Essentials of Trauma Anesthesia
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Edited by

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To my wife, Dina, for loving and putting up with me; and to my sons, Michael and Victor, who give me infinite 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 wife Bobby, children Adrienne, Emily, and Rebecca, and parents Thelma and David for their love and support.

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Preface

Trauma is the leading cause of death among children, adolescents, and young adults in the United States; it is the second most common single cause of death worldwide.

Those who survive trauma suffer the physical and psychological consequences of injury, which have an enormous impact on patients, their families, and society.

Although few anesthesiologists care exclusively for trauma patients, most will care for trauma patients at one time or another in their clinical practice. These encounters usually occur at the end of the day or in the middle of the night and challenge clinicians to expeditiously manage multi-system 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 this text is 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. Although a textbook of this size cannot give exhaustive coverage of all issues, we attempt to provide a review of the most important aspects of trauma care from the anesthesiologist’s perspective. We also try to identify new trends in surgery and anesthesiology practices that impact on the management of trauma patients.

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, initial evaluation and management, airway management, shock resuscitation and fluid therapy, vascular cannulation, blood component therapy, general and regional anesthesia, monitoring, echocardiography, and postoperative care. A review of chemical and radiological exposure in trauma is also presented. The second section is designed to review anesthetic considerations for traumatic injuries by anatomical area. The third and final section discusses anesthetic management in special trauma populations including burn, pediatric, geriatric, and pregnant patients.

The editors of this book are academic anesthesiologists each with 25 years of experience caring for trauma patients. We were fortunate to recruit expert contributors who are actively engaged in clinical care at leading US 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 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 the practitioner, will benefit from this book and more importantly that this will improve their care of trauma patients.

The editors wish to 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 and Eric Scot Shaw who helped edit some of the chapters. Finally, we wish to acknowledge the support of Deborah Russell, Nisha Doshi, Caroline Mowatt, and all the staff at Cambridge University Press in the preparation and timely publication of Essentials of Trauma Anesthesia.

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Abbreviations

AANS = American Association of Neurological Surgeons
ABG = Arterial blood gas
ACES = Abdominal cardiac evaluation with sonography in shock
ACLS = Advanced cardiac life support
ACS = American College of Surgeons
AEC = Airway exchange catheter
AI = Aortic insufficiency
AKI = Acute kidney injury
ALI = Acute lung injury
ARDS = Acute respiratory distress syndrome
ARF = Acute renal failure
ASA = American Society of Anesthesiologists
ASD = Atrial septal defect
ASIA = American Spinal Injury Association
ASRA = American Society of Regional Anesthesia and Pain Management
ATLS = Advanced trauma life support
BBB = Blood brain barrier
BIS = Bispectral index
BP = Blood pressure
BSA = Body surface area
BUN = Blood urea nitrogen
BVM = Bag-valve-mask
CAD = Coronary artery disease
CBC = Complete blood count
CFB = Cerebral blood flow
CDC = Centers for Disease Control
CDF = Color flow Doppler
CHEMM = Chemical Hazards Emergency Medical Management
CMAP = Compound muscle action potential
CMRO₂ = Cerebral metabolic rate of oxygen
CNS = Central nervous system
CO = Carbon monoxide
CO₂ = Carbon dioxide
COPD = Chronic obstructive pulmonary disease
COT = Committee on Trauma
CP = Cricoid pressure
CPAP = Continuous positive airway pressure
CPB = Cardiopulmonary bypass
CPP = Cerebral perfusion pressure
CPR = Cardiopulmonary resuscitation
CRM = Crisis resource management
C-section = Caesarean section
CSF = Cerebral spinal fluid
CSFP = Cerebral spinal fluid pressure
C-spine = Cervical spinal
CT = Computed tomography
CTA = Computed tomography angiography
CVP = Central venous pressure
CXR = Chest X-ray
DIC = Disseminated intravascular coagulation
DLT = Double lumen tube
DNA = Deoxyribonucleic acid
DPL = Diagnostic peritoneal lavage
DVT = Deep venous thrombosis
ECG = Electrocardiogram
ED = Emergency department
eFAST = Extended focused assessment with sonography for trauma
EMG = Electromyography
EMS = Emergency medical services
ER = Emergency room
ESKD = End-stage kidney disease
EtCO₂ = End-tidal carbon dioxide
ETT = Endotracheal tube
Ex fix = External fixation
FAST = Focused assessment with sonography for trauma
FEV₁ = Forced expiratory volume in one second
FFP = Fresh frozen plasma
FiO₂ = Fraction of inspired oxygen
FOB = Fiberoptic bronchoscope
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>FRC</td>
<td>Functional residual capacity</td>
</tr>
<tr>
<td>GABA</td>
<td>Gamma-aminobutyric acid</td>
</tr>
<tr>
<td>GCS</td>
<td>Glasgow Coma Scale</td>
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<tr>
<td>GFR</td>
<td>Glomerular filtration rate</td>
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<tr>
<td>GSW</td>
<td>Gunshot wound</td>
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<tr>
<td>Gy</td>
<td>Grays</td>
</tr>
<tr>
<td>H₂S</td>
<td>Hydrogen sulfide</td>
</tr>
<tr>
<td>HCN</td>
<td>Hydrogen cyanide</td>
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<tr>
<td>HTS</td>
<td>Hypertonic saline</td>
</tr>
<tr>
<td>ICH</td>
<td>Intracranial hypertension</td>
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<tr>
<td>ICP</td>
<td>Intracranial pressure</td>
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<tr>
<td>ICU</td>
<td>Intensive care unit</td>
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<tr>
<td>IDSA</td>
<td>Infectious Disease Society of America</td>
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<tr>
<td>INR</td>
<td>International normalized ratio</td>
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<tr>
<td>IO</td>
<td>Intraosseous</td>
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<td>IOP</td>
<td>Intraocular pressure</td>
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<tr>
<td>IR</td>
<td>Interventional radiology</td>
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<tr>
<td>ISS</td>
<td>Injury severity score</td>
</tr>
<tr>
<td>IV</td>
<td>Intravenous</td>
</tr>
<tr>
<td>IVC</td>
<td>Inferior vena cava</td>
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<tr>
<td>LA</td>
<td>Left atrium</td>
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<tr>
<td>LAX</td>
<td>Long axis</td>
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<tr>
<td>LMA</td>
<td>Laryngeal mask airway</td>
</tr>
<tr>
<td>LR</td>
<td>Lactated Ringer’s solution</td>
</tr>
<tr>
<td>LTA</td>
<td>Laryngeal tube airway</td>
</tr>
<tr>
<td>LV</td>
<td>Left ventricle</td>
</tr>
<tr>
<td>MAC</td>
<td>Minimum alveolar concentration</td>
</tr>
<tr>
<td>MAP</td>
<td>Mean arterial pressure</td>
</tr>
<tr>
<td>MEP</td>
<td>Motor evoked potential</td>
</tr>
<tr>
<td>MILI</td>
<td>Manual in-line immobilization</td>
</tr>
<tr>
<td>MR</td>
<td>Mitral regurgitation</td>
</tr>
<tr>
<td>MRI</td>
<td>Magnetic resonance imaging</td>
</tr>
<tr>
<td>MV</td>
<td>Motor vehicle</td>
</tr>
<tr>
<td>N₂O</td>
<td>Nitrous oxide</td>
</tr>
<tr>
<td>NASCIS</td>
<td>National Acute Spinal Cord Injury Study</td>
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<tr>
<td>NG</td>
<td>Nasogastric</td>
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<tr>
<td>NHTSA</td>
<td>National Highway Traffic Safety Administration</td>
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<tr>
<td>NIH</td>
<td>National Institutes of Health</td>
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<tr>
<td>NIOSH</td>
<td>National Institute for Occupational Safety and Health</td>
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<tr>
<td>NMBD</td>
<td>Neuromuscular blocking drug</td>
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<tr>
<td>NMDA</td>
<td>N-methyl-D-aspartate</td>
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<tr>
<td>NS</td>
<td>Normal saline</td>
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<tr>
<td>NSAID</td>
<td>Non-steroidal anti-inflammatory drug</td>
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<tr>
<td>OCR</td>
<td>Oculo-cardiac reflex</td>
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<tr>
<td>OLV</td>
<td>One-lung ventilation</td>
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<tr>
<td>OR</td>
<td>Operating room</td>
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<tr>
<td>ORIF</td>
<td>Open reduction internal fixation</td>
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<tr>
<td>PA</td>
<td>Pulmonary artery</td>
</tr>
<tr>
<td>PaCO₂</td>
<td>Arterial carbon dioxide tension</td>
</tr>
<tr>
<td>PACU</td>
<td>Postanesthesia care unit</td>
</tr>
<tr>
<td>PaO₂</td>
<td>Arterial oxygen tension</td>
</tr>
<tr>
<td>PAOP</td>
<td>Pulmonary artery occlusion pressure</td>
</tr>
<tr>
<td>PAP</td>
<td>Pulmonary artery pressure</td>
</tr>
<tr>
<td>PAPR</td>
<td>Powered air-purifying respirators</td>
</tr>
<tr>
<td>PCA</td>
<td>Patient-controlled analgesia</td>
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<tr>
<td>PCC</td>
<td>Prothrombin complex concentrates</td>
</tr>
<tr>
<td>PE</td>
<td>Pulmonary emboli</td>
</tr>
<tr>
<td>PEEP</td>
<td>Positive end-expiratory pressure</td>
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<tr>
<td>Perc fix</td>
<td>Percutaneous fixation</td>
</tr>
<tr>
<td>PFO</td>
<td>Patent foramen ovale</td>
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<tr>
<td>PPE</td>
<td>Personal protective equipment</td>
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<tr>
<td>PPV</td>
<td>Pulse pressure variation</td>
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<tr>
<td>PRBC</td>
<td>Packed red blood cell</td>
</tr>
<tr>
<td>PT</td>
<td>Prothrombin time</td>
</tr>
<tr>
<td>PaCO₂</td>
<td>Mixed venous carbon dioxide tension</td>
</tr>
<tr>
<td>PaO₂</td>
<td>Mixed venous oxygen tension</td>
</tr>
<tr>
<td>RA</td>
<td>Right atrium</td>
</tr>
<tr>
<td>rad</td>
<td>Radiation absorbed dose</td>
</tr>
<tr>
<td>RBCs</td>
<td>Red blood cells</td>
</tr>
<tr>
<td>rem</td>
<td>Roentgen-equivalent man</td>
</tr>
<tr>
<td>rFVIIa</td>
<td>Recombinant factor VIIa</td>
</tr>
<tr>
<td>RIFLE</td>
<td>Risk, Injury, Failure, Loss, and End-stage kidney disease</td>
</tr>
<tr>
<td>RR</td>
<td>Respiratory rate</td>
</tr>
<tr>
<td>RSI</td>
<td>Rapid sequence induction</td>
</tr>
<tr>
<td>RUL</td>
<td>Right upper lobe</td>
</tr>
<tr>
<td>RUSH</td>
<td>Rapid ultrasound for shock and hypotension</td>
</tr>
<tr>
<td>RV</td>
<td>Right ventricle</td>
</tr>
<tr>
<td>RWMA</td>
<td>Regional wall motion abnormality</td>
</tr>
<tr>
<td>SAX</td>
<td>Short axis</td>
</tr>
<tr>
<td>SBP</td>
<td>Systolic blood pressure</td>
</tr>
<tr>
<td>SCA</td>
<td>Society of Cardiovascular Anesthesiologists</td>
</tr>
</tbody>
</table>
SCCP = Spinal cord perfusion pressure  
SCI = Spinal cord injury  
SCIWORA = Spinal cord injury without radiographic abnormality  
SCM = Sternocleidomastoid muscle  
$S_{v}O_2$ = Central venous oxygen saturation  
SIRS = Systemic inflammatory response syndrome  
SjvO$_2$ = 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  
STASCIS = Surgical Treatment for Acute Spinal Cord Injury Study  
STE = Speckle-tracking echocardiography  
$S_v$ = Sievert  
$S_{v}O_2$ = Mixed venous oxygen saturation  
SVR = Systemic vascular resistance  
SVV = Stroke volume variation  
TBI = Traumatic brain injury  
TBSA = Total body surface area  
TEE = Transesophageal echocardiography  
TIG = Tetanus immune globulin  
TIVA = Total intravenous anesthesia  
TOXALS = Advanced life support for acute toxic injury  
TTE = Transthoracic echocardiography  
US = Ultrasound  
VAP = Ventilator-associated pneumonia  
VATS = Video-assisted thoracic surgery  
VFib = Ventricular fibrillation  
WISER = Wireless information system for emergency responders  
YPLL = Years of potential life lost