CRASH
Guiding the future of patient care

2026 Trauma Anesthesia Panel

Beth Benish MD

Rich Ing MD

AJ Ferrone MD

Anesthesiology
UNIVERSITY OF COLORADO
ANSCHUTZ MEDICAL CAMPUS

1

Disclosures

No financial disclosures

2

Panel Learning Objectives

- Management of Pediatric Blunt Thoracic Trauma
- Management of Severe Brain Trauma
- Role of POCUS in Trauma

3

CRASH
Guiding the future of patient care

Anesthetic Considerations in Blunt Thoracic Trauma for Pediatric Patients

Richard Ing, MBBCh, FCA (SA)
CRASH 2026
University of Colorado
Department of Anesthesiology
Richard.ing@childrenscolorado.org

Anesthesiology
UNIVERSITY OF COLORADO
ANSCHUTZ MEDICAL CAMPUS

4

Objectives

1. Understand the mechanism of injury and pathophysiology of severe blunt force thoracic injuries especially in children.
2. Preparing anesthesia for the severely injured polytrauma child.
3. Develop an Approach to Managing Blunt Heart Injuries

5

Epidemiology of Blunt Chest Trauma

Blunt Thoracic Aortic Injuries (BTAI)

USA and Canada: 7500- 8000 Deaths Annually

80 % of Patients die before Hospital Arrival

15-23 % of those who Reach Hospital :
Succumb to associated injuries within 24 hrs

Fabian TC et al. J Trauma 1997 42(3) 374-80

6

Blunt Chest Trauma (BCT)

15% of all Trauma Admissions to ER Worldwide

2nd Leading Cause of Death after Head Injury in MVA's

Mortality from BCT reported 9-60%

Trauma : 45 % of deaths in children :1 to 14 years.

Eghbalzadeh K Blunt Chest Trauma : a Chameleon. Heart. 2017 Dec 4.

7

Blunt Thoracic Trauma in Children

Thoracic Trauma accounts for <10% of injuries in Pediatric trauma patients.

2nd commonest cause of death in Pediatric Trauma.

Blunt Thoracic trauma accounts for 85-90% of injuries.

MVA accounts for 70-77% of thoracic injuries.

Falls account for 8-11%.

CT ionizing radiation concerns in children, gentler imaging recommended

Orscheln E et al. Imaging in Blunt Thoracic trauma. Pediatric Radiology 2025 Aug 9.Online ahead of print PMID: 40782254

8

Unique Pediatric Considerations

Thinner, more complaint chest wall.

More energy transmission less Rib Fractures

Shearing forces a bit less

Increased Susceptibility to Tension Physiology (Blood or Air)

Pedestrian (shorter, great direct chest impact risk)

Orscheln E et al. Imaging in Blunt Thoracic trauma. Pediatric Radiology 2025 Aug 9.Online ahead of print PMID: 40782254

9

Imaging

Chest Xray

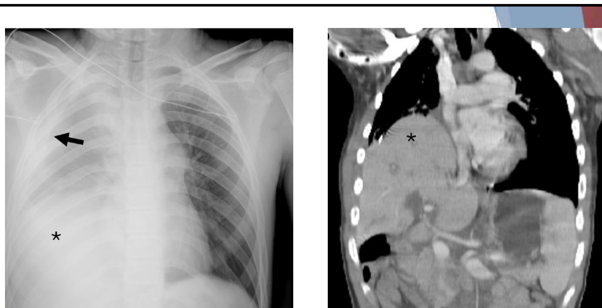
1235 Pediatric Patients Blunt Thoracic Trauma.

Specificity of Chesty Xray 90%

Subsequent CT change in management less than 9%.

Ugalde IT, et al Chest X-ray vs. computed tomography of the chest in pediatric blunt trauma. J Pediatr Surg (2021) 56:1039-1046

10



Ugalde IT, et al Chest X-ray vs. computed tomography of the chest in pediatric blunt trauma. J Pediatr Surg (2021) 56:1039-1046

11

Scoring Trauma in Pediatrics

Helps with Triage

3 Main Ways TO SCORE TRAUMA

The body regions affected by trauma

The mechanism of trauma

The severity of the trauma

12

Accident Risk : High Energy Impact

Fall Height
<2 yrs of age:>1 m
≥ 2 yrs of age : >1.5 m
Or 2-3 times height of child
High risk auto: ejection, intrusion of car , other passenger death
Head struck
Auto vz pedestrian
Fall greater than from 5 stairs

Teppas JJ Pediatric Trauma Score J Pediat Surg :1987: 22: 14-8
Sasser SM, Guidelines on Field triage 2011 MMWR 2012: 61: 1-20
Anil M J pediatric Emerg Intensive Care 2017: 4: 1-7

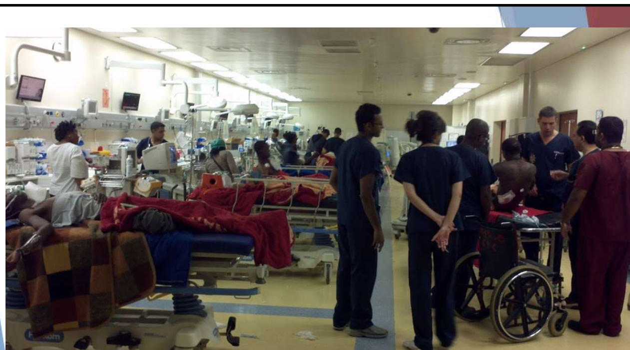
13

Why this Topic?

3rd Largest Hospital World
3200 beds
429 buildings
173 acres
70% admissions emergencies
150 000 annual inpatients
500 000 outpatients

Chris Hani Baragwanath Hospital Soweto South Africa
Med student till end of resident training 1984 - 1995

14



15

Demetrios Demetriades, MD

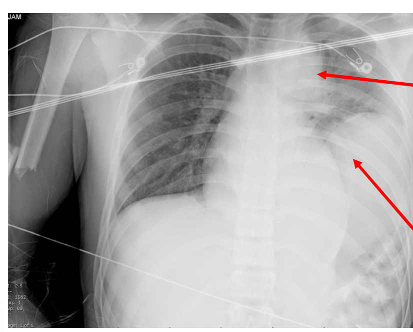
George Velmahos, MD

16

40 feet
150 feet

15-year-old boy 75 kg
Motorcycle injury
Wearing a Helmet no LOC
Abrasion front lower abdomen
Fractured R Humerus
Neck Collar
Pale Hb 9.8 g/dl
2 Peripheral 20 Gauge IVs

17



Aortic disruption mediastinal hematoma that extends into the retroperitoneum

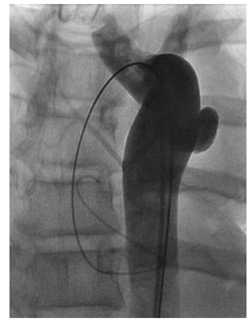
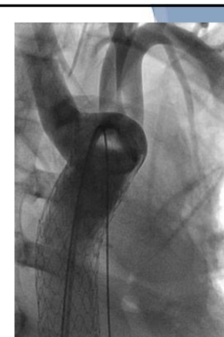
Herniation of the Stomach into the left Hemi-Thorax: Diaphragmatic Injury

18

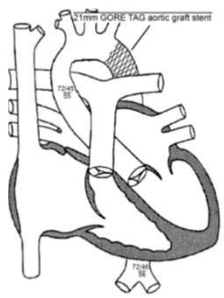
Anesthetic Approach

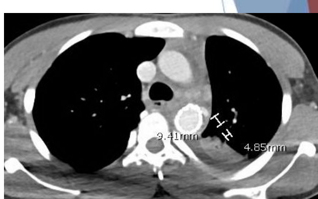
- Prepare for a lengthy Anesthetic 3:45 am -10:45am.
- Radiology Suite (Cold) Exposed Extremities ± Thoracotomy / Laparotomy
- Airway Considerations: Neck Collar
- Appropriate Vascular Access and Invasive Monitoring (Art line CVP)
- Serial Hb/ ABG: Associated abdominal injury ongoing bleeding
- Heparinization
- Inotropes
- Urinary Catheter (Contrast enhanced diuresis + length of procedure)
- Blood Products / Patient Air Convection Warmer
- Antibiotic Prophylaxis and Redose

19

20

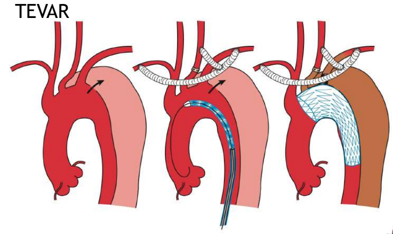




21mm by 10cm Gore Thoracic Aortic Graft (TAG)

21

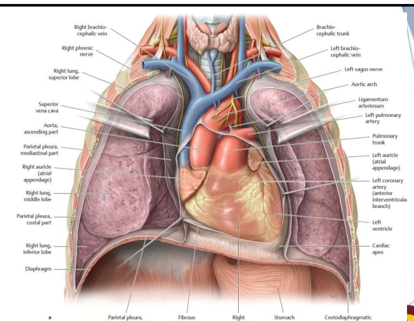
Within a week he underwent bilateral carotid-subclavian bypass and a second TEVAR



22

Anatomy and Mechanisms of Injury

23



https://basicmedicalkey.com/organs-of-the-cardiovascular-system-and-their-neurovasculature-2/

24

Pneumothorax

- Pathophysiology:
  - Penetrating- flap
  - Blunt- deep breath against closed glottis or puncture from rib
- Diagnosis:
  - Absent or diminished breath sounds
  - CXR (upright and expiratory better)
  - CT scan
- Management:
  - Penetrating: repair injury if sucking then chest tube
  - Occult: On CT alone, chest tube, watch or nothing
  - On CXR: chest tube or pigtail
  - Prophylactic antibiotics for three doses

25

Blunt Thoracic Aortic Injuries

26

Chest Trauma Primary Assessment

Feel
Deviated trachea (away from tension)
Crunchy (crepitus)

Listen
Decreased or no Breath Sounds
Murmurs/Rubs
Distant Heart Sounds

Look
Cyanosis
Shortness of breath
One side not moving
Foreign bodies
Bruises
Flail Chest (Rib # s)
JVD (esp. low BP)

27

Pneumothorax

- Pathophysiology:
  - Penetrating- flap
  - Blunt- deep breath against closed glottis or puncture from rib
- Diagnosis:
  - Absent or diminished breath sounds
  - CXR (upright and expiratory better)
  - CT scan
- Management:
  - Penetrating: Three-sided cover if sucking then chest tube
  - Occult: On CT alone, chest tube if OR or nothing
  - On CXR: chest tube or pigtail
  - Prophylactic antibiotics for three doses

28

Other Important Injuries

Tracheobronchial injuries

Usually 2 cm from carina (R)

Signs :

Dyspnea cough, stridor

Subcutaneous emphysema,

hemoptysis,

Pneumothorax.

May need rigid Bronch for ETT

Pulmonary injury

Hypoxia,

Intraparenchymal hemorrhage, Atelectasis,

Hemothorax

Pulmonary contusion

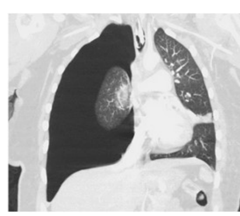
Acute respiratory distress syndrome (ARDS).

Mechanical Ventilation

Vishnu Madapura MBBS, and Gabriel Pollock MD, Cedars – Sinai Medical Center, Los Angeles, CA. OpenAnesthesia

29

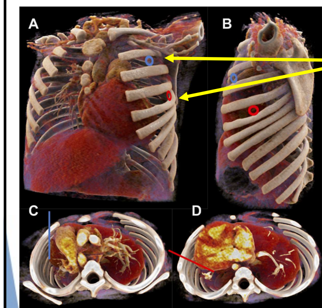
Tension Pneumothorax



Increased intrathoracic pressure, compression and pushing mediastinal contents
can kink the vena cava
Therapy : Needle decompression
Chest tube

https://pedemmorsels.com/traumatic-pneumothorax/

30



2nd ICS MCL and 4th ICS AAL

In Children Aged:

0 Yrs 22G/2.5 cm
5 Yrs 20G/3.2 cm
10 Yrs 18G/4.5 cm

21 month old girl Leonhard et al. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine (2019) 27:90 https://doi.org/10.1186/s13049-019-0671-x

31

BTAI Mechanism of Injury & Epidemiology

Direct Impact Anterior Chest
Compression of Thorax
Deceleration Injury

MVA	70%
Motorcycles	13%
Auto-Pedestrian Collisions	7%
Falls & Crush Injury	7%

Head on	72%
Side Impact	24%
Rear Impact	4%

Fabian TC J Trauma 1997 42(3) 374-80

32

CDC reported 41911 traffic related deaths in 2008.

Autopsy Analysis : Los Angeles; Chatsworth, train accident 25 fatalities.

Thoracic Aortic Rupture 33% of fatalities.
Cardiac Rupture 21% of fatalities.

Extrapolation Based on this study;
Every Year, 14,000 Traffic Fatalities have Blunt Thoracic Aortic Injuries.

Demetriades D. Blunt thoracic aortic injuries: crossing the Rubicon. J Am Coll Surg. 2012 Mar;214(3):247-59.

33

DELAYED POST-TRAUMATIC RUPTURE OF THE AORTA IN A YOUNG HEALTHY INDIVIDUAL AFTER CLOSED INJURY

MECHANICAL-ETIOLOGICAL CONSIDERATIONS

MAX A. ZEHNDER, LT. COL. (M.C.), U.S.A.R.[1]

Experiments:
1,000 - 2,500 mmHg pressure required to rupture the Aorta.
Confirming the earlier work of Oppenheim from 1918

OPPENHEIM, F.: Gibt es eine spontan ruptur der gesunden aorta und wie kommt sie zustande? Muenchen med. Wchnschr., 65: 1234, 1918.

ZEHNDER MA. Delayed post-traumatic rupture of the aorta in a young healthy individual after closed injury; mechanical-etiological considerations. Angiology. 1956 Jun;7(3):252-67.

34

Nonpenetrating Traumatic Injury of the Aorta

By LOREN F. PARMLEY, LT. COLONEL, MC, THOMAS W. MATTINGLY, BRIG. GEN., MC, WILLIAM C. MANION, M.D., AND EDWARD J. JAHNKE, JR., MAJ., MC

275 Autopsy cases:

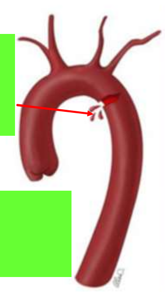
15% of cases temporarily survive.

This article influenced and aggressive therapeutic approach for the next 50 years.

PARMLEY LF, et al. Nonpenetrating traumatic injury of the aorta. Circulation. 1958 Jun;17(6):1086-101.

35

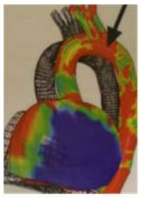
Medial Aspect Aortic Isthmus
90% Reaching Hospital
80% Autopsy Fatal Cases



False Aneurysm	58%
Dissection	5%
Intimal Tear	20%

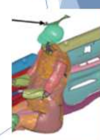
Demetriades D. Blunt thoracic aortic injuries: crossing the Rubicon. J Am Coll Surg. 2012 Mar;214(3):247-59

36



Lateral impact Motor vehicle accidents impart **46,051 to 313,502 Joules Energy** to the chest.
Force of > 1,000 mmHg Intra-Aortic pressure needed to Rupture the Aorta



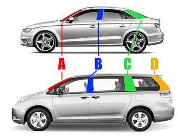


Siegel JH et al. Analysis of the mechanism of lateral impact aortic isthmus disruption in real-life motor vehicle crashes using a computer-based finite element numeric model: with simulation of prevention strategies. J Trauma. 2010 Jun;68(6):1375-95.

37

B Pillar of Car Frames

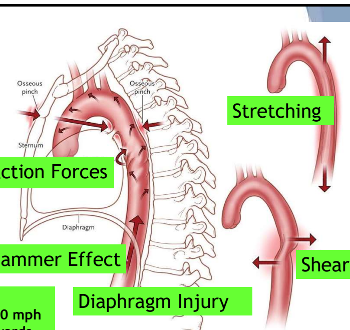
Force of the B Pillar of the car frame impact has on On the Human body in car accidents determines the extent of injuries



Siegel JH et al. Analysis of the mechanism of lateral impact aortic isthmus disruption in real-life motor vehicle crashes using a computer-based finite element numeric model: with simulation of prevention strategies. J Trauma. 2010 Jun;68(6):1375-95.

38

High Speed
Sudden
Deceleration
Compression



Side impact MVA
Sudden Change in speed of > 20 mph
Car wall moves > 15 inches inwards

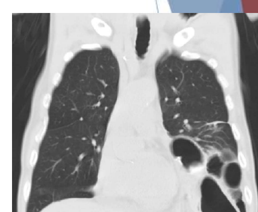
Horton TG, J Trauma 2000; 48: 1008-13

Neschis DG NEJM 2008; 359 1708-17016

39

Blunt diaphragmatic and thoracic aortic rupture: An emerging injury complex

In one study of 3,886 Pts
69 (1.8%) had BDR
44(1.1%) TAR
7/69 (10%): both injuries



Rizoli S. The Annals of Thoracic Surgery 1994 58 (5) 1404-1408
Mahmoud A.F. Rupture diaphragm: Early diagnosis and Mx. EJCM 2017 . 25, (2), 163-170

40

Massive Blunt Chest Compression

Vascular Injuries to Ascending / Descending Aorta, Innominate Artery

Heart time End-Diastole **{Distended Ventricle}** Most Susceptible of high Intraventricular Cavity Volume

Lungs Airway Contusion, Hemothorax, Pneumothorax, Laceration

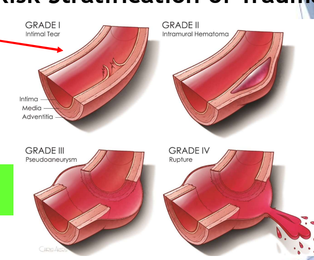
Skeletal Fractures of Sternum/ Thoracic Vertebrae/ Ribs

Sandhu H.K. J Vasc Surg. 2018 Feb;67(2):389-398

41

Classification & Risk Stratification of Traumatic Aortic

Watch expectantly
Conservative therapy
depending on injury site



Starnes: Stratify as Minimal or Significant injury based on presence of an external aortic contour abnormality

Sandhu H.K. J Vasc Surg. 2018 Feb;67(2):389-398
Starnes BW, et al. A new classification scheme for treating blunt aortic injury. J Vasc Surg. 2012 55(1):47-54.
Lee WA et al. Endovascular repair of traumatic thoracic aortic injury: J Vasc Surg. 2011 53(1):187-92

42

Diagnostics: A clinical chameleon

Prepare for Rapidly Changing Clinical Condition

Individual Signs Symptoms Prompt Investigations

No Gold-Standard Diagnostic Test (ATLS Protocol)

Complex Cardiac Arrhythmia	Angina-like Chest pain
Heart Murmurs	Dyspnoea
Hypotension	Distended Jugular Veins
	Pneumothorax/ Cardiac Tamponade

Teyssier J et al. Photonic crystals cause active colour change in chameleons. Nat Commun. 2015 Mar 10;6:6368. Eghbalzadeh K Blunt Chest Trauma : a Chameleon. Heart. 2017 Dec 4.

43

Diagnostic Approach

Physical Examination
Chest X-Ray (14% may be normal)
Serial 12 lead ECG
Cardiac Enzymes CK-MB and Troponin
Cardiac Echo

Chest X-Ray: Rib, Sternum, Spine
Scapula, Clavicle Fracture
Widened Mediastinum >8 cm
Tracheal Deviation, NG tube R
Loss of Aorto-Pulmonary Window

Contrast CT scan
Suspected Coronary Artery
Injury: Coronary Angiogram

Eghbalzadeh K Blunt Chest Trauma : a Chameleon. Heart. 2017 Dec 4.

44

Demetriades D. Blunt thoracic aortic injuries: crossing the Rubicon. J Am Coll Surg. 2012 Mar;214(3):247-59

45

Management of Thoracic Trauma

3 Distinct Phases of Care:

Pre-hospital trauma life support

In-hospital or emergency room trauma life support

Surgical trauma life support

Ludwig C. Management of Chest Trauma J Thorac Dis 2017;9(Suppl 3):S172-S177

46

Initial Management

Active Extravasation : Immediate life-saving Surgery. No Delay.

Most patients reaching hospital have a contained rupture.

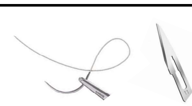
Rigorous Blood Pressure Control

(Systolic as low as tolerated 90-110 mm Hg usually)

Decreases risk of rupture from 12% down to 1.5% in first 24 hrs. B-blockers commonly prescribed.

Fabian TC et al. Prospective study of blunt aortic injury: Multicenter Trial of the American Association for the Surgery of Trauma. J Trauma. 1997 Mar;42(3):374-80
Demetriades D. Blunt thoracic aortic injuries: crossing the Rubicon. J Am Coll Surg. 2012 Mar;214(3):247-59

47



Treatment Options

1997, Kato and colleagues first reported endovascular stent grafting in 10 patients all alive at 15 months follow-up.

However not all ruptured Aortas amenable to this therapy: Ongoing bleeding, greater than 1 liter blood loss hemodynamically unstable patient: Surgery

Kato N et al. Traumatic thoracic aortic aneurysm: treatment with endovascular stent-grafts. Radiology. 1997 Dec;205(3):657-62.

Schellenberg M Inaba K. Critical Decisions in the Management of Thoracic Trauma. Emerg Med Clin N Am 2018 135-147

48

Endovascular Repair

0% used in 1997
65% used in 2007

Performed Under Sedation
Local Anesthesia
Minimizes Blood Loss
Well Tolerated in High Risk Pts
Minimizes Paraplegia
Reduces Mortality

Demetriades D et al. Operative repair or endovascular stent graft in blunt traumatic thoracic aortic injuries: results of an American Association for the Surgery of Trauma Multicenter Study. J Trauma. 2008 Mar;64(3):561-70

49

Disadvantages

Endoleak 14 %
Groin access vascular damage
Stent Migration
Subclavian/ Carotid occlusion

We still don't know the extent of medium and long term durability of these stents

High volume centers better outcomes

Demetriades D et al. Operative repair or endovascular stent graft in blunt traumatic thoracic aortic injuries: results of an American Association for the Surgery of Trauma Multicenter Study. J Trauma. 2008 Mar;64(3):561-70

50

National trends in utilization and outcome of thoracic endovascular aortic repair (TEVAR) for traumatic thoracic aortic injuries

In-hospital Mortality after TEVAR decreased:
33.3% in 2005 to 4.9% in 2011 (P < .001)

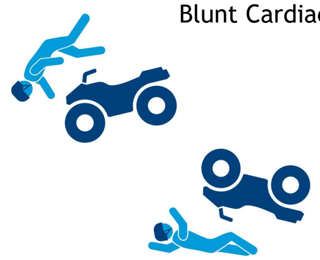
Procedural Mortality (TEVAR or open repair) decreased:
14.9% to 6.7% (P < .001)

Mortality after any TTAI Admission declined:
24.5% to 13.3% during the study period (P < .001).

Ultee KHJ et al. J Vasc Surg 2016;63:1232-9
Demetriades D et al. J Trauma. 2008 Mar;64(3):561-70

51

Blunt Cardiac Injuries



https://www.childrenscolorado.org/pediatric-innovation/research/surgery/screening-for-pediatric-cardiac-injuries-after-atv-accidents/
https://medictests.com/quick-dirty-guide-chest-trauma/

52

Heart Injury due to Blunt Chest Injury

1 st blunt injury to the heart reported in 17th Century
Took 3- 400 years to record the first successful repair

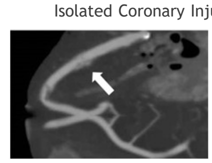
End-Diastole {Distended Ventricle}
Most Susceptible time of high Intraventricular Cavity Vol / Pressure

Warburg E. Myocardial and Pericardial lesions due to Non-penetrating Injury. Br Heart J 1940;2(4):271-80.
Bellister SA, et al. Blunt and Penetrating Cardiac Trauma. Surg Clin North Am. 2017 Oct;97(5):1065-1076.

53

Heart Injuries

Commotio Cordis Ventricular fibrillation with no structural damage
10 to 30 ms before the peak of the T wave
Contusio Cordis Myocardium, Valves, Conduction System
Isolated Coronary Injuries / Rupture / Dissection



Inokuchi G et al. Fatal right coronary artery rupture following blunt chest trauma: detection by postmortem selective coronary angiography. Int J Legal Med. 2016 May;130(3):759-63.
Link MS et al. An experimental model of sudden death due to low-energy chest-wall impact (commotio cordis) N Engl J Med. 1998 Jun 18;338(25):1805-11.

54

Blunt Cardiac Injury : Spectrum

Minor ECG or Enzyme Abnormality
Complex Arrhythmia
Coronary Artery thrombosis
Free Wall Rupture
Septal Rupture
Cardiac Failure

Categories of Force Causing Myocardial Injury
Direct
Indirect
Compressive
Decelerate
Blast

Mattox KL et al. Blunt cardiac injury. J Trauma. 1992 Nov;33(5):649-50.

55

Physical Examination

Thoracic trauma
Hypotension
Jugular venous distention
Tachypnoea/ Wheezing/ Rhonchi
Chest abrasion/ tenderness/ palpable crepitus/ flail chest
Fractured clavicle/ sternum/ ribs
Distant heart sounds/ tachycardia/ rub/ murmurs/ pulsus paradoxus

Elie MC. Blunt cardiac injury. Mt Sinai J Med. 2006 Mar;73(2):542-52.

56

Diagnostics: ECG

Blunt Chest Trauma : Significant Injuries
85% Have an Abnormal Admission ECG.
Commonly: Sinus Tachycardia and PAC or PVC

Other changes:
T wave changes: Depression or elevation/ atrial fibrillation/ flutter
Conduction delay/ New Q waves

Christensen MA et al. Myocardial contusion: new concepts in diagnosis and management. Am J Crit Care. 1993 Jan;2(1):28-34.

57

Diagnostics: Cardiac Enzymes

CK-MB not recommended:
Skeletal muscle, Lung, Stomach, Pancreas, Liver, Small Intestine

Troponin I : Heart specific . If elevated > 2.0 ng/ml : Significant

Normal ECG and No rise in Troponin at 8 hours:
No Other Injuries
Negative Predictive value 100% : Discharge the patient

Velmahos GC et al. Normal electrocardiography and serum troponin I levels preclude the presence of clinically significant blunt cardiac injury. J Trauma. 2003 Jan;54(1):45-50

58

Diagnostics: Point of Care Echo

Up to 30% of BCI patients have abnormal cardiac echo
Pericardial Effusion and Tamponade are Common

Focused Assessment with Sonography for Trauma (FAST)
Rapid screening 1.30 +/- 0.08 mins vs. X- Ray ; 14.18 +/- 0.91 mins, p < 0.0001
Indications: Heart failure, Hypotension, Arrhythmia

Frazee RC et al. Objective evaluation of blunt cardiac trauma. J Trauma. 1986 Jun;26(6):510-20.
Sisley AC et al. Rapid detection of traumatic effusion using surgeon-performed ultrasonography. J Trauma. 1998 Feb;44(2):291-6

59

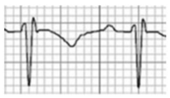
2 Patients: June and July 2013, ATV Accidents

Case 1
35 kg 11 yr old
LOC at scene brief CPR
Lacerated Knee: Debridement at outside hospital under GA.
Post op CT found large heart:
Cardiac Echo
Troponin 38.9 (0-0.119 ng/mL)
CPB at CHCO
Tricuspid valve papillary muscle
Avulsion repaired. Home POD 5

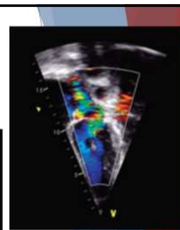
Ngo KD, Pian P, Hanfland R, Nichols CS, Merritt GR, Campbell D, Ing RJ. Pediatr Emerg Care. 2016 Jul;32(7):468-71. Cardiac Injury After All-Terrain Vehicle Accidents in 2 Children and a Review of the Literature.

60

Case 2



68 kg 13 yr old : No LOC
Troponin 9.4 ng/mL.
ECG wide complex tachycardia.
Cardiac Echo: TR, MR, VSD.
CPB repair:
Received Porcine TV, MV.
VSD Patch Necrotic Septum.
3rd degree Heart block :
Epicardial pacemaker
Home POD 6 Warfarin Aspirin



61

Anesthetic Induction Approach

Start normal saline bolus of 10 mL/kg
If signs of inadequate perfusion are present -
relative bradycardia; SBP < 70 + (2 x age):
EPINEPHRINE 1 mcg/kg slow IV/IO every 3-5 minutes as required
KETAMINE 0.5 mg/kg IV/IO
In patients with adequate perfusion and heart rate (can consider adding gas)
KETAMINE 1 mg/kg IV/IO
EPINEPHRINE on "stand-by" 1 mcg/kg slow IV/IO
every 3-5 minutes as required or infusion 0.02-0.05 mcg/kg/min

62

Maintenance

KETAMINE: ½ of the induction dose every 10-15 minutes as required to maintain sedation

Additional of benzodiazepine at 0.1 mg/kg as required

FENTANYL: consider 1-3 mcg/kg IV/IO every 10-15 minutes if pain is believed to be a major factor

Normal saline: 10 mL/kg as required

EPINEPHRINE as required

63

Anesthetic Considerations

In Thoracic Blunt Injury Poly-Trauma:
Consider Multi-Organ Involvement
(C-spine, head injury, lung, airway, diaphragm, aorta, heart, pericardium, long bone, pelvis)
Anticipate Lengthy Surgery, Invasive Monitoring and IV Access.
Any Endovascular Procedure may need to be:
Converted to Open Surgical
Transfusion & Inotropes & Intensive Care Post-Op Disposition

64

Additional Anesthetic Considerations

Always check for Occult bleeding (abdomen when working on chest)

Large Bore IV access upper and lower limb depending on injuries

Arterial line & CVP

Temperature management/ blood warmer/ Belmont rapid IV infuser

Keep up with Bleeding

Blood Product Cross Match (Massive Transfusion Protocol)

65

Anesthetic Considerations

Metabolic Considerations

Dependent on Rate and Volume of Resuscitation:

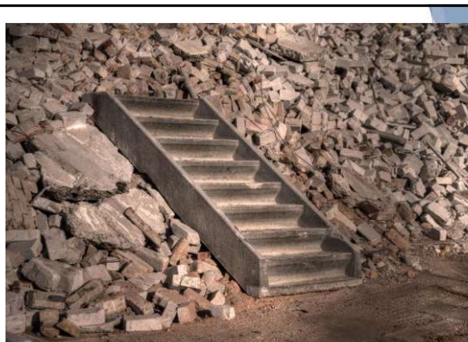
Antibiotics 4 hrly IV Cefazolin 30-40 mg/kg

Metabolic Acidosis with hyperlactemia is common (Cardiac Output)

Hypocalcemia, Hypomagnesemia, Hyper / Hypo kalemia

TACO & TRALI risk is ever present in Children

66



67

Crush Syndrome Traumatic Rhabdomyolysis

1. Involvement of muscle mass
2. Prolonged compression (usually 4-6 hrs, but possibly <1 hr);
3. Compromised local circulation.

Hypovolemic shock and hyperkalemia

Increased creatine kinase > 10.000u/l

Intravenous fluids during extrication 10- 20 mls/kg /hr

Low urine pH cause myoglobin to form

a gel renal tubular damage

Gonzalez D. Crush Syndrome Crit Care Med 2005 Vol. 33, No. 1

68

Conclusions

Blunt Chest Trauma can lead to Severe Aortic and Myocardial injuries

Clinical signs : Subtle and Change Rapidly

Strict Preoperative Blood Pressure Control In Aortic Injuries

Diagnosis : CT scan, ECG , Cardiac Enzymes, Cardiac Echo

69

CRASH

Guiding the future of patient care

Update: Anesthesia for Traumatic Brain Injury

Bethany Benish MD
Assoc Chair Anesthesiology
Director of Trauma Anesthesia
Denver Health Medical Center

DENVER HEALTH

Anesthesiology
UNIVERSITY OF COLORADO
ANSCHUTZ MEDICAL CAMPUS

70

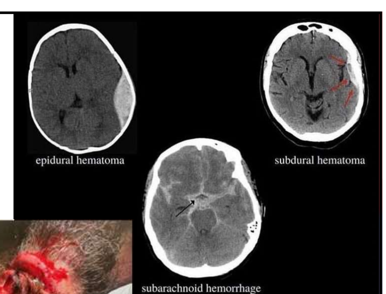
Traumatic Brain Injury

- 70 million people sustain TBI each year, 5.5 million severe
  = 8.1 million years lived with disability
- Moderate to severe TBI → 30% rate of full dependence or death by 6 months
  - significant financial burden; healthcare costs, & loss of employment productivity
- Increased over last few decades
  - More falls
  - More MVAs in developing countries
  - Older, more comorbidities, median age has doubled over last 40 years
  - Higher all cause mortality rate

71

TBI management

- Blunt and Penetrating
- EDH,SDH, SAH



72

Focus of care for Severe TBI Patients

- Prevent intraoperative **cerebral tissue hypoxia** and maintaining systemic homeostasis
- Careful anesthetic planning and meticulous control of the physiological parameters
- Management protocols adequate for the ICU for Neurotrauma are assumed to be also valid for the OR

73

Initial approach: Emergent vs Non-Emergent

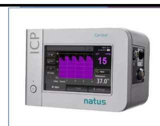
If non-emergent:
- Resuscitation and hemodynamic stability is priority before surgery!
- Severe hypovolemia/anemia ⟶ severe hypotension upon induction

- Impaired cerebral autoregulation for weeks after TBI, worse with higher GCS and higher ICP. Longer this lasts, worse the outcome

PreOp – evaluate other injuries (abd, chest, ortho) and severity
- Prioritize stopping extracranial hemorrhage before craniotomy
- If time permits, place ICP monitor before surgery to guide Intraoperative management

74

Who needs ICP monitoring?



Gold standard is EVD (diagnostic and therapeutic)

Recommended when:
- GCS <8 with structural damage on CT
- Worsening CT or clinical deterioration
- Patient that requires urgent extra-cranial surgery

- Also consider with GCS >8 when knowing ICP can facilitate management decisions
- Can assist with sedation weaning and extubation
- Associated with lower in-hospital mortality, lower 6-month mort

75

ICP treatment trigger?

- ICP alert threshold > 22 (range 20-25) for >5 min
- Threshold may be more dependent on individual patients and injury types
- Both degree and duration of ICP are important
  - Gradual ICP rise vs short term elevations

76

Management of Severe TBI (3 Tiers SIBICC)

First-Tier
- Optimize sedation & analgesia
- Head elevation & neutral position
- Hyperosmolar therapy (based on labs or clinical findings suggestive of elevated ICP):
  - Consider in patients with dilated and nonreactive pupils, asymmetric pupils, extensor posturing or no motor response, Cushing Response while awaiting definitive management
  - **3% Hypertonic saline bolus** (e.g., 2-5 mL/kg) or **23.4% HTS** (30mL over 5min)
  - **Mannitol** (0.5-1 g/kg)
  - Hold if serum sodium >165 or osmolarity >330
- CSF drainage if EVD is present

77

2nd Tier:
- Ensure airway, oxygenation. Temporary **hyperventilation** ($PaCO_2$ ~30-35 mm Hg) only as bridge
- Continuous hyperosmolar infusion (3%) if needed
- Paralysis for refractory ICP with appropriate sedation

78

Third-Tier

- Decompressive craniectomy for refractory ICP per neurosurgery consultation

79

POSSIBLE CAUSES OF NEUROWORSENING

- Expanding intracranial mass lesion
- Cerebral edema
- Elevated ICP
- Stroke
- Electrolyte or other metabolic disturbance
- Medical comorbidity
- Medication effect
- Impaired renal or hepatic function
- Systemic hypotension
- Seizure or post-ictal state
- Hypoxemia/tissue hypoxia
- CNS infection
- Infection or sepsis
- Substance withdrawal
- Dehydration
- Hyper or hypothermia

80

What not to do:

- Routine steroids
- Continuous mannitol infusion
- CSF drain
- Furosemide
- Scheduled Hypertonic (q 4-6hr)
- Therapeutic hypothermia
- Hypocarbia $PaCO_2$ <30mmHg
- CCP above 90
- High dose propofol for burst suppression

81

Airway concerns with TBI

- Swelling face, blood/vomit, obtunded/uncooperative
- C-collar
- Approximately 6% of severe TBI also have C-spine injury, many unstable
  - VL should be the primary intubation tool in TBI, DL as backup
  - If unstable c-spine, flexible bronchoscope or hyperangulated VL are best
- Balance of appropriate depth of sedation
  - Avoid sudden MAP increases
  - Avoid hypoventilation/hypercarbia

82

Induction agents:

- **Etomidate**--maintains CPP, superior hemodynamics, consider if hypotensive
  - unfavorable effects in aneurysm clipping, risk of cerebral hypoxia
  - Lacks analgesia
  - no role in sedation/maintenance
- **Ketamine**--safe, preserves CPP/may prevent secondary neuro injury
  - Maintains HD stability
  - BP effect may offset hypotension associated with Fentanyl in RSI
  - weak & conflicting data of effect on neurophysiology
  - No increase O_2 consumption, no change in regional glucose consumption
  - Maintains spontaneous ventilation and airway reflexes if needed
  - Potent analgesic—excellent for RSI in TBI, great for sedation &maintenance
- Avoid Propofol in RSI unless hypertensive, lower your dose significantly
- **Ketofol**—maybe a great option

83

RSI options:

- NMB—succinylcholine or rocuronium are both fine
  - Succinylcholine RSI? Studies in ventilated TBI patients, no increase in ICP or CPP
    - Ensure adequate induction medications before DL
    - Can consider 2-5 mg Rocuronium pre-Succinylcholine as defasciculating dose
  - Rocuronium RSI 1.2mg/kg

84

Avoiding hypoxia during RSI is essential!

Preoxygenation can be challenging

Delayed sequence induction (DSI)-method used for intubating uncooperative TBI patients

- Dissociative dose of ketamine (0.5-1 mg/kg) before adequate preoxygenation and positioning, followed by neuromuscular blocking agent and subsequent intubation
- Resulted in higher first-attempt success and lower hypoxia rates, making it a viable alternative to RSI
- Good option in agitated patients

85

Maintenance?

Volatile vs Propofol TIVA – similar neurologic outcomes

- TIVA with propofol/opioid associated with lower BP
- A meta-analysis including 14 studies with over 1800 patients who underwent craniotomy, TIVA compared with inhalation anesthesia
  - ICP was 5 mmHg lower and CPP approximately 16 mmHg higher with TIVA than with volatile anesthesia,
  - No difference in operative conditions after dural opening, recovery profiles, postoperative complications, or neurologic outcome

If VA is use, Sevoflurane is preferred agent, most favorable profile on CMR and CBF, keep less than 1 MAC

86

What about other maintenance adjuvants?

Ketofol TIVA vs Propofol

- higher MAPs, lower vasopressor need
- Similar brain relaxation

Adding **dexmedetomidine** to propofol-based TIVA

- Reduces doses of propofol and fentanyl without any difference in ICP, CPP, hemodynamics, or brain relaxation scores

87

Ventilation Goals

- Normoxemia and normocarbia
- Protective lung ventilation strategies, titrate PEEP for oxygenation
  - minimal effect on ICP up to PEEP 15
- Use ABGs to guide hyperventilation rather than by end-tidal CO2 (ETCO2)
  - As briefly as possible to prevent herniation
  - Goal PaCO2 30-35mmHg
  - Goal PaO2 80-120mmHg
- Avoid ventilator dyssynchrony

88

BP and CPP Goals

- Goal in TBI: AVOID HYPOTENSION
- Incidence of hypotension during emergency craniotomy is 32-65%
  - Increased risk of death, persistent vegetative state/disability compared with patients without hypotensive episodes
  - The duration of intraoperative hypotension is inversely correlated with neurologic outcome
- Targeting SBP ≥ 110 mm Hg/MAP > 80 mm Hg will allow adequate cerebral perfusion in most cases when ICP is not being monitored
- Mortality increases linearly with every 10-point drop of SBP below 119 mm Hg in patients with TBI, suggesting that higher targets may be indicated than previously recognized.
- Treat hypotension early and aggressively, minimizing time CPP <60

89

Role of Osmotherapy

- Cerebral autoregulation is blunted/abolished
- **ICP should be reduced first, rather than increasing BP** in TBI, to avoid worsening cerebral edema & further elevating ICP
- **Mannitol**: use if impending herniation, 1g/kg
  - If EDH/SDH, can make extra-axial bleeding worse
- **Hypertonic saline**
  - More commonly used
- Recent meta-analysis involved 12 RCTs containing 464 patients and showed no significant difference between hypertonic saline and mannitol in terms of mortality or neurological outcome despite both drugs reducing ICP and improving cerebral perfusion pressure

90

Controversial role of TXA:

CRASH 3 (polytraumas with TBI)

- Criticisms:
  - No details included in study on type of TBI or CT findings
  - Not able to confirm that TXA administration reduced intracranial bleeding
  - Patients with moderate/severe TBI who received TXA showed a lower degree of fibrinolysis as assessed by reductions in D-dimer and plasmin-antiplasmin levels
  - Not demonstrated on TEG (insensitivity of this tool for the assessment of fibrinolysis)
- Studies show increased mortality in isolated severe TBI
  - Hypercoagulable state affecting cerebral microcirculation?
- Recent large meta-analysis on TXA in TBI
  - No effect on mortality or neurologic recovery

91

Choice of Fluids:

- Avoid dropping sodium (LR is hypotonic)
- Avoid excessive NS (hyperchloremic acidosis)
- Use plasmalyte, or alternate LR and NS
- Albumin?
  - Hypoalbumin is independent risk factor for mortality in TBI, normalization of oncotic pressure with slowly infused hyperoncotic 20-25% albumin reduced mortality
  - SAFE trial (saline vs albumin) increased mortality with 4% albumin
    - Probably no role for colloid/albumin in TBI
- Match urine output with fluids

92

Transfusion triggers:

- Keep Hgb >7, liberal trigger of >9 → worse neurologic outcome
  - age of blood doesn't matter
- Avoid thrombocytopenia
- Early evaluation of coagulopathy
  - TEG based resuscitation
  - patients with TBI (n = 74),there was an improvement in 24-h survival with the use of viscoelastic testing (OR 2.12 (95%CI 0.84-5.34).
  - INR <1.4
- Reverse anticoagulants

93

TBI coagulopathy

- TBI frequently develop coagulopathies, closely associated with poor outcomes
- Incompletely understood complex derangement of coagulation
- Characterized by immediate post-injury hypercoagulability, followed by hyperfibrinolysis and bleeding
- In addition, many patients presenting with TBI are taking anticoagulants or antiplatelet drugs for other medical conditions

94

- Pre-injury anticoagulation and antiplatelet therapy are associated with higher risk of ICH and higher mortality
- In patients with VKAs presenting with coagulopathy and life-threatening bleeding, the INR should be corrected
- Prothrombin concentrate is preferred over FFP, as it corrects the INR faster

95

Platelets

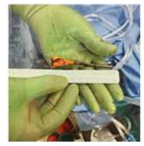
- Early thrombocytopenia and platelet dysfunction is common after TBI
  - Independent risk factor for mortality and poor outcomes
- Routine administration of platelets is not recommended even in patients on antiplatelet agents because of the lack of outcome data
- Quantify platelet dysfunction (e.g., TEG) and using transfusions or desmopressin to improve platelet function
- Platelets to reverse effect so antiplatelets in TBI does reduce hematoma expansion, no improvement in mortality or neuro outcome

96

Other considerations

- Early Seizure prophylaxis with Levetiracetam (Keppra) or Phenytoin (Dilantin) — Similar efficacy
- Treat hypo/hyperglycemia (goal 80-140)
- Avoid high dose glucocorticoids in TBI
- Prevent Hyponatremia—goal Na 135-145
- Consider VTE prophylaxis within 24-4hr if ICH is stable on CT

97




Penetrating Brain injuries

98

Concerns specific to Penetrating TBI

Traumatic vascular injury?
- Proximal vascular control? neck exposure?
- Large cranial decompression/wide craniectomy
- Circulatory pause? Adenosine in room
- PRBC/FFP/Plt ready

Protruding foreign body?
- Timing and setting of removal
- CSF leak/Dural repair

Traumatic aneurysm?
- Endovascular management?

Mass lesion/Edema?

Skull base Involved?
- CSF leak

99

Concerns with extubation

- TBI patients fail extubation wean frequently, higher unplanned extubation and reintubation rates compare to other ICU patients
- HTN, coughing, vomiting—increasing ICP, bleeding
- Avoid hypoventilation—hypercarbia, increasing CBF/ICP
- Extubation criteria:
  - ICP normalized
  - No evolving lesions on CT
  - Intact upper airway reflexes and cough

100

Emergence HTN

- Very common
- Recognize and treat quickly.
  - Avoid intracranial hemorrhage
  - Avoid worsening cerebral edema in those areas where the blood-brain barrier is disrupted
- Treatment should be titrated to avoid hypotension, cerebral hypoperfusion, and enlargement of an area of cerebral ischemia
- Labetalol and Nicardipine both effective

101

Summary of goals in Severe TBI

- Facilitate early decompression if ICH with expanding hematoma
- Maintain CPP 65-80mmHg (MAP-ICP)
- Avoid Hypotension, hypoxemia, hyper/hypocarbia, hypo/hyperglycemia, coagulopathy, seizures
- Adequate analgesia/amnesia
- Facilitate early postop neuro evaluation when feasible
  - If high ICP, not a good time to wean/extubate
- Aline—always but do not delay evacuation of hematoma
- ICP—ideally yes—remember to monitor closely during transport
  - EVD clamp or not to clamp? Clamp trial

102

Outcomes in TBI

- Like all trauma, heterogenous population/injury patterns
- Extracranial surgery worsens outcome, lower GCS and lower cognitive performance at 60 days and 6 months
  - If not urgent, postpone other procedures beyond the acute phase
  - Time urgent surgery for when ICP is well controlled (ideally within 48hrs)
  - Damage control orthopedic surgery(early ex-fix), timing of definitive treatment can be challenging
  - Avoid laparoscopic because of increased intraabdominal pressure and hypercarbia risk
  - Facial fractures rarely need emergent intervention
- Difficulty predicting long term outcomes based on initial exam/imaging

103

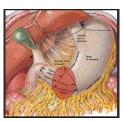
References:

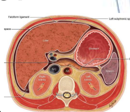
- Coronado, V.G.; McGuire, L.C.; Faul, M.; Sugerman, D.E.; Pearson, W.S. Traumatic Brain Injury Epidemiology and Public Health Issues. In Brain Injury Medicine; Springer Publishing Company: New York, NY, USA, 2012.
- Lawati KA, Sharif S, Maqbali SA, et al. Efficacy and safety of tranexamic acid in acute traumatic brain injury: a systematic review and meta-analysis of randomized-controlled trials. Intensive Care Medicine 2021; 47: 14-27.19.
- Yokobori S, Yatabe T, Kondo Y, Kinoshita K. Efficacy and safety of tranexamic acid administration in traumatic brain injury patients: a systematic review and meta-analysis. Journal of Intensive Care 2020; 8: 46.20.
- Williams J, Roberts I, Shakur-Still H, Lecky FE, Chaudhri R,Miners A. Cost-effectiveness analysis of tranexamic acid for the treatment of traumatic brain injury, based on the results of theCRASH-3 randomized trial: a decision modelling approach. British Medical Journal Global Health 2020; 5.
- Wiedermann CJ. Use of hyperoncotic human albumin solution in severe traumatic brain injury revisited-a narrative review and meta-analysis. J Clin Med 2022; 11:2662.
- SAFE Study Investigators, Australian and New Zealand Intensive Care Society Clinical Trials Group, Australian Red Cross Blood Service et al. Saline or albumin for fluid resuscitation in patients with traumatic brain injury. N Engl J Med 2007; 357:874-884
- Fang, T., Valdes, E. & Frontera, J.A. Levetiracetam for Seizure Prophylaxis in Neurocritical Care: A Systematic Review and Meta-analysis. *Neurocrit Care* **36**, 248-258 (2022).
- Baksaas-Aasen K, Gall LS, Stensballe J, et al. Viscoelastic haemostatic assay augmented protocols for major trauma haemorrhage (ITACTIC): a randomized, controlled trial. Intensive Care Medicine 2021; 47: 49-59
- Brogi E, Corbella D, Coccolini F, et al. The role of platelet transfusions after intracranial hemorrhage in patients on antiplatelet agents: a systematic review and meta-analysis. World Neurosurgery 2020; 141: 455-66.e13.
- Guidelines for the Management of Severe TBI, 4th Edition — Brain Trauma Foundation
- Guidelines — Brain Trauma Foundation
- Guidelines for Prehospital Management of TBI, 3rd Edition — Brain Trauma Foundation
- SIBICC Severe TBI Algorithm for Patients with ICP Monitoring (2019) — Brain Trauma Foundation

104

PoCUS FOR TRAUMA: IT'S MORE THAN SIMPLY FAST

Dr. AJ Ferrone, MD
Denver Health and Hospital Authority
University of Colorado





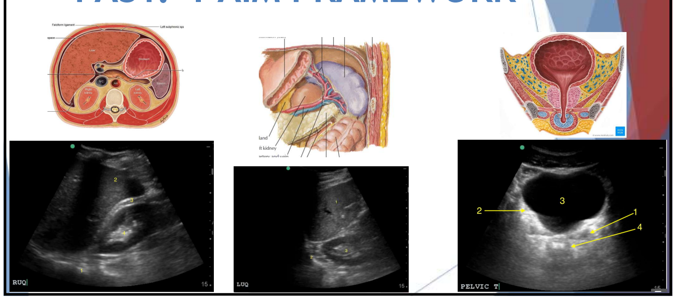
105

LEARNING OBJECTIVES

- Understand the I-AIM framework as it applies to the E-FAST exam.
- Identify the indications for the E-FAST.
- Know how to position the patient for the E-FAST.
- Understand how to acquire the necessary images for the E-FAST.
- Interpret the ultrasound images and use the results to augment medical decision-making.

106

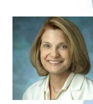
FAST: I-AIM FRAMEWORK



107

INTRODUCTION: FAST

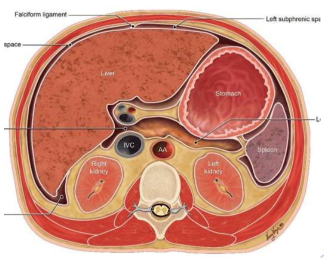
- FAST: Focused Assessment with Sonography in Trauma
- Grace Rozycki: trauma surgeon who developed protocol to obtain the four FAST images
  - Peri-hepatic right upper quadrant (RUQ) view
  - Peri-splenic left upper quadrant (LUQ) view
  - Pelvic view (longitudinal and short axis)
  - Subcostal four-chamber (SC4C) view



- Excellent specificity, moderate sensitivity → best initial imaging modality, but negative FAST necessitates additional measures

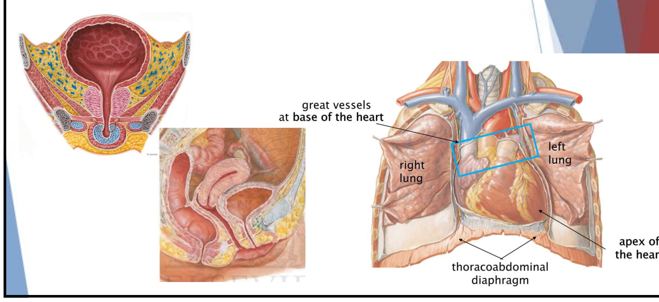
108

ANATOMY



109

ANATOMY, CONT…



110

I-AIM FRAMEWORK

Focused assessment with sonography in trauma (FAST) for the regional anesthesiologist and pain specialist

William Clark Manson,[1] Meghan Kirksey,[2] Jan Boublik,[3] Christopher L Wu,[4] Stephen C Haskins[4]

*I*ndication

*A*cquisition

*I*nterpret

*M*edical decision-making

111

INDICATION

Box 1 Clinical indications for the focused assessment with sonography in trauma (FAST) exam

- Hypotension in the postanesthesia care unit (PACU).
- Narrowing the differential diagnosis in patients who are critically ill.
- Nausea and/or abdominal pain following hip arthroscopy.
- Identify a pericardial effusion causing tamponade physiology.
- Persistent hypotension in the intensive care unit (ICU).
- Initial evaluation of hypotensive trauma patients.
- Re-evaluation of trauma patients.

- NOT a definitive imaging modality
- Does NOT rule out free fluid in abdomen (best w/ 300 – 1000cc)

IAFE: intra-abdominal fluid extravasation

Haskins SC, Desai NA, Fields KG, et al. Diagnosis of intraabdominal fluid extravasation after hip arthroscopy with point-of-care ultrasonography can identify patients at an increased risk for postoperative pain. Anesth Analg 2017;124:791–9.

112

ACQUISITION

- Probe selection: curvilinear (+/- phased array, for subcostal four-chamber)
- On-screen orientation marker:
  - curvilinear: LEFT
  - cardiac: RIGHT

113

ACQUISITON, CONT…

- Patient positioning
  - supine, w/ arms abducted (or raised overhead, if possible)
  - slight T-berg will increase RUQ and pelvic sensitivity
  - generous fanning

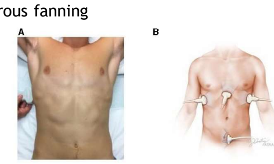
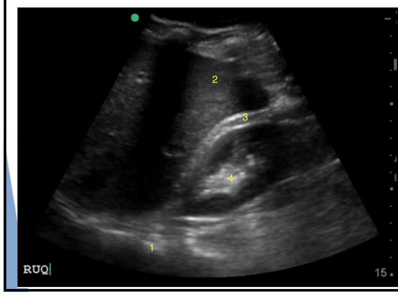


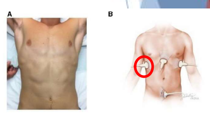
Figure 2 (A) Patient position for the FAST exam. (B) Probe positions for the FAST exam. FAST, focused assessment with sonography in trauma.

114

INTERPRETATION, RIGHT UPPER QUADRANT (RUQ)

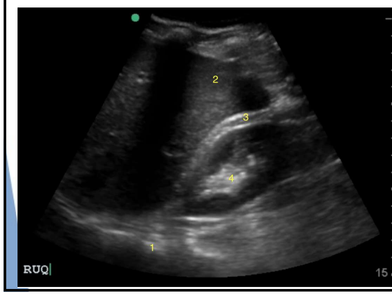


- orientation marker cephalad (coronal plane)
- b/t 8th-11th intercostal spaces
- mid-posterior axillary line
- !! MUST VISUALIZE LOWER LIVER TIP !!



115

INTERPRETATION, RIGHT UPPER QUADRANT (RUQ), CONT…



1. Spine
2. Liver
3. Hepato-renal ligament (Morison's Pouch)
   - most dependent (common) area to pool
   - pools once 500cc accumulates
   - high index of suspicion → repeat T-berg
4. Kidney

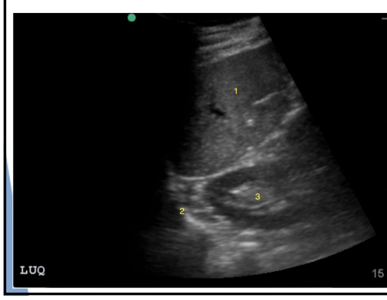
116

INTERPRETATION, RIGHT UPPER QUADRANT (RUQ), CONT…

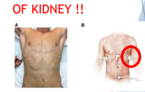
- Fluid in Morison's pouch
  - indeterminate due to image quality
  - free fluid IS visualized in peritoneal cavity
  - free fluid IS NOT visualized in peritoneal cavity

117

INTERPRETATION, LEFT UPPER QUADRANT (LUQ)



- orientation marker cephalad (coronal plane)
- b/t 6th – 9th intercostal spaces
- posterior axillary line
  - spleen in smaller than the liver
  - spleen in more posterior
  - stomach interferes
- !! MUST VISUALIZE INFERIOR POLE OF KIDNEY !!



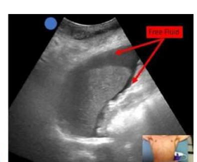
118

INTERPRETATION, LEFT UPPER QUADRANT (LUQ), CONT…

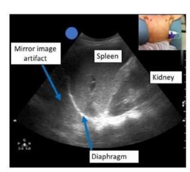
1. Spleen
2. Diaphragm
3. Kidney

119

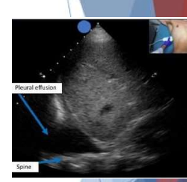
INTERPRETATION, LEFT UPPER QUADRANT (LUQ), CONT…



Free fluid



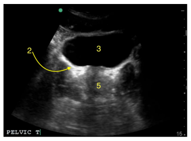
Mirror image artifact

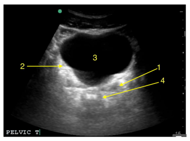


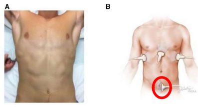
Spine sign
fluid in thorax

120

INTERPRETATION, PELVIC, MALE



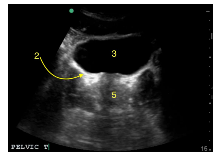


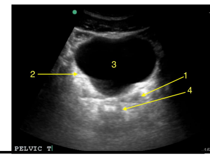


- orientation marker cephalad, lateral/medial
- suprapubic area
- Planes:
  - Transverse
  - sagittal

121

INTERPRETATION, PELVIC, MALE, CONT…

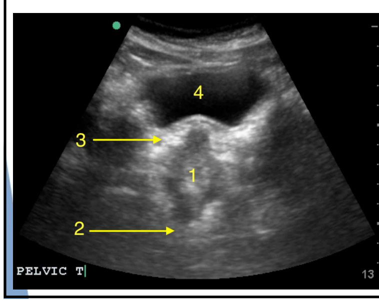




1. Seminal vesicle
2. Posterior acoustic enhancement
3. Bladder
4. Rectum
5. Prostate

122

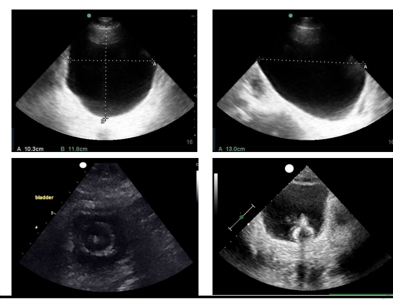
INTERPRETATION, PELVIC, FEMALE



1. Uterus
2. Recto-uterine space (pouch of Douglas)
3. Vesiculo-uterine space
4. Bladder

123

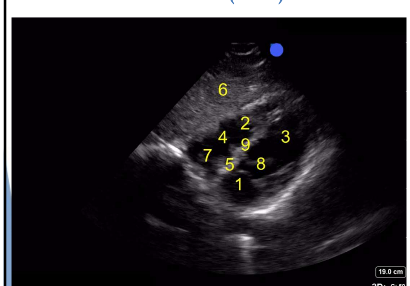
INTERPRETATION, PELVIC, CONT…



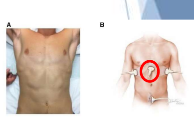
- Bladder volume = 0.75 * D1*D2*D3
- >500cc = damage to detrusor muscle
- Margin of error ~ +/- 200cc

124

INTERPRETATION, SUBCOSTAL FOUR-CHAMBER (S4C)



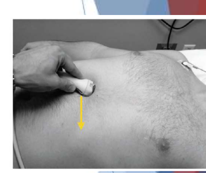
- hold like a screw-driver
- orientation marker initially to patient's right, then 10-15 degrees counterclockwise
- deep inspiration improves imaging

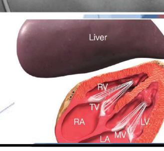


125

SUBCOSTAL FOUR-CHAMBER (S4C)

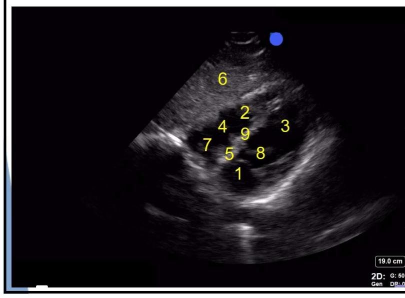
- Positioning: supine position; if poor views, place pillow behind knees to reduce abdominal tone
- Breathing: optimized w/ partial or full inhale followed by breath hold (diaphragm falls, probe closer to heart)
- Probe position: place probe 1-2 cm below xyphoid process, indicator to patient's (L), pushed down into patient's abdomen, and forward (create window using liver).





126

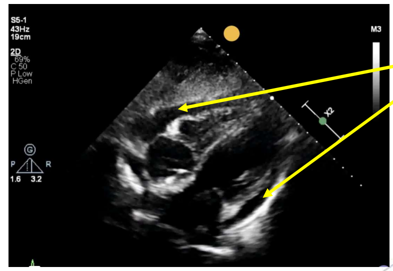
INTERPRETATION, SUBCOSTAL FOUR-CHAMBER (S4C), CONT…



1. left atrium
2. right ventricle
3. left ventricle
4. tricuspid valve
5. interatrial septum
6. liver
7. right atrium
8. mitral valve
9. Inter - ventricular septum

127

INTERPRETATION, SUBCOSTAL FOUR-CHAMBER (S4C), CONT…



128

MEDICAL DECISION-MAKING

	RUQ	LUQ	PELVIC	CARDIAC
Free fluid IS visualized				
Free fluid IS NOT visualized				
Indeterminate				

YES / NO ➡

OVERALL

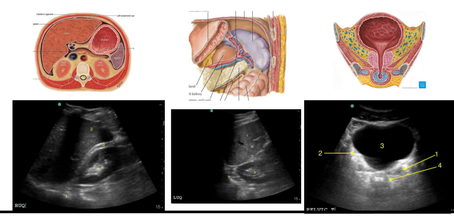
FREE FLUID?

- NO → HDS?
  - NO
    - repeat in T-berg
    - continued fluid resuscitation
    - other dx steps
  - YES
    - 2° survey
    - other dx steps
- YES → HDS?
  - NO
    - surgical consult
  - YES
    - observation
    - 2° survey
    - other dx steps
    - consult

129

REVIEW AND REFERENCES

Manson WC, Kirksey M, Boublik J, Wu CL, Haskins SC. Focused assessment with sonography in trauma (FAST) for the regional anesthesiologist and pain specialist. Reg Anesth Pain Med. 2019 May;44(5):540-548. doi: 10.1136/rapm-2018-100312. Epub 2019 Mar 21. PMID: 30902912.



130

I-AIM FRAMEWORK

Intensive Care Med (2012) 38:577–591
DOI 10.1007/s00134-012-2513-4

CONFERENCE REPORTS AND EXPERT PANEL

International evidence-based recommendations for point-of-care lung ultrasound

Giovanni Volpicelli
Mahmoud Elbarbary
Michael Blaivas
Daniel A. Lichtenstein
Gebhard Mathis
Andrew W. Kirkpatrick
Lawrence Melniker
Luna Gargani
Vicki E. Noble
Gabriele Via
Anthony Dean
James W. Tsung
Gino Soldati
Roberto Copetti
Belaid Bouhemad
Angelika Reissig
Eustachio Agricola
Jean-Jacques Rouby
Charlotte Arbelot
Andrew Liteplo
Ashot Sargsyan
Fernando Silva
Richard Hoppmann
Raoul Breitkreutz
Armin Seibel
Luca Neri
Enrico Storti
Tomislav Petrovic
International Liaison Committee on Lung Ultrasound (ILC-LUS) for the International Consensus Conference on Lung Ultrasound (ICC-LUS)

Indication

Acquisition

Interpret

Medical decision-making

131

INDICATION

(I) Indication

Diagnostic Tool

- Unexplained respiratory symptoms (dyspnea, pleuritic chest pain) or signs (tachypnea, desaturation, abnormal finding on respiratory physical examination)
- Unclear chest radiograph finding
- Suspicion of:
  - Pneumothorax
  - Pleural effusion
  - Airspace disease (increased lung density)
    - Increased lung weight
      - Extra Vascular Lung Water (*e.g.*, cardiogenic or nonhydrostatic pulmonary edema—ARDS, idiopathic interstitial pneumonias, lung consolidation, pneumonitis, pulmonary infarct)
      - Pus (*e.g.*, infection, pneumonitis, lung consolidation)
      - Blood (*e.g.*, alveolar hemorrhage)
      - Protein/Collagen (*e.g.*, idiopathic interstitial pneumonias, alveolar proteinosis, lung consolidation, pulmonary infarct)
      - Cells (*e.g.*, primary or metastatic lung cancer)
      - Lipids (*e.g.*, lipoid pneumonia)
    - Decreased lung aeration with no increased lung weight (*i.e.*, atelectasis)

Monitoring and Prognostic tool

- Mechanical ventilation:
  - Re… itment str… ies
  - … fail…
- Dis…
  - Effu… on, resolution, changes in characteristics
  - Int… e/consolidation: progression or resolution of lung deaeration/increased density
  - … expansion or increase in size
- Fl… nce
- Ident… ation of pa… ts with worse prognosis (heart failure and end-stage renal disease)

132

ACQUISITION

(A) Acquisition

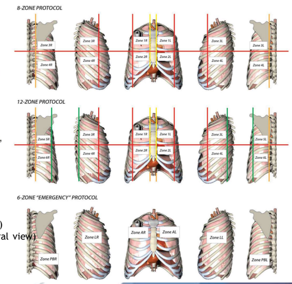
PATIENT
- Position
  - o Pneumothorax: supine
  - o Effusion: supine or semisitting
  - o Interstitial syndrome/consolidation: supine or semisitting
  - o Posterior lung zones: torso rotation and ipsilateral arm abduction
- Adjust ambient light
- Expose and drape hemithorax
- Surface preparation (adjust monitoring cables/leads and dressings, if possible)

PROBE
- Probe selection
  - o Pleural line: consider higher frequency probe (≥ 5 MHz)
  - o Posterior/Supradiaphragmatic lung: curvilinear, microconvex, or phased array probe
  - o Lung parenchyma: consider curvilinear, microconvex, or phased array probe
- Probe orientation: marker placed cephalad or toward patient's right

133

ACQUISITON, CONT…

Scan — Antero-Lateral Lung:
- STEP 1: Sagittal scanning plane with visualization of minimum two ribs; identify pleura
- STEP 2: Tilt the probe to achieve probe angulation perpendicular to pleural line; confirm perpendicular angle by the presence of A-line pattern (in absence of B-lines) and/or best definition of pleural line appearance
- STEP 3: Hold transducer still to identify pleural movement with respiration (M-mode if required)
- STEP 4: Adjust depth to identify vertical artifacts/B-lines, sliding/pulse and pleural line characteristics



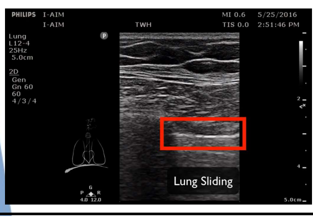
1. mid-clavicular line, 2nd-3rd intercostal space ("anterior view")
2. Anterior axillary line, 4th-5th intercostal space ("antero-lateral view")
3. Mid-to posterior axillary line, 5th-7th intercostal space ("postero-lateral view)

134

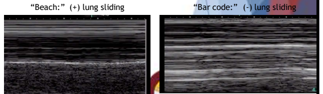
INTERPRETATION

Lung sliding — Shimmering movement synchronous with respiration at the pleural line indicating sliding of the visceral pleura against the parietal pleura (Supplemental Digital Content 2, http://links.lww.com/ALN/B514)

- Present in normal lung or in pathologic conditions that do not affect ventilation
- Absent or reduced when visceral pleura does not slide against parietal pleura: apnea, inflammatory adherences, loss of lung expansion (overinflation/distension or severe bullous disease), decrease in lung compliance, airway obstruction/atelectasis, pleural symphysis, endobronchial intubation
- Absent when visceral and parietal pleura are separated (*i.e.*, pneumothorax; Supplemental Digital Content 1, http://links.lww.com/ALN/B515)



"Beach:" (+) lung sliding — "Bar code:" (-) lung sliding



These are "adjuncts;" they are NOT studied, recognized

135

INTERPRETATION, CONT…

"Beach:" (+) lung sliding — "Bar code:" (-) lung sliding

These are "adjuncts;" they are NOT studied, recognized "signs"

- M-mode's extremely high temporal resolution may result in anY tissue movement being interpreted as lung pulse
- An absence of lung sliding DOES NOT MEAN PNEUMOTHORAX!!
- M-mode in isolation can miss subcutaneous emphysema

136

MEDICAL DECISION-MAKING, CONT…

CHEST — Original Research — CHEST IMAGING

Occult Traumatic Pneumothorax*

Diagnostic Accuracy of Lung Ultrasonography in the Emergency Department

Gino Soldati, MD; Americo Testa, MD; Sara Sher, MD; Giulia Pignataro, MD; Monica La Sala, MD; and Nicolò Gentiloni Silveri, MD

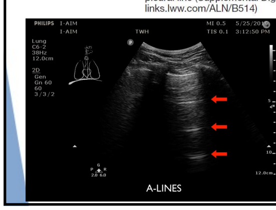
Background: The role of chest ultrasonography (US) in the diagnosis of pneumothorax (PTX) has been established, but how it compares with lung CT scanning in the diagnosis of radiooccult PTX and in the determination of its topographic extension has not yet been completely evaluated.
Objective: To determine the diagnostic accuracy of chest US in the emergency department (ED) in the diagnosis of occult PTX in trauma patients and to define its ability to determine PTX extension.
Design: An 18-month prospective study.
Patients: A total of 109 conscious, spontaneously breathing patients who had been admitted to the ED for chest trauma or polytrauma.
Methods: All eligible patients underwent a standard anteroposterior supine chest radiograph (Rx) and a spiral CT lung scan within 1 h of ED admission. Lung US was carried out by an operator who was unaware of the other examination results, both for diagnosis and for the quantitative delimitation of the PTX.
Results: Twenty-five traumatic PTXs were detected in the 218 hemithoraxes (109 patients; 2 patients had a bilateral PTX) evaluated by spiral CT scan; of these, only 13 of 25 PTXs (52%) were revealed by chest Rx (sensitivity, 52%; specificity, 100%), while 23 of 25 PTXs (92%) were identified by lung US with one false-positive result (sensitivity, 92%; specificity, 99.4%). In 20 of 25 cases, there was agreement on the extension of the PTX between CT lung scan and lung US with a mean difference of 1.9 cm (range, 0 to 4.5 cm) in the localization of retroparietal air extension; chest Rx was not able to give quantitative results.
Conclusions: Lung US scans carried out in the ED detect occult PTX and its extension with an accuracy that is almost as high as the reference standard (CT scanning).
(CHEST 2008; 133:204–211)

137

INTERPRETATION, CONT…

A-lines — Hyperechoic horizontal lines at increasing depth separated by same distance as that between the probe and the pleural line. Considered reverberation artifacts arising from the strongly reflective interfaces of the probe and pleural line (Supplemental Digital Content 2, http://links.lww.com/ALN/B514)

- Present when air is homogenously distributed below the pleural line:
  - o Normally aerated lung
  - o Pneumothorax
  - o Pathologic conditions with minimal effect on lung aeration (*e.g.*, acute pulmonary embolism, asthma/acute COPD exacerbation, early phases of airway obstruction/atelectasis)
- Absent or reduced when:
  - o Increased lung density and nonhomogeneous distribution of air
  - o Nonperpendicular angulation of the ultrasound beam with the pleural line (Supplemental Digital Content 2, http://links.lww.com/ALN/B514)



PRO TIP: probe must be perpendicular to pleura, not chest wall

138

INTERPRETATION, CONT…

B-lines and interstitial syndrome

Discrete laser-like, vertical, hyperechoic artifacts that arise from the pleural line, extend to the bottom of the screen without fading, and move synchronously with lung sliding (Supplemental Digital Content 6, http://links.lww.com/ALN/B516 and Supplemental Digital Content 8, http://links.lww.com/ALN/B520)[2]

Three or more B-lines/intercostal space (sagittal scan) represent a positive region of increased lung density[2]:

- Normal aeration: fewer than two isolated B-lines/intercostal space
- Moderate loss of lung aeration (B1 pattern): presence of ≥ 3 well-defined spaced B-lines/intercostal space
- Severe loss of lung aeration (B2 pattern): multiple coalescent B-lines/intercostal space[27,28]

Vertical artifacts at the transition from consolidated to normally aerated lung ("shred sign") represent the same physical and pathophysiologic phenomenon as B lines, although not defined as such.[2]

- Present in conditions associated with increased lung density and involvement of alveolar units in close relationship with visceral pleura such as:
  - o Lung deflation (i.e., atelectasis)
    - ■ Normal pattern (if isolated at lung bases)
- Increased lung weight:
  - o Extra vascular lung water (e.g., cardiogenic or non-hydrostatic pulmonary edema—ARDS, idiopathic interstitial pneumonias, lung consolidation, pneumonitis, pulmonary infarct)
  - o Pus (e.g., infection, pneumonitis, lung consolidation)
  - o Blood (e.g., alveolar hemorrhage)
  - o Protein/Collagen (e.g., idiopathic interstitial pneumonias, alveolar proteinosis, lung consolidation, pulmonary infarct)
  - o Cells (e.g., primary or metastatic lung cancer)
  - o Lipids (e.g., lipoid pneumonia)
- Absent when visceral and parietal pleura are separated (i.e., pneumothorax; Supplemental Digital Content 1, http://links.lww.com/ALN/B515) and in normally aerated lung

B-lines are a sign of increased lung density and appear as a vertical ring-down artifact that propagates down from the pleural line, widens as it descends to the bottom of the screen, and usually (BUT NOT ALWAYS) effaces A-lines where the two lines intersect.

139

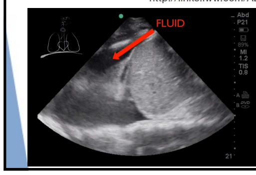
INTERPRETATION, CONT…

Pleural effusion

Anechoic (fluid) collection between the parietal and visceral pleura (Supplemental Digital Content 2, http://links.lww.com/ALN/B514 and Supplemental Digital Content 3, http://links.lww.com/ALN/B518). Associated with positive spine sign and absent curtain sign (Supplemental Digital Content 3, http://links.lww.com/ALN/B518 and Supplemental Digital Content 4, http://links.lww.com/ALN/B519)

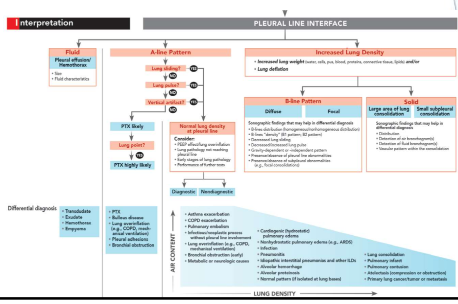
- Present most often in supradiaphragmatic regions; complex or loculated collections may be elsewhere

Note: Ultrasound cannot differentiate the nature of the pleural effusion (e.g., hemothorax, transudate, exudate) although visualization of mobile echoic particles or septa is highly suggestive of complex effusion (e.g., empyema; Supplemental Digital Content 3, http://links.lww.com/ALN/B518)



140

MEDICAL DECISION-MAKING



141

MEDICAL DECISION-MAKING, CONT…

- image quality is inadequate (or suspected subQ emphesyma)
- normal lung parenchyma and pleura (diffuse lung sliding and diffuse A-lines)
  - COPD/asthma
  - PE
  - Intra-cardiac / intra-pulmonary shunting
  - DEEP lung pathology (atelectasis, pneumonia)
- focal absence of lung sliding
  - Pneumothorax
  - Emphysematous bleb
  - Lung adhesions/pleurodesis
  - Mainstem intubation
- unilateral B-lines
  - Early atelectasis
  - Early pneumonia
  - Early malignancy
  - Lung contusion
  - pneumonitis
  - Early evolving PE
- bilateral B-lines
  - Hydrostatic pulmonary edema (CHF, NPPE, TACO)
    - Homogenously spaced, diffuse B-lines
    - Smooth and linear pleural line
  - Non-hydrostatic pulmonary edema (ARDS, TRALI)
    - Heterogenous spaced B-lines
    - Pleural line irregularities
  - Multifocal pneumonia
  - Interstitial lung disease / pulmonary fibrosis
- consolidation and/or effusion
  - Consolidation
  - Effusion
    - Transudate
    - Exudate
- gross extra-thoracic abnormalities
  - Ascites
  - Grossly full stomach

142

MEDICAL DECISION-MAKING, CONT…

The results of the lung ultrasound contribute in one of four ways to affect the outcome of the pre-test diagnostic hypothesis:

- Corroborate and support
- Mislead
- Inconsequential
- Completely change

143

BILLING

Logistics of perioperative diagnostic point-of-care ultrasound: nomenclature, scope of practice, training, credentialing/ privileging, and billing

Yuriy S. Bronshteyn, MD, FASE[a,b], Jeanna Blitz, MD[a], Nazish Hashmi, MD[a], Sundar Krishnan, MD[a]

Table 4
American Society of Anesthesiologists/American Society in Regional Anesthesia Expert Panel-recommended minimum numbers of supervised studies needed to achieve competence in specific diagnostic PoCUS domains.

PoCUS Application	Minimum Number of Supervised Studies Personally Performed and Interpreted ("Level 1" Studies)	Minimum Number of Additional Supervised Studies Interpreted but Need not be Personally Performed ("Level 2" Studies)
Focused cardiac ultrasound	50	100
Focused lung ultrasound	30	20
Focused Assessment with Sonography in Trauma (FAST)	30	20
Focused gastric ultrasound	30	20

PoCUS indicates point-of-care ultrasound.
Adapted from Bronshteyn et al[2] with permission from Elsevier. Adaptations are themselves works protected by copyright. So in order to publish this adaptation, authorization must be obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation.

Table 2
American Society of Anesthesiologists Expert Panel-suggested categorization of the relevance to perioperative anesthesiologists of common diagnostic point-of-care ultrasound modalities.[2]

Primary (Daily) Relevance to Perioperative Anesthesiologists	Secondary (Occasional) Relevance to Perioperative Anesthesiologists
Focused cardiac ultrasound	Focused airway ultrasound
Focused pleural-pulmonary (lung) ultrasound	Focused musculoskeletal/soft tissue ultrasound
Gastric ultrasound	Focused ocular ultrasound
Focused Assessment with Sonography in Trauma (FAST) exam	Focused renal/genitourinary ultrasound
	Focused transcranial Doppler ultrasound
	Focused ultrasound for deep venous thrombosis

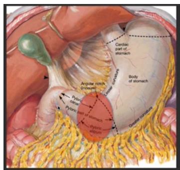
Table 7
CPT codes and work RVU for select anesthesiology-relevant diagnostic PoCUS applications.[29]

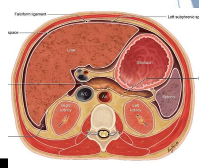
CPT Code	Clinical Application(s)	Full Description	Work RVU (2021)
76604	(1) Focused cardiac ultrasound and/or (2) lung ultrasound	Ultrasound, chest (includes mediastinum), real time with image documentation	0.59
76705	(1) Abdominal screening for free fluid (ie, FAST exam) or (2) focused gastric ultrasound	Ultrasound, abdominal, real time with image documentation; limited (eg, single organ, quadrant, follow-up)	0.59
76775	Renal/genitourinary ultrasound	Ultrasound, retroperitoneal (eg, renal, aorta, nodes) real time with image documentation (AAA)	0.58
76536	Airway ultrasound	Ultrasound, soft tissues of head and neck, real time with image documentation	0.56
93971	Lower extremity venous compression ultrasound	Duplex scan of extremity veins including responses to compression and other maneuvers; unilateral or limited study	0.45
93308	Limited point-of-care TTE (eg, CCE or PTTE)	Echocardiography, transthoracic, real time with image documentation (2D), includes M-mode recording, when performed; follow-up or limited study	0.53
93306	Comprehensive point-of-care TTE (eg, CCE or PTTE)*	Echocardiography, transthoracic, real time with image documentation (2D), includes M-mode recording, when performed, complete with spectral Doppler echocardiography, and with color flow Doppler echocardiography	1.46

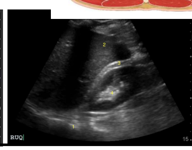
*Rarely performed in clinical practice.
CCE indicates critical care echocardiogram; CPT, Current Procedural Terminology; FAST, Focused Assessment with Sonography in Trauma; PTTE, perioperative transthoracic echocardiography; RVU, relative value unit; TTE, transthoracic echocardiography.

144

QUESTIONS?







145