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Edited by
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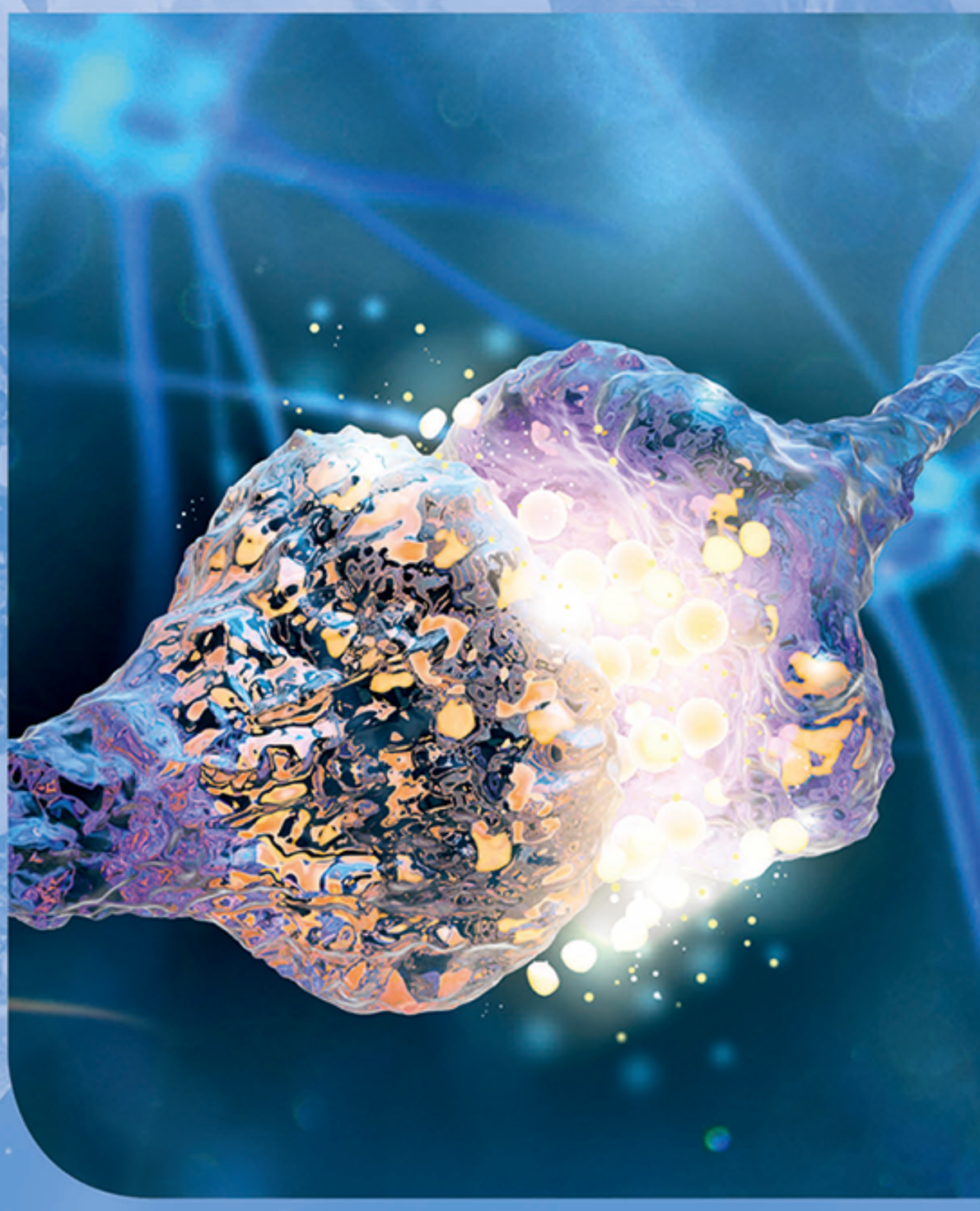
Kristin Engelhard



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Oxford Textbook of Neuroscience and Anaesthesiology

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Dedication

George A. Mashour
Dedicated to my wonderful children, Alexander Fulgens Mashour and Anna Luise Mashour—may they live long, healthy, and joyful lives, and reach the fullest potential of their beautiful minds.

Kristin Engelhard
Dedicated to my mentors and teachers Eberhard Kochs and Christian Werner, who always encouraged and supported me throughout my academic career.

Preface-the three pillars of Neuroanaesthesiology

While serving as the President of the Society for Neuroscience in Anesthesiology and Critical Care, I espoused a vision for neuroanaesthesiology that was supported by three 'pillars'. The traditional pillar of neuroanaesthesiology relates to the care of neurosurgical and neurological patients. The clinical care of individuals with neurologic compromise is incredibly rewarding and represents a true opportunity to make a positive difference in the lives of others. However, the specialty of anaesthesiology is itself a form of clinical neuroscience. On a daily basis, even as anaesthetists for non-neurosurgical cases, we modulate peripheral nerves, the spinal cord, subcortical arousal systems, thalamocortical and corticocortical networks supporting consciousness, pain networks, memory systems in the medial temporal lobe, the neuromuscular junction, and the autonomic nervous system. From this perspective, 'neuroanaesthesiology' is more a compression of 'neuroscience in anaesthesiology' than 'neurosurgical anaesthesiology'. The mechanistic study of our therapeutic interventions, which represents another pillar, is exciting neuroscience in its own right, and has profound implications for nervous system function. Finally, the question of how the peri-operative period might negatively impact the brain is the new frontier of outcomes studies and has been a major priority for the field of anaesthesiology in the past decade. Questions related to anaesthetic neurotoxicity, cognitive dysfunction, stroke, and other neurologic outcomes of non-neurosurgical interventions represent a critically important third pillar for the subspecialty.

The *Oxford Textbook of Neuroscience and Anaesthesiology* is the first book of its kind to comprehensively address all three pillars related to neuroscience in anaesthesiology. The first section treats the neuroscientific foundations of anaesthesiology, including the neural mechanisms of general anaesthetics, cerebral physiology, the neurobiology of pain, and more. The second section represents the traditional pillar related to the care of patients with neurologic disease in the operating room or intensive care unit, with a focus on clinical neuroanaesthesia. These chapters systematically treat the peri-operative considerations of both brain and spine surgery, and provide introductions to neurocritical care and pediatric neuroanaesthesia. Finally, the last section examines some connections of neurology and anaesthesiology, examining how conditions such as dementia, stroke, or epilepsy interface with the peri-operative period.

This international textbook gathers the best available expertise of authors and leaders in the field from Canada, Germany, Italy, New Zealand, Spain, Switzerland, the UK, and the US. They have done an outstanding job of crafting concise yet highly informative chapters describing the cutting edge of neuroscience and neuroanaesthesia. It is my hope that this textbook is itself a 'chapter' in the evolution of the field, creating a lasting foundation and appreciation for the three pillars of neuroscience in anaesthesiology.

George A. Mashour, M.D., Ph.D.

Contents

SECTION 3
Neurologic Patients Undergoing Non-Neurologic Surgery

Abbreviations

133Xe	Xenon
3D	Three-dimensional
AANS	American Association of Neurological Surgeons
ABC	Airway, breathing, circulation
ABCB-1	ATP-binding cassette subfamily B member 1
ABI	Acute brain injury
ABP	Arterial blood pressure
ABR	Auditory brain stem responses
ACA	Anterior cerebral artery
ACC	Anterior cingulate cortex
ACDF	Anterior cervical discectomy with fusion
ACh	Acetylcholine
AChE	acetylcholinesterase
ACSNSQIP	American College of Surgeons National Surgical Quality Improvement Program
ACTH	Adrenocorticotropic hormone
ADH	Antidiuretic hormone
ADHD	attention deficit hyperactivity disorder
AED	Anti-epileptic drug
AION	Anterior ischemic optic neuropathy
AIS	Abbreviated Injury Scale
AIS	Acute ischemic stroke
AMPA	α-amino-3-hydroxy-5-methyl-4-isoxazolepropionate
ANP	Atrial natriuretic peptide
ANS	Autonomic nervous system
AQP1	Aquaporin-1
AQP4	Aquaporin-4
AQPs	Aquaporins
ARAS	Ascending reticular activating system
ARCTIC	Acute Rapid Cooling of Traumatic Injuries of the Cord study
ARDS	Acute respiratory distress syndrome
ASA	American Society of Anesthesiologists
ASA PS	American Society of Anesthesiologists Physical Status
ASIA	American Spinal Injury Association
ASICs	Acid-sensing ion channels
ATP	Adenosine triphosphate
AV	Atrioventricular
AVM	Arteriovenous malformations
Aβ	Amyloid-beta
BAC	Balloon-assisted coiling
BAER	Brainstem auditory evoked response
BBB	Blood-brain barrier
BDNF	Brain-derived neurotrophic factor
BF	Basal forebrain
BIS	Bispectral index
BIS	Bispectral index
BK	Bradykinin
BP	Blood pressure
BTF	Brain Trauma Foundation
Ca	Aterial concentration
cAMP	Cyclic adenosine monophosphate
CAS	Carotid artery stenosis
CAT-1	Cationic amino-acid transporter type 1
CBF	Cerebral blood flow
CBV	Cerebral blood volume
CBVS	Cerebrovascular surgery
CCS	Central cord syndrome
CCT	Cranial computed tomography
CEA	Carotid endarterectomy
CE-MRC	Contrast material-enhanced MR cisternography
CGRP	Calcitonin gene-related peptide
CHD	Congenital heart disease
CHF	Congestive heart failure
CI	Cardiac index
CIC	Intracerebral compliance
CM	Cerebral microdialysis
CMAP	Compound muscle action potential
CMR	Cerebral metabolic rate
$CMRO_2$	Cerebral metabolic oxygen consumption
CMT	Central medial thalamus
CNAP	Compound nerve action potential
CNS	Central nervous system
CNT-2	Concentrative nucleoside transporter type 2
COMT	Catechol-O-methyl transferase
COX	Cycloxygenase
COX-2	Cyclooxygenase-2
CPB	Cardiopulmonary bypass
CPP	Cerebral perfusion pressure
CPR	Cardiopulmonary resuscitation
CRP	C-reactive protein
CRPS	Chronic regional pain syndrome
CSF	Cerebrospinal fluid
CSWS	Cerebral salt wasting syndrome

CT	Computed tomography
CTA	CT angiography
CTP	CT-perfusion
Cv	Venous concentration
CVA	Cerebrovascular accident
CVR	Cerebrovascular resistance
DA1	Dopamine type 1
DA2	Dopamine type 2
DBH	dopamine β-hydroxylase
DBS	Deep brain stimulation/stimulator
DCI	Delayed cerebral ischaemia
DDAVP	desmopressin acetate
DIND	Delayed ischemic neurological deficit
DL	Direct laryngoscopy
DLPFC	Dorsolateral prefrontal cortex
DMN	Default Mode Network
DOAC	Direct acting oral anticoagulant
DOPA	Dihydroxyphenylalanine
DpMe	Deep mesencephalic reticular formation
DR	Dorsal raphe
DRG	Dorsal root ganglion
DVT	Deep vein thrombosis
DWI	diffusion-weighted imaging
ECG	Electrocardiogram
ECMO	Extracorporeal membrane oxygenation
ECoG	Electrocorticography
ECT	Electroconvulsive therapy
ED	Effective dose
EEG	Electroencephalography
EG	Endothelial glycocalyx
EMG	Electromyography
ENS	Enteric nervous system
EP	Evoked potentials
ESL	Endothelial surface layer
ESO	European Stroke Organization
ET	Endotracheal tube
$ETCO_2$	End-tidal carbon dioxide
ETV	Endoscopic third ventriculostomy
EVD	External ventricular drain/drainage
FDA	Food and Drug Administration
FFP	Fresh frozen plasma
FiO_2	Fraction of inspired oxygen
FLAIR	Fluid-attenuated inversion recovery
fMRI	Functional magnetic resonance imaging
FOUR	Full outline of unresponsiveness
FSH	Follicle stimulating hormone
FV	Flow velocity
GA	General anaesthesia
GABA	Gamma-aminobutyric acid
GCS	Glasgow Coma Scale
GH	Growth hormone
GI	Gastrointestinal
GLUT-1	Glucose transporter type 1
GPi	Globus pallidus internus
H reflex	Hoffmann's reflex
Hb	Haemoglobin
HCN	Hyperpolarization-activated cyclic nucleotide-gated
HD	Hydrocephalus
HF	Heart failure
HHT	Hereditary Haemorrhagic Telangiectasia
HIF-1α	Hypoxia-inducible factor 1 alpha
HS	Hypertonic saline
Hz	Hertz
IADL	Instrumental activities of daily living
IARS	International Anesthesia Research Society
IBA1	Ionized calcium binding adaptor molecule 1
IBV	Intracranial blood volume
ICA	Internal carotid artery
ICH	Intracranial haemorrhage
ICP	Intracranial pressure
ICU	Intensive care unit
ICV	Intracranial volume
IHAST	Intraoperative Hypothermia for Aneurysm Surgery Trial
IIT	Intensive insulin therapy
IL-6	Interleukin-6
IOM	Intra-operative neurophysiological monitoring
ION	Ischemic optic neuropathy
IOM	Intra-operative neurophysiological monitoring
IONM	Intraoperative neurophysiological monitoring
IPG	Internal pulse generator
IPL	Inferior parietal lobule
IQ	Intelligence quotient
IV-tPA	Intravenous tissue-type plasminogen activator
K	Potassium
K2P	Two-pore-domain potassium channel
Kv	Voltage-gated potassium channel
LA	Local anaesthesia
LAT-1	Large neutral amino-acid transporter type 1
LC	Locus coeruleus
LD	Lumbar drain/drainage
LDF	Laser Doppler flowmetry
LDT	Laterodorsal tegmentum
LGICs	Ligand-gated ion channels
LH	Luteinizing hormone
LMA	Laryngeal mask airway
LMWH	Low molecular weight heparin
LoRR	Loss of righting reflex
LOX	Lipoxygenase
LP	Lactate:pyruvate
LVH	Left ventricular hypertrophy
MABL	Maximal allowable blood loss
MAC	Minimum alveolar concentration
MAC	Monitored anaesthesia care
MADRS	Montgomery-Asberg Depression Rating Scale
MAO	Monoamine oxidase
MAO-B	Monoamine oxidase-B
MAOIs	MAO inhibitors
MAP	Mean arterial blood pressure
MCA	Middle cerebral artery
MCI	Mild cognitive impairment
MCT-1	Monocarboxylic acid transport type 1
MDD	Major depressive disorder
MDR-1	Multidrug resistance gene
MEG	Magnetoencephalography
MEN-1	Multiple endocrine neoplasia type 1
MEP	Motor evoked potentials

MER	Microelectrode recordings
MERCI	Mechanical Embolus Removal in Cerebral Ischemia trial
MH	Malignant hyperthermia
miRNA	Micro-RNA
ml	Millilitres
MLS	Manual-in-line stabilization
MnPO	Median preoptic nucleus
MOCAIP	Morphological clustering and analysis of ICP pulse
mPFC	Medial prefrontal cortex
mps	Metres per second
MRI	Magnetic resonance imaging
mRNA	Messenger RNA
mRS	Modified Rankin score
Mx	Mean flow velocity reactivity
N_2O	Nitrous oxide
nAChR	Nicotinic acetylcholine receptor
NANC	non-adrenergic non-cholinergic neurotransmitter
Nav	Voltage-gated sodium
NCF	Nucleus cuneiformis
NGF	Nerve growth factor
NICU	Neurological intensive care unit
NIHSS	National Institutes of Health Stroke Scale
NIRS	Near infrared spectroscopy
NMB	Neuromuscular block
NMDA	N-methyl-D-aspartate
NMS	Neuroleptic malignant syndrome
NO	Nitric oxide/Nitrogen monoxide
NOS	Nitric oxide synthase
NPH	Normal pressure hydrocephalus
NPPB	Normal perfusion pressure breakthrough
NPY	Neuropeptide Y
NREM	Non-REM
NS	Nociceptive specific
NSAIDs	Non-steroidal anti-inflammatory drugs
NSF	N-ethyl maleimide sensitive factor
NSM	Neurogenic stunned myocardial
NSQIP	National Surgical Quality Improvement Program Risk
OPP	Ocular perfusion pressure
OR	Operating room
ORx	Near-infrared spectroscopy
OSA	Obstructive sleep apnoea
OWLS	Oral and written language scale
$PaCO_2$	Partial pressure of arterial carbon dioxide
PACU	Post-anaesthesia care unit
PAG	Periaqueductal grey
PaO_2	Partial pressure of arterial oxygen
PB	Parabrachial nucleus
PCA	Posterior cerebral artery
PCA	Patient-controlled analgesia
PCC	Prothrombin complex concentrate
PC-MRI	Phase-contrast MRI
PCOM	Posterior communicating
PD	Parkinson's disease
PEEP	Positive end-expiratory pressure
PET	Positron emission tomography
PFC	Prefrontal cortex
PFO	Patent foramen ovale
PGE2	Prostaglandin E2
PICC	Peripherally inserted central catheter
PIN	Pressure inside the endoscope
PION	Posterior ischemic optic neuropathy
PIV	Pressure-induced vasodilation
PKA	Protein kinase A
PKC	Protein kinase C
PNMT	Phenylethanolamine N-methyl transferase
PnO	Pontine reticular nucleus, oral part
PNS	Parasympathetic nervous system
POCD	Postoperative cognitive dysfunction
PONV	Postoperative nausea and vomiting
PORC	Postoperative residual curarization/Postoperative residual neuromuscular block
POVL	Postoperative vision loss
PPT	Pedunculopontine tegmentum
PPV	Positive prediction value
PRES	Posterior reversible encephalopathy syndrome
PRx	Pressure reactivity index
PSI	Patient state index
$PtiO_2$	Brain tissue oxygenation
PZ	Parafacial zone
RA	Rheumatoid arthritis
RBC	Red blood cell
RCRI	Revised cardiac risk index
RCT	Randomized controlled trial
RE	Response entropy
REM	Rapid eye movement
RLN	Recurrent laryngeal nerve
RN	Raphe nuclei
RNA	Ribonucleic acid
ROI	Region of interest
ROS	Reactive oxygen/oxidative species
Rout	Resistance to CSF outflow
RSI	Rapid sequence induction
rSO_2	Regional cerebral oxygenation
rTPA	Recombinant tissue plasminogen activator
R-type	High-voltage-activated calcium channels
RVM	Rostroventralmedial medulla
RVP	Rapid ventricular pacing
SA	Sinoatrial
SAH	Subarachnoid haemorrhage
SBP	Systolic blood pressure
SBT	Spontaneous breathing test
SCI	Spinal cord injury
SE	State entropy
SE	Status epilepticus
SEP	Sensory evoked potentials
SI	Primary somatosensory cortex
SIADH	Syndrome of inappropriate antidiuretic hormone secretion
sICH	Symptomatic intracerebral haemorrhage
SII	Secondary somatosensory cortex
$SjvO_2$	Supra normal jugular venous oxygen saturation
SMA	Supplemental motor area
SMT	Spinomesencephalic tract
SNACC	Society for Neuroscience in Anesthesiology and Critical Care
SNAPs	Synaptosomal-associated protein
SNARE	Soluble NSF receptor

SNS	Sympathetic nervous system
SPECT	Single-photon emission CT
SRT	Spinoreticular tract
SSEP	Somatosensory evoked potentials
SSRIs	Selective serotonin and norepinephrine reuptake inhibitors
STAIR	Stroke Therapy Academic Industry Roundtable
STN	Subthalamic nucleus
STT	Spinothalamic tract
SVS	Slit ventricle syndrome
SWS	Slow-wave sleep
TBI	Traumatic brain injury
TCA	Tricyclic antidepressant
TCD	Transcranial Doppler sonography
TCS	Transcranial stimulation
TDF	Thermal diffusion flowmetry
TEE	Transoesophageal echocardiogram
THx	High temporal resolution
THx	Therapeutic hypothermia
TIVA	Total intravenous anaesthetic
TMN	Tuberomamillary nucleus
TNF-α	Tumour necrosis factor α
tPA	Tissue plasminogen activator
TRP	Transient receptor potential
TRPM	TRP melastatin receptor
TRPV	TRP vanilloid receptor
TSH	Thyroid stimulating hormone
VAE	Venous air embolism
VEP	Visual Evoked Potentials
VIP	Vasoactive intestinal protein
VLPO	Ventrolateral preoptic nucleus
vPAG	Ventral periaqueductal gray
VPL	Ventroposterolateral
VPS	Ventriculoperitoneal shunt
VR-1	Vanilloid receptor
VRL-1	Vanilloid-like receptor 1
VTA	Ventral tegmental area
WDR	Wide dynamic range
WFNS	World Federation of Neurological Surgeons
ZO	Zona occludens
β-ARK	β-adrenergic receptor