Essentials of Trauma Anesthesia

Second Edition

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Edited by

Albert J. Varon MD MHPE FCCM
Miller Professor and Vice Chair for Education, Department of Anesthesiology, University of Miami Miller School of Medicine, Miami, FL, USA; Chief of Anesthesiology, Ryder Trauma Center at Jackson Memorial Hospital, Miami, FL, USA

Charles E. Smith MD
Professor of Anesthesia, Case Western Reserve University School of Medicine, Cleveland, OH, USA; Attending Anesthesiologist and Director of Anesthesia Research, Department of Anesthesiology, MetroHealth Medical Center, Cleveland, OH, USA

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To my grandchildren, Lisa and Jack, for coming into our lives and giving us so much joy.

AJV

To the victims of blunt and penetrating trauma, and to all those who work long and hard to transport, stabilize, diagnose, treat, and rehabilitate them. To my children Adrienne, Emily, and Rebecca, grandchildren Jane and Lucy, and parents, Thelma and David for their love.

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Contents

Section 3 – Anesthetic Management in Special Trauma Populations

Contributors

John M. Albert
Fellow, Cardiothoracic Anesthesia, Weill Medical College of Cornell University; New York–Presbyterian Hospital, New York, NY

Shawn E. Banks
Associate Professor and Residency Program Director, Department of Anesthesiology, University of Miami Miller School of Medicine; Attending Anesthesiologist, Ryder Trauma Center at Jackson Memorial Hospital, Miami, FL

Michael D. Bassett
Assistant Professor, Case Western Reserve University School of Medicine; Attending Anesthesiologist, MetroHealth Medical Center, Cleveland, OH

Rachel Budithi
Assistant Professor, Department of Anesthesiology, Medical College of Wisconsin; Froedtert Memorial Lutheran Hospital Milwaukee, WI

John J. Como
Professor of Surgery, Case Western Reserve University School of Medicine; Associate Trauma Medical Director, Division of Trauma, Critical Care, Burns, and Acute Care Surgery, MetroHealth Medical Center, Cleveland, OH

Armagan Dagal
Associate Professor, Department of Anesthesiology & Pain Medicine, Adjunct Associate Professor, Department of Neurological Surgery, Medical Co-Director, Enhanced Perioperative Recovery Program, Division Head of Spine and Orthopedic Anesthesia Services, Harborview Medical Center, University of Washington, Seattle, WA

Christian Diez
Associate Professor and Vice Chair for Clinical Affairs, Department of Anesthesiology, University of Miami Miller School of Medicine; Attending Anesthesiologist, Ryder Trauma Center at Jackson Memorial Hospital, Miami, FL

Roman Dudaryk
Assistant Professor, Department of Anesthesiology, University of Miami Miller School of Medicine; Attending Anesthesiologist and Intensivist, Ryder Trauma Center at Jackson Memorial Hospital, Miami, FL

Monique Espinosa
Assistant Professor of Anesthesiology, University of Miami Miller School of Medicine; Attending Anesthesiologist, Ryder Trauma Center at Jackson Memorial Hospital, Miami, FL

Ashraf Fayad
Associate Professor, Department of Anesthesiology and Pain Medicine and Director, Perioperative Echocardiography for Non-cardiac Surgery Program, University of Ottawa, Ottawa, Ontario, Canada

L. Yvette Fouche
Assistant Professor of Anesthesiology, University of Maryland School of Medicine; Division Head, Trauma Anesthesiology, R Adams Cowley Shock Trauma Center, Baltimore, MD

Michael T. Ganter
Professor of Anesthesiology and Critical Care Medicine and Chair, Institute of Anesthesiology – Emergency Medical Service, Perioperative Medicine, Pain Therapy, Kantonsspital Winterthur, Winterthur, Switzerland

Suneeta Gollapudy
Associate Professor, Department of Anesthesiology, Medical College of Wisconsin; Director, Division of Neuroanesthesia and Director, Division of Post Anesthesia Care Unit, Froedtert Memorial Lutheran Hospital, Milwaukee, WI

Thomas E. Grissom
Associate Professor of Anesthesiology, University of Maryland School of Medicine; Attending Anesthesiologist, R Adams Cowley Shock Trauma Center, Baltimore, MD

Craig S. Jabaley
Assistant Professor of Anesthesiology, Emory University School of Medicine; Department of Anesthesiology, Division of Critical Care Medicine, Emory University Hospital, Atlanta, GA

Olga Kaslow
Associate Professor, Department of Anesthesiology, Medical College of Wisconsin; Director, Trauma Anesthesiology Service, Froedtert Memorial Lutheran Hospital, Milwaukee, WI

Michelle E. Kim
Assistant Professor of Anesthesiology, University of Maryland School of Medicine; Attending Anesthesiologist, R Adams Cowley Shock Trauma Center, Baltimore, MD

Jack Louro
Assistant Professor of Anesthesiology, University of Miami Miller School of Medicine; Attending Anesthesiologist, Ryder Trauma Center at Jackson Memorial Hospital, Miami, FL

Jessica A. Lovich-Sapola
Associate Professor, Case Western Reserve University School of Medicine; Attending Anesthesiologist, Department of Anesthesiology, MetroHealth Medical Center, Cleveland, OH

K. H. Kevin Luk
Assistant Professor, Divisions of Neuroanesthesiology & Perioperative Neurosciences, and Critical Care Medicine, Department of Anesthesiology & Pain Medicine, Harborview Medical Center, University of Washington, Seattle, WA

Richard McNeer
Associate Professor of Anesthesiology and Biomedical Engineering, University of Miami Miller School of Medicine; Attending Anesthesiologist, Ryder Trauma Center at Jackson Memorial Hospital, Miami, FL

Daria M. Moaveni
Assistant Professor of Anesthesiology, University of Miami Miller School of Medicine; Director, Obstetric Anesthesiology Fellowship Program, Jackson Memorial Hospital, Miami, FL

Hernando Olivar
Clinical Associate Professor, Department of Anesthesiology & Pain Medicine, Harborview Medical Center/University of Washington, Seattle, WA

Marie-Jo Plamondon
Assistant Professor, Department of Anesthesiology and Pain Medicine;

Director Trauma and Vascular Anesthesiology, University of Ottawa, Ottawa, Ontario, Canada

Ramesh Ramaiah
Assistant Professor, Department of Anesthesiology & Pain Medicine, Harborview Medical Center/University of Washington, Seattle, WA

Sripad Rao
Assistant Professor of Anesthesiology, University of Miami Miller School of Medicine; Attending Anesthesiologist, Ryder Trauma Center at Jackson Memorial Hospital, Miami, FL

Sam R. Sharar
Professor, Department of Anesthesiology & Pain Medicine, Harborview Medical Center/University of Washington, Seattle, WA

Robert Sikorski
Assistant Professor, Department of Anesthesiology and Critical Care Medicine, The Johns Hopkins School of Medicine; Director of Trauma Anesthesiology, The Johns Hopkins Hospital, Baltimore, Maryland

Charles E. Smith
Professor, Case Western Reserve University School of Medicine; Attending Anesthesiologist and Director of Anesthesia Research, Department of Anesthesiology, MetroHealth Medical Center, Cleveland, OH

Marc P. Steurer
Associate Professor of Anesthesiology, Department of Anesthesia and Perioperative Care, University of California San Francisco; Director of Trauma Anesthesiology, San Francisco General Hospital, San Francisco, CA

Albert J. Varon
Miller Professor and Vice Chair for Education, Department of Anesthesiology, University of Miami Miller School of Medicine; Chief of Anesthesiology, Ryder Trauma Center at Jackson Memorial Hospital, Miami, FL

Preface

Traumatic injuries kill more than five million people annually. Millions more suffer the physical and psychologic consequences of injury, which have an enormous impact on patients, their families, and society. In the United States, trauma is the third leading cause of death in people of all ages, and the leading cause of death in individuals 46 years and younger. Trauma is also the single largest cause for years of life lost.

Although few anesthesiologists care exclusively for trauma patients, most will treat trauma patients at one time or another in their clinical practice. These encounters can occur at the end of the day or in the middle of the night and challenge clinicians to expeditiously manage multisystem derangements despite incomplete patient information.

Active participation of anesthesiologists in the care of severely injured patients provides the best opportunity for improved outcome. We believe participation should not only include involvement in anesthetic management, but also the initial evaluation, resuscitation, and perioperative care of these patients. Unfortunately, current training does not expose trainees to the entire spectrum of trauma care. Although there are a few textbooks that deal with trauma anesthesia, these books are quite extensive, serve mostly as reference books, and are not meant to be read cover-to-cover.

Our intention in creating the first edition of *Essentials of Trauma Anesthesia* was to provide anesthesiology trainees and practitioners with a concise review of the essential elements in the care of the severely injured patient and to emphasize the role of anesthesiologists in all aspects of trauma care: from time of injury until the patient leaves the critical care areas of the facility. This second edition of *Essentials of Trauma Anesthesia* continues to pursue that goal while identifying many recent advances in trauma care including paradigm shifts in the management of bleeding and coagulopathy, new neuromuscular blockade and anticoagulant reversal drugs, and updated clinical practice guidelines.

As in the first edition, we present, in three parts, the essential elements of trauma anesthesia care. The first section deals with the core principles of trauma anesthesia including epidemiology, mechanisms of injury and prehospital care, initial evaluation and management, airway management, shock, resuscitation and fluid therapy, vascular cannulation, blood component therapy, general and regional anesthesia for trauma, monitoring, echocardiography, and postoperative care of the trauma patient. A new chapter dealing with coagulation monitoring of the bleeding trauma patient has been added to the first section. The second section reviews the anesthetic considerations for traumatic injuries by anatomical area, and includes chapters on traumatic brain injury, spinal cord injury, ocular and maxillofacial trauma, and chest, abdominal and musculoskeletal trauma. The last section discusses anesthetic management of specific trauma populations including burn, pediatric, geriatric, and pregnant patients. Although we have maintained the structure, style, and format of the previous edition, all chapters have undergone extensive revisions to ensure content is current.

The editors of this book are academic trauma anesthesiologists, each with 30 years of experience caring for trauma patients. We were fortunate to recruit expert contributors who are actively engaged in clinical care at leading United States and Canadian trauma centers. The chapter contributors were given the task of creating an easily readable and clinically

relevant review of current trauma management. As editors, we have worked closely with the contributors to attain a consistent style, cover the subject matter in a coherent and logical manner, prevent unnecessary duplication, and provide cross-referencing between chapters. The liberal use of bullet-points and tables facilitated the creation of a portable text that is conducive to the rapid appreciation of the essential elements in trauma care.

We hope the second edition of this textbook will serve as a useful, practical guide to anesthesiology trainees and practitioners who currently manage or will manage trauma patients. We hope that all anesthesia providers, from the novice to advanced practitioners, will benefit from this book and, more importantly, that this will improve their care of trauma patients.

The editors thank the members of the American Society of Anesthesiologists' Committee of Trauma and Emergency Preparedness (COTEP) and our trauma anesthesiology colleagues at MetroHealth Medical Center and the Ryder Trauma Center for helping us select the topics for this book. The editors are also grateful to the chapter authors for contributing to this effort despite their already heavy clinical workload. Most of the contributors of this book are members of the Trauma Anesthesiology Society (TAS), which has enthusiastically supported and endorsed this project. Finally, we wish to acknowledge the support of Sarah Payne, Jade Scard, and all the staff at Cambridge University Press in the preparation and timely publication of *Essentials of Trauma Anesthesia*.

Albert J. Varon, MD, MHPE, FCCM
Charles E. Smith, MD

Abbreviations

AANS	American Association of Neurological Surgeons
ABA	American Burn Association
ABG	Arterial blood gas
ABSI	Abbreviated burn severity index
ACE	Angiotensin-converting enzyme
ACES	Abdominal cardiac evaluation with sonography in shock
ACL	Anterior cruciate ligament
ACLS	Advanced cardiac life support
ACS	American College of Surgeons
ACT	Activated clotting time
ADH	Antidiuretic hormone
AEC	Airway exchange catheter
AI	Aortic insufficiency
AIS	American Spinal Injury Association impairment scale
AKI	Acute kidney injury
aPTT	Activated partial thromboplastin time
ARBs	Angiotensin-receptor blockers
ARDS	Acute respiratory distress syndrome
ASA	American Society of Anesthesiologists
ASD	Atrial septal defect
ASE	American Society of Echocardiography
ASIA	American Spinal Injury Association
ASRA	American Society of Regional Anesthesia and Pain Medicine
ATC	Acute traumatic coagulopathy
ATLS	Advanced trauma life support
$AVDO_2$	Arteriovenous oxygen content difference
AVN	Avascular necrosis
AX	Axillary
BAI	Blunt aortic injury
BIS	Bispectral index
BP	Blood pressure
bpm	Beats per minute
BSA	Body surface area
$BtpO_2$	Brain tissue O_2 partial pressure
BVM	Bag-valve-mask
CBC	Complete blood count
CBF	Cerebral blood flow
CDC	Centers for Disease Control and Prevention
CFD	Color flow Doppler
CMAP	Compound muscle action potential
$CMRO_2$	Cerebral metabolic rate of oxygen
CNS	Central nervous system
CO	Cardiac output
COHb	Carboxyhemoglobin
COPD	Chronic obstructive pulmonary disease
COT	Committee on Trauma
CP	Cricoid pressure
CPB	Cardiopulmonary bypass
CPDA	Citrate-phosphate-dextrose with adenine
CPP	Cerebral perfusion pressure
CPR	Cardiopulmonary resuscitation

CR	Clot rate
CRASH-2	Clinical randomization of an antifibrinolytic in significant hemorrhage 2 study
CRM	Crisis resource management
CSF	Cerebrospinal fluid
CSF_P	Cerebrospinal fluid pressure
C-spine	Cervical spine
CT	Computed tomography
CTA	Computed tomography angiography
CVC	Central venous catheter
CVP	Central venous pressure
CXR	Chest X-ray
DC	Decompressive craniectomy
DIC	Disseminated intravascular coagulation
DLT	Double-lumen tube
DOACs	Direct oral anticoagulants
DPL	Diagnostic peritoneal lavage
DVT	Deep venous thrombosis
EACA	Epsilon-aminocaproic acid
ECG	Electrocardiogram/electrocardiography
ED	Emergency department
eFAST	Extended FAST
EMG	Electromyography
EMS	Emergency medical services
EMT-A	Emergency medical technician – ambulance
EPCR	Endothelial protein C receptor
$EtCO_2$	End-tidal carbon dioxide
Ex fix	External fixation
EXT	External
FAST	Focused assessment with sonography for trauma
FB	Flexible bronchoscopy/bronchoscope/bronchoscopic
FC	Fibrinogen concentrate
FDA	Food and Drug Administration
FES	Fat embolism syndrome
FFP	Fresh frozen plasma
FOCUS	Focused cardiac ultrasound
FS	Fractional shortening
GABA	Gamma-aminobutyric acid
GCS	Glasgow Coma Scale
GSW	Gunshot wound
Hb	Hemoglobin
HTS	Hypertonic saline
ICH	Intracranial hypertension
ICP	Intracranial pressure
ICU	Intensive care unit
IJ	Internal jugular vein
INR	International normalized ratio
INT	Internal
IO	Intraosseous
IOP	Intraocular pressure
IV	Intravenous
IVC	Inferior vena cava
LA	Left atrium
LAX	Long axis
LMA	Laryngeal mask airway
LTA	Laryngeal tube airway
LV	Left ventricular/left ventricle

MA	Maximum amplitude
MAC	Minimum alveolar concentration
MAP	Mean arterial pressure
MATTERs	Military application of tranexamic acid in trauma emergency resuscitation study
MCF	Maximum clot firmness
MEP	Motor evoked potential
MILS	Manual in-line stabilization
MR	Mitral regurgitation
MRI	Magnetic resonance imaging
MTP	Massive transfusion protocol
MVC	Motor vehicle collision
N_2O	Nitrous oxide
nAChRs	Nicotinic acetylcholine receptors
NBR	National Burn Repository
NG	Nasogastric tube
NHTSA	National Highway Traffic Safety Administration
NIH	National Institutes of Health
NMBD	Neuromuscular blocking drug
NMDA	N-methyl-D-aspartate
NSAIDs	Non-steroidal anti-inflammatory drugs
OCR	Oculocardiac reflex
OLV	One-lung ventilation
OR	Operating room
ORIF	Open reduction internal fixation
PA	Pulmonary artery
$PaCO_2$	Arterial carbon dioxide tension
PACU	Postanesthesia care unit
PaO_2	Arterial oxygen tension
PAOP	Pulmonary artery occlusion pressure
PAR1	Protease-activated receptor 1
PBW	Predicted body weight
PCA	Patient-controlled analgesia
PCC	Prothrombin complex concentrate
PE	Pulmonary emboli
PEEP	Positive end-expiratory pressure
Perc	Percutaneous
PFO	Patent foramen ovale
POC	Point-of-care
Pplat	Plateau pressure
ppm	Parts per million
PPV	Pulse pressure variation
PRBCs	Packed red blood cells
PROPPR	Pragmatic, randomized, optimal platelets, and plasma ratios
PT	Prothrombin time
P_vCO_2	Mixed venous carbon dioxide tension
P_vO_2	Mixed venous oxygen tension
RA	Right atrium
RBC	Red blood cell
RCTs	Randomized controlled trials
REBOA	Resuscitative endovascular balloon occlusion of the aorta
rFVIIa	Recombinant Factor VIIa
Rh(D)	Rhesus antigen D
ROTEM	Rotational thromboelastometry
RR	Respiratory rate
RSI	Rapid sequence induction
RUSH	Rapid ultrasound for shock and hypotension

RV	Right ventricular/right ventricle
RWMA	Regional wall motion abnormality
SAX	Short axis
SBP	Systolic blood pressure
SCA	Society of Cardiovascular Anesthesiologists
SCCP	Spinal cord perfusion pressure
SCI	Spinal cord injury
SCIWORA	Spinal cord injury without radiographic abnormality
SCM	Sternocleidomastoid
SCV	Subclavian vein
$S_{cv}O_2$	Central venous oxygen saturation
SGA	Supraglottic airway device
$S_{jv}O_2$	Jugular venous oxygen saturation
SpO_2	Oxygen saturation measured by pulse oximeter
SPV	Systolic pressure variation
SSEP	Somatosensory evoked potentials
START	Simple triage and rapid assessment
STE	Speckle-tracking echocardiography
SV	Stroke volume
S_vO_2	Mixed venous oxygen saturation
SVR	Systemic vascular resistance
SVV	Stroke volume variation
TAFI	Thrombin-activated fibrinolysis inhibitor
TBI	Traumatic brain injury
TBSA	Total body surface area
TCPA	Traumatic cardiopulmonary arrest
TEE	Transesophageal echocardiography
TEG	Thrombelastography
TEVAR	Thoracic endovascular aortic repair
TF	Tissue factor
TIG	Tetanus immune globulin
TIVA	Total intravenous anesthesia
TOF	Train-of-four
TT	Tracheal tube
TTE	Transthoracic echocardiography
TXA	Tranexamic acid
VHA	Viscoelastic hemostatic assay
VL	Videolaryngoscopy/videolaryngoscope
VWF	von Willebrand factor