Seminars in Pediatric Surgery 31 (2022) 151216

Contents lists available at ScienceDirect

Seminars in Pediatric Surgery

journal homepage: www.elsevier.com/locate/sempedsurg

Evidence-based management of pediatric solid organ injury

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Background

Blunt solid organ injury (SOI) is estimated to occur in approximately 8,800 children each year.[1,2] The liver is the most commonly injured solid organ in children (44%), followed by spleen (32%), a combined liver and spleen (6%), kidney (18%) and pancreas (6%).[2,3] In 2000, the American Pediatric Surgery Association (APSA) made recommendations for an admission period equal to the grade of injury +1 in days.[4,5] In 2019, APSA did a PRISMA (systemic review and meta-analysis) study examining the accumulated literature and made significant changes to their prior recommendations.[4] A host of new information was also available on other import topics, including data from the PECARN group and Pediatric Surgery Research Collaborative looking at appropriate use of imaging.[6-8] Numerous studies from the ATOMAC group enrolled more than 1000 children with solid organ injuries.[9] These studies operationalized the ATOMAC guideline for blunt liver and spleen injury and evaluated the results prospectively. This article will review current evidence-based recommendations for care.

Who requires a CT scan?

Several important studies have been published examining prediction rules for avoiding abdominal CT imaging of children with blunt abdominal trauma, and numerous additional studies have validated the prediction rule.[6,8,10-14] The prediction tools can effectively be broken down into rules that require labs and imaging, and those that are based solely on physical exam. PECARN's prediction rule requires a patient who is able to answer questions and has a GCS of 14 or 15, and a reliable physical exam (Figure 1) For patients who receive blood work and chest imaging, Streck et al found that the one-third of patients with no abdominal complaints, normal abdominal exam, normal chest x-ray, normal AST, and normal lipase can be safely managed without an abdominal CT scan (Figure 2).

What is the role of FAST?

Focused abdominal sonography in trauma (FAST) and its various extensions have played a very controversial role in pediatric trauma since the inception.[15] Now, however, after two additional decades of technology improvements, and the FDA approval of ultrasound contrast agents, the role for ultrasound is beginning to take shape. Non-contrast FAST abdominal ultrasound appears to miss a significant number of injuries.[16,17] The injuries that are missed, however, are unlikely to result in transfusion or surgical intervention.[16,18-20] Studies comparing contrast-enhanced ultrasound to CT scan are beginning to suggest the potential to replace abdominal CT in the future, but more studies are needed.[21-23] In unstable patients, FAST appears to play an important role in determining abdominal bleeding as the source of the hemodynamic instability.[20]

How do we manage solid organ injuries?

Liver and spleen

In 2015, the ATOMAC group published version 11.0 of a comprehensive management algorithm for children with blunt liver or spleen injury.[24] The algorithm incorporated several newly accepted concepts: (1) Most patients with blunt SOI never bleed intra-peritoneally (2) Management decisions can be made on clinical signs of recent or ongoing bleeding (including hemodynamic status) (3) A patient who bled to the point of shock may not still be bleeding (4) The best way to determine if a child is still bleeding is to transfuse blood and evaluate the hemodynamic response (5) Avoiding excess crystalloid is important in child (6) Admission to the intensive care unit can be determined by hemodynamic status, not grade of injury. (7) An abbreviated period of activity restriction is safe (8) A transfusion threshold of 7.0g/dL is safe (8) No role exists for the use of vasopressors in pediatric abdominal trauma, and finally (9) Clinical evaluation is adequate to identify which patients are in shock.

Later studies confirmed several concepts that were not fully incorporated into the 11th version. (1) Serial hemoglobin measurements lacks utility in the face of a consistent exam and vital signs.[25,26,52] (2) Routine follow up imaging studies are not required[27] (3) Laparoscopy is often used in stable patients for delayed washout of blood, particularly in liver injury[28] (4) Angioembolization is rarely required, and probably overutilized[9] (5).

Abbreviations: SOI, Solid organ Injury; APSA, American Pediatric Surgery Association; ATOMAC, Arizona-Texas-Oklahoma-Memphis-Arkansas Consortium; CT, Computed Tomography; GCS, Glasgow Comma Scale; PECARN, Pediatric Emergency Care Applied Research Network; PRISMA, referred Reporting Items for Systematic Reviews and Meta-Analyses; NOM, Non-operative Management; IAI, intra-abdominal injury; IAI-I, Intra-abdominal injury requiring intervention; CXR, Chest X-ray; AST, aspartate aminotransferase; FAST, Focused abdominal sonography in trauma.

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https://doi.org/10.1016/j.sempedsurg.2022.151216

The PECARN 7-element prediction rule for omitting abdominal CT
Must be GCS 14 or 15
No abdominal pain
No vomiting
No abdominal tenderness
No chest wall tenderness
No abdominal bruising
Normal breath sounds bilaterally

Figure 1. The PECARN 7-element criteria for omitting abdominal computed tomography. CT= computed tomography; GCS= Glasgow Coma Scale; PECARN = Pediatric Emergency Care Applied Research Network. Modified from Holmes JF, Lillis K, Monroe D, et al. Identifying Children at Very Low Risk of Clinically Important Blunt Abdominal Injuries. Ann Emerg Med 2013.

The updated algorithm (Figure 3) simplifies the prior management algorithm and included changes such as elimination of serial hemoglobin measurements. Version 12.0 eliminated the 'crossover' pathway from stable to unstable because patients judged not to be bleeding at admission are very unlikely to ever bleed.[9,29] The pathway also allows for an evidence-based recommendation for discharging some isolated low-grade injuries from the emergency department, and an incorporation of CT findings into the determination for recent/ongoing bleeding. This data was supported by a reanalysis of two large prospective studies by Evans et al.[29] as well as a look at the ATOMAC prospective data.

Angioembolization

Angioembolization is adults has a strong track record of decreasing operative management.[30] The utility, however, in children appears to be less clear.[4] Early studies showed that even children with "blush" or contrast extravasation on CT were unlikely to fail non-operative management.[31] In the ATOMAC study of 1007 children, only 32 patients underwent an angiography, and only 19 (1.9%) of these patients underwent an embolization: 7 of these 19 still required surgery, although not for ongoing bleeding.[9] The current role for angiography in children is that is helpful in a small number of cases, but probably overutilized.[4]

Renal injuries

Renal injuries are less common than spleen and liver injuries. Hematuria is a common presenting sign, but many patients with renal arterial occlusion have no findings or symptoms, while hematuria without gradable injury also appears common.[32,33] Nonoperative management is the standard for all hemodynamically stable injuries.[34] Those injuries which continue to bleed are good candidates for angiography and selective embolization.[35] High grade injuries are more likely to need intervention and the results of embolization are superior to surgery. Posttraumatic renal hypertension after nonoperative management occurs in approximately 4% and all patients should have long-term blood pressure follow up.[34] Urine leaks after injury occur in about 13% of patients, mainly higher-grade injuries, but most can be managed with internal stenting and/or percutaneous drainage with high success.[36,37] Management of renal artery occlusion is complicated by little scientific data, but successful endovascular treatment even after significant delay has been reported.[38,39] Bedrest in not required after blunt renal injury, and early ambulation appears safe.[40]

Pancreatic injuries

As noted in the initial figures, pancreatic injury is rare. Moreover, the data available to make recommendations about management are clouded by an organ grading system that does not characterize the grades of injury in an escalating fashion, nor does it require definitive evidence of the status of the pancreatic duct. CT scanning is inadequate for evaluating the pancreatic duct integrity[41] and often leads to overestimating the injury grade.

Low grade (grade 1 and 2) pancreatic injuries do not require operative intervention. Some studies suggest that higher grade injuries do not require surgery, but the data driving those recommendations is adulterated by many injuries with an intact duct.[42,43] High value studies show that nonoperative management of complete pancreatic duct transection results in distal atrophy,[44] suggesting that non-operative management in the setting of a complete ductal transection results in autodigestion and loss of the pancreatic tissue, even if successful in avoiding surgery. Carrying this logic forward, a major duct injury near the duodenum would have a devastating effect on function if reconstruction is not performed. In contrast, a mid-duct injury could be allowed to auto digest the distal pancreas with the same loss as surgery but with a known higher complication rate and more days on TPN. With the advent a laparoscopy, however, a distal pancreatectomy appears to be the preferred approach when a prompt diagnosis is made.[45] Injuries to the head of the pancreas with an intact duct can be managed non-operatively, similar to grade 2 injuries. Grade 5 injuries are rare, and complex reconstruction is required but the initial management is wide drainage and a damage control approach with complete resuscitation prior to attempting reconstruction.

Risk of rebleeding

Delayed bleeding from any SOI is very, very rare. In the spleen, most large studies have few or no cases of delayed splenic bleeding[46-48] Most series estimate the incidence of delayed splenic bleeding as less than 0.2%.[4] In a re-assessment of prior cases of delayed splenic bleeding by Davies et al, the majority cases were probably cases of ongoing bleeding with delayed recognition.[47,48] In the ATOMAC prospective study, none of the 499 liver injuries or 466 splenic injuries had a delayed inta-abdominal bleed. One internal liver bleed (hemobilia) presented in a delayed fashion as a gastrointestinal bleed.

Re-imaging in solid organ injury

The relationship between arterial pseudoaneurysms and bleeding has made the concern over reimaging more controversial than would be justified. For more than two decades, the APSA guidelines have recommended no routine re-imaging after successful nonoperative management of solid organ injuries. With the increased use of ultrasound, pseudoaneurysms may be quite commonly identified after blunt solid organ injury. The vast majority are never clinically relevant, and the natural history appears to be spontaneous thrombosis in the vast majority of cases.[48-50] In the prospective ATOMAC trial, no routine re-imaging was done, and 6% of patients underwent re-imaging for symptoms. While abnormal findings such as cysts were common in this 6%, no patient underwent any solid organ intervention related to the findings. Moreover, no pseudoanersyms were found in the small subset of re-imaged patients.[27] While these pseudoaneurysms exist (based on rigorous re-imaging studies), they very rarely become clinically relevant.[49,50]

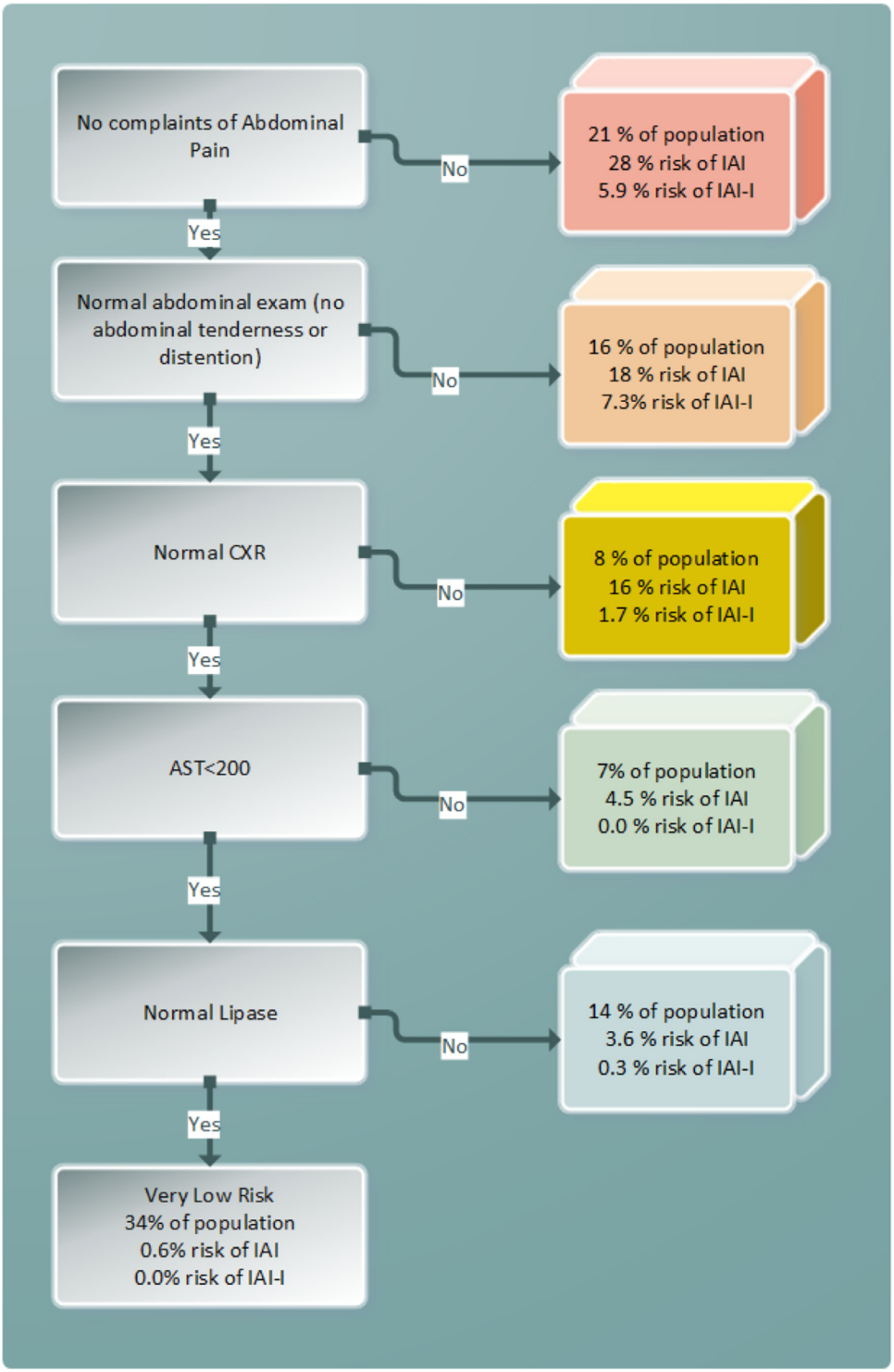

Figure 2. 5-element prediction model showing frequency of patients meeting exclusion criteria, as well as each element's associated risk of intra-abdominal injury. IAI = intra-abdominal injury; IAI-I = Intra-abdominal injury requiring intervention. CXR = chest radiograph; AST = aspartate aminotransferase. Modified from Streck CJ, Vogel AM, Zhang J, et al. Identifying Children at Very Low Risk for Blunt Intra-Abdominal Injury in Whom CT of the Abdomen Can Be Avoided Safely. J Am Coll Surg 2017;224(4):449-58 e3.

Activity restriction

The 2000 APSA guideline recommended activity restriction for a period equal to the grade of the injury plus two in weeks[5] The recommendation was based on instructions used in >25% of patients at the participating hospitals. Graziano et al found that bedrest was not required at all in renal injury, and this suggests that perhaps activity restriction, in general, may not have a role beyond preventing re-injury to the same organ. ATOMAC found that no difference in return to the emergency department or rebleeding regardless of adherence to the recommend activity restriction guideline.[51] The updated APSA manuscript notes that grade +2 in weeks is safe, but acknowledges the safety of shorter periods of activity restriction are unknown.

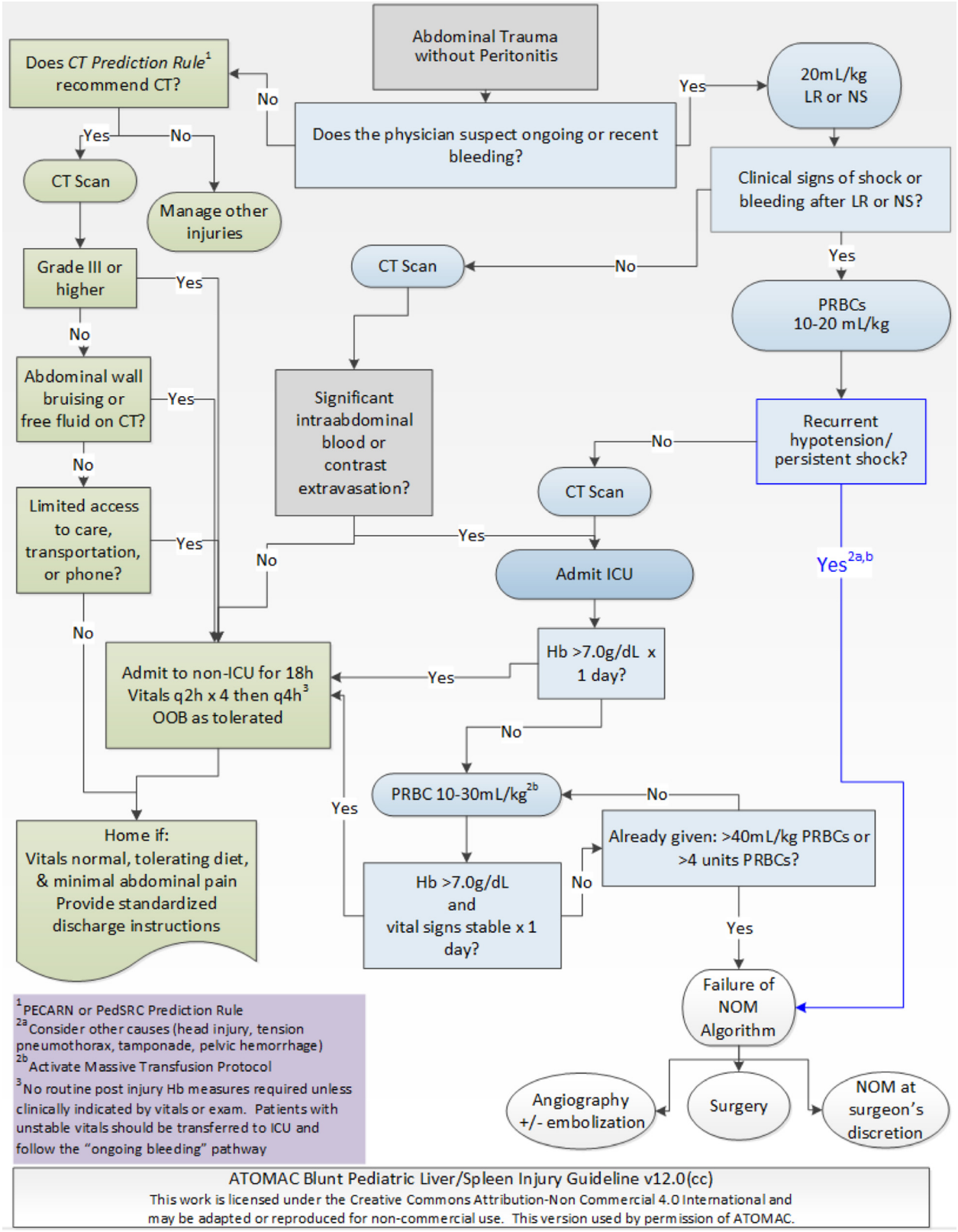

Figure 3. ATOMAC guideline v12.0 for management of blunt liver or spleen injury. LR=lactated ringers; NS=normal saline; PRBCs=packed red blood cells; CT = computed tomography; ICU= Intensive Care Unit; Hb=hemoglobin; NPO=nothing by mouth; q6h=every 6 hours; NOM=nonoperative management; ICU=intensive care unit; q2h=every 2 hours. PECARN=Pediatric Emergency Care Applied Research Network; PedSRC = Pediatric Surgery Research Consortium; For Abdominal CT prediction rules, see (1) Streck CJ, Vogel AM, Zhang J, et al 2017 and (2) Wisner DH, Kuppermann N, Cooper A, et al.2015. Algorithm used by permission of ATOMAC.

Acknowledgement

I'd like to thank the ATOMAC authors for reviewing the revised ATOMAC guideline v12.0, with special thanks to James Eubanks, III, Dorothy H. Rowe, MD, Carey Lynn Lewis, CPNP, AC/PC, Megan Gilbert, CPNP, Christian J Streck, MD and Jessica Naiditch, MD.

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