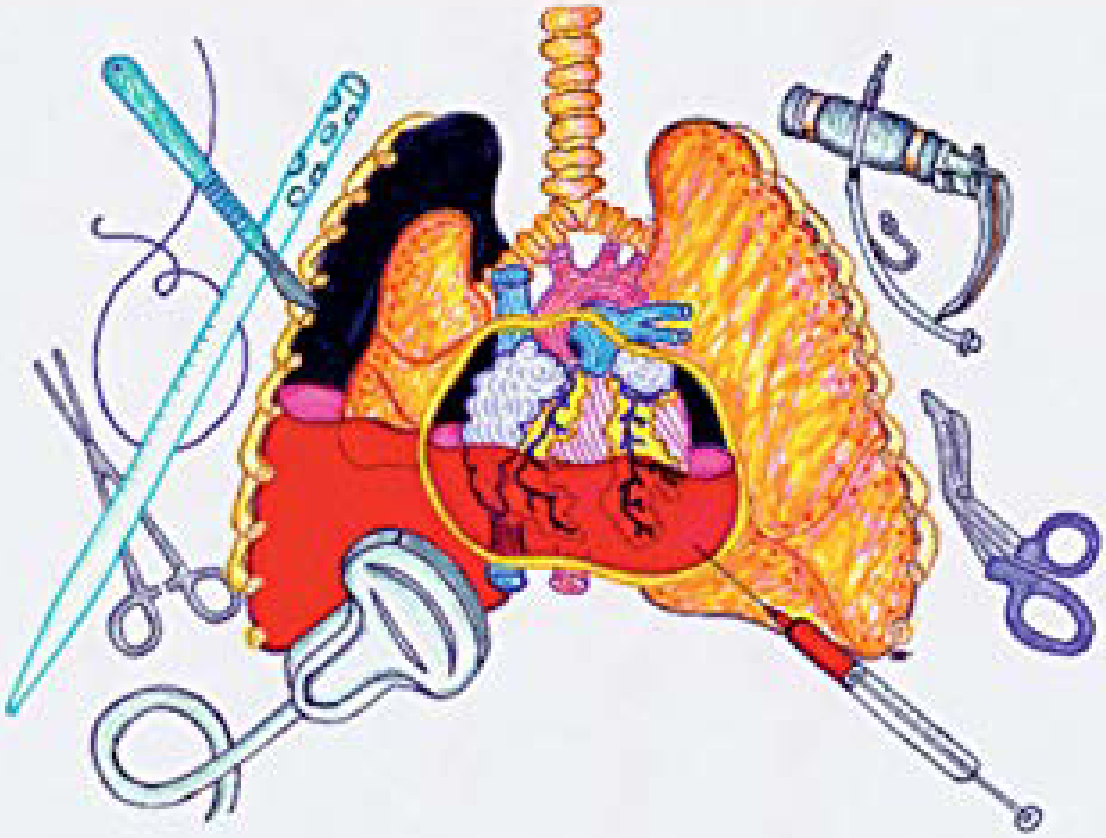
THE EMERGENCY MEDICINE TRAUMA HANDBOOK

EDITED BY ALEX KOYFMAN & BRIT LONG



CAMBRIDGE Medicine

The Emergency Medicine Trauma Handbook

The Emergency Medicine Trauma Handbook

Edited by
Alex Koyfman
UT Southwestern Department of Emergency Medicine

Brit Long
SAUSHEC Department of Emergency Medicine

CAMBRIDGE
UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom

One Liberty Plaza, 20th Floor, New York, NY 10006, USA

477 Williamstown Road, Port Melbourne, VIC 3207, Australia

314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre, New Delhi – 110025, India

79 Anson Road, #06–04/06, Singapore 079906

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning, and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781108450287
DOI: 10.1017/9781108647397

First published 2020

Printed in Singapore by Markono Print Media Pte Ltd

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

Library of Congress Cataloging-in-Publication Data
Names: Koyfman, Alex, editor. | Long, Brit, 1986- editor.
Title: The emergency medicine trauma handbook / edited by Alex Koyfman, Brit Long.
Description: Cambridge, United Kingdom ; New York, NY : Cambridge University Press, 2020. | Includes bibliographical references and index.
Identifiers: LCCN 2019004817 | ISBN 9781108450287 (pbk. : alk. paper)
Subjects: | MESH: Emergency Treatment–methods | Wounds and Injuries–therapy | Emergencies
Classification: LCC RD93 | NLM WB 105 | DDC 617.1–dc23
LC record available at https://lccn.loc.gov/2019004817

ISBN 978-1-108-45028-7 Paperback

Contents

Contributors

Michael K. Abraham, MD, MS
Department of Emergency Medicine, University of Maryland School of Medicine, Baltimore, MD

Michael D. April, MD, DPhil, MSc
SAUSHEC Department of Emergency Medicine, Fort Sam Houston, TX

Ashley Brady, MD
Department of Emergency Medicine at the University of Texas Southwestern Medical Center, Dallas, TX

Christopher B. Colwell, MD
Zuckerberg San Francisco General Hospital and Trauma Center, and Department of Emergency Medicine, UCSF School of Medicine, San Francisco, CA

R. Erik Connor, MD
SAUSHEC Department of Emergency Medicine, Fort Sam Houston, TX

Katja Goldflam, MD
Department of Emergency Medicine, Yale School of Medicine, New Haven, CT

Michael Gottlieb, MD, RDMS
Department of Emergency Medicine, Rush University Medical Center, Chicago, IL

Matthew Greer, MD
Department of Anesthesia, Washington University in Saint Louis, School of Medicine, Saint Louis, MO

Jeffery Hill, MD, Med
Department of Emergency Medicine, University of Cincinnati, Cincinnati, OH

Timothy Horeczko, MD
Department of Emergency Medicine and Pediatric Medicine, Harbor-UCLA Medical Center, Torrance, CA

Mike Jackson, DO, LCDR
Department of Emergency Medicine, Naval Medical Center Portsmouth, Portsmouth, VA

Colin Kaide, MD
Department of Emergency Medicine, Wexner Medical Center at the Ohio State University, Columbus, OH

Norah Kairys, MD
Emergency Medicine, Temple University Hospital, Philadelphia, PA

Kristen Kann, MD
SAUSHEC Department of Emergency Medicine, Fort Sam Houston, TX

Dennis Kim, MD, FACS
Division of Surgery/Critical Care, Harbor-UCLA Medical Center, Torrance, CA

Andrew King, MD
Wexner Medical Center at the Ohio State University, Columbus, OH

Ryan LaFollette, MD
Department of Emergency Medicine, University of Cincinnati, Cincinnati, OH

Matthew R. Levine, MD
Department of Emergency Medicine, Northwestern Memorial Hospital, Chicago, IL

E. Liang Liu, MD
Department of Emergency Medicine at the University of Texas Southwestern Medical Center, Dallas, TX

Brit Long, MD
SAUSHEC Department of Emergency Medicine, Fort Sam Houston, TX

Brandon Morshedi, MD, DPT
Department of Emergency Medicine at the University of Texas Southwestern Medical Center, Dallas, TX

R. Grant Morshedi, MD
Little Rock Eye Clinic, Little Rock, AR

Jason F. Naylor, DSc, PA-C
US Army Institute of Surgical Research, Department of Emergency Medicine, JBSA Fort Sam Houston, TX

Ryan O'Halloran, MD, MS
Emergency Medicine Residency, Icahn School of Medicine at Mount Sinai, New York, NY

John D. Pemberton, DO, MBA
Oculoplastics, Harvey and Bernice Jones Eye Institute, University of Arkansas College of Medicine, Little Rock, AR

Zachary Repanshek, MD
Emergency Medicine, Lewis Katz School of Medicine at Temple University, Philadelphia, PA

Steven G. Schauer, DO, MS
US Army Institute of Surgical Research, JBSA Fort Sam Houston, TX

Kaushal Shah, MD
Education Emergency Department, Mount Sinai Hospital, Icahn School of Medicine, New York, NY

Manpreet Singh, MD
Department of Emergency Medicine, Harbor-UCLA Medical Center, Torrance, CA

Richard Slama, MD, LT
Department of Emergency Medicine, Naval Medical Center Portsmouth, Portsmouth, VA

Terren Trott, MD
Emergency Medicine, Critical Care Medicine Cooper Health/Rowan School of Medicine, University of Kentucky, Lexington, KY

Brian T. Wessman, MD, FACEP, FCCM
Washington University in Saint Louis, School of Medicine, Saint Louis, MO

Preface

Student, you do not study to pass the test. You study to prepare for the day when you are the only thing between a patient and the grave.
– *Mark Reid*

Next to creating a life, the finest thing a man can do is save one.
– *Abraham Lincoln*

The best way to find yourself is to lose yourself in the service of others.
– *Mahatma Gandhi*

One of the major causes of death worldwide is trauma. Many of these patients are managed in the emergency department (ED). Emergency clinicians are masters of evaluating and managing life-threatening diseases in the chaotic setting of the ED. From the first contact of the injured patient, emergency clinicians play a vital role in their assessment and treatment.

Though trauma is often considered "the bread and butter" of emergency medicine, several conditions associated with trauma can be challenging, as patients can be at death's door upon initial presentation. If patients do not receive timely, quality care, they may die. Knowledge of these conditions is imperative to ensuring we optimally care for trauma patients, whether they arrive by emergency medical services with "lights and sirens," they are dropped off at the door, or they simply walk in to the ED.

This text, *The Emergency Medicine Trauma Handbook*, presents a focused breakdown of topics in trauma, with the goal to provide emergency physicians, residents, medical students, nurses, and other healthcare workers vital information for the evaluation and management of the patient with trauma, whether minor or life-threatening.

We thank all of the authors involved in the construction of this book, and we greatly appreciate the assistance of the staff at Cambridge University Press. We also extend our gratitude to our families for their amazing support and patience during the writing and editing phases. We hope this book improves your clinical knowledge and practice, and thank you for reading!

Disclaimer

This book and the content within does not reflect the views or opinions of the US government, Department of Defense, Brooke Army Medical Center, US Army, US Air Force, or SAUSHEC EM Residency Program.

Chapter 1

General Approach to Traumatic Injuries

Ryan O'Halloran and Kaushal Shah

Introduction

Trauma is the fourth leading cause of death overall in the United States and the number one cause of death for ages 1 to 44 – second only to heart disease and cancer in those older than 45 (CDC).[1] As the disease burden from infectious diseases declines and secondary prevention of chronic conditions improves, the relative importance of the practice of trauma care becomes even more apparent. Though safety engineering has improved across many industries (one need only consider examples such as crosswalk and bike lane planning, football helmet technology, and motor vehicle computerized improvements), trauma remains a significant threat to life and limb in emergency medicine.

The Trauma Team

The American College of Surgeons, the governing body for credentialing trauma centers, has provided guidelines for optimal resources necessary for a coordinated response to a critically injured trauma patient. Box 1.1 demonstrates the players suggested for an optimal response.

While response teams may vary, several principles are key to the functioning of a good, interdisciplinary team. These include clearly establishing roles for members of the team, following policy and protocols established in advance, briefing prior to the arrival of the patient, and debriefing after the event, whether immediately after the event or through quality case review. Successful team dynamics include the ability to be fluid, adaptable, and communicative.

Team leaders must focus on the big picture: overall physiologic status of the patient, triage of resources available in the trauma room, assigning tasks to individuals or groups of

Box 1.1 Human Resource Response to Trauma Activations

- Emergency Physician
- Emergency/Trauma Nurses
- Trauma Surgeon
- Anesthesiologist
- Radiology Tech (and radiologist)
- Blood Bank, Laboratory Support Staff
- Respiratory Therapist
- Social Worker
- Security

Table 1.1 Adapted in part from ALiEM article by Arlene Chung, an effective team debriefing checklist[2]

✓ Set ground rules (purpose, safe environment) and time expectations (5–10 minutes)	
✓ Present facts of the case (avoid excessive detail)	*Can you give us an overview about what happened from your viewpoint?*
✓ Elicit thoughts	*What was your first thought or most prominent thought?*
✓ Discuss reactions (emotions)	*How did that go? What were you feeling?*
✓ Discuss the facts of the case, medicine, and teamwork	*What was the worst? What was the best?*
✓ Teaching and learning	*What could have gone better?*
✓ Re-entry and closure (validate emotions, highlight learning points)	

Box 1.2 Trauma Teams That Are Successful at Helping Patients Work Together Well

- Institutionally organized policy and plans for interdepartmental cooperation
- Designated team leader
- "Pre-briefing" prior to arrival of trauma patients
- Debriefing and/or quality clinical reviews, of trauma resuscitations
- Closed-loop, concise, out-loud communication
- Systematic, reproducible approach to every trauma patient
- Ability to be fluid, adaptable, and communicative

individuals, and planning for the next series of actions for the patient and team. A systematic approach to the patient is important (discussed in Box 1.2), as is a systematic approach to directing the team. Critical actions, while they may be pre-designated to a member of the team by policy, must be verbalized and confirmed. Intravenous access, for example, is crucial for a sick trauma patient. Direct, closed-loop communication among team members is essential in trauma management. This call-and-response principle can be extrapolated to all critical tasks in the trauma room.

Trauma team members are often exposed to high stress, highly emotional situations. Team debriefing is critical for emotional well-being, education, and resolution of deficiencies, demonstrated in Table 1.1. It is ideal that a formal debriefing, even if only a few minutes, be completed after every trauma team activation. These meetings may be delayed based on the circumstances of the patient (e.g., going immediately to the operating room), but should be attempted as often as is practical, with as many of the team members as possible.

Emergency Medical Services (EMS)

The first step in the series of steps that can optimize outcome in trauma is accurate triage (with overtriage preferred over undertriage), rapid care that addresses immediate life

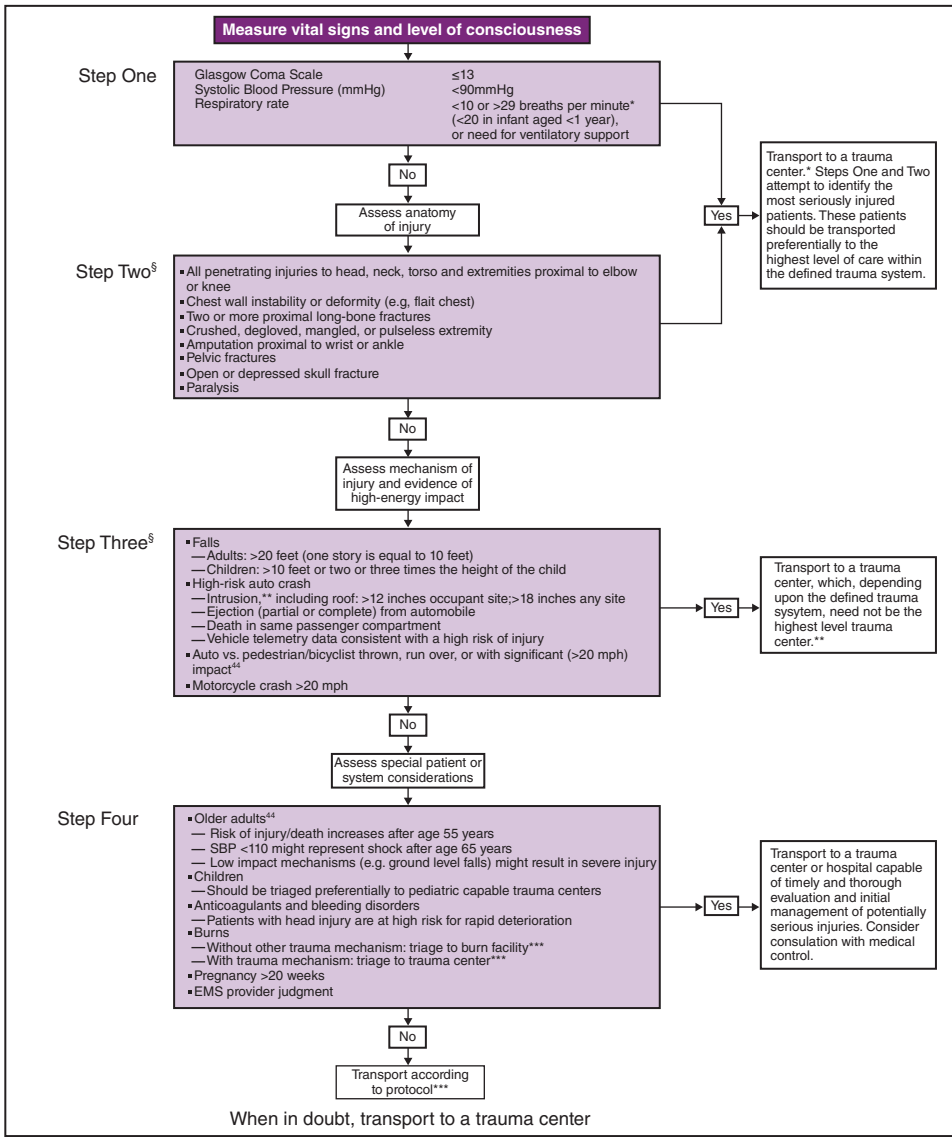


Figure 1.1 CDC guidelines for field triage of injured victims[3] (courtesy of the Centers for Disease Control, USA)

threats, and prompt transport to the appropriate level trauma center (see CDC guidelines chart, Figure 1.1) by EMS personnel.[3]

EMS professionals perform an abridged version of the hospital team's primary and secondary surveys. Many EMS systems rely on basic-level Emergency Medical Technicians (EMTs) to respond to calls for traumatic injuries. Modern EMT-staffed Basic Life Support ambulances carry equipment more advanced than simple standard first aid, such as tourniquets and hemostatic dressings for severe hemorrhage, and supraglottic airway devices. Paramedics, the highest trained pre-hospital providers, are capable of intubation,

needle decompression, and IV and IO access. Regardless of the level of skill, or equipment available, rapid transport to the appropriate hospital is key to survival. Some controversial studies have suggested that police officers ought not to wait for EMS to transport victims – inferring that speed, rather than care provided in the interim of transport, is most important.[4–9]

EMS notification to the receiving hospital allows for the trauma team to assemble, prepare equipment, and "pre-brief," as described earlier, in anticipation of their arrival. In some urban systems this may be a quick "heads-up" that the ambulance is around the corner. In rural settings, the patient may be coming by air or ground from hours away. In extreme circumstances, notification may provide time for the calling-in backup personnel (such as in multiple or mass casualty incidents) or setup of decontamination equipment.

Upon entering the trauma room, the team leader ought to obtain a brief history from EMS about the mechanism of injury, vital signs, interventions started, and IV or IO access already obtained. This information, while easily ignored in haste to begin assessment and treatment, may be invaluable. A brief period of time should be set aside (30–60 seconds) where the EMS personnel can convey the critical data points or "bullet" to the team leader, discussed in Table 1.2.

Primary Survey

The primary survey is a rapid (less than two minutes), focused, and requisitely thorough process of identifying immediate threats to life, shown in Table 1.3. It should be completed

Table 1.2 Critical information to obtain from EMS during transition of care

EMS Bullet Information	
Critical Information	**Additional Information (if possible to obtain)**
Mechanism of Injury	Details of the mechanism (e.g., size of knife, type of gun, passenger space intrusion)
Latest Vital Signs (and trends)	Number of additional anticipated victims
Mental Status (and trend)	Past medical or surgical history, medications, allergies
IV/IO Access (if already obtained)	
Interventions	

Table 1.3 Immediately life-threatening conditions that must be identified during the primary survey

A – Airway	B – Breathing	C – Circulation	D – Disability	E – Exposure
• Swelling	• Pneumothorax	• Uncontrolled bleeding	• Herniation	• Any hiding injury
• Excessive fluid	• Hemothorax	• Hypotension	• Neurologic deficit suggestive of SCI	
• Burns	• Hypoxia			
• Tracheal injury	• Respiratory failure			

by a physician at the head-of-the-bed and start with a brief introduction: "my name is Dr. Smith, focus on me and my voice; lots of people are here to help and will be doing lots of things around you."

In the era of terrorism, high-power gunfire on city streets, and improvised explosive devices, it is important to immediately consider significant, life-threatening bleeding. Major uncontrolled external bleeding should be addressed before proceeding with the traditional "ABCDE" primary assessment; first with direct pressure, then consideration given to applying a tourniquet to the proximal extremity (or the "CABCDE" assessment).

At the end of the primary survey, while there is still more work to be done, the team leader has enough information to start considering the anticipated next steps, for example, the CT scanner, the intensive care unit, the operating room, or an operating room alternative such as interventional radiology.

A – Airway (Key Question: Do We Need to Take Control of the Airway Right Now?)

In many patients, a thorough assessment of the airway can be completed by asking one question: "what is your name?" A speaking patient, answering a question directly, typically has a patent and self-maintained airway. Changes in voice, gurgling, stridor, or the inability to speak in full sentences should be noted as clues to impending airway problems. Ultimately the decision must be made if it is necessary to immediately take control of the airway. Box 1.3 lists the most important things to consider when deciding to intubate a trauma patient.[10,11]

If the patient must be intubated, it is critical to mentally and physically prepare for an anatomically and physiologically difficult airway. Anatomy may be severely distorted by the trauma or simply difficult to visualize due to a cervical collar in place, swelling, or bleeding. The need for a backup plan should always be anticipated; before intubating, have a gum elastic bougie, supraglottic airway, video laryngoscope, and/or scalpel for cricothyrotomy available. As with any other anticipated difficult airway, a verbalized plan for front-of-the-neck access should be in place should a cricothyrotomy be required.

The already-physiologically-stressed trauma patient may respond profoundly to induction and paralytic agents – as many are already reliant on a sympathetic surge to maintain their cardiac output. Consider medication selection in the context of the patient's physiology. For example, ketamine[12–18] or etomidate[19–23] are better choices for induction in the context of hypotension, as they are less likely to cause a drop in blood pressure. Relative contraindications for paralytic agents should also be considered.[24–26] Likewise, consider

Box 1.3 Indications For Early or Immediate Intubation in the Trauma Room[10,11]

- Severe head injury, with significantly decreased mental status (GCS <8, mGCS <6)
- Penetrating neck trauma (such as gunshot wounds, or poorly visualized stab wounds)
- Severe burns (especially involving inhalation injury to the airway)
- Significant blunt or penetrating chest trauma impairing breathing efforts
- Severely intoxicated or agitated patients prohibiting assessment of life-threatening injuries
- Anticipated course (such as transport to another facility, or immediate surgery)
- Severely ill, unresponsive, or otherwise in extremis

adjusting the dosages of medications for hypotension; lower doses of sedatives and higher doses of paralytics may be required.[27] Attention should be given to beginning pre-oxygenation and optimization of the patient's physiology (mean arterial pressure, oxygen saturations, etc.). If the mental status allows, insert a supraglottic airway, place a nasal cannula, apply a bag valve mask, and/or utilize noninvasive ventilation to pre-oxygenate as would be expected with any non-trauma patient.

B – Breathing (Key Questions: Are Chest Tubes Required? Is There Bleeding in the Chest?)

Assessment of breathing is a look (ensure equal chest rise, quantify the respiratory rate, check for wounds), listen (auscultate bilaterally), and feel (press on the chest wall to assess for crepitus or flail rib segments) process. Glance at the monitor and note the oxygen saturation. Pneumothorax can be more subtle than anticipated. Careful attention to asymmetric breath sounds (as referred sounds from one side of the chest could be heard on the collapsed-lung side), neck veins, and tracheal deviation could be crucial to picking up a pneumothorax or hemothorax before it develops tension physiology.

If there is concern for pneumothorax or hemothorax in a hemodynamically unstable patient, needle decompression of the chest or placement of a chest tube should be completed immediately. This is both a diagnostic and therapeutic procedure in critically ill trauma patients, especially those with penetrating trauma to the chest.

C – Circulation (Key Question: Where Are They Bleeding and Do They Need Blood?)

Coagulopathy, acidosis, and hypothermia – the trauma triad of death –all primarily stem from shock in trauma. Finding and promptly methodically stopping major hemorrhage is paramount. The trauma adage is that blood can be found in six major places: the chest, the abdomen, the pelvis, the retroperitoneum, the thighs (or areas around other long bones), and the street.

External hemorrhage may be obvious or discovered when exposing the patient. Internal hemorrhage may be more subtle and requires considering the patient's heart rate, blood pressure, and appearance. Obtain a complete set of vital signs and assess peripheral circulation. Weak pulses and cool extremities imply a shock state, as does a more objective rise in the shock index (heart rate divided by systolic blood pressure). While cutoffs for tachycardia and blood pressure are more poorly defined in the literature, a shock index <0.7 or >1.3 is correlated with poorer outcomes,[28] and a shock index >0.95 is correlated with the need for massive transfusion.[29]

Ensure that good intravenous access has been obtained – at least two large-bore (i.e., at least 18-gauge) IVs in most trauma patients. While short, 18-gauge peripheral IVs are excellent methods for volume resuscitation, consideration should be given to placement of an intraosseous or central venous line if peripheral access is limited or difficult. While obtaining IV access, lab work should be sent, including a typical trauma panel of labs: complete blood count, venous blood gas (serum lactate), basic chemistry, coagulation studies, and type-and-screen for potential transfusion. Additional labs may be obtained, but they usually do not guide initial management. Initial hemoglobin and hematocrit levels may be falsely reassuring, as it takes time for blood concentrations of heme to equilibrate to

rapid blood loss. Patients known to be on anticoagulants, or with elevated coagulation times, ought to be reversed in the context of active hemorrhage.

Hypotension/Shock

Classically taught "classes of shock" based on various vital sign cutoffs is important to appreciate; however, the literature demonstrates that they are not entirely reliable and often insensitive predictors of shock.[30,31] Normotensive elderly patients might be in shock. Children and healthy adults might compensate very well, leading to deceptively normal vital signs. The trajectory in tachycardia, mean arterial pressure, and mental status must be considered in any trauma patient with the potential for active bleeding.

If the patient is hypotensive, blood loss must be at the top of the differential for the cause, but also consider non-bleeding causes of hypotension in trauma; namely, tension pneumothorax, cardiac tamponade, spinal cord injury, myocardial dysfunction (from contusion, underlying heart disease, arrhythmia, or infarction), and toxic ingestions. Box 1.4 discusses causes of hypotension in trauma.

External bleeding should be stopped with direct pressure. Consider that holes in the skin are not always lined up with where blood originates. Attempts to apply pressure at potentially retracted vascular structures, or over proximal pressure points, may be reasonable additional measures. If blood loss from an extremity cannot be stopped with direct pressure, consider placing hemostatic stitches (e.g., a figure-of-eight or whip stitch) or staples if the wound is small enough. If bleeding cannot be controlled from a larger wound, such as an amputation, utilize a tourniquet (preferably a commercially available product or manual blood pressure cuff).

Blood loss from the pelvis is often associated with pelvic fractures, which may be stabilized with binding (either with a commercially available device or properly placed and secured bedsheet). While there are various types of pelvic fractures – some of which do not benefit from binding – a hypotensive patient with suspected active bleeding in the pelvis might benefit from empiric binding as a temporary measure.

Box 1.4 Differential for Hypotension in the Trauma Patient

Hemorrhagic Shock

- Bleeding (chest, abdomen, pelvis, retroperitoneum, long bones, street)

Obstructive Shock

- Tension pneumothorax
- Cardiac tamponade

Neurogenic Shock

- Spinal cord injury

Cardiogenic Shock

- Myocardial dysfunction (contusion, underlying heart disease, arrhythmia, infarction)

Distributive Shock (or other mechanisms)

- Toxic ingestion (poisoning, substance use)

Whether suffering from internal or external bleeding, a hemodynamically unstable patient needs to have replaced what has been lost: whole blood. Transfusion with packed red blood cells alone may not be adequate. Consider initiating a massive transfusion protocol. Protocols vary by institution but should include a mix of products containing packed fresh frozen plasma (FFP), platelets, and red blood cells (PRBC). The PROPPR and PROMMTT trials have demonstrated that overall transfusion in a ratio of 1:1:1 of FFP: Platelets:PRBCs is optimal.[32,33] Prothrombin Complex Concentrate (PCC) can be considered as an alternative to FFP, as it does not require thawing and is often more readily available. Consider supplemental calcium, as citrate in blood products can chelate body stores of calcium, potentiating hypotension. The CRASH-2 trial also demonstrated the efficacy of tranexamic acid (TXA), if given within the first three hours, to improve mortality in patients in hemorrhagic shock from trauma.[34] While IV fluids can temporarily elevate the circulating blood volume, they dilute clotting factors and perhaps unnecessarily increase the mean arterial pressure affecting hemostasis. They should be used sparingly and only as a bridge to blood products. Vasopressors have no role in hemorrhagic shock from trauma. Target resuscitation to a MAP of 65 mm Hg typically – and increase this goal to 80 mm Hg in any patient suspected of head injury or spinal cord injury.[35–37] This strategy of allowing penetrating trauma patients to remain slightly hypotensive is sometimes referred to as "permissive hypotension," and, although it has been demonstrated to be effective in one randomized trial, subsequent human trials have not been able to validate the benefit; therefore, the strategy remains controversial.[38]

Lastly, consideration may be given to more invasive hemostasis options such as a resuscitative thoracotomy[39–41] or placement of a Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA),[42–44] in select patients nearing death.

D – Disability (Key Question: Is There a Major Neurologic Deficit?)

During the primary survey the neurological assessment should include Glasgow Coma Scale (GCS),[45] pupillary exam, and gross motor/sensory assessment of all four extremities. Mental status is a key assessment in the overall status of the trauma patient. GCS can help assess the trajectory of the patient over time. Studies have indicated that simply assessing the motor component of the GCS can be a simplified, binary assessment (can the patient follow simple commands?) and is equally predictive of the need for airway management and mortality, discussed in Table 1.4.[46] Localized neurologic (or vascular) deficits in the context

Table 1.4 Glasgow Coma Scale GCS score[45] is used to stratify mental status in trauma patients[46]

Eye		Verbal		Motor	
4	Spontaneous opening	5	Oriented	6	Obeys commands
3	Opens to voice	4	Confused	5	Localizes pain
2	Opens to pain	3	Inappropriate	4	Withdraws from pain
1	No eye opening	2	Incomprehensible	3	Flexes to pain
		1	No verbal response	2	Extends to pain
				1	No motor response

Table 1.5 Key questions to consider in each portion of the primary survey

Airway	*Do we need to take control of the airway right now?*
Breathing	*Are chest tubes required? Is there bleeding in the chest?*
Circulation	*Where are they bleeding and do they need blood?*
Disability	*Is there a major neurologic deficit?*
Exposure	*What injuries haven't been found yet?*

of a mangled or deformed extremity may prompt a rapid bone or joint reduction and improve the likelihood of limb salvage.

All trauma patients with a significant mechanism of injury should be placed in a cervical collar until it is demonstrated they do not have an injury to the cervical spine, whether by clinical decision rules (in highly assessable patients, such as NEXUS or the Canadian C-Spine Rule) or by imaging and exam.[47,48]

If using induction or paralytic agents for intubation, the next possible neurologic exam will likely be significantly delayed. Consider performing a thorough baseline exam, if possible, prior to intubation.

If there is clinical evidence of brain herniation from head trauma, hyperosmolar therapy should be started to partially abate rises in intracerebral pressure (and subsequent losses in cerebral perfusion pressure).[49–56] Any intubation performed in this context should be completed by an experienced provider, as first-pass success minimizes hypotension and hypoxia.[55,57,58] Definitive therapy will require neurosurgical intervention.

E – Expose (Key Question: What Injuries Haven't Been Found Yet?)

Norman McSwain, a trauma surgeon and developer of the initial Advanced Trauma Life Support (ATLS) program, noted that "paranoia prevents disasters: the most severe injury is under the unremoved clothes." Every trauma patient should be exposed from head-to-toe in order to be examined thoroughly for injuries. Careful attention must be paid to areas that hide injuries, such as the axilla, skin folds, and the perineum. All patients must be rolled to examine the back. Key questions to consider in the primary survey are listed in Table 1.5.

Secondary Survey

As a continuation of the exposure portion of the primary survey, start from the head and work inferiorly, visualizing every square inch of the trauma patient. Descriptions of wounds ought to be as objective as possible and documented either with drawings of the body or precise anatomical locations. For example, "exit wound on the right flank" may be better stated as "1 cm ballistic wound in the R flank at the level of T5, 4 cm to the right of the midline." Excess qualifiers ("exit wound") serve to define the mechanism of injury in ways not typically known to the trauma team and do not provide additional, useful medical information. Remember these statements in the medical record may have criminal or legal implications for the patient or assailant.

A complete head-to-toe secondary survey, including rolling the patient and checking the posterior anatomy, should take no more than three to four minutes. Decisions should be

Table 1.6 General overview of the process of the trauma assessment

Primary Survey	Secondary Survey
• Massive Bleeding/Circulation	• Head-to-toe exam, including the back
• Airway	• Medications and allergies
• Breathing	• Past medical and surgical history
• Circulation	• Last oral intake
• Disability	• Discuss events leading to the trauma
• Expose	• Consider imaging

made at this point about what imaging needs to be completed in the trauma bay, i.e. what imaging is pivotal to deciding the next steps for the patient. While rolling the patient, consider placing plain film radiology plates underneath the patient's chest and pelvis.

Lastly, the secondary survey includes asking about the patient's past medical and surgical history, current medications (paying special attention to those immediately relevant to the trauma resuscitation, such as anticoagulant or antiplatelet agents), allergies, last oral intake, tetanus status, and any other details of the incident that led to the trauma in the first place. The general overview of the trauma assessment is listed in Table 1.6.

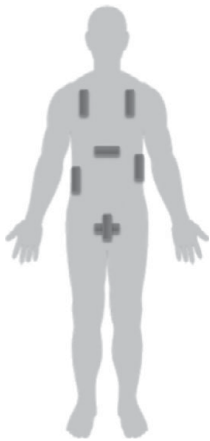
Imaging

Trauma Bay Imaging

A chest x-ray has long been the tradition for the trauma bay imaging of choice to evaluate for pneumothorax. In reality, a chest x-ray is poor at identifying this pathology, with sensitivity of 28–75%, especially if performed supine. The alternative is the eFAST (Extended Focused Assessment with Sonography in Trauma). This ultrasound exam is more sensitive (86–98%) than chest x-ray, and equally specific. It can be performed faster (no pun intended), and synergize better with the next steps.[59] If the patient is unstable with traumatic mechanism and there is clinical evidence to suggest pneumothorax (especially tension pneumothorax), a chest tube should be placed empirically without waiting for imaging.

The eFAST is a six-part study that assesses for abdominal free fluid, pericardial effusion, and pneumothorax. The prominent role for this procedure was largely designed to replace the need for diagnostic peritoneal lavage (DPL) to rule-out or rule-in abdominal sources of bleeding in blunt trauma patients with unstable vital signs, primarily as a means to guide operative therapy. In practice, the eFAST exam is also performed routinely on stable trauma patients, looking to identify the same abdominal and pericardial pathology early, and to identify pneumothoraces without the need for a chest x-ray. Positioning of the patient is key to enhancing the sensitivity of the exam. Brief periods in Trendelenburg (for the right and left upper quadrant views), reverse-Trendelenburg (for the suprapubic view), and supine (for the subxiphoid and lung views) will help position organ tissue, fluid, and air to improve diagnostics. Serial eFAST exams are not unreasonable in a stable patient, or one in whom the clinical picture has changed (sudden hypoxia or hypotension). Ultrasound has been

Extended Focused Assessment with Sonography in Trauma (eFAST) Views



1. Right upper quadrant view
2. Left upper quadrant view
3. Suprapubic view (two axes)
4. Subxiphoid view
5. Lung views (bilaterally)

Figure 1.2 The eFAST assesses six locations, looking for intraperitoneal fluid, pericardial fluid, and pneumothorax. Extended Focused Assessment with Sonography in Trauma (eFAST) views: (1) Right upper quadrant view; (2) Left upper quadrant view; (3) Suprapubic view (two axes); (4) Subxiphoid view; and (5) Lung views (bilaterally)

noted to be as high as 100% sensitive for identifying the need for laparotomy in unstable patients, though only 75% sensitive (and 98% specific) for identifying free fluid in stable and unstable trauma patients cohorted together.[60–65] Figure 1.2 describes ultrasound views.

If the mechanism or primary and secondary survey suggest a possible pelvic fracture, a portable film of the pelvis should be completed as well. As mentioned above, any unstable patient where a pelvic source of bleeding is suspected should empirically have the pelvis placed in a binding device. Suspected pelvic fracture is an indication for portable pelvis x-ray in the trauma bay, but this may be omitted to pursue more expedient definitive CT imaging in the hemodynamically stable patient.

CT Scans

Given the limitations of chest x-ray, pelvic x-ray, and the eFAST exam, more advanced imaging is often required to completely assess injuries. CT scans should be completed for areas where potentially clinically relevant injury has occurred. Priority should be given to scans identifying immediate life threats (such as intracranial hemorrhage in an obtunded fall victim with clinical evidence of herniation) over operative planning scans (such as three-dimensional reconstruction images of a trimalleolar ankle fracture) that do not immediately impact the next steps in management or disposition of the patient.

Some decision rules may aid in ruling-out clinically relevant injury, such as the NEXUS,[47] Canadian Head CT,[66] and C-spine[48] rules, though clinical judgment will dictate when most CT imaging is ordered. Some strategies involve major trauma patients routinely receiving whole-body or "pan-scan" CT imaging; others advocate for more selective imaging based on mechanism and exam. Whole Body CT (WBCT) typically includes non-contrast studies of the head and c-spine, as well as IV contrast enhanced studies of the chest, abdomen, and

pelvis. In the era of multi-detector CT scanners, a trauma "pan-scan" typically delivers approximately 20 mSv of radiation (a 0.35% increased risk of cancer in one's lifetime, compared to the population's lifetime inherent risk of death from cancer of approximately 25%).[67] Proponents of whole-body scans argue that diagnoses are less likely to be missed and are identified faster. Advocates for the selective scanning highlight the unnecessary radiation exposure and increased incidental, clinically irrelevant findings that lead to further unnecessary – or at worst potentially harmful – testing and treatment. Little prospective evidence exists on the matter. Most recently, the REACT-2 trial, a prospective, multicenter study with intention-to-treat analysis of major trauma patients, found no difference in mortality (24-hour, 30-day, or overall) for WBCT vs. selective imaging. While the evidence is scant, WBCT may be a better option in patients who are not easily assessed (intoxicated, severely injured, altered mental status with unreliable exam, etc.).[68]

Disposition and Ongoing Care

Final disposition of the trauma patient is based on the dynamic assessment of hemodynamic status and findings on evaluation. Due to improved CT imaging, many trauma patients can be discharged home more rapidly and, similarly, many patients who might have been taken for exploratory laparotomy can now be observed for progression of injuries.

Unstable patients with active bleeding, internally or externally, require source control, and are often taken to the operating room or interventional radiology suite. Efficient use of resources (personnel, imaging, and multidisciplinary brain power) in the trauma bay, as explained in this chapter, will get the patient what they need, when they need it, and as methodically as possible.

Key Points

- Trauma systems are complex and expensive, but regionalized, systemized, tiered care saves lives of the sickest injured patients.
- The team dynamic is critical to success in trauma; having the right people, empowered to do their jobs, who communicate well, is necessary for the best outcomes.
- EMS has valuable information; be sure to ask about details of the mechanism of injury, interventions already completed, and trends in vital signs or mental status.
- The primary survey (airway, breathing, circulation, disability, exposure) is designed to identify immediate threats to life. The secondary survey is designed to identify every injury, complete a thorough evaluation, and guide imaging.
- The eFAST exam is sensitive for bleeding (most strongly in unstable patients) and more sensitive than chest x-ray for pneumothorax. CT scans make critical diagnoses and should not be delayed, even in the stable trauma patient.

References

1. Kochanek K, Murphy S, Xu J, Tejada-Vera B. National vital statistics reports deaths: final data for 2014. Centers for Disease Control. www.cdc.gov. 2016.
2. Chung A. Wellness and resiliency during residency: debriefing critical incidents and podcast. *Academic Life in Emergency Medicine*. Online blog entry. www.aliem.com/2017/01/wellness-resiliency-debriefing-critical-incidents/. 2017.

3. McCoy CE, Chakravarthy B, Lotfipour S. Guidelines for field triage of injured patients: In conjunction with the morbidity and mortality weekly report published by the center for disease control and prevention. *West J Emerg Med*. 2013;14 (1):69–76.

4. Gonzalez RP, Cummings GR, Phelan HA, Mulekar MS, Rodning CB. Does increased emergency medical services prehospital time affect patient mortality in rural motor vehicle crashes? A statewide analysis. *Am J Surg*. 2009;197(1):30–34.

5. McCoy CE, Menchine M, Sampson S, Anderson C, Kahn C. Emergency medical services out-of-hospital scene and transport times and their association with mortality in trauma patients presenting to an urban level I trauma center. *Ann Emerg Med*. 2013;61(2):167–74.

6. Seamon MJ, Fisher CA, Gaughan J, et al. Prehospital procedures before emergency department thoracotomy: "scoop and run" saves lives. *J Trauma*. 2007;63(1):113–20.

7. Branas CC, Sing RF, Davidson SJ. Urban trauma transport of assaulted patients using nonmedical personnel. *Acad Emerg Med*. 1995;2(6):486–93.

8. Demetriades D, Chan L, Cornwell E, et al. Paramedic vs private transportation of trauma patients: effect on outcome. *Arch Surg*. 1996;131(2):133–38.

9. Band RA, Salhi RA, Holena DN, et al. Severity-adjusted mortality in trauma patients transported by police. *Ann Emerg Med*. 2014;63(5):614.e3.

10. Shah K, Lee J, Medlej K, Weingart SD, eds. *Practical Emergency Resuscitation and Critical Care*. Cambridge: Cambridge University Press; 2013.

11. Strayer R. Reasons to intubate. Emergency Medicine Updates Web Site. http://emupdates.com/2016/12/29/reasons-to-intubate/. Updated 2016. Accessed October 5, 2017.

12. Price B, Arthur AO, Brunko M, et al. Hemodynamic consequences of ketamine vs etomidate for endotracheal intubation in the air medical setting. *Am J Emerg Med*. 2013;31(7):1124–32.

13. Heffner AC, Swords D, Kline JA, Jones AE. The frequency and significance of postintubation hypotension during emergency airway management. *J Crit Care*. 2012;27(4):417.13.

14. Fields AM, Rosbolt MB, Cohn SM. Induction agents for intubation of the trauma patient. *J Trauma*. 2009;67 (4):867–69.

15. Weingart SD, Trueger NS, Wong N, et al. Delayed sequence intubation: a prospective observational study. *Ann Emerg Med*. 2015;65(4):349–55.

16. Dewhirst E, Frazier WJ, Leder M, Fraser DD, Tobias JD. Cardiac arrest following ketamine administration for rapid sequence intubation. *J Intensive Care Med*. 2013;28(6):375–79.

17. Morris C, Perris A, Klein J, Mahoney P. Anaesthesia in haemodynamically compromised emergency patients: does ketamine represent the best choice of induction agent? *Anaesthesia*. 2009;64 (5):532–39.

18. Miller M, Kruit N, Heldreich C, et al. Hemodynamic response after rapid sequence induction with ketamine in out-of-hospital patients at risk of shock as defined by the shock index. *Ann Emerg Med*. 2016;68(2):188.e2.

19. Oglesby AJ. Should etomidate be the induction agent of choice for rapid sequence intubation in the emergency department? *Emerg Med J*. 2004;21 (6):655–59.

20. Zed PJ, Abu-Laban RB, Harrison DW. Intubating conditions and hemodynamic effects of etomidate for rapid sequence intubation in the emergency department: an observational cohort study. *Acad Emerg Med*. 2006;13(4):378–83.

21. Sokolove PE, Price DD, Okada P. The safety of etomidate for emergency rapid sequence intubation of pediatric patients. *Pediatr Emerg Care*. 2000;16(1):18–21.

22. Jellish WS, Riche H, Salord F, Ravussin P, Tempelhoff R. Etomidate and thiopental-based anesthetic induction: comparisons between different titrated levels of electrophysiologic cortical depression and

response to laryngoscopy. *J Clin Anesth*. 1997;9(1):36–41.

23. Guldner G, Schultz J, Sexton P, Fortner C, Richmond M. Etomidate for rapid-sequence intubation in young children: hemodynamic effects and adverse events. *Acad Emerg Med*. 2003;10(2):134–39.
24. Taha SK, El-Khatib MF, Baraka AS, et al. Effect of suxamethonium vs rocuronium on onset of oxygen desaturation during apnoea following rapid sequence induction. *Anaesthesia*. 2010;65(4):358–61.
25. Curley GF. Rapid sequence induction with rocuronium – a challenge to the gold standard. *Crit Care*. 2011;15(5):190.
26. Heier T, Caldwell JE. Rapid tracheal intubation with large-dose rocuronium: a probability-based approach. *Anesth Analg*. 2000;90(1):175–79.
27. Reich DL, Hossain S, Krol M, et al. Predictors of hypotension after induction of general anesthesia. *Anesth Analg*. 2005;101(3):8, table of contents.
28. Singh A, Ali S, Agarwal A, Srivastava RN. Correlation of shock index and modified shock index with the outcome of adult trauma patients: a prospective study of 9860 patients. *N Am J Med Sci*. 2014;6 (9):450–52.
29. Rau C, Wu S, Kuo SCH, et al. Prediction of massive transfusion in trauma patients with shock index, modified shock index, and age shock index. *Int J Environ Res Public Health*. 2016;13(7):683.
30. Thomas I, Dixon J. Bradycardia in acute haemorrhage. *BMJ*. 2004;328 (7437):451–53.
31. Guly HR, Bouamra O, Little R, et al. Testing the validity of the ATLS classification of hypovolaemic shock. *Resuscitation*. 2010;81(9):1142–47.
32. Holcomb JB, Tilley BC, Baraniuk S, et al. Transfusion of plasma, platelets, and red blood cells in a 1:1:1 vs a 1:1:2 ratio and mortality in patients with severe trauma: the PROPPR randomized clinical trial. *JAMA*. 2015;313(5):471–82.
33. Holcomb JB, Fox EE, Wade CE, PROMMTT Study Group. The PRospective Observational Multicenter Major Trauma Transfusion (PROMMTT) study. *J Trauma Acute Care Surg*. 2013;75(1 Suppl 1):1.
34. Roberts I, Shakur H, Coats T, et al. The CRASH-2 trial: a randomised controlled trial and economic evaluation of the effects of tranexamic acid on death, vascular occlusive events and transfusion requirement in bleeding trauma patients. *Health Technol Assess*. 2013;17(10):1–79.
35. Wiles MD. Blood pressure management in trauma: from feast to famine? *Anaesthesia*. 2013;68(5):445–49.
36. Berry C, Ley EJ, Bukur M, et al. Redefining hypotension in traumatic brain injury. *Injury*. 2012;43(11):1833–37.
37. Maas AI, Dearden M, Teasdale GM, et al. EBIC-guidelines for management of severe head injury in adults. European brain injury consortium. *Acta Neurochir (Wien)*. 1997;139(4):286–94.
38. Bickell WH, Wall MJ, Jr, Pepe PE, et al. Immediate versus delayed fluid resuscitation for hypotensive patients with penetrating torso injuries. *N Engl J Med*. 1994;331(17):1105–09.
39. Moore EE, Knudson MM, Burlew CC, et al. Defining the limits of resuscitative emergency department thoracotomy: a contemporary Western trauma association perspective. *J Trauma*. 2011;70(2):334–39.
40. Hunt PA, Greaves I, Owens WA. Emergency thoracotomy in thoracic trauma – a review. *Injury*. 2006;37(1):1–19.
41. Seamon MJ, Haut ER, Van Arendonk K, et al. An evidence-based approach to patient selection for emergency department thoracotomy: a practice management guideline from the Eastern Association for the Surgery of Trauma. *J Trauma Acute Care Surg*. 2015;79(1):159–73.
42. Brenner M, Hoehn M, Teeter W, Stein D, Scalea T. Trading scalpels for sheaths: catheter-based treatment of vascular injury can be effectively performed by acute care surgeons trained in endovascular techniques. *J Trauma Acute Care Surg*. 2016;80(5):783–86.
43. Biffl WL, Fox CJ, Moore EE. The role of REBOA in the control of exsanguinating

torso hemorrhage. *J Trauma Acute Care Surg*. 2015;78(5):1054–58.

44. Stannard A, Eliason JL, Rasmussen TE. Resuscitative endovascular balloon occlusion of the aorta (REBOA) as an adjunct for hemorrhagic shock. *J Trauma*. 2011;71(6):1869–72.
45. Teasdale G, Jennett B. Assessment of coma and impaired consciousness. A practical scale. *Lancet*. 1974;2(7872):81–84.
46. Chou R, Totten AM, Carney N, et al. Predictive utility of the total Glasgow coma scale versus the motor component of the Glasgow coma scale for identification of patients with serious traumatic injuries. *Ann Emerg Med*. 2017;70(2):157.e6.
47. Hoffman JR, Wolfson AB, Todd K, Mower WR. Selective cervical spine radiography in blunt trauma: methodology of the national emergency X-radiography utilization study (NEXUS). *Ann Emerg Med*. 1998;32 (4):461–69.
48. Stiell IG, Wells GA, Vandemheen KL, et al. The Canadian C-spine rule for radiography in alert and stable trauma patients. *JAMA*. 2001;286(15):1841–48.
49. Battison C, Andrews PJ, Graham C, Petty T. Randomized, controlled trial on the effect of a 20% mannitol solution and a 7.5% saline/6% dextran solution on increased intracranial pressure after brain injury. *Crit Care Med*. 2005;33(1):8.
50. Ware ML, Nemani VM, Meeker M, et al. Effects of 23.4% sodium chloride solution in reducing intracranial pressure in patients with traumatic brain injury: a preliminary study. *Neurosurgery*. 2005;57 (4):36.
51. Shackford SR, Bourguignon PR, Wald SL, et al. Hypertonic saline resuscitation of patients with head injury: a prospective, randomized clinical trial. *J Trauma*. 1998;44(1):50–58.
52. Sakowitz OW, Stover JF, Sarrafzadeh AS, Unterberg AW, Kiening KL. Effects of mannitol bolus administration on intracranial pressure, cerebral extracellular metabolites, and tissue oxygenation in severely head-injured patients. *J Trauma*. 2007;62(2):292–98.
53. McGraw CP, Howard G. Effect of mannitol on increased intracranial pressure. *Neurosurgery*. 1983;13(3):269–71.
54. James HE. Methodology for the control of intracranial pressure with hypertonic mannitol. *Acta Neurochir (Wien)*. 1980;51 (3–4):161–72.
55. Brain Trauma Foundation, American Association of Neurological Surgeons, Congress of Neurological Surgeons, et al. Guidelines for the management of severe traumatic brain injury. II. hyperosmolar therapy. *J Neurotrauma*. 2007;24(Suppl 1):14.
56. Hinson HE, Stein D, Sheth KN. Hypertonic saline and mannitol therapy in critical care neurology. *J Intensive Care Med*. 2013;28 (1):3–11.
57. Jaeger M, Dengl M, Meixensberger J, Schuhmann MU. Effects of cerebrovascular pressure reactivity-guided optimization of cerebral perfusion pressure on brain tissue oxygenation after traumatic brain injury. *Crit Care Med*. 2010;38(5):1343–47.
58. Elf K, Nilsson P, Ronne-Engstrom E, Howells T, Enblad P. Cerebral perfusion pressure between 50 and 60 mm hg may be beneficial in head-injured patients: a computerized secondary insult monitoring study. *Neurosurgery*. 2005;56(5):71.
59. Wilkerson RG, Stone MB. Sensitivity of bedside ultrasound and supine anteroposterior chest radiographs for the identification of pneumothorax after blunt trauma. *Acad Emerg Med*. 2010;17(1):11–17.
60. Stengel D, Rademacher G, Ekkernkamp A, Guthoff C, Mutze S. Emergency ultrasound-based algorithms for diagnosing blunt abdominal trauma. *Cochrane Database Syst Rev*. 2015;(9): CD004446.
61. Quinn AC, Sinert R. What is the utility of the focused assessment with sonography in trauma (FAST) exam in penetrating torso trauma? *Injury*. 2011;42(5):482–87.
62. Wherrett LJ, Boulanger BR, McLellan BA, et al. Hypotension after blunt abdominal trauma: the role of emergent abdominal sonography in surgical triage. *J Trauma*. 1996;41(5):815–20.

63. Rozycki GS, Ballard RB, Feliciano DV, Schmidt JA, Pennington SD. Surgeon-performed ultrasound for the assessment of truncal injuries: lessons learned from 1540 patients. *Ann Surg*. 1998;228(4):557–67.

64. McKenney M, Lentz K, Nunez D, et al. Can ultrasound replace diagnostic peritoneal lavage in the assessment of blunt trauma? *J Trauma*. 1994;37(3):439–41.

65. Ng A. The FAST examination how good is FAST. Trauma.org Web site. www.trauma.org/archive/radiology/FASThowgood.html. Updated 2001. Accessed October 5, 2017.

66. Stiell IG, Wells GA, Vandemheen K, et al. The Canadian CT head rule for patients with minor head injury. *Lancet*. 2001;357(9266):1391–96.

67. Brenner DJ, Elliston CD. Estimated radiation risks potentially associated with full-body CT screening. *Radiology*. 2004;232(3):735–38.

68. Sierink JC, Treskes K, Edwards MJ, et al. Immediate total-body CT scanning versus conventional imaging and selective CT scanning in patients with severe trauma (REACT-2): a randomised controlled trial. *Lancet*. 2016;388(10045):673–83.

Chapter 2

Trauma Airway

Colin Kaide and Andrew King

Airway management is of paramount importance in trauma resuscitations; in fact, virtually all management algorithms begin with the assessment and protection of the airway. Trauma airways are often compromised and among the most difficult to manage due to hemodynamic instability from multi-organ dysfunction, cervical trauma, or direct trauma to airway structures.

Important Considerations for Airway Management in Trauma Patients

Airway management in the trauma patient can pose many challenges, even for the most experienced clinicians. These factors can occur independently or collectively to complicate the care of the trauma patient. There are a few specific, unique aspects of trauma airway management that require special preparation and caution (Box 2.1).

Consider Pre-existing Difficult Airway

A fundamental rule of airway management is to ensure caution when considering the paralysis of a patient who is expected to be a difficult or impossible intubation, unless the clinician has a specific plan to address a failed airway. Further, the ability to adequately mask ventilate should be considered when determining the type and method of airway intervention.

Trauma Immobilization

The physical process of trauma immobilization with a cervical collar and backboard can significantly limit access to the airway and the anterior neck. A properly placed collar limits mouth opening and intentionally prevents repositioning of the head and neck. If time

Box 2.1 Complicating Factors in the Trauma Airway

- Pre-existing difficult airway (anterior larynx, short neck, poor jaw mobility, etc.)
- Physical constraints of trauma immobilization
- Potential or actual injuries to the cervical spine
- Mechanical distortion of the airway anatomy from direct trauma to oral, pharyngeal, or laryngeal structures
- Mechanical distortion of the airway from injuries to contiguous structures (lower neck, thorax, or trachea)
- Other non-airway factors such as hypotension, brain injury, or pneumothorax which compete with the urgency to control the airway
- Hypoxia from underlying lung injury, such as pulmonary contusion

allows, patients should be log rolled off a backboard, and providers should remove the cervical collar and utilize inline stabilization during intubation attempts.

Mechanical Distortion of the Airway and Contiguous Structures

Direct trauma; previous surgery; or cancers to the face, larynx, or thorax can alter the normal anatomical relationships of the airway structures and can significantly increase the difficulty of the intubation.

Indications for Airway Intervention

The decision to intubate a trauma patient is among the most important and definitive steps in the management algorithm. The primary goals of airway management are to improve gas exchange, relieve respiratory distress by decreasing the work of breathing, and protection against aspiration (Box 2.2). Secondary goals range from the control of the agitated patient to the delivery of heated, humidified oxygen to facilitate core rewarming.[1]

Traumatic Injuries with Associated Difficult Airways

Closed Head Injury

- Changes in hemodynamics, oxygenation, and ventilation should be minimized in an attempt to maintain adequate cerebral perfusion pressure (CPP).
- CPP = MAP – ICP, where ICP is intracranial pressure and MAP is mean arterial pressure.
- Laryngoscopy causes an increase in ICP secondary to its resultant hypertension.
- The goal during intubation is to minimize the two main contributors to increased ICP – patient position and hypoventilation (Box 2.3).
- Obtain a focused neurologic examination prior to intubation and the administration of sedatives and paralytics in an effort to guide further care.
- Opiates, such as Fentanyl, may be given two-to-three minutes prior to intubation in an effort to blunt the sympathetic response.
- Ketamine, etomidate, or propofol can be used as an induction agent.

Box 2.2 Intubation Considerations

Indications for Intubation

- Oxygenation Failure: PO_2 <60 on FiO_2 >40%
- Ventilation Failure: pH of <7.3 associated with hypoventilation or pCO_2 >55 with previously normal pCO_2 or rise in pCO_2 by 10 acutely in COPD
- Intentional Hyperventilation
- Profound Shock: Reduces energy expenditure used during rapid breathing
- Intentional Paralysis: To accomplish necessary procedures in a non-compliant patient
- Aspiration Protection
- Mechanical Obstruction
- Core rewarming

Box 2.3 Airway Management Pearls in Closed Head Injury

- Preparation: Ensure proper positioning, pre-oxygenation, and use apneic oxygenation with nasal cannula
- Elevate the head of the bed to improve cerebral perfusion pressure and decrease aspiration risk
- Premedication regimens are controversial. Fentanyl or esmolol may decrease catecholamine surge and control the hemodynamic response to intubation
- Ketamine and etomidate are the best induction agents – with the least hemodynamic effects
- Propofol has neuroprotective effects, but hypotension and decreased CPP can result
- Post-intubation analgesia and sedation are essential – drips should be prepared prior to intubation to minimize the effects of agitation on ICP

- Ketamine increases cerebral blood flow and counters systemic hypotension. Evidence suggests that it does not elevate ICP.
- Although propofol can be used, it should be used with caution and with reduced doses in patients who are hemodynamically unstable.

Maxillofacial Trauma

- Facial trauma can significantly distort normal anatomy, and injuries can range in severity from minimal to severe.
- In cases where airway obstruction is either present or imminent, immediate decisive action is required. Alternatively, some patients initially present with minor respiratory difficulty, but pose a significant risk of rapid deterioration.
- A few moments should be taken to plan an effective strategy to safely intervene without resulting in further harm.
- Expectant management or delayed decision-making may force a cricothyrotomy.
- Preparation including arrangements for back up plans significantly increases the chances of successfully securing the airway.
- The patient's neck should immediately be prepped for a surgical airway in the event of a likely difficult airway or failed intubation.
- There is an associated cervical spine injury in up to 5% of patients with maxillofacial trauma and neurologic injury in up to 36%.[2,3]
- If there is no concern for C-spine injury, place the patient in an upright position to allow blood and secretions to drain. Check the oropharyngeal anatomy and ensure jaw mobility.
- RSI is the initial method of choice – if not possible or contraindicated then a surgical airway should be performed (Box 2.4).

Direct Airway Trauma

- Important signs or symptoms of airway involvement include dyspnea, cyanosis, subcutaneous emphysema, hoarseness, and air bubbling through the wound site (Box 2.5).
- Penetrating trauma has a high degree of morbidity and mortality; in fact, the overall mortality is as high as 11%,[4] with up to 40% of patients requiring emergent intubation.[5,6]

Box 2.4 Airway Management Pearls in Maxillofacial Trauma

- Preparation: Examine oropharyngeal anatomy and ensure jaw mobility. Rapidly devise a specific strategy
- Can rapidly deteriorate – delayed decision-making may result in cricothyrotomy
- Associated cervical spine and neurologic injuries can occur
- RSI initial method of choice – if not possible or contraindicated then cricothyrotomy

Box 2.5 Airway Management Pearls in Direct Airway Trauma

- Important signs or symptoms of airway involvement include dyspnea, cyanosis, subcutaneous emphysema, hoarseness, and air bubbling through the wound site
- Indications for intubation in penetrating trauma include acute respiratory distress, airway compromise from blood or secretions, extensive subcutaneous emphysema, tracheal shift, or altered mental status
- GSW to the anterior neck is an indication for early intubation due to expanding hematoma; stab wounds need intubation only if there is evidence of airway or vascular trauma
- Awake airway evaluation or intubation can be performed with sedation (Ketamine) and topical anesthesia
- Blunt neck trauma has a high incidence of associated cervical spine injury

- Zone I – between the clavicles and cricoid cartilage – is the least common neck injury, but the most likely to require emergent airway management due to the close proximity of major pulmonary and vascular structures.[5]
- Tracheobronchial injury occurs in approximately 10–20% of patients with penetrating trauma to the neck.[7–10]
- Indications for intubation in the setting of penetrating trauma include acute respiratory distress, airway compromise from blood or secretions, extensive subcutaneous emphysema, tracheal shift, or altered mental status.[11]
- Gunshot wound to the anterior neck is also an indication for early intubation in order to prevent obstruction from an expanding hematoma.[12]
- A stab wound to the anterior neck is an indication for early intubation only if there is evidence of vascular or direct airway trauma.[13]
- Orotracheal intubation with RSI is the technique of choice in penetrating neck trauma[12]; however, administration of paralytics may result in an obstructed airway due to the relaxation of a damaged airway segment.
- An awake airway evaluation or an awake intubation can be performed under sedation and topical anesthesia. Ketamine has been suggested as a good induction agent to use in this setting without paralytics.[14]
- Occasionally the entrance wound provides a direct communication between the anterior neck and the trachea – in this case, it may be easier to intubate directly through the wound.
- Blunt trauma to the neck is frequently more complicated as it is associated with a high incidence of C-spine injuries. Specifically, up to 50% of blunt airway trauma patients have concurrent C-spine injuries.[15]

- In terms of securing the airway in patients with blunt neck trauma, there are essentially three initial methods of choice: RSI, awake intubation, and awake fiberoptic intubation. The exception occurs in a laryngeal fracture, in which emergent tracheostomy is the best first maneuver.

Cervical Spine Injury

- All trauma patients who present with cervical spine precautions should be assumed to have a cervical spine injury until proven otherwise (Box 2.6).
- The two initial methods of choice for securing the airway are oral intubation with RSI or awake fiberoptic intubation.
- When performing RSI, the anterior portion of the collar should be removed to allow for manual in-line axial head and neck stabilization (MILS).
- MILS has been shown to immobilize the c-spine better in the setting of endotracheal intubation than the c-collar alone.[16]
- However, MILS can make intubation attempts difficult, and it may not reduce the risk of cervical spine movment.[17,18]
- Consider airway adjuncts such as using video assisted laryngoscopy to improve the chance of success while maintaining MILS.

Thoracic Trauma

- Thoracic trauma may present difficulties when it causes a distortion of the trachea from its normal midline position (Box 2.7).
- Occasionally a large pneumothorax can cause significant subcutaneous emphysema tracking into the neck, which can interfere with the ability to identify the trachea and/or cricothyroid membrane.
- Pneumothorax, hemothorax, or significant trauma to the lung (pulmonary contusion) can inhibit the ability to adequately pre-oxygenate the patient prior to the intubation.
- A pneumothorax should be treated prior to intubation if possible.

Box 2.6 Airway Management Pearls Cervical Spine Injury

- All trauma patients should be assumed to have a C-spine injury until proven otherwise
- RSI or awake fiberoptic intubation are the preferred methods
- When performing RSI, the anterior portion of the cervical collar should be removed to allow for manual in-line stabilization
- Consider airway adjuncts to improve chances of success while maintaining manual in-line stabilization

Box 2.7 Airway Management Pearls Thoracic Trauma

- Thoracic trauma can displace the trachea from the normal midline position or distort the normal anatomy and landmarks
- RSI or awake fiberoptic intubation are the preferred methods
- Thoracic injuries can inhibit pre-oxygenation
- Treat pneumothorax prior to intubation if able

Box 2.8 Airway Management Pearls in Burns

- Upper airway edema is progressive over hours – advisable to secure an airway early, but reasonable to consult with burn specialist in many circumstances
- Liberal use of nasopharyngoscopy can help with the decision to intubate or manage expectantly
- If prolonged transport is needed to a burn center, consider a secure airway prior to transfer
- RSI is the method of choice, but could also consider awake intubation or fiberoptic intubation
- Indications for intubation:
  - Stridor or hoarseness
  - Known inhalation of toxic fumes
  - Increased work of breathing
  - Burn or edema to airway structures
  - Carbonaceous sputum or soot in nares or mouth

Burns

- Upper airway edema is progressive over 24–36 hours after the burn; therefore, it is advisable to secure an airway earlier rather than later (Box 2.8).
- Because burn injuries develop over hours, it is often is reasonable to consult a burn specialist prior to securing an airway when appropriate.
- If transport is needed to a burn center, particularly a prolonged transport, consider a secure airway with intubation prior to transfer.
- Indications for intubation include: Stridor or hoarseness, known inhalation of toxic fumes, and increased work of breathing. Nasopharyngoscopy by the treating clinician or an ENT consultant can help to look for evidence of burns or edema of the posterior pharyngeal or glottis structures. If no burns to these structures are discovered and the patient remains stable, intubation can be withheld. Remember, however, that this is a dynamic situation. Any change with respect to the patient's work of breathing or stridor should prompt another nasopharyngoscopic evaluation or definitive airway management with intubation.
- Standard oral endotracheal intubation with RSI is the initial method of choice to secure the airway when no obvious obstruction is visualized.
- If concerned about obstruction, "an awake look" should be performed under sedation and topical anesthetics.
- Because of the incidence of upper airway edema, there should be a low threshold for moving to fiberoptic intubation or cricothyrotomy.

Rapid-Sequence Intubation (RSI)

RSI is currently considered the method of choice for emergent airway control in the trauma patient, unless specific contraindications are present (Box 2.9).[19–21]

Rapid Sequence Intubation (RSI): The Technique

A teaching tool to describe the steps of RSI was developed by Walls.[21] The "P's" of RSI are described below in a modified form that reflects emphasis on some new considerations.

Box 2.9 RSI Contraindications

- Absolute Contraindications:
  - Total upper airway obstruction requiring surgical airway
  - Loss of facial/oropharyngeal landmarks requiring surgical airway
- Relative Contraindications:
  - Anticipated difficult airway scenario where endotracheal intubation may not be successful, relying on bag-valve-mask
  - Crash airway scenario with the patient in a cardiac arrest situation, unconscious, and apneic, which requires immediate intervention with no medications

P – Plan B

The first P in this series refers to the predetermined plan for dealing with a difficult or failed orotracheal intubation. A complicated situation can rapidly become a disaster if no pre-implemented plan is in place to mitigate unanticipated difficulty. An emergency airway cart, containing difficult intubation equipment, can keep all needed tools readily available. See Box 2.10 for an example emergency airway cart.

P – Predict a Difficult Intubation

A thorough evaluation of the patient prior to attempts at laryngoscopy can help to predict a difficult intubation. The LEMON law can be used as a tool for airway evaluation. The description below adds "S" for saturation.

By discussing out loud your primary plan, your plan B, and the conditions which will mandate an emergent cricothyrotomy, it will make it easier to move to cricothyrotomy if indicated.

L – Look Externally

External anatomical features that can predict difficult intubation are short muscular neck, protruding upper incisors, high-arched palate, receding mandible, and severe facial trauma.

E – Evaluate Internally: The 3-3-2 Rule

The rule describes the ideal external dimensions of the airway.

3 – the opening of the jaw should be far enough to accommodate three fingers (3–4 cm).
3 – the distance from the mentum to the hyoid bone should be at least three fingerbreadths.
2 – the distance from the floor of the mouth to the thyroid cartilage should be at least two fingerbreadths.

M – Mallampati

The Mallampati classification was developed to correlate a simple visual inspection of the patient's pharynx with the ability to obtain direct visualization of the larynx. Airways are designated as Class I, II, III, or IV. Mallampati classes roughly correlate with the Cormack and Lehane direct laryngoscopic views, graded as 1, 2, 3, and 4 (Figure 2.1).

Box 2.10 Airway Management Supplies

Emergency Airway Supplies (example)

- A complete set of RSI drugs
  - Induction/Sedation agents: Etomidate, ketamine
  - Paralytic agents: Succinylcholine, rocuronium, vecuronium
  - Adjunctive medications: Atropine, lidocaine
- Various ET tube sizes and types: Pediatric and adult
  - Oropharyngeal and nasopharyngeal airways
- Additional laryngoscope parts
  - Miller and Macintosh blades
  - Standard laryngoscope handle
  - Pediatric laryngoscope handle
- Video laryngoscopy tools
  - GlideScope
  - C-Mac
  - Airtraq
- Airway Adjuncts
  - Tracheal Introducer (Bougie)
  - LMA – laryngeal mask airway
  - ILMA – intubating LMA
  - King LT
  - Retrograde intubation sets
- Surgical Airway Tools
  - Percutaneous and open cricothyrotomy kits
  - Scalpels (#10, #11, #15 blades)
  - Extra instruments
- Various size needles and syringes

O – Obstruction

Blood in the upper airway, foreign body, expanding hematoma, abscess, swelling of intraoral structures, or laryngeal edema.

N – Neck mobility

Inability to flex or extend the neck (c-collar, arthritis, etc.), Cervical spine injury.

S – Saturation

An oxygen saturation <85% portends an impending desaturation that can occur very rapidly. This does not allow much time to perform the intubation and may result in cardiac arrest due to hypoxemia.