Technical Tips for the Management of Pediatric Trauma and Emergencies

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Engagement Award, PCORI

Honoraria, Up-to-Date

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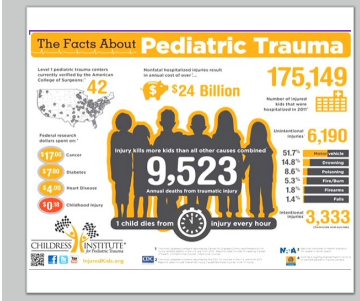
Trauma remains the leading COD in children

- Incidence of pediatric vascular trauma among those with traumatic injuries is rare (0.6-0.8%), but major mortality contributor
  - Blunt injuries most common
- Iatrogenic vascular trauma = most common form of pediatric vascular trauma



Extremity Trauma

- 3 yo boy restrained, in a car seat. MVC ('T-boned')
- Reported decline in mental status at the scene requiring intubation
- OSH - left open humerus fracture with active arterial bleeding that was 'ligated'
- Transferred - no radial or ulnar signal by Doppler interrogation

Wound Exploration

- Open and complex humerus fracture with extensive soft tissue loss
- Obvious clean ligation of the proximal and distal brachial artery with a long segment of missing vessel (vein and nerve)
- Estimated 5-6h ischemia

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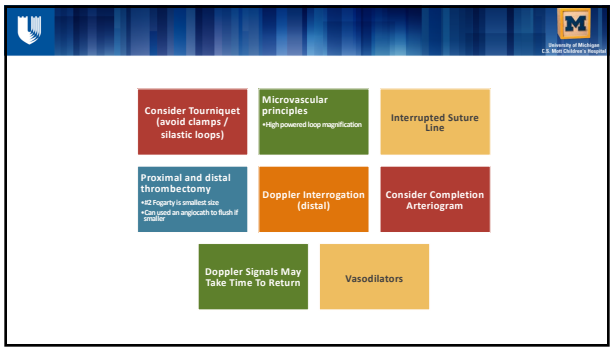
Surgical Repair

- Shunting of left brachial artery (6Fr Argyle)
- ORIF (Ortho)
- Left brachial-brachial bypass using reverse GSV [total shunt time = 2h 16 min]
  - Interrupted suture line (7-0 Prolene)
  - Nitroglycerin peri-adventitial
  - Did not reverse heparin
- Deferred venous reconstruction
- Forearm/hand fasciotomies (hand surgery) and complex wound closures



The Role of Endovascular Therapy in Pediatric Vascular Trauma is Evolving

- Future somatic growth
- Small vessel size limits utility of prosthetic conduits and access
  - Introduction of a covered stent or iliac limb requires access (12Fr sheath / 4mm artery)
- Vessel spasticity (ie: vasospasm)

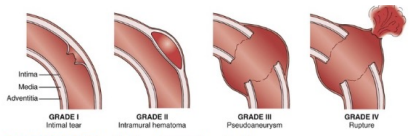
Blunt Aortic Injury

RARE (2.1% of pediatric trauma-related deaths)
Chest wall compliant
Avoidance of direct chest impact from the steering wheel as passengers
Car seats more protective

Lethal Problem – Initial survival 7%
30% of untreated survivors die within 6h
40-50% within 24h; 90% within 4mo

30-50% show no signs of chest trauma
High index of suspicion (high energy trauma – decelerations, crashes, compression)
CTA – 100% sensitivity; 100% NPV

Thoracic Aortic Trauma



- Gold standard for Grade III/IV injuries historically open repair
- EV limitations in children – TEVAR OFF-LABEL (age <21y)
  - Small diameter (access vessels)
  - Device availability (small aortic diameter)
  - Long term data lacking
    - Concerns re: Pseudo-coarctation, Graft migration, Durability

Blunt Aortic Injury

- 8yo – MVC, polytrauma; intubated en route; left HTX
- CTA

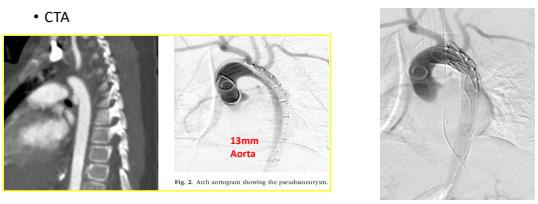


Fig. 2. Arch aortogram showing the pseudoaneurysm.

Hosn et al; Annals Vasc Surg; 2017

National Trauma Data Bank (2007-2019): Thoracic Aortic Injury (n=2,431)

- 5.5% children (age 1-11y; n=134)
  - Highest rates of blunt trauma
  - Lowest rates of TEVAR (3%)
- 30.2% adolescents (12-17y; n=733)
- 64.3% 'mature' patients (18-21y); n=1,564)
  - Highest rates of penetrating trauma
  - Significantly higher rates of TEVAR (29.2%)
- Patient age was NOT associated with an increased risk of in-hospital mortality.

Table 1. Patient characteristics and outcomes stratified by age

Covariate	Children 5.5% 1–11 years (*N* = 134)	Adolescent 30.2% 12–17 years (*N* = 733)	Mature 64.3% 18–21 years (*N* = 1,564)	*P* value
Male sex (%)	75 (56)	529 (72.7)	1,247 (79.7)	*<0.001*
Race				0.78
White	77 (57.5)	452 (61.7)	944 (60.4)	
Black	26 (19.4)	130 (17.7)	305 (19.5)	
Other	31 (23.1)	151 (20.6)	315 (20.1)	
SBP (median ± IQR)	114.6 ± 28.9	117.8 ± 27.1	121.2 ± 28.5	*0.003*
Pulse rate	125.6 ± 27	111.4 ± 26.8	108.2 ± 25.9	*<0.001*
GCS	9.5 ± 5.3	10.2 ± 5.4	10.7 ± 5.3	*0.009*
Injured systems	4.2 ± 1.8	4.6 ± 1.5	4.3 ± 1.6	0.079
Aortic AIS	4.3 ± 0.5	4.4 ± 0.6	4.4 ± 0.5	*0.012*
ISS	34.1 ± 15.1	38 ± 14.9	36.1 ± 13.9	*0.001*
Mechanism				*<0.001*
Blunt	121 (90.3)	655 (89.6)	1,351 (86.8)	
Penetrating	8 (6)	74 (10.1)	195 (12.5)	
Other/unknown	5 (3.7)	4 (0.5)	18 (1.2)	
TAI intervention				*<0.001*
NOM	126 (94)	498 (67.9)	1,013 (64.8)	
TEVAR	4 (3)	185 (25.2)	456 (29.2)	
OAR	4 (3)	49 (6.7)	87 (5.6)	
TEVAR & OAR	0 (0)	1 (0.1)	8 (0.5)	
Hospital disposition				0.054
Home	46 (34.3)	248 (33.9)	640 (40.9)	
Inpatient rehab	1 (0.7)	45 (6.1)	95 (6.1)	
Nursing facility	18 (13.4)	72 (9.8)	133 (8.5)	
Other hospital	13 (9.7)	112 (15.3)	254 (16.2)	
Deceased	25 (18.7)	134 (18.3)	263 (16.8)	
Other	31 (23.1)	122 (16.6)	179 (11.4)	
Mortality	25 (18.7)	134 (18.3)	263 (16.8)	0.63

Italics = Statistically Significant.
IQR, Interquartile Range; OAR, Open Aortic Repair; SBP, Systolic Blood Pressure (mm Hg); TAI, Thoracic Aortic Injury; TEVAR, Thoracic Endovascular Aortic Repair; y, Years Old.

Raufi et al; Ann Vasc Surg; 2021

TEVAR associated with higher likelihood of home dispo (54%) v. NOM (31.8%) and OAR (44%)

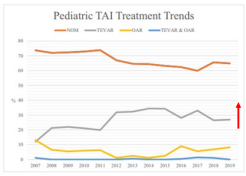


Fig. 1. TAI treatment trends.

Table V. Risk factors for inpatient mortality

Variable	RR	95% CI	*P* value
Pediatric age category			
Children (1–<11 years)	ref	ref	
Adolescent (12–17 years)	1.09	0.68–1.74	0.72
Mature (18–21 years)	1.05	0.67–1.66	0.82
TAI intervention			
NOM	ref		
TEVAR	0.22	0.15–0.33	<0.001
OAR	0.58	0.36–0.93	0.024
TEVAR & OAR	0.58	0.08–4.11	0.58
Mechanism			
Blunt	ref		
Penetrating	2.55	2.03–3.2	<0.001
Other/unknown	0	0	0.98
Male	1.09	0.85–1.4	0.48
Injury severity score	1.04	1.03–1.05	<0.001
Aorta AIS	0.94	0.79–1.12	0.48

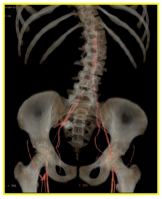
Italics = Statistically Significant.
ref, reference; RR, relative risk.

Conclusion: There is a role for endovascular treatment of aortic injury

- While there is no dedicated EV stent for pediatric trauma and insufficient data (long-term follow-up) to make definitive recommendations
- In anatomically feasible patients, consider TEVAR for higher grade(ie: >II) injuries over NOM or open repair
- 'Stop-gap' / bridge to formal repair
- Remember EV adjuncts for hemorrhage control (balloon occlusion and embolization)
- Judicious surveillance
- Future investigations required

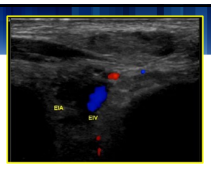
Iatrogenic Pediatric Femoral Arterial Injury – Natural History

- Arterial cannulation is a leading cause of acute arterial thrombosis and ischemia
- Femoral artery catheterization in children may be complicated by risk of arterial injury – as high as 3%
  - 11% in congenital cardiac practice (procedural catheterization)
- Long term risks
  - Claudication
  - LLD (33%)
  - Scoliosis (>2cm LLD)
  - Degenerative arthritis



Saini, 2021
Flanigan et al – Ann Surg - 1983
Lin et al – JVS - 2001

Catheter-Related ALI



- Systemic therapeutic heparinization
- Serial neurovascular exams – monitor for spontaneous and stimulated movement
- Oxygen Saturation Monitors on both feet for comparison

What if exam failed to improve with anticoagulation?

- Balloon (or suction) Thrombectomy
  - Catheter limitations (size) in infants
  - Consider micro-surgical techniques
- Thrombolysis (level 1C evidence)
  - Tissue plasminogen activator (tPA) - 0.5mg/kg/h infused for 6 hours
  - Consider multi-disciplinary approach; monitor for compartment syndrome
  - If there are contraindications to thrombolytic therapy or there is an imminent danger of limb loss, surgical intervention is recommended (level 1C evidence).

Catheter-Associated Thrombus in Critically Ill Children

- No evidence-based guidance on optimal treatment
- ~2/3 will have complete resolution – majority within 2-6 weeks
- LMWH particularly advantageous in the very young
  - Decreases endogenous release of von Willebrand factor (vWF) to a greater extent than UFH
- Reduced platelet aggregation at the site of endothelial injury.

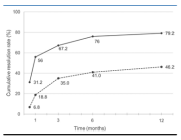


Figure. Cumulative resolution rate over time in children with EIC-related CAT (solid line) and cardiac catheter–related CAT (dashed line) as shown on follow-up Doppler ultrasound examinations.

Crameri et al; J Peds; 2021
Wang et al; 2017
Glatz et al; 2015
Albisetti et al; 2019


Thank You!
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