic resonance angiography
MRI magnetic resonance imaging
MRSA meticillin-resistant *Staphylococcus aureus*
MS mitral stenosis
 MSM mid systolic murmur
 MV mitral valve
MVR mitral valve replacement
 MW molecular weight

N

N₂O nitrous oxide
 NASPE North American Society of Pacing and Electrophysiology
 NCC non-compaction cardiomyopathy
 NEC necrotizing enterocolitis
 NG nasogastric
NIBP non-invasive blood pressure
NICE National Institute for Health and Care Excellence
 NIRS near-infrared spectroscopy
 NMDA N-methyl-D-aspartate
 NO nitric oxide
 NPV negative predictive value
NSAID non-steroidal anti-inflammatory drug
 NSR normal sinus rhythm

NSTEMI non-ST-elevation myocardial infarction
 NYHA New York Heart Association

O

OPCAB off-pump coronary artery bypass
 OS opening snap

P

P₂ pulmonary valve component of second heart sound
PA pulmonary artery
PaCO₂ arterial partial pressure of carbon dioxide
PaO₂ arterial partial pressure of oxygen
 PAD pulmonary artery diastolic
PAFC pulmonary artery floatation catheter
PAP pulmonary artery pressure
PAWP pulmonary artery wedge pressure
 PBF pulmonary blood flow
 PBMV percutaneous balloon mitral valvotomy
 PCA posterior cerebral artery
 PCC prothrombin complex concentrate
 PCI percutaneous coronary intervention
 PCoA posterior communicating (cerebral) artery
 PD peritoneal dialysis
 PDA patent ductus arteriosus
 PDE phosphodiesterase
PE pulmonary embolus/pulmonary embolism
 PEA pulseless electrical activity
PEEP positive end-expiratory pressure
 PET positron emission tomography
 PF₄ platelet factor 4
PFO patent foramen ovale
 PGE₂ prostaglandin E₂
 PGI₂ prostaglandin I₂/prostacyclin/epoprostenol
 PH-T pressure half-time
PHT pulmonary hypertension
 PISA proximal isovelocity surface area
 PO *per os* (by mouth)
 PPB plasma protein binding
 ppm parts per million
 PPM permanent pacemaker
 PPV positive predictive value
PR pulmonary regurgitation (incompetence)
PS pulmonary stenosis
 PSM pan systolic murmur
 PSV pressure-support ventilation
PT prothrombin time
 PTE pulmonary thromboendarterectomy
PV pulmonary valve
 PVC polyvinyl chloride
 PVL paravalvular leak
PVR pulmonary vascular resistance
PWD pulsed-wave Doppler (sonography)

Q

Q_P pulmonary flow
 Q_S systemic flow

Abbreviations

R

RA right atrium/atrial
RBBB right bundle branch block
RBC red blood cell
RCA right coronary artery
RCP retrograde cerebral perfusion
REMATCH Randomized Evaluation of Mechanical Assistance for the Treatment of Congestive Heart Failure
RHC right heart catheterization
RNA ribonucleic acid
RPA right pulmonary artery
rpm revolutions per minute
RR respiratory rate
RTT renal replacement therapy
rSO₂ regional cerebral oxygen saturation
RV right ventricle/ventricular
RVAD right ventricular assist device
RVEDA right ventricular end-diastolic area
RVEDP right ventricular end-diastolic pressure
RVEF right ventricular ejection fraction
RVESA right ventricular end-systolic area
RVFAC right ventricular fractional area change
RVH right ventricular hypertrophy
RVOT right ventricular outflow tract
RWMA regional wall motion abnormality

S

S₁ first heart sound
S₂ second heart sound
S₃ third heart sound
S₄ fourth heart sound
SACP selective antegrade cerebral perfusion
SAM systolic anterior motion (of the anterior mitral valve leaflet)
SaO₂ arterial oxygen saturation
SAVR surgical aortic valve replacement
SAX short axis surgical AV replacement (SAVR)
SCA Society of Cardiovascular Anesthesiologists
SIMV synchronized intermittent mandatory ventilation
SIRS systemic inflammatory response syndrome
SjvO₂ jugular venous oxygen saturation
SPECT single photon emission computed tomography
SSEP somatosensory evoked potential
SSFP steady-state free-precession
SSI surgical site infection
STEMI ST-elevation myocardial infarction
STS Society of Thoracic Surgeons
SV stroke volume
SVC superior vena cava
SvO₂ mixed venous oxygen saturation
SVR systemic vascular resistance
SVT supraventricular tachycardia

T

T₃ triiodothyronine
T₄ thyroxine
TAPSE tricuspid annular plane systolic excursion
TAPVD total anomalous pulmonary venous drainage
TAVI transcatheter aortic valve implantation
TB tuberculosis
TCD transcranial Doppler (sonography)
TCPC total cavopulmonary connection
TEA thoracic epidural analgesic
TEG thromboelastogram/ thromboelastography
TENS transcutaneous electrical nerve stimulation
TG transgastric
TGA transposition of the great arteries
TOE transoesophageal echocardiography
tPA tissue plasminogen activator
TPG transpulmonary gradient
TR tricuspid regurgitation (incompetence)
TS tricuspid stenosis
TT thrombin time
TTE transthoracic echocardiography
TV tricuspid valve
TXA tranexamic acid

U

UFH unfractionated heparin
uPA urokinase plasminogen activator

V

VA vertebral artery
VACTERL (syndrome) vertebral anomalies, anal atresia, cardiovascular anomalies, tracheoesophageal fistula, esophageal atresia, renal, limb defects
VAD ventricular assist device
VA-ECMO veno-arterial extracorporeal membrane oxygenation
VAP ventilator-associated pneumonia
V_D volume of distribution
VEP visual evoked potential
VF ventricular fibrillation
VO₂ oxygen consumption
VOT ventricular outflow tract
VSD ventricular septal defect
VT ventricular tachycardia
V_T tidal volume
VTI velocity-time integral
VV vitelline vein
VV-ECMO veno-venous extracorporeal membrane oxygenation

W

WHO World Health Organization