PEDIATRIC READINESS PROGRAM EDUCATION SESSION

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PRP
PEDIATRIC READINESS PROGRAM
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PEDIATRIC TRAUMA UPDATE

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CME DISCLOSURE

None of the planners and faculty for this educational activity have relevant financial relationship(s) to disclose with ineligible companies whose primary business is producing, marketing, selling, reselling, or distributing healthcare products used by or on patients.

Why is appropriate trauma care important in children?

- Leading cause of death in children in America
  - 11,000 <18 annually
- Over 17 million ED visits/year
- 90% blunt trauma

OBJECTIVES

- Discuss changes in initial fluid resuscitation in traumatically injured children.
- Review massive transfusion protocols and the use of whole blood in pediatric patients.
- Describe changes in the management for pediatric solid organ injuries.

Fluids, Transfusion and Coagulopathy

Fluid resuscitation

- Fluid resuscitation/volume repletion is cornerstone of initial trauma resuscitation
- Must recognize issue is intravascular volume loss
- Fluid >>> pressors

TABLE 1

Vital Signs for Children

Age Group, y	Weight Range, kg	Heart Rate, beats/min	Systolic Blood Pressure, mm Hg	Respiratory Rate, breaths/min
<1 (Infant)	0–10	<160	>60	<60
1–3 (Toddler)	11–14	<150	>70	<40
3–5 (Pre–school-aged)	15–18	<140	>75	<35
6–12 (School-aged)	19–36	<120	>80	<30
>12 (Adolescent)	37–70	<100	>90	<30

From American College of Surgeons, Committee on Trauma. *Advanced Trauma Life Support Program for Doctors*, 7th ed. Chicago: American College of Surgeons; 2004. p. 252. Reprinted with permission.

Shock

- Initial fluid resuscitation recommendations
  - 20ml/kg crystalloid bolus x 2
  - Hesitancy to transfuse children
    - Processing of blood, antibody concerns, etc…

TABLE 2

Systematic Responses to Blood Loss in the Pediatric Patient

System	Mild Blood Volume Loss (<30%)	Moderate Blood Volume Loss (30%–45%)	Severe Blood Volume Loss (>45%)
Cardiovascular	↑ Heart rate; weak, thready peripheral pulses	Low normal blood pressure, narrowed pulse pressure, markedly ↑ heart rate; absent peripheral pulses with weak thready central pulses	Hypotension; tachycardia then bradycardia
Central nervous system	Anxious, irritable, confused	Lethargic, dulled response to pain	Comatose
Skin	Cool, mottled; prolonged capillary refill	Cyanotic; markedly prolonged capillary refill	Pale, cold
Urinary output	Minimal ↓	Minimal	None

From American College of Surgeons, Committee on Trauma. *Advanced Trauma Life Support Program for Doctors*, 7th ed. Chicago: American College of Surgeons; 2004. p. 251. Reprinted with permission.

Transfusion Medicine Reviews 30 (2016) 235–241

Shock Index- Pediatric Adjusted (SIPA)

- Children become hypotensive later into shock and most common abnormal vital sign is heart rate
- Calculation of SIPA can help resuscitation
  - Calculated by maximum heart rate/minimum systolic blood pressure
  - Elevated at >1.22 for 4-6.9 y/o, >1.0 for 7-12.9y/o and >0.9 for 13-16.9 y/o
- Predicted need for OR, intubation and transfusion

Journal of Pediatric Surgery 52 (2017) 340–344

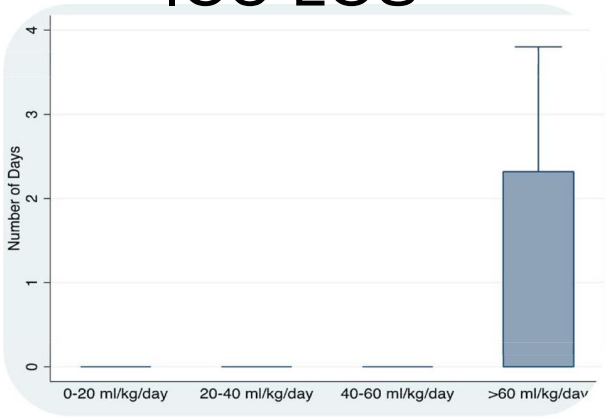
Crystalloid isn't all it's cracked up to be (duh, duh, dum)…

When stratifying amount of crystalloid resuscitation received, found that patients receiving

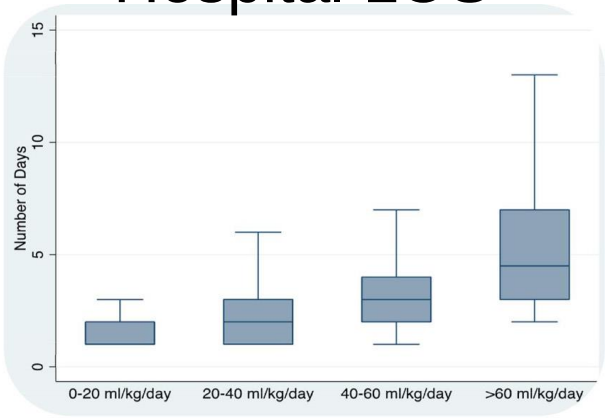
>60ml/kg in first 24 hours had significantly higher LOS, days NPO

>60ml/kg/day over 48 hours, higher ICU LOS, hospital LOS, vent days, days NPO

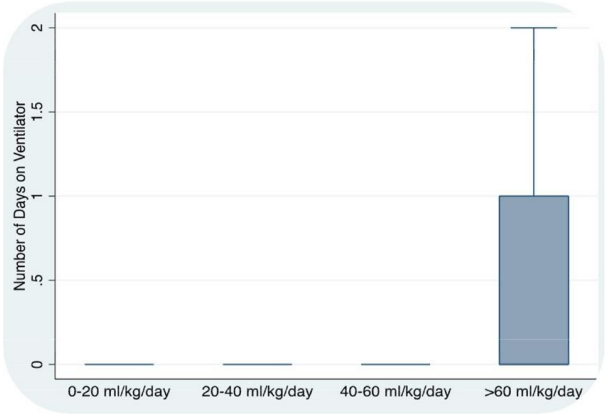
ICU LOS



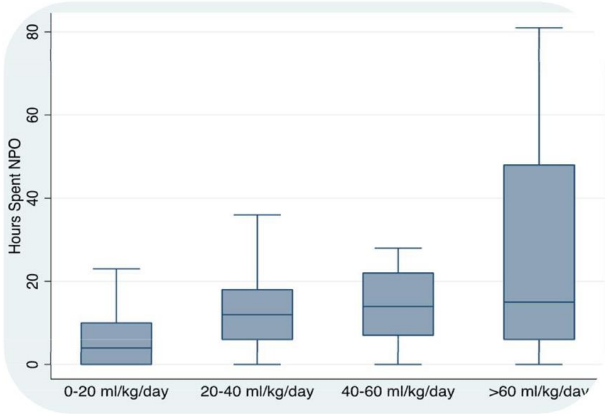
Hospital LOS



Vent Days



NPO Days



Fluid resuscitation first 24 hours

Journal of Pediatric Surgery 53 (2018) 2202–2208

Transfuse earlier, but when?

- Targeted transfusion

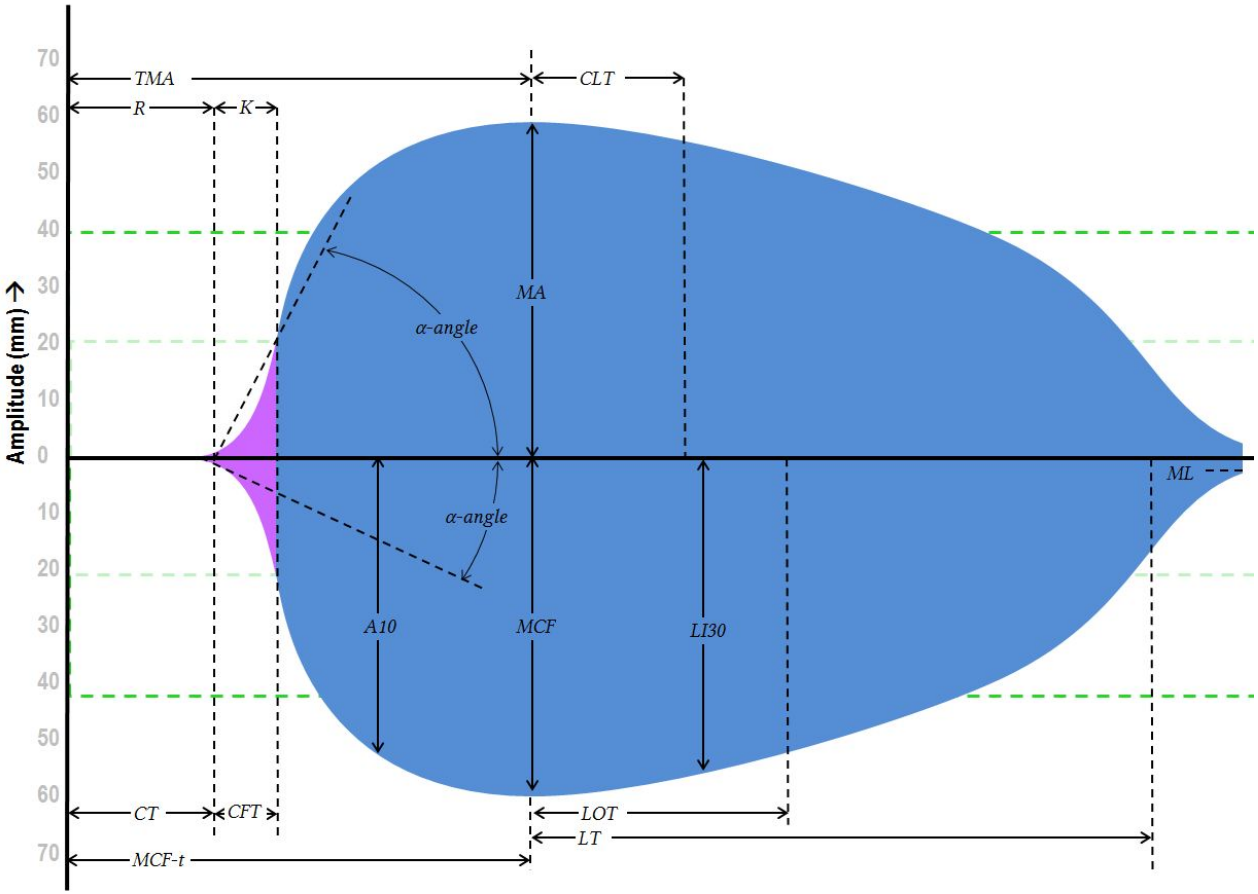
- Massive transfusion

Targeted transfusion

- Using ROTEM / TEG (ROtational ThromboElastoMetry and ThromboElastoGraphy)
  - Viscoelastic tests of clotting function
  - Point of care that take around 10-20 minutes for results
  - <1ml blood put in a little cup and a pin put in it, and it rotates
  - See how clotting works based on how the rotation is impeded (by clot formation)
    - **Tests fibrinolysis
    - Can differentiate between thrombocytopenia and low fibrinogen causes of coagulopathy

TEG NOMENCLATURE

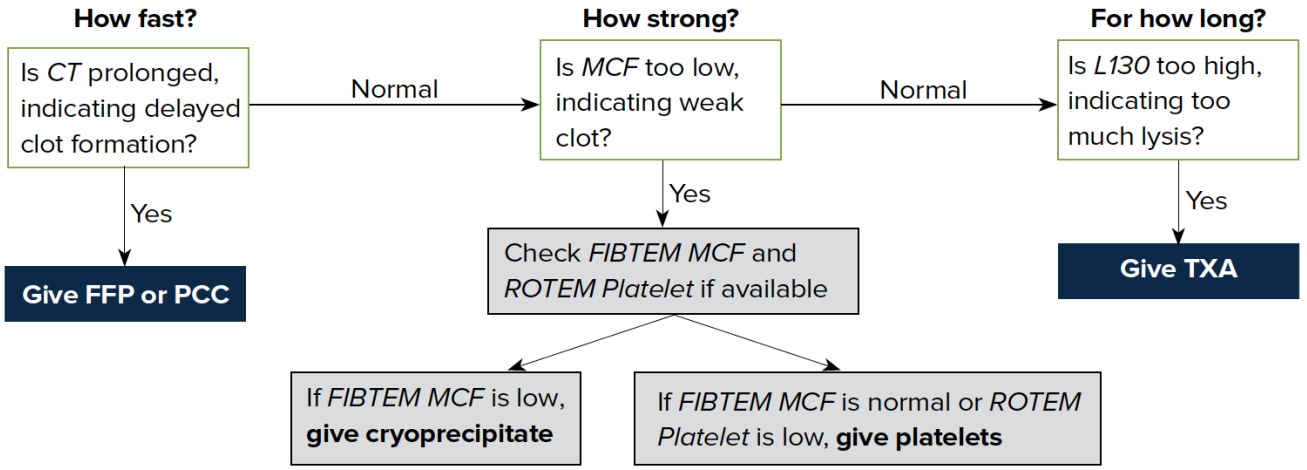
R = Reaction time (time from start to amplitude = 2mm)
K = Kinetics (time from amplitude = 2mm until amplitude = 20mm)
α-angle = slope from 2mm to 20mm amplitude
TMA = Time to Maximum Amplitude
MA = maximum amplitude
CLT = Clot Lysis Time (time taken for amplitude to decrease by 2mm from MA)



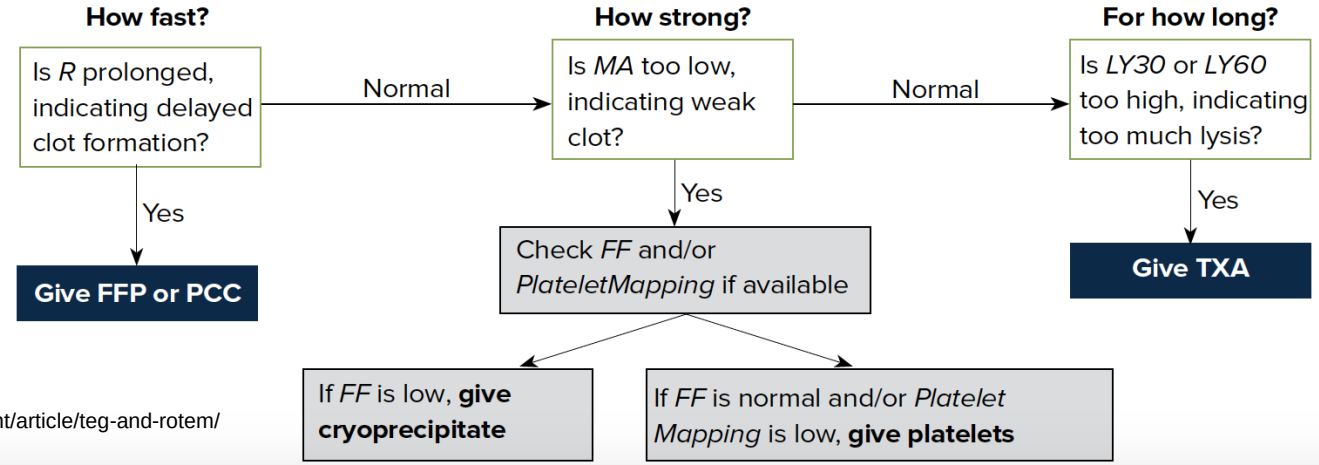
ROTEM NOMENCLATURE

CT = Clotting Time (time from start to amplitude = 2mm)
CFT = Clot Formation Time (time from amplitude = 2mm until amplitude = 20mm)
α-angle = slope of the line at 2mm amplitude
A10 = amplitude at 10 minutes; ...there can be any number of A(x) variables
MCF-t = Time to Maximum Clot Firmness
MCF = Maximum Clot Firmness
LOT = Lysis Onset Time (time taken for amplitude to decrease by 15% of MCF)
LT = Lysis Time (time taken for amplitude to drop to 10% of MCF)
LI30 = Lysis Index at 30 minutes (% drop in amplitude from MCF)
ML = Maximum Lysis (minimum amplitude achieved at the end of test run time)

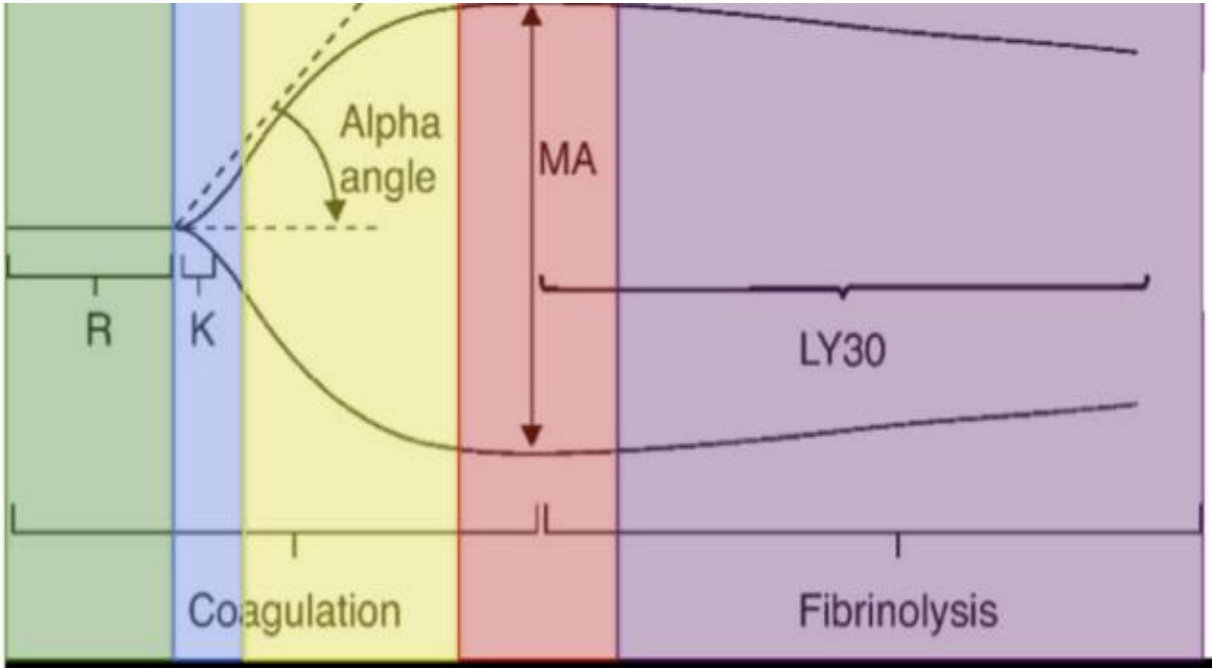
For ROTEM



For TEG



https://www.emra.org/emresident/article/teg-and-rotem/



R.E.B.E.L. EM

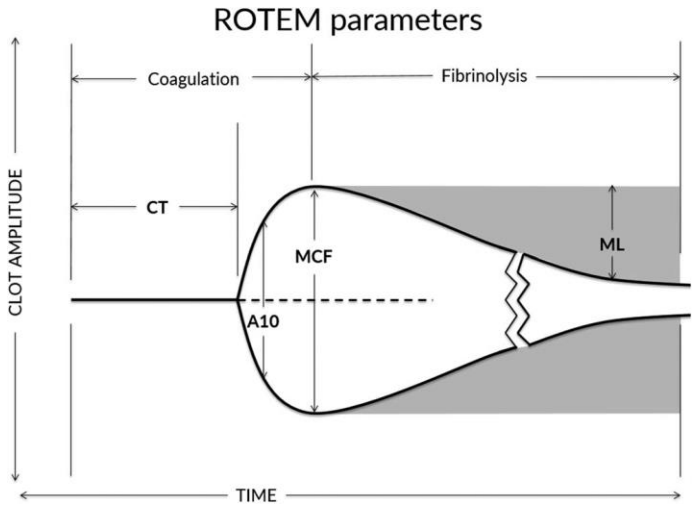
rebelem.com

Thromboelastogram (TEG)

Components	Definition	Normal Values	Problem with...	Treatment
R Time	Time to start forming clot	5 – 10 minutes	Coagulation Factors	FFP
K Time	Time until clot reaches a fixed strength	1 – 3 minutes	Fibrinogen	Cryoprecipitate
Alpha angle	Speed of fibrin accumulation	53 – 72	Fibrinogen	Cryoprecipitate

Can predict transfusion and disability

- **Study done here in Portland between OHSU/Doernbecher and Emanuel/Randall**
- **90 patients**
- **ROTEM thresholds:**
  - **Plasma: EXTEM CT > 84.5 seconds**
  - **Fibrinogen: EXTEM A10 < 43.5 mm**
  - **Platelets: EXTEM MCF < 64.5 mm**



J Trauma Acute Care Surg.2020;88: 134–140

ROTEM results

TABLE 2. ROTEM Measurements

	Total	PRBC Transfusion		
	N = 90	Yes (n = 24)	No (n = 66)	*p*
EXTEM CT, median (IQR), s	65.0 (60.0–72.0)	70.0 (61.3–91.5)	64.0 (59.8–71.0)	0.049
EXTEM A10, median (IQR), mm	56.0 (49.0–59.0)	51.5 (43.0–56.8)	57.0 (50.8–59.0)	0.025
EXTEM MCF, median (IQR), mm	63.0 (58.0–66.0)	60.5 (51.5–64.0)	64.0 (59.8–71.0)	0.025
EXTEM ML, median (IQR), %	7.0 (4.0–10.0)	5.0 (2.3–10.0)	8.0 (5.0–10.0)	0.200
INTEM CT, median (IQR), s	145.5 (133.0–170.5)	144.0 (132.3–204.5)	147.0 (133.0–169.3)	0.777
INTEM A10, median (IQR), mm	55.0 (49.0–58.0)	52.0 (42.3–57.8)	55.0 (49.8–58.0)	0.096
INTEM MCF, median (IQR), mm	61.0 (56.8–64.0)	60.0 (53.0–63.8)	62.0 (57.0–64.0)	0.176
INTEM ML, median (IQR), %	7.0 (4.0–10.0)	5.0 (2.0–10.5)	7.0 (4.0–10.0)	0.270

Continuous variables reported as medians (IQR).

TABLE 3. Predicted Thresholds for Pediatric ROTEM—Based on PRBC Transfusion

	AUROC	95% CI	*p*	Threshold	Sensitivity	Specificity	PPV	NPV
EXTEM Clotting Time (CT)	0.636	0.494–0.779	0.049	84.5 s	0.333	0.939	0.460	0.900
EXTEM Amplitude at 10 min (A10)	0.655	0.520–0.790	0.025	43.5 mm	0.292	0.939	0.446	0.887
EXTEM MCF	0.654	0.518–0.791	0.026	64.5 mm	0.833	0.424	0.723	0.524

95% CI, 95% confidence interval; PPV, positive predictive value; NPV, negative predictive value.

What if they are *really* bleeding?

- Massive transfusion protocol (MTP)
  - Considered in adult when > 10u pRBC over 24 hours, but no such definition exists in children
    - More physiologic
    - Studies
  - 1:1:1 (vs 1:1:2)
  - Helpful because comes with all components and they are all just given
  - *Do not pick and choose what you want from the box*
    - 8 minutes to get PRBC
    - 34 minutes to get FFP (plasma)
    - 42 minutes for platelets
  - 28-day mortality 36.1%[2]

2.Critical Care Medicine. 2021;49:1943-54

ACH Pediatric Massive Transfusion Protocol (MTP)

Appropriate Initial Interventions

- √ Intravenous Access → 2 large bore IVs, IOs, CVC
- √ Crystalloid→ Minimize crystalloid
- √ Labs → **T&S, CBC, coagulation, lytes & ionized Ca, acid/base status – communicate urgency 5–7390**
- √ Continuous monitoring → VS, acid/base, Intake/Output
- √ Aggressive re-warming – including warmed RBC's & plasma
- √ Prevent/reverse acidosis
- √ Correct hypocalcemia
  →Ca gluconate 20–50 mg/kg/dose IV slowly (1 mL/min)
- √ Transfuse with unmatched RBCs on hand

Other Considerations

- √ Heparin reversal → **Protamine 1 mg IV/100U of unfractionated Heparin, 1 mg IV/1 mg enoxaparin, (max dose 50 mg)**
- √ Warfarin reversal → **Vitamin K 5 mg IV/IM**
  → Prothrombin Complex as per TM protocol dosing for INR and weight
- √ CRF
  → DDAVP 0.3 mcg/kg IV over 20 min (max dose 20 mcg)
- √ Antifibrinolytics:
  → Tranexamic acid 15 mg/kg (max 1 gm) bolus followed by 5 mg/kg/hr for 8 h (max dose 1 gm)
- √ Intraoperative cell salvage
- √ **rFVIIa - Niastase RT** (40 mcg/kg) consult with TM physician on call @ 41367.

General Pediatric Guidelines for Lab Based Blood Component Replacement

PRODUCT	THRESHOLD	DOSE
RBCs	Aim for Hgb ≥100 in **bleeding coagulopathic patient**	Hgb ≥70 is sufficient in most stable non-bleeding patients
FFP	If INR greater than 1.5	Give 10–15 mL/kg
Platelets **Do NOT Cool**	If less than 50 x 10^9/L or projected to be soon less than 50 x 10^9/L	Give 5–10 mL/kg **Platelets should drip freely and not be transfused using a warmer or pressurized infuser.**
Cryoprecipitate	Fibrinogen less than 1g/L **OR** evidence of microvascular bleeding	Give 1U/5 kg **NOTE**: 4 U FFP contains equivalent fibrinogen to 10 U cryo

Identify & Manage Bleeding
Collect Type & Screen, CBC and Coagulation Samples – Deliver **STAT**

Anticipate replacement of 50% of blood volume (40 mL/kg) in 3 h
OR
Estimated blood loss exceeding 0.5 mL/kg/min

MD ORDERS MTP ACTIVATION
Recommend Tranexamic Acid within 3 hours of injury[b,c]

ASSIGN a clinical team member to activate MTP (MUST be a Nurse – not a Unit Clerk)
PHONE Transfusion Medicine at 52332
PROVIDE Patient name and sex, RHRN, weight, location, ordering physician
ARRANGE for pick up of pack (page STAT porter for expedited pick up at 04678)

SCM

There is NO order in SCM to activate MTP.

Post MTP: enter *Clinical Communication: MD to Nurse:* **list** all Blood products transfused during MTP.

Standard MTP Pack
√ 3U RBCs √ 2U FFP √ 1 dose Platelets
OR at clinician discretion
PACK IS TO FOLLOW PATIENT

Q30 Min

Hemostasis & resolution of coagulopathy?

No

Clinical Team member calls TM at 52332 for another MTP pack
MD can adjust pack based on labs prn

Yes

Stop MTP
* Notify TM & return any unused blood ASAP
* Resume standard ordering in SCM

REPEAT CBC, INR, PTT & fibrinogen q1h
►STAT hand delivery of samples is best

Repeat ABG, lytes,ionized Ca, serum magnesium and K+ q30 min

Components are Key

- The role of plasma
- PTQIP center study from 2014-2016
  - Of patients who received ≥1:1 FFP:pRBC, there was a 51% lower risk of death
  - Of patients who received 1:1> FFP:pRBC ≥1:2, there was a 40% lower risk of death
  - Platelet:pRBC ratio not associated with mortality change

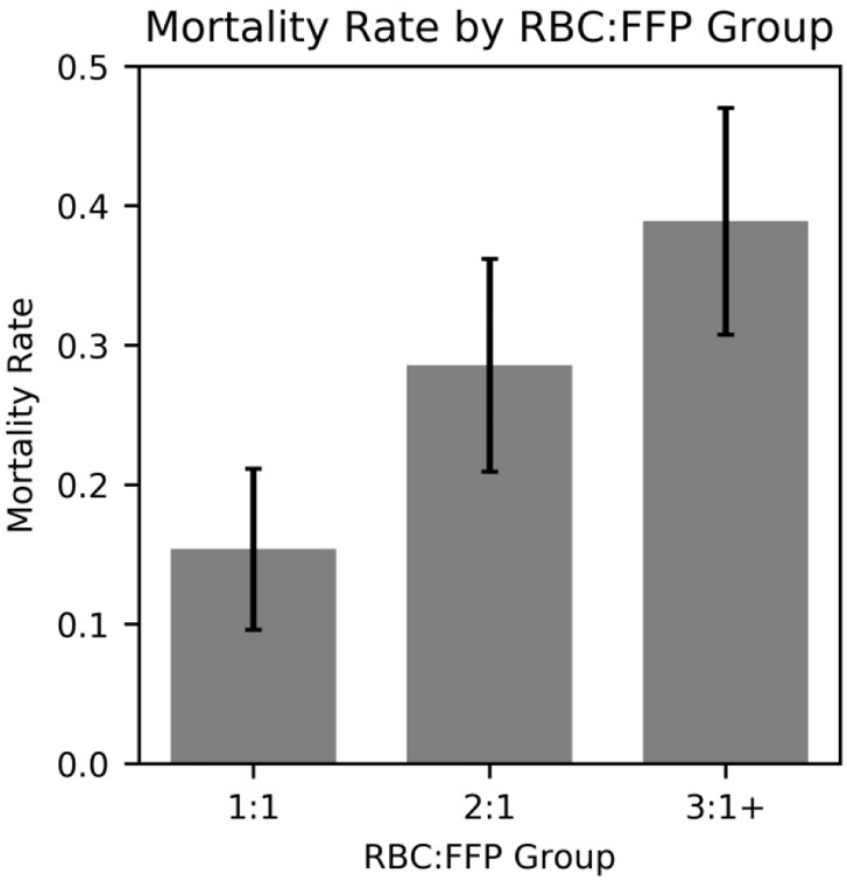
TABLE 3. Multivariable Poisson Regression Analysis Evaluating the Association Between Blood Component Ratios and 24-Hour Mortality in 583 Massively Transfused Pediatric Trauma Patients[a]

Independent Variables	Adjusted Relative Risk (95% CI)
4 hr blood products	
Total blood products, mL/kg	1.003 (1.001–1.005)
FFP:PRBC ratio, continuous	0.47 (0.28–0.80)
Platelet:PRBC ratio, continuous	1.53 (0.84–2.77)
FFP:PRBC ratio, categorical	
Low < 1:2	1 (reference)
Medium ≥ 1:2 and < 1:1	0.67 (0.43–1.05)
High ≥ 1:1	0.48 (0.26–0.88)
Platelet:PRBC ratio, categorical	
None 0	1 (reference)
Low > 0 and < 1:2	1.81 (1.11–2.94)
High ≥ 1:2	1.73 (0.90–3.34)

Crit Care Med 2019; 47:975–983

1:1 seems to be the best in kids

- ATOMAC study:
- Patients >20 ml/kg or MTP included
- Increased mortality (OR 3.08) per unit increase over 1:1 ratio pRBC : FFP



Journal of Pediatric Surgery 54 (2019) 345–349

Components are Key

- The role of cryoprecipitate
- PTQIP center study from 2014-2017
  - Of patients who underwent massive transfusion within the first 4 hours of ED arrival:
    - Patients receiving cryoprecipitate had lower 24 hour mortality compared to those who did not (6.9% less)
    - Also associated with lower 7-day mortality in children with penetrating trauma or those transfused at least 100ml/kg total blood products

JAMA Surg. 2021;156(5):453-460

Let's Give All the Components at Once!

- Whole blood is making a comeback
- Demonstrated to be safe in adults, but…

TABLE 2. Quantity of Blood Products Administered Within 24 Hours of Presentation by Cohort

Units of Blood Products Median (IQR)	Component Therapy Only n = 83	Received WB n = 42	*p* Value
WB Units	—	6.5 (3–11)	—
RBCs	6 (3–12)	4 (1–8)	0.003
FFP	5 (2–10)	4 (0–6)	0.01
Platelets	0 (0–2)	1 (0–2)	0.2
Cryoprecipitate	0 (0–0)	0 (0–0)	0.9
Total bags of product	12	18.5	0.19

J Trauma AcuteCare Surg. 2020;89: 238–245.

That said…

Whole Blood is Superior to Component Transfusion for Injured Children

Propensity score matching of 28:28 patients

- Whole blood faster resolution of base deficit (2 vs 6 hours)
- Improved post-transfusion INR
- Lower plasma volumes and platelet volumes
- No difference in LOS, ICU LOS, ventilator or survival

(Ann Surg 2020;272:590–594)

Others Agree

- 2017 TQIP database
- Propensity score 1:2 ratio
  - 135 WB : 270 components
- Decreased total products transfused with no difference in mortality, LOS, major complications, but did have fewer ventilation days with WB

J Trauma Acute Care Surg. 2021;91: 573–578.

What about TXA?

- Tranexamic acid (TXA) has been shown to decrease mortality in adult trauma
- Studied initially in combat (Iraq and Afghanistan)
- When patients needed ≥40ml/kg blood products, use of TXA led to in hospital death decrease from 18.3% to 8.5%

- That said, only 35% of pediatric trauma centers use it
  - Dosing 15mg/kg bolus with 2mg/kg/hr x 8 hours

JTACS. 2020;89:S242-5.

J Trauma Nurs. 2021;28:21-5.

Take Home Points

Following adult shift to earlier transfusion

Whole blood is safe in children, but we are still learning

There is a role for advanced coagulation monitoring

Blunt Solid Organ Injuries in Children

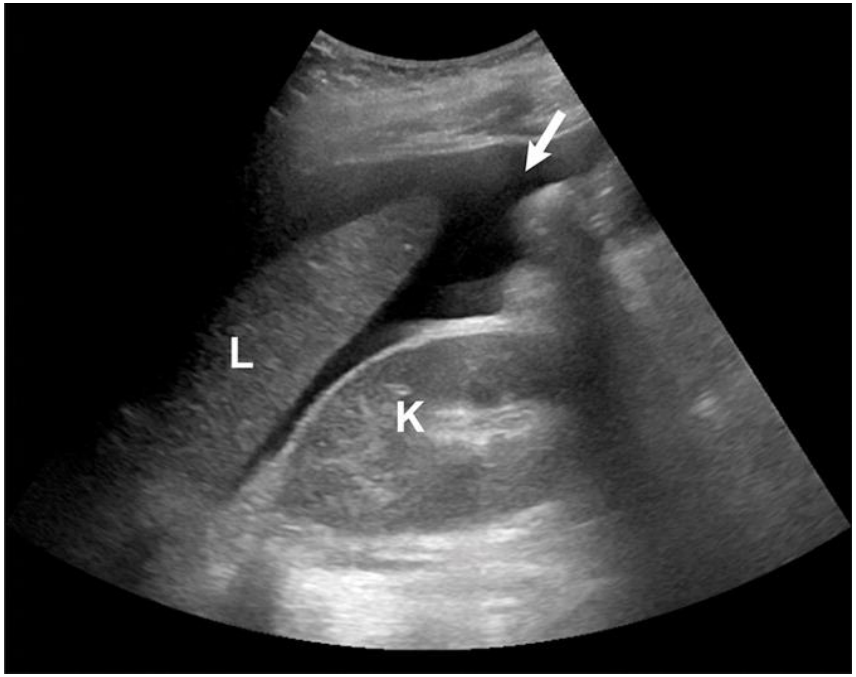
Abdominal Trauma

- ~10% of patients with blunt trauma will have intra-abdominal injury
- 40% less fatal than thoracic injuries
- Children smaller, so kinetic energy more impactful
- Ribs less calcified→more force gets into chest and upper abdomen
- Abdominal walls thinner and muscles weaker

Emerg Med Clin N Am 36 (2018) 237–257

Screening patients

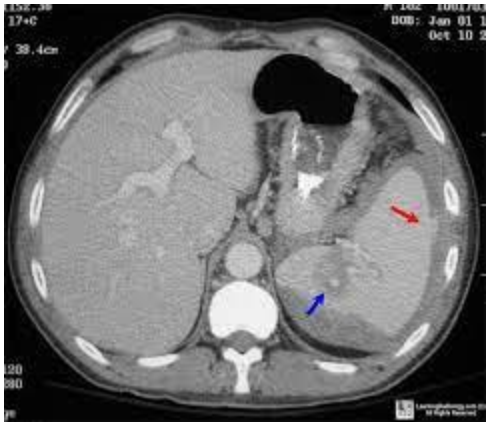
- FAST exam
  - Combined with AST/ALT >100 is effective screen
- Urinalysis
  - >8 red cells associated with splenic/renal lacerations
    - *J Urol. 1996;156:2014-8.*
- Also check Amylase &/or Lipase

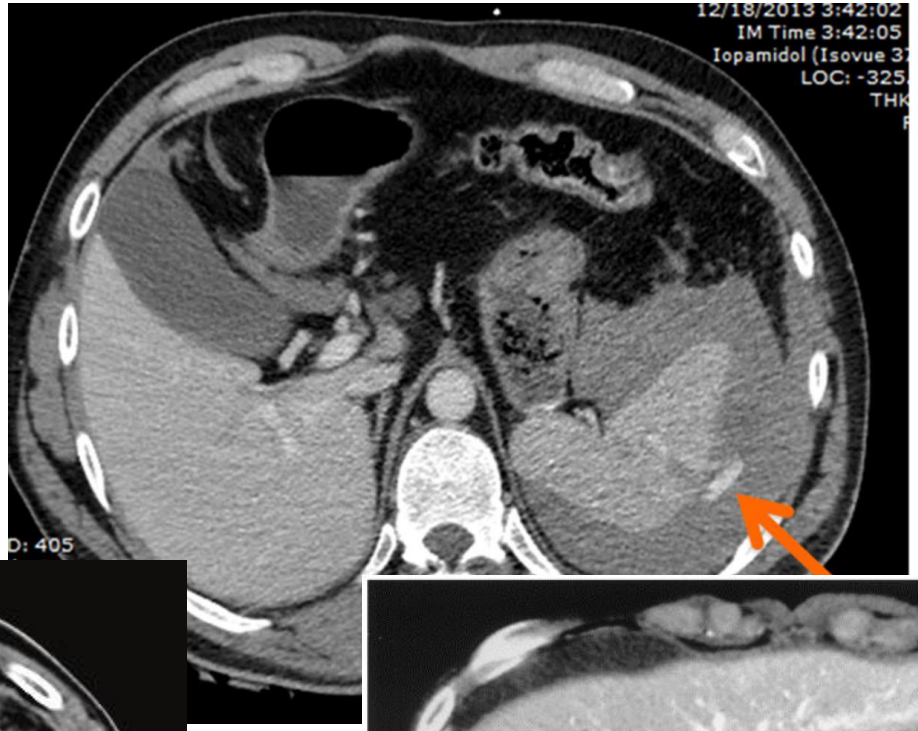


https://pubs.rsna.org/doi/full/10.1148/radiol.2017160107

J Surg Res. 2009;157:103-7

CT Scan

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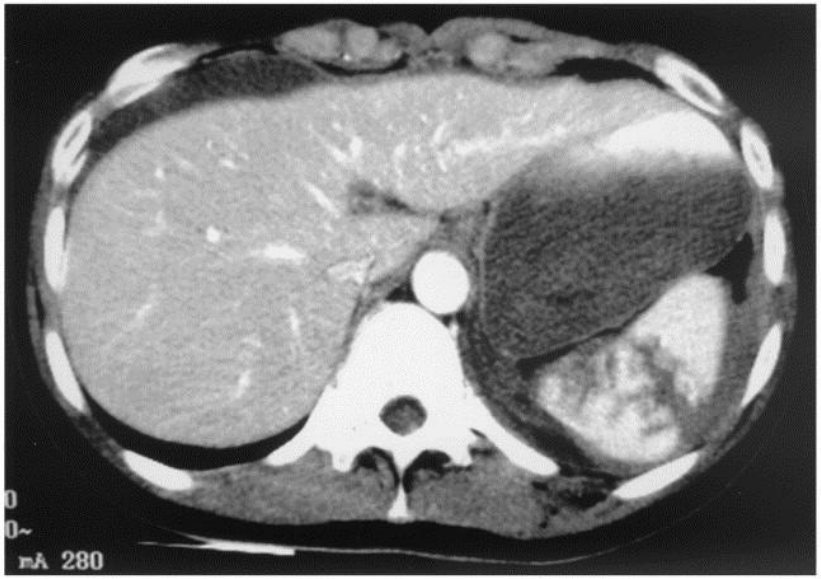

mA 280

The long ago…

Table 1. APSA Evidence-Based Guidelines

	CT Grade*			
	I	II	III	IV
ICU stay (d)	None	None	None	1
Hospital stay (d)	2	3	4	5
Predischarge imaging†	None	None	None	None
Postdischarge imaging‡	None	None	None	None
Activity restriction (wk)	3	4	5	6

*Trade of solid organ injury based on the AAST organ injury scale.
†any ultrasound scan or CT before hospital discharge.
‡any ultrasound scan or CT after hospital discharge.
From Stylianos et al,[7] with permission.

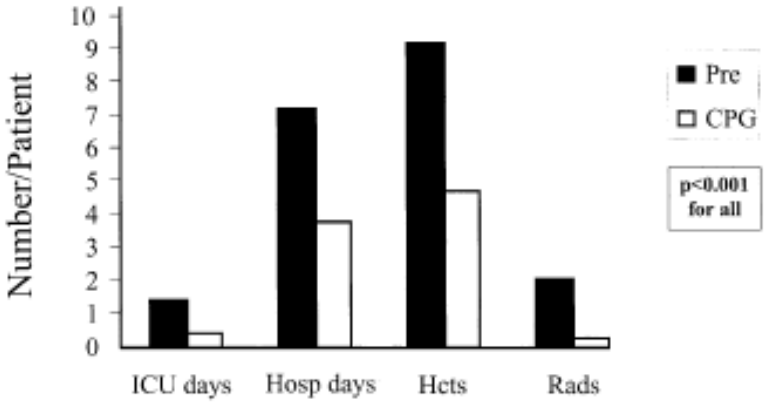


Fig 3. Resource utilization. ICU days indicates mean length of intensive care unit stay, Hosp days indicates mean length of hospital stay, Hcts indicates mean number of hematocrit assays, Rads indicates number of follow-up radiologic studies, Pre means before the enactment of the clinical pathway guidelines, and CPG indicates after the enactment of the clinical pathway guidelines.

J Pediatr Surg 39:487-490.

APSA Blunt Solid Organ Injury Guidelines

Admission

ICU Admission Indicators

- Abnormal vital signs after initial volume resuscitation

ICU

- Activity – bed rest until vitals normal
- Labs – Q6hour CBC until vitals normal
- Diet – NPO until vitals normal and Hb stable

Ward

- Activity – no restrictions
- Labs – CBC on admission and/or 6 hours after injury
- Diet - Regular

Set Free

- Based on clinical condition **NOT** injury severity (grade)
- Tolerating a diet
- Minimal abdominal pain
- Normal vita signs

Procedures

Transfusion

- Unstable vitals after 20 cc/kg bolus of isotonic IVF
- Hb < 7 g/dL
- Signs of ongoing or recent bleeding

Angioembolization

- Signs of ongoing bleeding despite RBC transfusion
- Not indicated for CT contrast blush without instability

Operative exploration to control bleeding

- Unstable vitals despite RBC transfusion
- Consider massive transfusion protocol

Aftercare

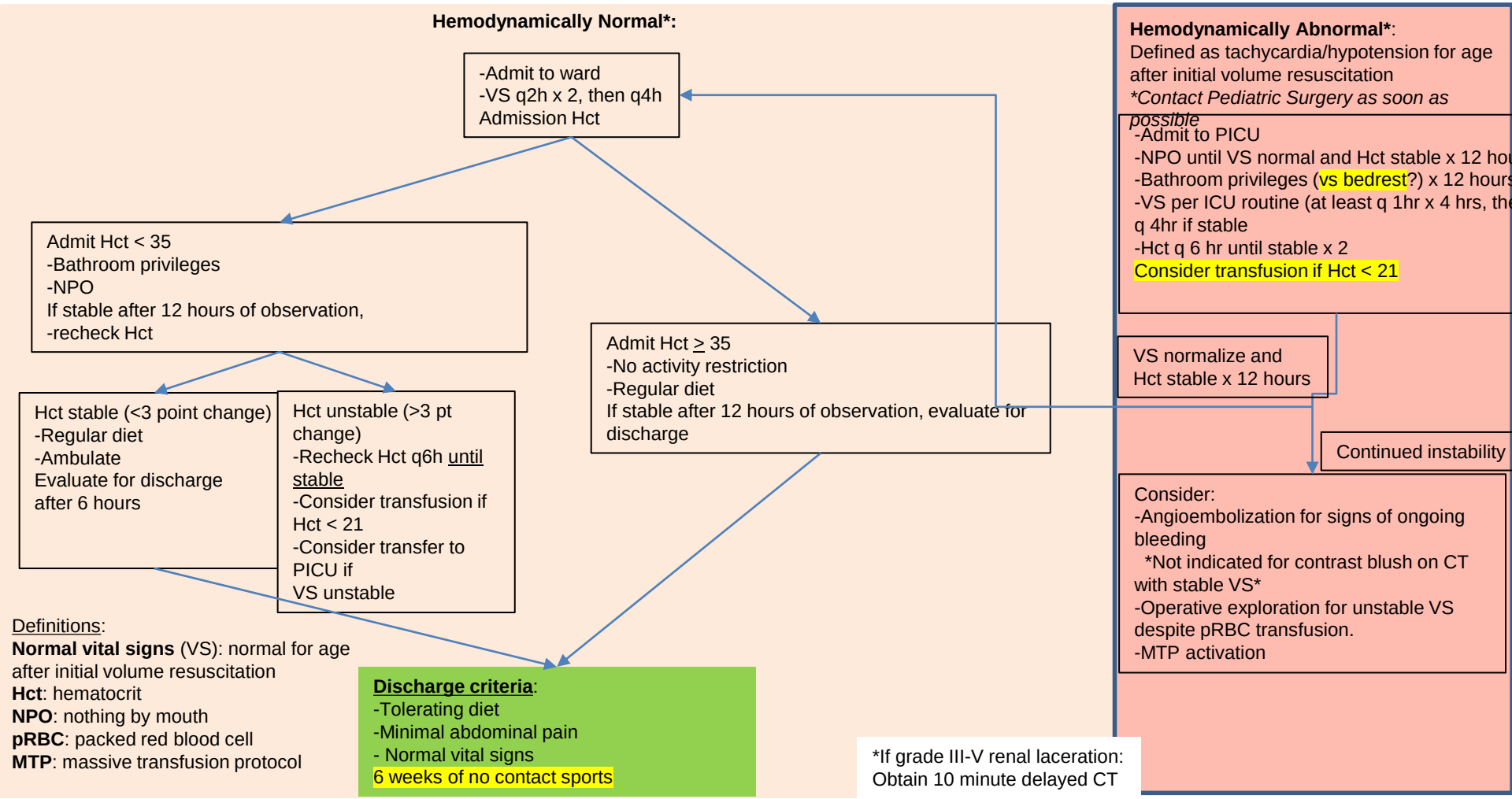
Activity Restriction

- Restricting activity to grade plus 2 weeks is safe
- Shorter restrictions may be safe but there is inadequate data to support decreasing these recommendations

Follow up Imaging

- Risk of delayed complications following spleen and liver injuries is low
- Consider imaging for symptomatic patient with prior high-grade injuries

Oregon Pediatric Solid Organ Injury Management Protocol



Unique aspects of retroperitoneal organs

Kidney

- When grade > 3, should get delayed images to examine for urine leak
  - *J Pediatr Urol. 2016;12:294e1-6.*
  - May be unnecessary, as adult study showed interventions increased without symptoms in patients reimaged
  - *JTACS 2021;90:143-7.*

Pancreas

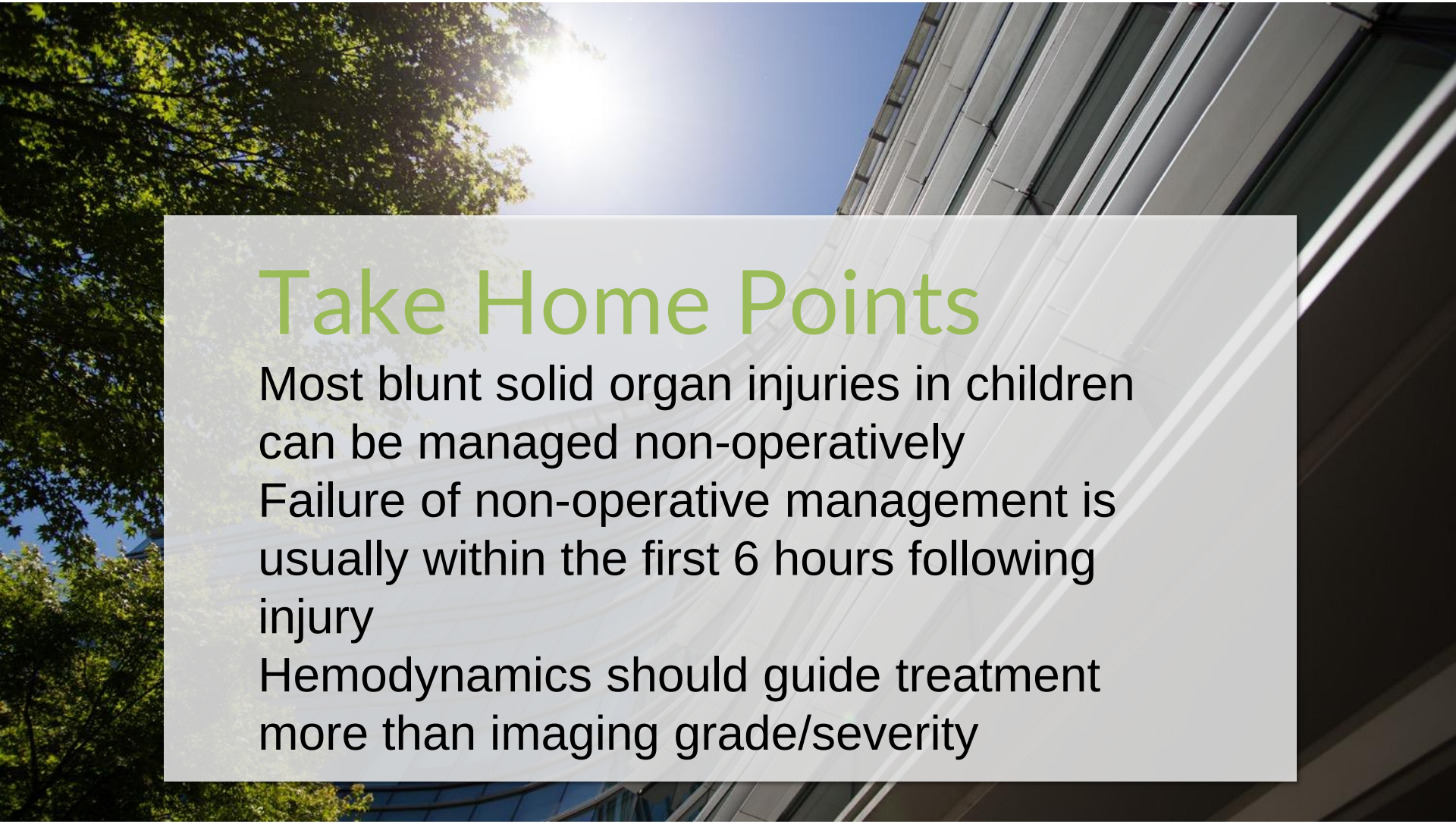
- No one really knows what to do with these
  - Head- try to drain +/- ERCP/stent
    - Try to avoid operation
  - Tail- ongoing study of observation +/- stent vs distal pancreatectomy

Role for post-injury imaging/follow up

- In renal trauma, complications (urinoma, sepsis, hydronephrosis, persistent hypertension) occurs in grade 3-4 injuries.
  - Concern for loss of renal function warrants follow up 3-4 months
    - Ultrasound, renal scan
- For liver or spleen injury, routine imaging unwarranted

Pediatr Radiol. 1994;24:573-6

Journal of Pediatric Surgery 54 (2019) 340–344



Take Home Points

Most blunt solid organ injuries in children can be managed non-operatively

Failure of non-operative management is usually within the first 6 hours following injury

Hemodynamics should guide treatment more than imaging grade/severity

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