

Pediatric IR in Trauma: Who, what, and what follows

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9/29/2026

Disclosures

- None

Objectives

- Describe the role of Pediatric Interventional Radiology (IR) in the management of pediatric trauma and who may benefit from IR consultation – the who
- Discuss common tools used by and the flagship procedure performed by IR in the management of trauma patients– the what
- Discuss common clinical outcomes and post-procedural considerations following embolization – the aftermath

The Who



Peds IR Role

- Adjunct to non-operative management (NOM)
- Can assist with many aspects, but...
 - Solid organ/vascular injury

Who needs IR?

HEMODYNAMICALLY STABLE

ACTIVELY CRASHING



STABLE

The stable patient
does not need me

90%

of children succeed with
nonoperative management



IN LIMBO

The patient in limbo is mine

- ✓ Transfused + confirmed hypotension
(SBP < 90 mmHg in adults; age-specific
in kids)
- ✓ Transfusion dependent
- ✓ Stable / responding, but not resolving
- ✓ Proven vascular lesion



CRASHING

The crashing child
does not have time
for me

3.6 h

median door-to-angiography in
the National Trauma Data Bank



The foundation – NOM works

- 4% failure rate
 - Endovascular and endoscopic procedures not considered failures
 - Predictors: injury severity score (ISS); American Association for the Surgery of Trauma (AAST) grade; age (older kids did worse)
- Generally accepted that pediatric patients have better compensatory abilities for blood loss
- Authors point out that endovascular intervention is a corner stone of adult NOM but remains underutilized in pediatrics

The What



Toolkit

- Ongoing hemorrhage or vascular injury – the focus
 - Embolization for solid organ, mesenteric, extremity, or other arterial injury
 - Temporizing agent such as gel foam for vital arteries, permeant agent can be considered if the artery is non-essential or there is collateral flow
 - Vital vessel injury that cannot be sacrificed
 - Stent grafts
 - Venous?
- Management of other complications because of solid organ injury
 - Urologic
 - Biliary
 - Access
 - Foreign body retrieval



The Flagship Indication

- Splenic artery embolization (SAE)
 - Goal is to convert a failing NOM back into a successful one.
 - Splenic salvage – preserved immunologic function
- Outcomes
 - No large peds outcomes study
 - Small series out of Korea, 40 children <17yo NOM, 17 underwent SAE
 - 88.2% clinical success (2 patients had to be treated a second time)
 - 100% spleen salvage, no embolization related complications
 - No difference between World Society of Emergency Surgery (WSES) grade

Table 3 WSES Spleen Trauma Classification for adult and pediatric patients

	WSES class	Mechanism of injury	AAST	Hemodynamic status ^{a, b}	CT scan	First-line treatment in adults	First-line treatment in pediatric
Minor	WSES I	Blunt/penetrating	I–II	Stable	Yes + local exploration in SW ^d	NOM ^c + serial clinical/laboratory/radiological evaluation Consider angiography/angioembolization	NOM ^c + serial clinical/laboratory/radiological evaluation Consider angiography/angioembolization
Moderate	WSES II	Blunt/penetrating	III	Stable			
	WSES III	Blunt/penetrating	IV–V	Stable		NOM ^c All angiography/angioembolization + serial clinical/laboratory/radiological evaluation	
Severe	WSES IV	Blunt/penetrating	I–V	Unstable	No	OM	OM

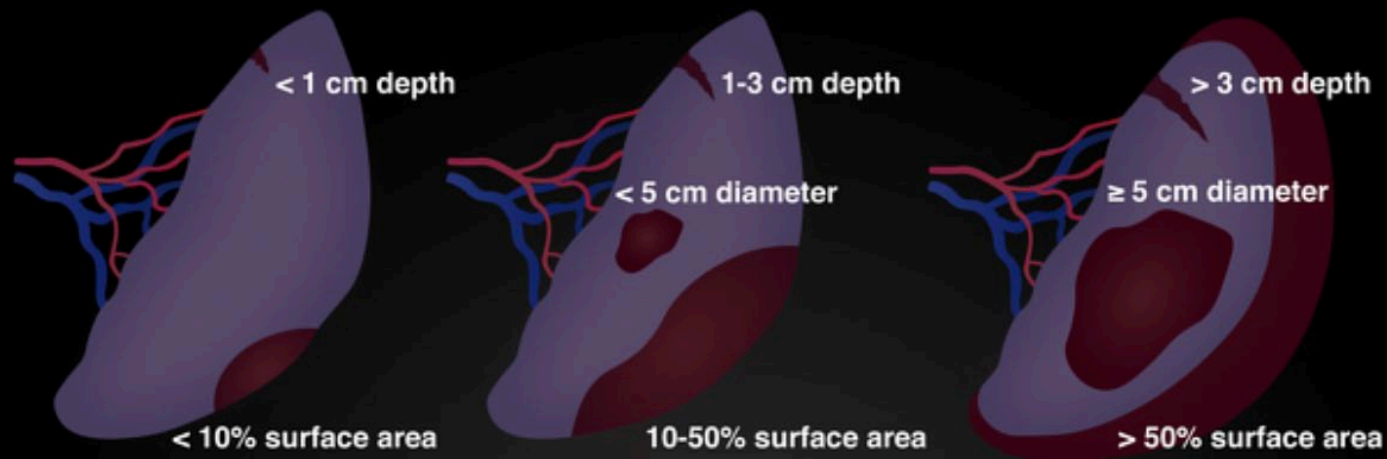
SW stab wound, GSW gunshot wound

^aHemodynamic instability in adults is considered the condition in which the patient has an admission systolic blood pressure < 90 mmHg with evidence of skin vasoconstriction (cool, clammy, decreased capillary refill), altered level of consciousness and/or shortness of breath, or > 90 mmHg but requiring bolus infusions/transfusions and/or vasopressor drugs and/or admission base excess (BE) > – 5 mmol/l and/or shock index > 1 and/or transfusion requirement of at least 4–6 units of packed red blood cells within the first 24 h; moreover, transient responder patients (those showing an initial response to adequate fluid resuscitation, and then signs of ongoing loss and perfusion deficits) and more in general those responding to therapy but not amenable of sufficient stabilization to be undergone to interventional radiology treatments

^bHemodynamic stability in pediatric patients is considered systolic blood pressure of 90 mmHg plus twice the child's age in years (the lower limit is inferior to 70 mmHg plus twice the child's age in years, or inferior to 50 mmHg in some studies). Stabilized or acceptable hemodynamic status is considered in children with a positive response to fluid resuscitation: 3 boluses of 20 mL/kg of crystalloid replacement should be administered before blood replacement; positive response can be indicated by the heart rate reduction, the sensorium clearing, the return of peripheral pulses and normal skin color, an increase in blood pressure and urinary output, and an increase in warmth of extremity. Clinical judgment is fundamental in evaluating children

^cNOM should only be attempted in centers capable of a precise diagnosis of the severity of spleen injuries and capable of intensive management (close clinical observation and hemodynamic monitoring in a high dependency/intensive care environment, including serial clinical examination and laboratory assay, with immediate access to diagnostics, interventional radiology, and surgery and immediately available access to blood and blood products or alternatively in the presence of a rapid centralization system in those patients amenable to be transferred

^dWound exploration near the inferior costal margin should be avoided if not strictly necessary because of the high risk to damage the intercostal vessels



Grade I

- laceration or capsular tear
- subcapsular haematoma

Grade II

- laceration
- intraparenchymal haematoma
- subcapsular haematoma

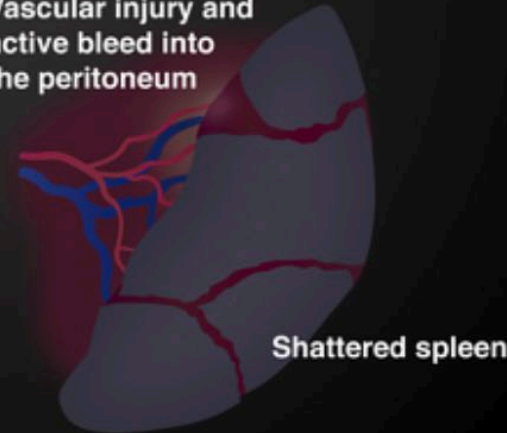
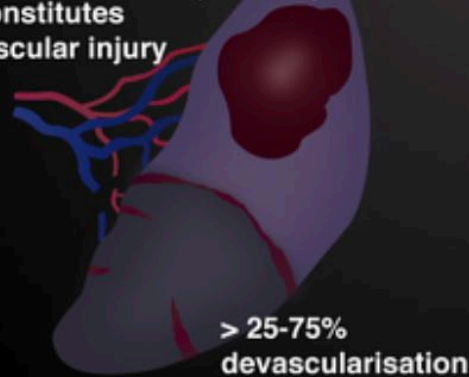
Grade III

- laceration
- intraparenchymal or ruptured subcapsular haematoma
- subcapsular haematoma

A pseudoaneurysm or AV fistula constitutes a splenic vascular injury

Confined active parenchymal bleed

Vascular injury and active bleed into the peritoneum



Grade IV

- laceration
- vascular injury
- intraparenchymal haematoma

Grade V

- vascular injury
- shattered spleen

*Advance one grade for each additional injury upto grade III.

SHapu

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PEDIATRIC PATIENTS

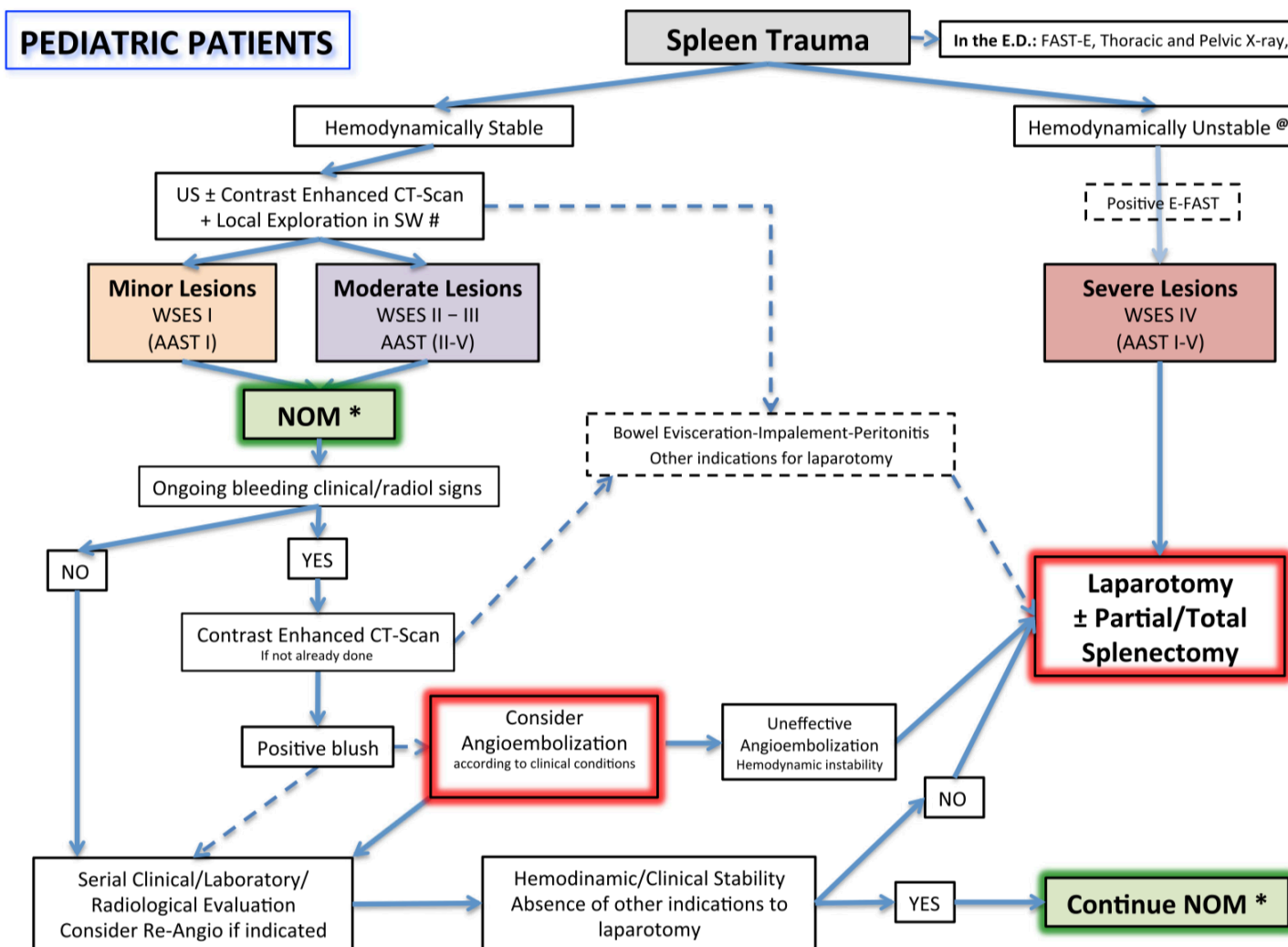


Fig. 3 Spleen Trauma Management Algorithm for Pediatrics Patients. (SW stab wound, GSW gunshot wound; *NOM should only be attempted in centers capable of a precise diagnosis of the severity of spleen injuries and capable of intensive management (close clinical observation and hemodynamic monitoring in a high dependency/intensive care environment, including serial clinical examination and laboratory assay, with immediate access to diagnostics, interventional radiology, and surgery and immediately available access to blood and blood products or alternatively in presence of a rapid centralization system in those patients amenable to be transferred; @ Hemodynamic stability is considered systolic blood pressure of 90 mmHg plus twice the child's age in years (the lower limit is inferior to 70 mmHg plus twice the child's age in years, or inferior to 50 mmHg in some studies). Stabilized or acceptable hemodynamic status is considered in children with a positive response to fluids resuscitation: 3 boluses of 20 mL/kg of crystalloid replacement should be administered before blood replacement; positive response can be indicated by the heart rate reduction, the sensorium clearing, the return of peripheral pulses and normal skin color, an increase in blood pressure and urinary output, and an increase in warmth of extremity. Clinical judgment is fundamental in evaluating children. # Wound exploration near the inferior costal margin should be avoided if not strictly necessary because of the high risk to damage the intercostal vessels)

Research Question: 5. When is splenic artery embolization (SAE) indicated for patients treated with NOM for splenic trauma?

Priority level: *Urgent*

Statement: In stable patients with high-grade splenic injuries (WSES Classes II–III, AAST Grade $\geq$ III), splenic artery angioembolization (SAE) represents an effective adjunctive tool to NOM, reducing the failure of the conservative approach and the need for surgery. Angiography and SAE should be performed at an early stage when contrast extravasation or vascular injuries (pseudoaneurysm, arteriovenous fistula formation, vessel truncation) are detected on admission CT scan, as well as in high-grade splenic injuries (WSES Class III, AAST Grades IV–V) even if contrast extravasation is not detected. However, small pseudoaneurysms can be safely observed without SAE [**Quality of Evidence: High**]. Some discrepancies in the management of WSES Class II (AAST Grade III) blunt splenic injury without contrast extravasation still exist among the experts. However, based on the available evidence, SAE in WSES Class II (AAST Grade III) splenic injury without vascular extravasation cannot be currently recommended as routine practice. In children, SAE has not been shown to be efficacious [**Quality of Evidence: Low**]. The available literature is inconclusive regarding whether proximal or distal embolization should be used to avoid significant re-bleeding, and larger prospective cohort studies are required. However, both techniques have an equivalent rate of post-procedural splenic infarctions and infections. Minor complications occur more often after distal embolization. This is primarily explained by the higher rate of segmental infarctions after distal embolization [**Quality of Evidence: Low**]

Recommendation: The panel suggests splenic artery angioembolization (SAE) as the first-line intervention in patients with hemodynamic stability and arterial blush on CT scan, irrespective of injury grade, where the expertise and resources required to carry out the procedure are readily available [**Strength of Recommendation: Conditional recommendation, based on Moderate quality of evidence, Agreement 93.5%**]. A low threshold for SAE is suggested for patients with WSES Class II (AAST Grade III) blunt splenic injury without contrast extravasation in the presence of risk factors for NOM failure (i.e., age above 55 years old, high injury severity score, the need for red cell transfusions in ED or during the first 24 h, patients on anti-coagulant therapy, HIV disease, cirrhosis, and drug addiction) [**Strength of Recommendation: Conditional recommendation, based on Low quality of evidence, Agreement 89.1%**]. The panel suggests angiography and eventual SAE in all hemodynamically stable adult patients with WSES Class III (AAST Grades IV–V) splenic injuries, even in the absence of CT blush, in centers with adequate experience and where SAE is rapidly available, especially when concomitant surgery that requires change of position and that may cause dislodgement of clots and rebleeding (i.e., spinal surgery in the prone position) is needed [**Strength of Recommendation: Conditional recommendation, based on Moderate quality of evidence, Agreement 83.7%**]. The panel suggests SAE be reserved for children who demonstrate evidence of ongoing bleeding with a vascular blush seen on CT [**Strength of Recommendation: Conditional recommendation, based on Low quality of evidence**]. The panel suggests preferring proximal SAE over distal SAE when splenic artery angioembolization is needed [**Strength of Recommendation: Conditional recommendation, based on Low quality of evidence, Agreement 84.8%**]



Procedures

- **Transfusion**

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

- **Angioembolization or Operative Exploration**

- Signs of ongoing bleeding despite pRBC transfusion
- Angioembolization is not indicated for contrast blush on admission CT without unstable vitals
- Operative exploration may be indicated when additional procedures or information needed



Blush?

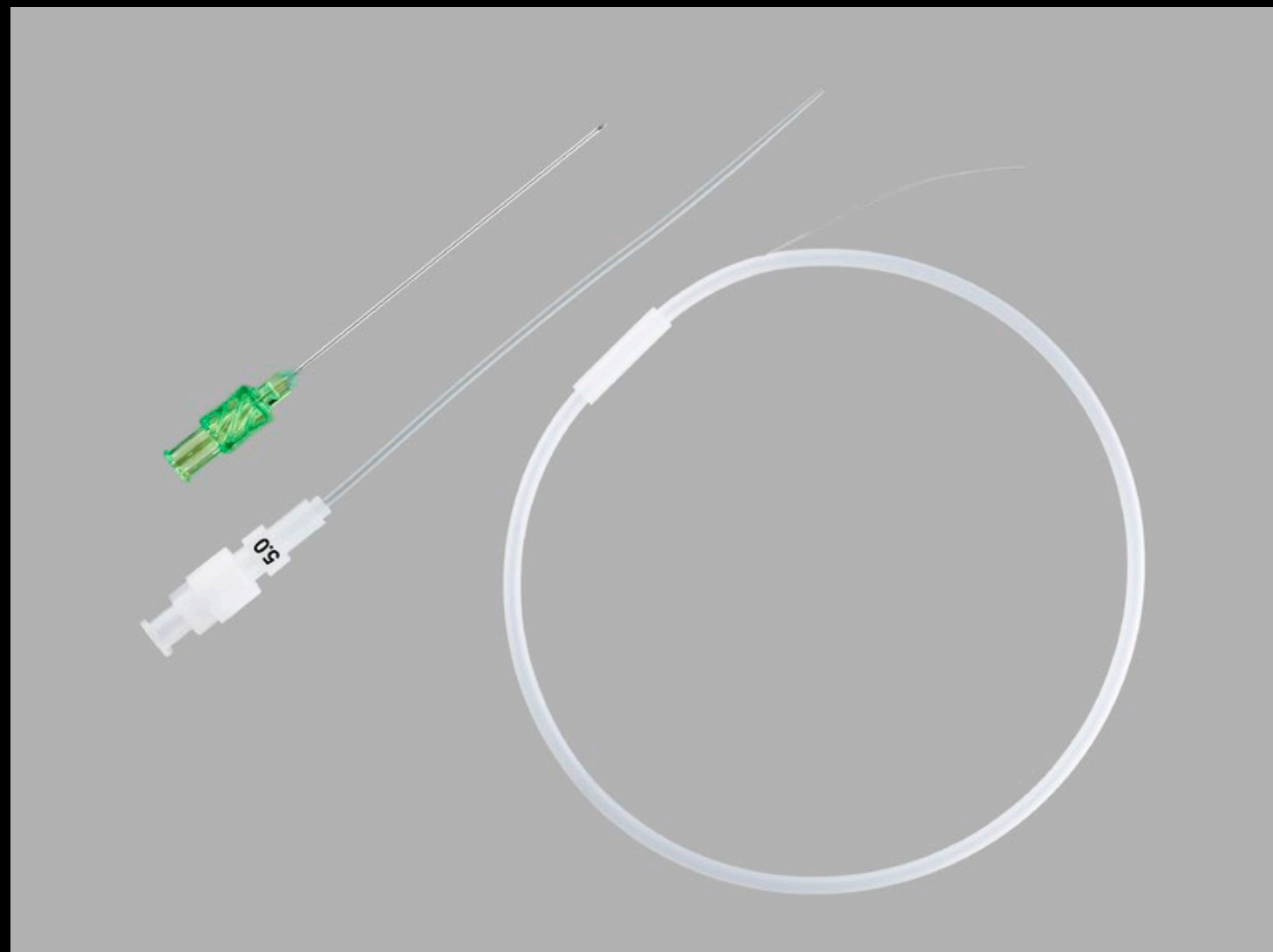
- “Active Extrav”

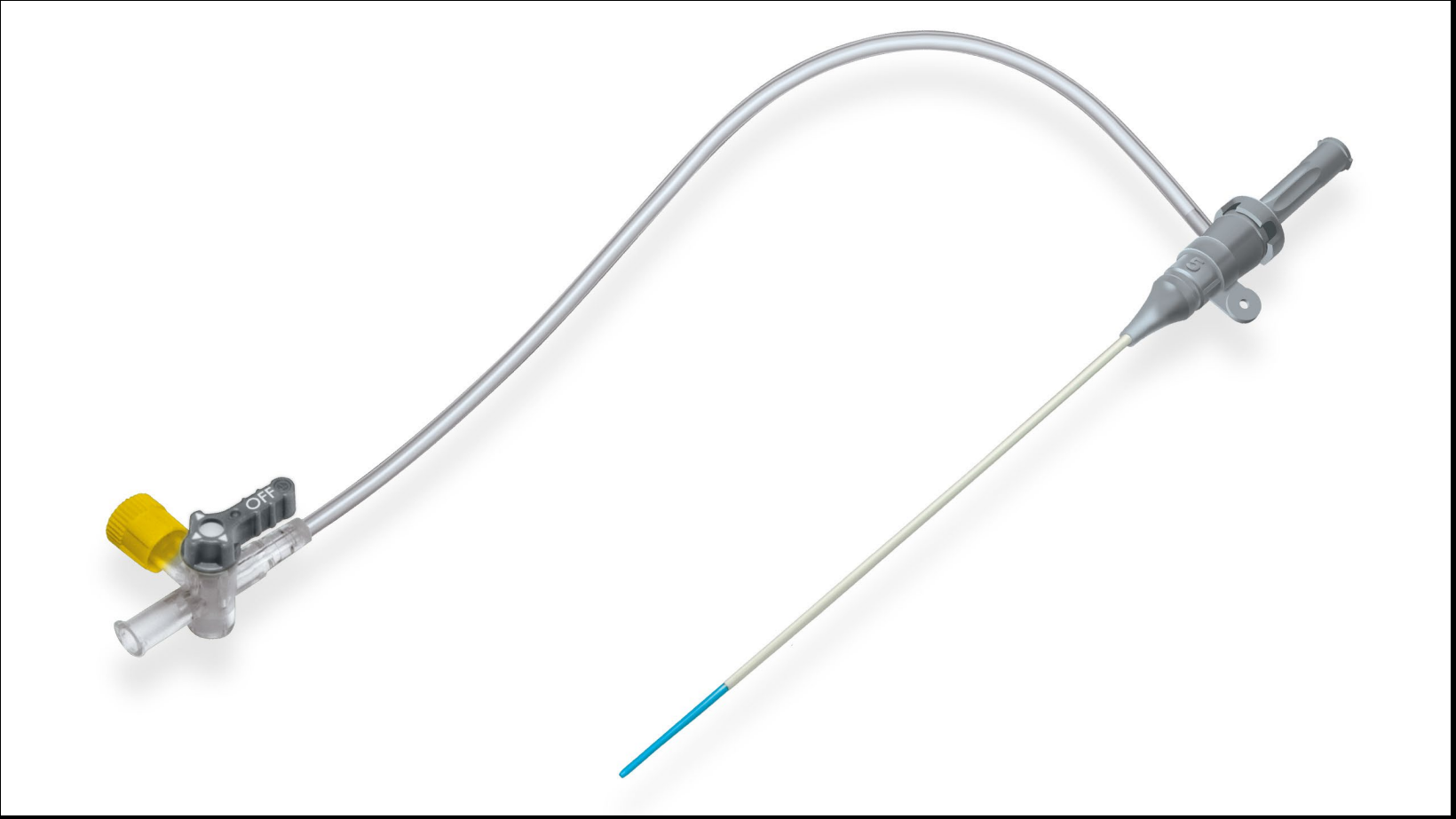
Hepatic and splenic blush on computed tomography in children following blunt abdominal trauma

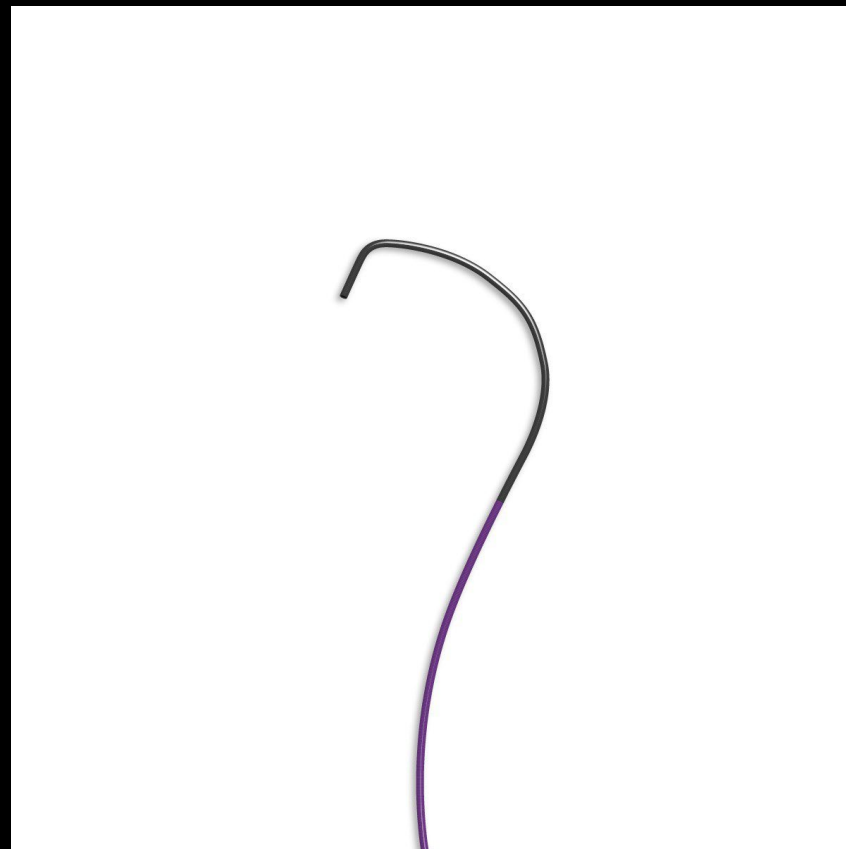
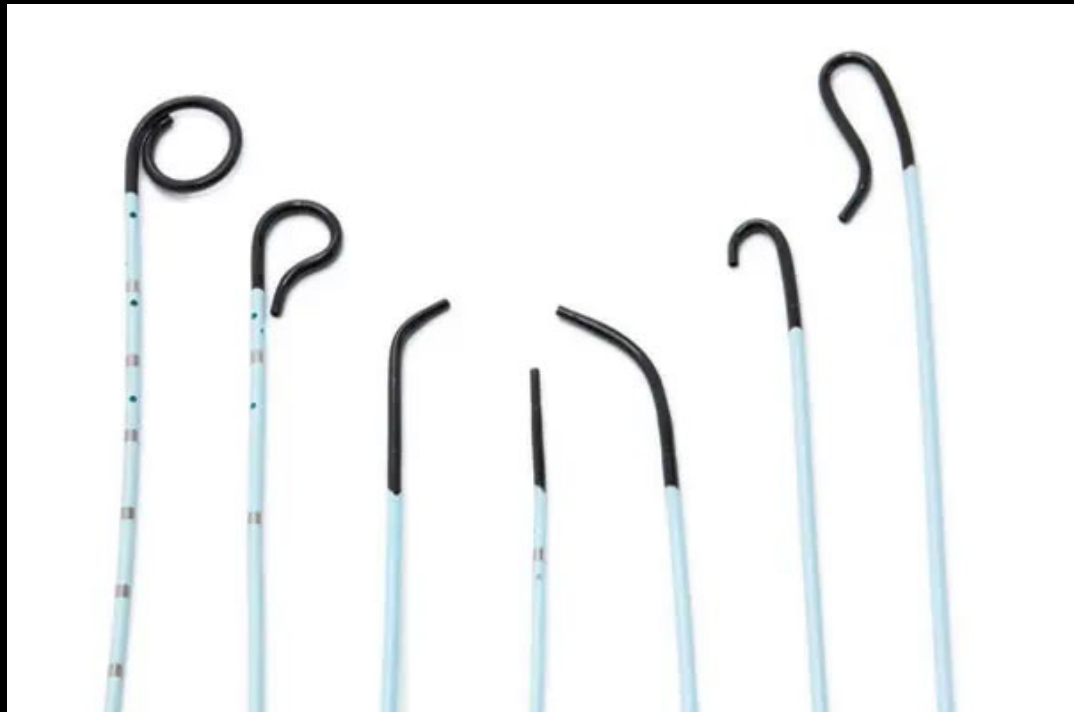
- Journal of Trauma and Acute Care Surgery, 2016
- Liver and spleen patients with solid organ blush
 - Only 17% of the cohort required definitive treatment
 - Flawed because they only embolized 1 patient

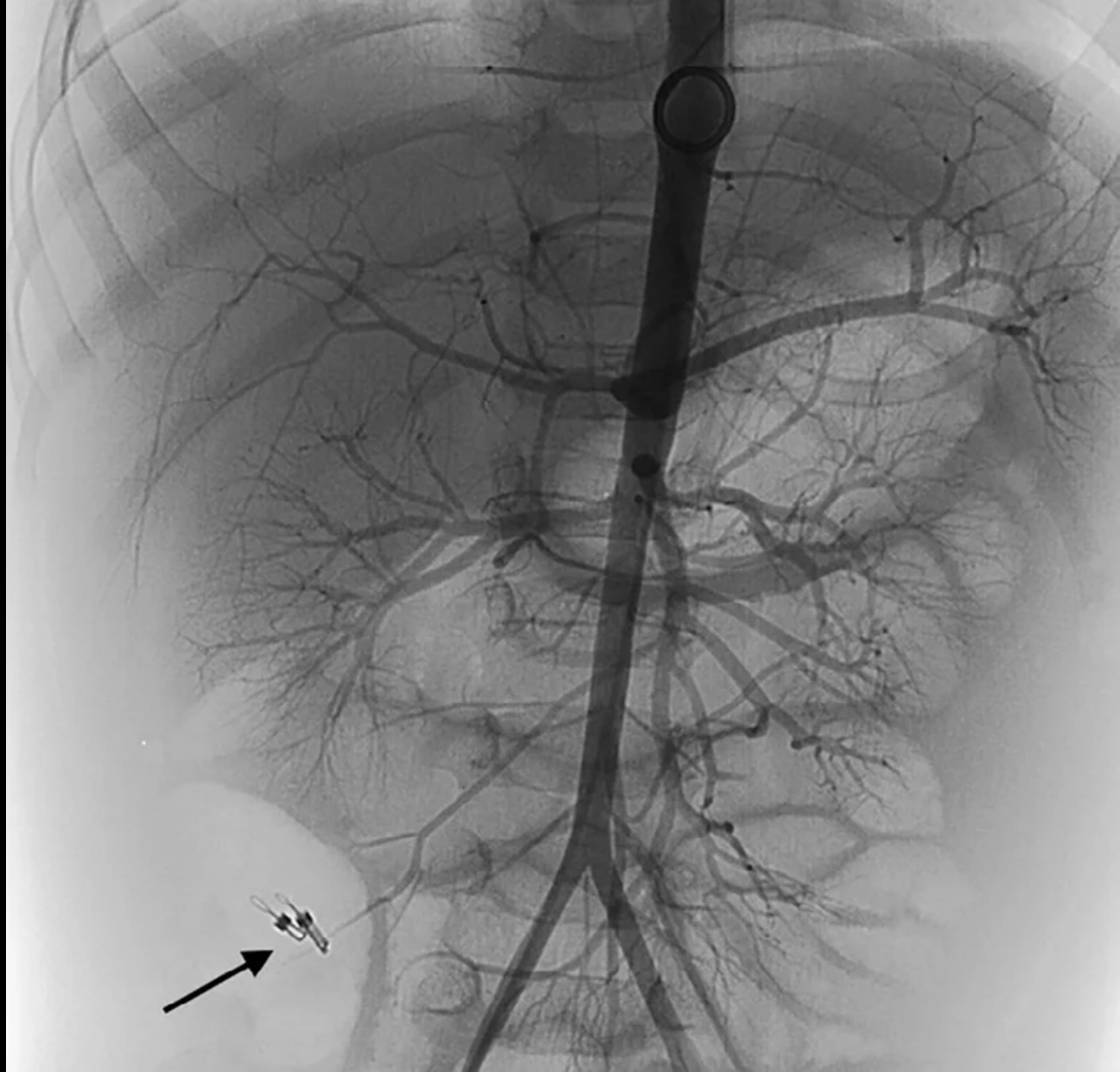
How It's Done – Basic Equipment

- Right femoral (usually) access w/ 21G micropuncture system
- 4F sheath
- Base catheter: 4F angled glide/C2/Simmons/reverse curve
- +/- microcatheter: 2.4/2.8F Progreate
- Wires: 0.035 Benson/angled glide; 0.014 Progreate kit wire





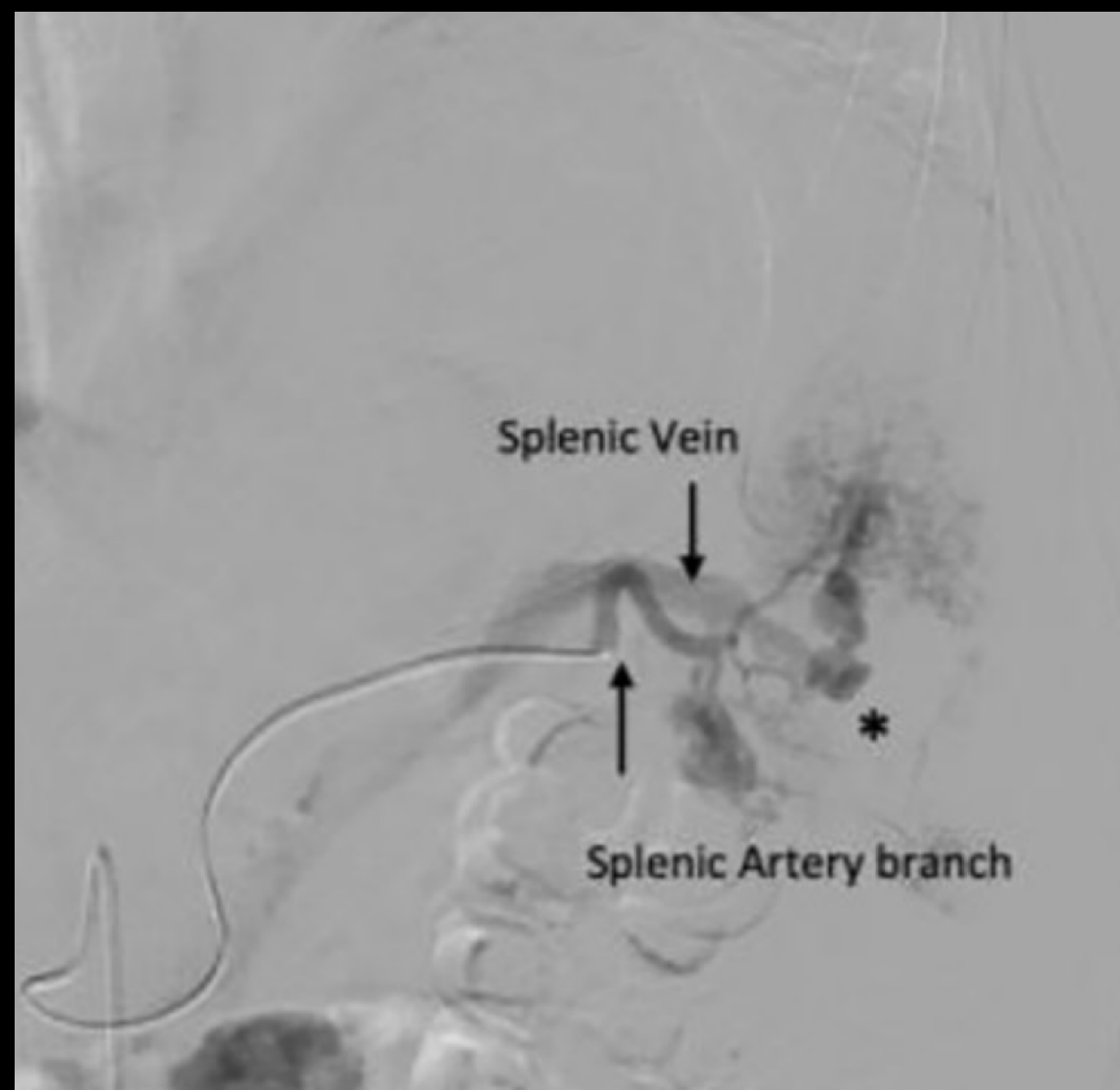








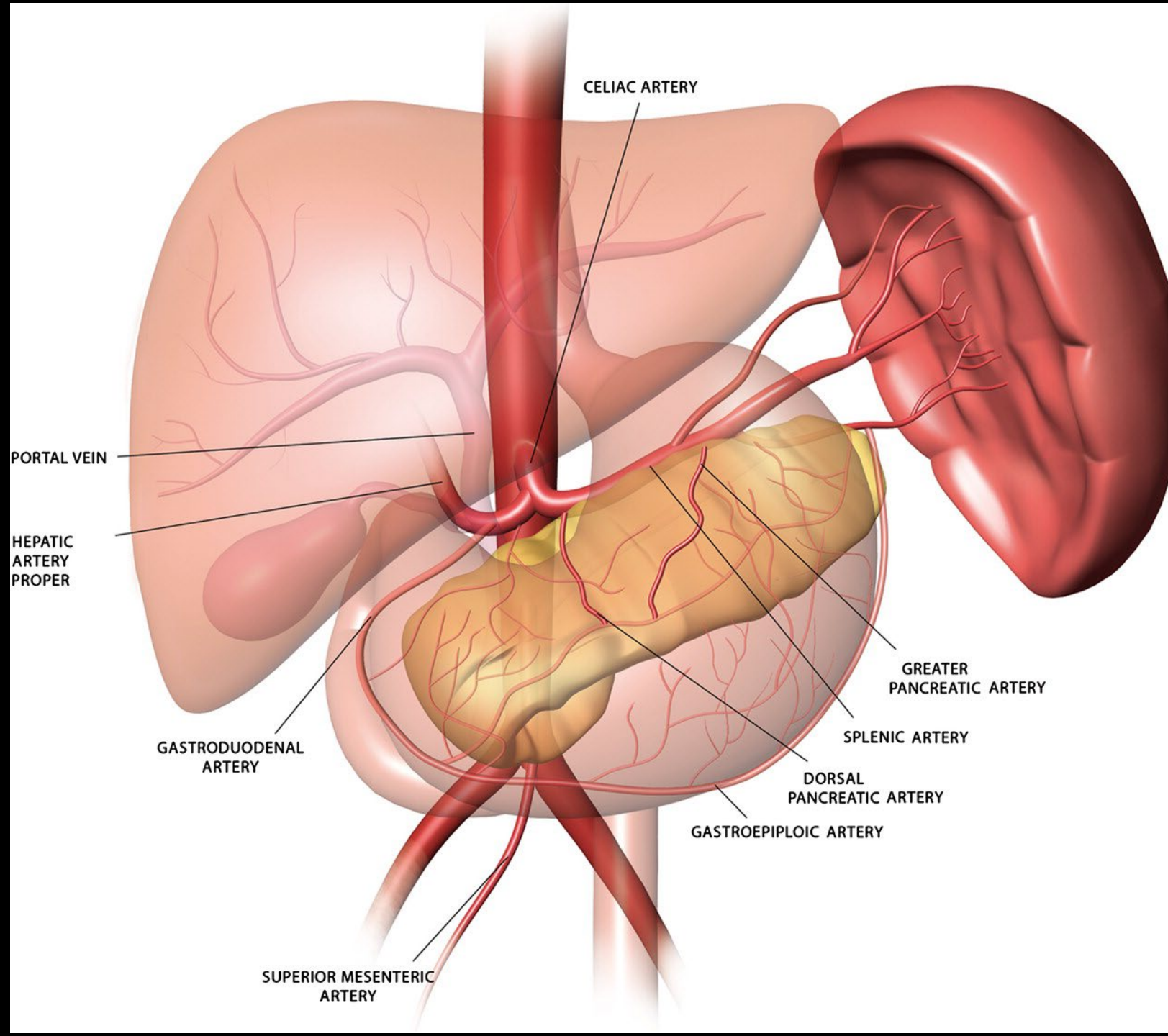


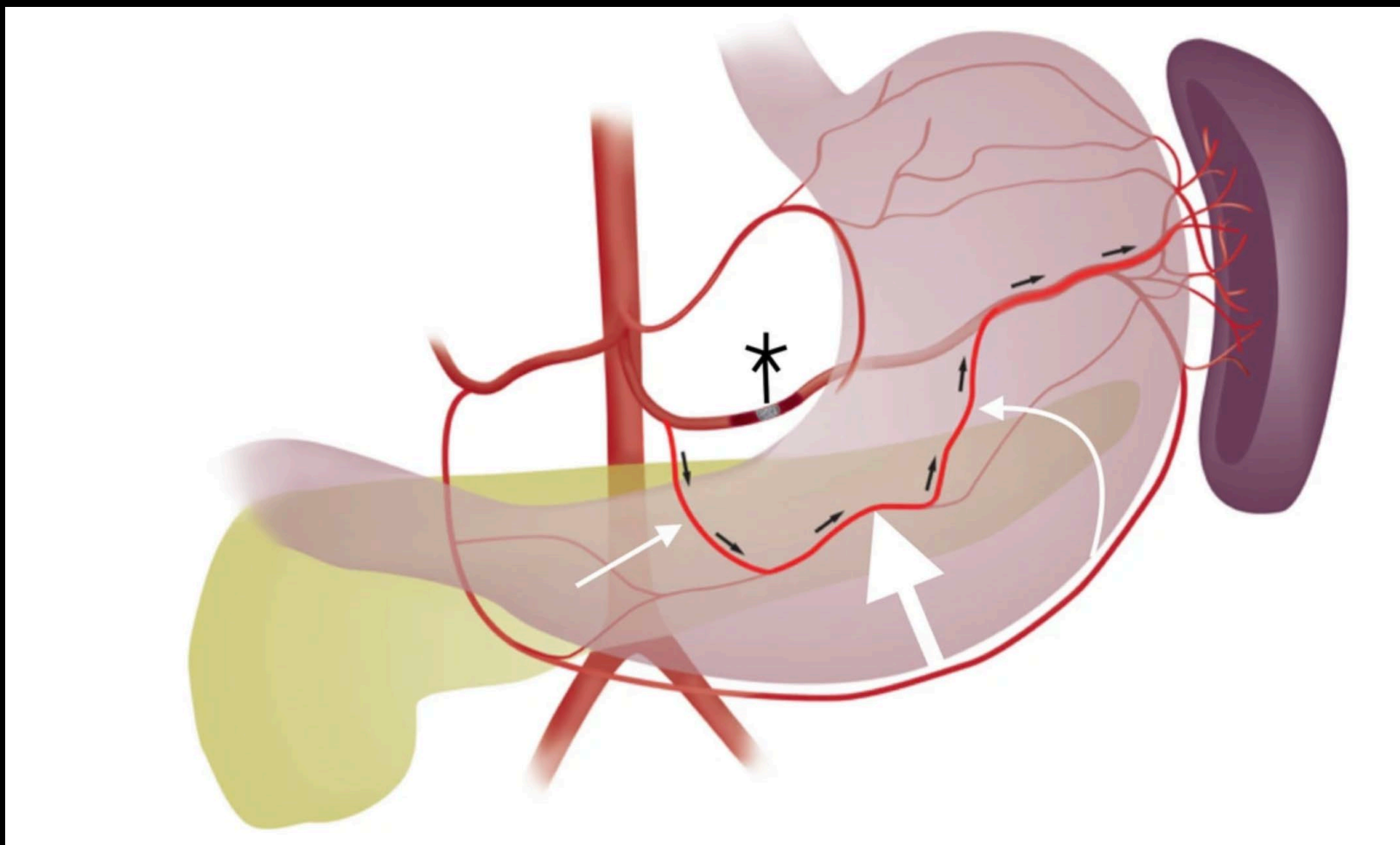


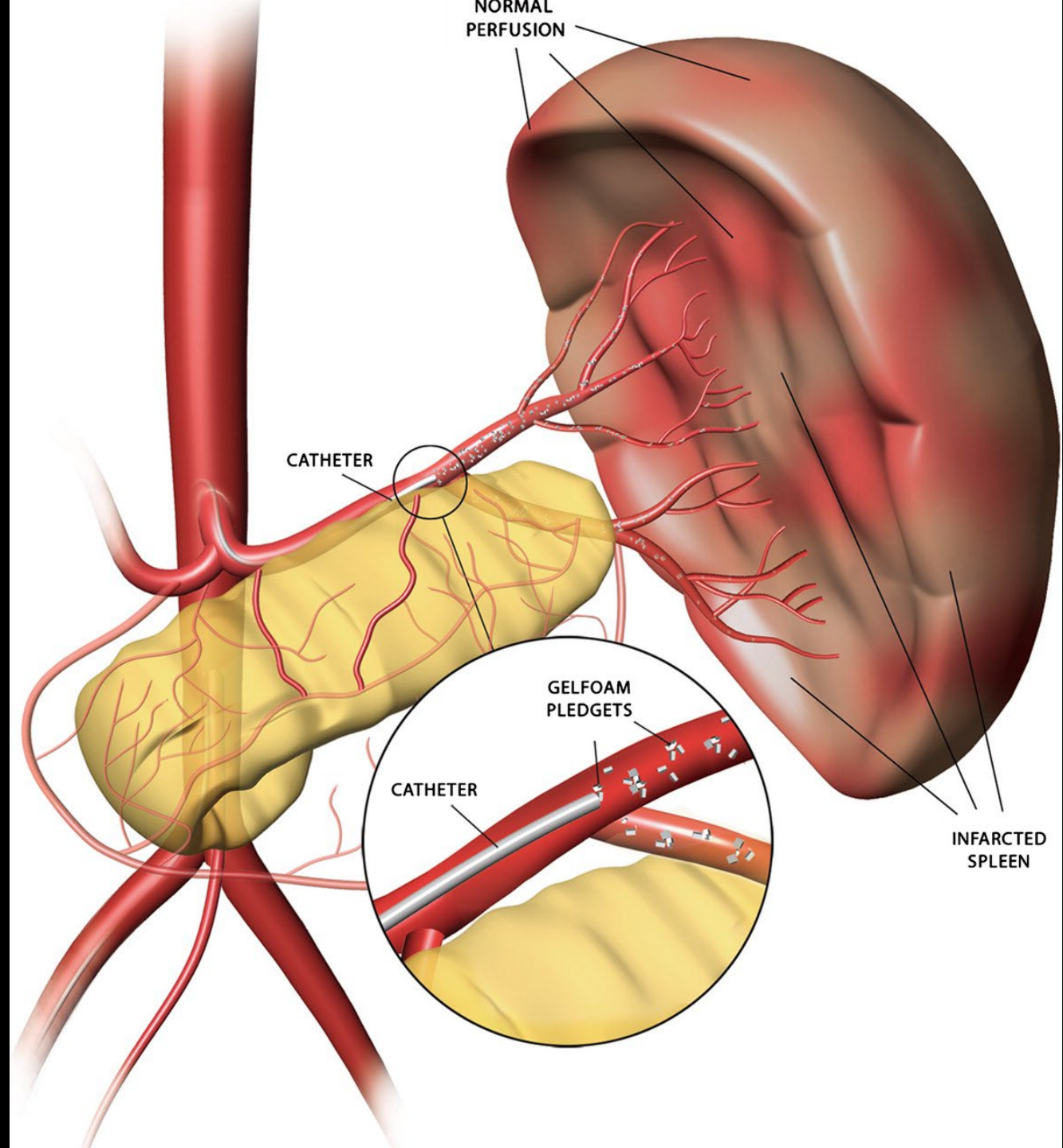


Embolic Agents

Agent	Level	Duration	Best use in pediatric trauma	Cost / caution
Gelatin sponge (slurry or torpedo)	Small artery / arteriolar	Temporary, ~2–6 weeks	Diffuse parenchymal bleeding; petechial hemorrhage; the fast option in an unstable child	Least precise. Slurry refluxes. Recanalizes — which is often exactly what you want in a child
Pushable & detachable microcoils	Named branch	Permanent	Discrete pseudoaneurysm; single bleeding branch; proximal splenic artery flow reduction	Only occludes where deployed — collaterals reconstitute. Detachable coils allow repositioning
Vascular plug	Named artery	Permanent	Proximal splenic artery occlusion in a single device	Needs a larger catheter; reduces fluoroscopy time versus packing coils
n-BCA glue	Any, incl. distal	Permanent	Coagulopathic child; pseudoaneurysm; lesion a microcatheter cannot quite reach	Operator-dependent, unforgiving. Non-target embolization and catheter gluing are real
Particles (PVA, microspheres)	Arteriolar	Permanent	Rarely first-line in trauma — mostly diffuse mucosal or pelvic bleeding	Highest infarction risk. Avoid small calibres in solid organs you intend to preserve









The Aftermath



Post-Embolic Syndrome (PES)

- Normal inflammatory process to tissue death
- Temporary
 - 24 - 72 hours after completion of procedure
 - Lasts 1-2 weeks
- Personal experience in kids...varies more
 - Peaks at 48hrs and lasts up to 7 days
 - Generally, more nervous beyond day 7 in kids
- Low-grade fever, pain at the treatment site, nausea/vomiting, fatigue, mild increase in white count.
- Supportive therapy, no need to look for “infection”
- When to worry?
 - >102 or beyond a week, new rising white count after initial improvement.



Splenic Embolization

- Complications (adult data)
 - Major complications – all roughly 4%
 - Rebleeding, major infarction, abscess
 - Minor complications – between 4-18%
 - Fever, pleural effusion, coil migration, splenic atrophy, hematoma, access site complications
 - Peds?
- Parenchyma
 - Proximal embolization: perfusion pressure falls, collateral inflow via greater panc, short gastrics, and gastroepiploic maintains viability
 - Segmental infarction is uncommon
 - Distal: the embolized segment infarcts. It demarcates on imaging over days and involutes over weeks to months
 - Gel foam is variable, may see small wedge shaped infarcts on follow-up CT



Does the spleen still work?

- No consistent measurement of determining residual splenic function after embolization in the setting of trauma.
- Selective reduction literature, need 30-50% of residual parenchyma to maintain function
- Vaccination?
 - Eastern Association for the Surgery of Trauma (EAST)
 - Conditionally recommended against routine vaccination
 - Fewer infections vs splenectomy patients
 - Splenic immune function did not differ from controls
 - Adult guidelines
 - Low certainty evidence
 - Assumes some preserved spleen
 - If vaccinating, wait 14 days



Liver Embolization – A Different Beast

- Much higher complication rate – Adult data
 - 27-50% in some series
- Hepatocytes survive on portal venous flow, bile ducts are exclusively arterial fed
- Morbidity centered around ischemic cholangiopathy
- Delayed presentation – days to week
 - New/worsening fever, rising bili, new bilious output from a preexisting drain
- Higher threshold to embolize?
- IR can help manage



Follow-up Imaging?

- Asymptomatic, no extrav on admission CT = no additional imaging
 - APSA
- Extrav on admission CT = consider before discharge, can use doppler US
- Continued symptoms w/ prior high-grade injury = image
- After embolization = image if clinical course demands it (new/high grade fever, new Hbg drop, new/worsening pain)



Research Question: 7. What is the best imaging method to follow-up patients treated with NOM for high-grade splenic injuries in the acute phase during NOM (Ultrasound without contrast, Contrast-enhanced ultrasound, CT-Angio)?

Priority level: *High*

Statement: Although contrast-enhanced CT scan is the gold standard modality for imaging abdominal organ traumatic injury, contrast-enhanced ultrasound (CEUS) has developed a role in the follow-up of traumatic injuries, including splenic trauma. CEUS is a valuable tool for detecting post-traumatic lesions; it is comparable to CT after splenic embolization and may replace CT in follow-up studies in expert hands [**Quality of Evidence: Low**]. CEUS may be considered in children, although repeat imaging in children is rarely needed [**Quality of Evidence: Low**]

Recommendation: The panel suggests, in expert hands and dedicated institutions, using CEUS as an alternative imaging modality in the follow-up of conservatively managed splenic trauma to reduce the number of CT examinations, especially in children [**Strength of Recommendation: Conditional recommendation, based on Low quality of evidence, Agreement 91.3%**]

In Summary...When to Contact Me?

- Transfused and still showing signs of ongoing bleeding
- Transient responder: Improves w/ volume and product, then drifts down
- Delayed Hbg drop in a patient who initially had extravasation but was stable
- Any post-traumatic collections
- Persistent high-grade fever after embolization

Questions?

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Questions for CME

1. What percentage of patients fail NOM?

4%

2. Are vaccinations routinely recommended to patients who have undergone SAE per EAST guidelines?

No

3. What type of SAE tries to preserve splenic flow via collaterals?

Proximal