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POLICY STATEMENT

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Optimizing Advanced Imaging of the Pediatric Patient in the Emergency Department

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AMERICAN ACADEMY OF PEDIATRICS
Committee on Pediatric Emergency Medicine, Section on Radiology

AMERICAN COLLEGE OF EMERGENCY PHYSICIANS
Pediatric Emergency Medicine Committee

AMERICAN COLLEGE OF RADIOLOGY

POLICY STATEMENT
Organizational Principles to Guide and Define the Child Health Care System and/or Improve the Health of All 17 Children

Optimizing Advanced Imaging of the Pediatric Patient in the Emergency Department

ABSTRACT. Advanced imaging, including ultrasonography, computed tomography, and magnetic resonance imaging (MRI), is an integral component to the evaluation and management of ill and injured children in the emergency department. As with any test or intervention, the benefits and potential impacts on management must be weighed against the risks to ensure that high-value care is being delivered. There are important considerations specific to the pediatric patient related to the ordering and interpretation of advanced imaging. This policy statement provides guidelines for institutions and those who care for children to optimize the use of advanced imaging in the emergency department setting and was coauthored by experts in pediatric and general emergency medicine, pediatric radiology, and pediatric surgery. The intent is to guide decision-making where children may access care.

ABBREVIATIONS: ALARA (as low as reasonably achievable); CT (computed tomography); ED (emergency department); PCP (primary care provider); PE (pulmonary embolism)

INTRODUCTION

As diagnostic imaging has advanced over the last several decades, imaging modalities have become more accurate, faster, and more widely available. Advanced imaging (ie, ultrasonography, computed tomography [CT], and magnetic resonance imaging [MRI]) is commonly used in the emergency department (ED) to assist and facilitate diagnosis and management, and such use has increased dramatically over time.[1,2] However, imaging carries risks including those from radiation exposure,[3-5] false-positive and incidental findings and the downstream testing that may result,[6-10] increases in ED length of stay,[11,12] sedation,[13] transport away from the ED, and overall health care costs.[14] In addition, there is the risk that a study will need to be repeated if not optimally performed, thus compounding the aforementioned risks. It is important that physicians, physician assistants, and nurse practitioners weigh the risks and benefits when ordering advanced imaging studies to ensure there is a net benefit delivered to patients.

Pediatric patients represent a distinct population that requires unique considerations with respect to advanced imaging in the ED. Pediatric patients typically have a small body habitus and less subcutaneous fat, which makes ultrasonography an ideal imaging tool for several indications.[15] Children are particularly sensitive to ionizing radiation, such as from CT, because of the larger organ-specific dosing conferred, the increased susceptibility of these organs to developing malignancy secondary to radiation, and the increased life span over which those cancers may develop.[16] MRI is becoming increasingly available as an option in the emergent evaluation of pediatric patients because of abbreviated protocols, which have decreased the duration of studies and increased the feasibility.[17] This policy statement provides recommendations for optimizing advanced imaging of ill and injured children in the ED, and the accompanying technical report may be used as a more detailed resource. Point-of-care ultrasonography use by emergency physicians is not addressed in this document, as it is outside the scope.[18-20]

INSTITUTIONAL CONSIDERATIONS

To provide timely and appropriate imaging to pediatric patients presenting to the ED, there are important institutional considerations. More than 80% of pediatric patients in the United States receive emergency care from general EDs.[18,19] However, over 80% of EDs treat fewer than 10 children per day.[21] It is important that general EDs are prepared and have access to adequate resources to care for pediatric patients. Such "pediatric readiness" includes the provision of advanced imaging studies.[20] In keeping with the "as low as reasonably achievable" (ALARA) principle,[22] weight and size-based CT parameters should be adjusted for pediatric patients, and there is guidance available for institutions about how to implement this.[23] However, nearly 25% of EDs do not have reduced-dose radiation protocols for CT and radiograph imaging.[20] The use of ultrasonography as a nonradiating imaging modality has increased in pediatric patients over time[2] and may supplant the use of CT for many patients.[24] However, ultrasonography is operator-dependent, and many facilities do not have sonographers with sufficient training or experience in pediatrics. Facilities that have access to MRI should ensure that pediatric-specific protocols and size adjustments are available.

Imaging services extend beyond the actual imaging study, and patients will sometimes benefit from remote imaging consultation from a pediatric radiologist or other pediatric subspecialist. Such consultation should be considered depending on the nature of the suspected pathology, severity of illness, or comfort level of the treating clinician. Discussion may include the best imaging strategy prior to imaging being completed, if any, as well as interpretation of imaging results. These policies may reduce the need for transfer to a pediatric institution. When transfers are deemed necessary, it is imperative that any imaging and interpretation report performed during the referring ED encounter be transferred with the patient or remotely accessible to the receiving facility. In many circumstances, patients are destined for transfer to a pediatric facility regardless of imaging results at the referring ED. In cases when the results of imaging will not alter the decision to transfer or impact management prior to and/or during transport, it is in the best interest of the patient that imaging be

deferred to the receiving hospital. Imaging prior to transfer delays definitive treatment, may increase the number of imaging studies performed for a patient, and can result in higher radiation exposure and increased health care costs.[25-28] Advanced imaging is best performed when it will allow the patient to be discharged from the ED or remain at the originating hospital.

Physicians, Physician Assistants, and Nurse Practitioners Considerations

Although this statement is primarily directed toward those who work in the acute care setting, the care of the ill or injured child may begin with the primary care provider (PCP) who serves an important role, whether evaluating patients by phone, remotely, or in-person. It is important that PCPs are familiar with optimal imaging strategies (Table 1) for common pediatric conditions to adequately prepare patients who are referred to the ED and may require advanced imaging. It is equally as important for PCPs to be familiar with imaging resources at local EDs to best inform families and also decide to which ED a referral may be made when multiple options are available. In the ED, physicians and physician assistants and nurse practitioners are tasked with determining first whether advanced imaging is indicated and second which test is optimal to order. Such decisions are based on patient factors (eg, clinical presentation, age, need for sedation, comorbidities, availability of PCP follow-up) and ED resources available, including imaging availability and resources to manage abnormalities diagnosed. Guidelines such as published clinical decision rules that assist with risk stratification[29–31] hospital clinical guidelines (see technical report supplemental file), Choosing Wisely recommendations,[32] and the American College of Radiology Appropriateness Criteria[33] can assist with these decisions, as can consultation with a pediatric medical subspecialist (eg, pediatric emergency physician, pediatric radiologist) or pediatric surgical specialist, when available. Evidence-based guidelines may additionally reduce racial and ethnic disparities in ED imaging,[34–37] as these tools reduce variability in practice and provide a standardized approach to the evaluation for certain conditions.[38–40] Imaging typically falls into 3 categories: imaging that determines the need for emergent intervention provided by the originating ED; imaging that may determine whether transfer is needed; and, imaging in a patient who will be transferred regardless of the imaging findings (Table 2). Framing imaging decisions in this manner may help to curb unnecessary imaging.

In many cases, there may be more than one reasonable choice regarding advanced imaging, and shared decision making is appropriate to ensure that the patient and family's needs and values are considered and incorporated into decision making.[41] For example, a child with abdominal pain may be at moderate risk of appendicitis and need advanced imaging to evaluate the appendix; however, neither ultrasonography nor MRI are available at the referring ED. This situation presents an opportunity to weigh the options for imaging with the family including a CT at the referring ED or transfer to a pediatric facility for ultrasonography or MRI. For patients who are at low risk, an additional option to discuss with family members and document in the electronic health record is discharging home with monitoring for worsening symptoms and follow-up with the PCP.

RECOMMENDATIONS

1. EDs (including hospital and freestanding) that care for pediatric patients should ensure appropriate imaging resources are available to meet the needs of children or that they have transfer protocols and guidelines in place with a pediatric center. It is important that all EDs:
   a. Evaluate their pediatric readiness, including pediatric imaging services, and have a plan to address any deficiencies. This plan is ideally facilitated by appointing a pediatric emergency care coordinator.[18]
   b. Have a mechanism to securely transmit or share images with receiving hospitals electronically; and, have mechanisms for sharing images on physical media when online image transfer is not available.[42] This capability may reduce the need for repeat imaging at the receiving ED.
   c. Have processes in place to ensure timely and efficient transfer of pediatric patients who require specialized care, which minimizes potentially avoidable imaging and facilitates definitive imaging at the receiving hospital. Sample protocols are available from the Emergency Medical Services for Children Innovation and Improvement Center.[43]
   d. Have policies in place for imaging consultation with a pediatric radiologist or general radiologist with expertise in pediatric imaging to discuss best imaging practices and minimize transfers that may only

require imaging review. Ideally, such policies should outline processes and billing by pediatric radiologists for secondary readings of images completed prior to transfer.

e. Strive to provide high-quality ultrasonography services as first-line imaging for pediatric patients when indicated for common pediatric complaints (eg, abdominal pain with concern for appendicitis or nephrolithiasis). It is important for EDs that lack comprehensive imaging services for children to have guidelines and agreements in place. Guidelines should include alternatives when ultrasonography is the preferred imaging modality but not readily available and protocols for timely remote consultation with a pediatric medical subspecialist or transfer to a pediatric center.
f. Partner with imaging services to ensure that CT protocols and parameters are pediatric-specific and adhere to the ALARA principle. Specific guidelines are available.[22]

2. Primary care and emergency physicians and physician assistants and nurse practitioners who care for ill and injured children and/or who refer patients for ED evaluation and management can optimize advanced imaging by:
   a. Familiarizing themselves with pediatric imaging resources available at local emergency departments and using this information to decide where best to refer patients. Pediatric specialists, including pediatric radiologists and/or hospitalists, can help support decision making for ED clinicians.
   b. Discussing and deferring advanced imaging in children for whom the decision to transfer and management prior to and during transfer will not be altered by the results of imaging.
   c. Using shared decision making with the patient/family, when appropriate, prior to ordering imaging in EDs without access to ultrasonography or MRI when these modalities are considered first-line for the evaluation of the patient. Specifically, the risks and benefits of each of the following options should be considered: deferring immediate imaging and obtaining as an outpatient, transferring the patient to a referral center for imaging and interpretation, and performing the imaging that is available locally.
   d. Using publicly available evidence-based guidelines and protocols, such as the ACR Appropriateness Criteria[33] and/or clinical decision rules (with or without clinical decision support) that objectively risk-stratify patients, to minimize potentially unnecessary imaging and also reduce racial and ethnic disparities in imaging delivery.
3. Condition-specific imaging recommendations:
   a. *Seizures*
      i. Emergent neuroimaging is not recommended for simple febrile seizures.
      ii. Emergent neuroimaging is not recommended for complex febrile seizures if the patient is without neurologic deficits and returns to baseline, as the incidence of emergent and/or significant intracranial findings is very low.
      iii. Advanced imaging of children (≥6 months) with afebrile generalized seizures may often be deferred to outpatient or nonurgent settings in the absence of high-risk historical (eg, comorbidities, developmental regression) or clinical examination findings. Imaging is typically not indicated after a seizure in patients with a pre-existing diagnosis of epilepsy if the seizure is typical of the patient's seizure semiology. It is prudent to have a low threshold for neuroimaging in patients who present with status epilepticus or who do not return to their neurologic baseline.
      iv. In children with a seizure for whom neuroimaging is indicated, noncontrast MRI is generally the preferred imaging modality for stable patients. Noncontrast CT is acceptable if MRI is not readily available.
   b. *Headache*
      i. The incidence of pathology in children presenting with a headache and without other neurological signs or symptoms is low, and emergent neuroimaging may be reserved for those with neurologic signs and/or symptoms.
      ii. When neuroimaging is indicated, MRI is generally preferred over CT in stable patients. CT is acceptable if MRI is not readily available.
   c. *Ventricular shunt evaluation*
      i. Interpreting neuroimaging in patients with concern for shunt malfunction is best performed when compared with the patient's prior imaging, in order to detect subtle changes in ventricular size. If

there is strong clinical suspicion of a shunt malfunction without baseline imaging available, imaging may be deferred and performed where definitive treatment can be delivered.

ii. Children with ventricular shunts typically undergo frequent neuroimaging evaluations. Therefore, rapid MRI, when available, should be considered for the evaluation of shunt malfunction to reduce lifetime radiation exposure when resources are available to reprogram a programmable shunt if needed. Ultra low-dose CT protocols specific to ventricular shunt evaluation that reduce radiation exposure without compromising image quality are another option if MRI or the ability to reprogram the shunt is not available.

d. *Pediatric stroke*

i. Consultation with clinicians with expertise in pediatric stroke can aid in determining the optimal imaging strategies for children with stroke symptoms. Although there is no clear recommendation for thrombolytics in children, emergent advanced neuroimaging performed within 1 hour of arrival for children with stroke symptoms can aid in identifying children who may benefit from timely, specific stroke therapies.

ii. MRI has a high sensitivity for ischemic stroke in children and can also aid in identifying stroke mimics. Rapid MRI stroke protocols may overcome challenges associated with traditional protocols in pediatric patients.

iii. In children with stroke-like symptoms, and negative noncontrast CT, anti-thrombotic therapies are typically not warranted given the high rate of stroke mimics in this age group.

e. *Trauma*

i. Advanced imaging should be obtained for an injured patient if it will allow the patient to be discharged from the ED or remain at the initial ED. It is optimal for injured patients who have indications for transfer to a pediatric trauma center to not undergo advanced imaging at the referring center unless performed in consultation with a receiving pediatric trauma center.

ii. Cervical spine CT and chest CT imaging are seldom indicated as screening studies in pediatric patients. Evidence-based clinical guidelines and pathways, including those for minor head injury, cervical spine injury, and abdominal trauma should be used when possible to avoid CT use in patients at very low-risk for clinically important injuries. Alternatively, the child may be transferred to a pediatric trauma center where advanced imaging can be obtained if needed.

iii. Imaging decisions should be made with the intention of identifying clinically- important, rather than just radiographically-apparent, injuries (with the exception of injuries from child abuse, as all injuries are important for forensic documentation; see specific imaging recommendations below for evaluating suspected abuse).

iv. Routine whole-body CT (ie, "pan scan") should not be performed in pediatric trauma patients. When it is necessary, it should be performed with single-phase contrast to avoid scanning body regions multiple times. Selective region-specific scanning based on clinical prediction models is preferred unless the patient has an unreliable physical examination because of severe neurotrauma with or without intubation and a high-energy mechanism of injury.[44] If there is concern for vascular or renal collecting system injury, consultation with the radiologist is recommended to ensure appropriate timing of contrast for each body region.

f. *Child abuse*

i. When possible, imaging studies for the evaluation of child abuse are best interpreted by a pediatric radiologist to minimize the risk of missed findings or misinterpretation of normal developmental anatomy as abnormal. If clinical suspicion for abuse is high, consultation or transfer to a center with a child abuse specialist is important.

ii. Skeletal surveys should be performed to evaluate for occult or healing fractures when there is concern for abuse and should be performed in those less than 2 years of age. There is limited utility in older children unless recommended by a child abuse specialist.

iii. Either noncontrast CT or MRI of the brain is recommended in any child in whom there is suspicion of abusive head trauma. Given the high incidence of occult brain injury in children <6 months, physicians and physician assistants and nurse practitioners should have a low threshold to perform

neuroimaging. The imaging modality used depends on several factors, with CT preferred for unstable patients and those with acute trauma and concern for skull fracture. It is important to note that the PECARN head injury clinical decision rule[29] excluded children with concern for abuse, and therefore, should not be applied to these patients. The Pittsburgh Infant Brain Injury Score[45] may be used as a clinical decision aid to risk stratify children with subtle signs and symptoms suggestive of abusive head trauma.

iv. In patients with suspected or confirmed abusive head trauma, the cervical spine should be immobilized until definitive MRI imaging can be performed to evaluate for associated ligamentous injury and/or spinal cord injury without radiographic or CT abnormality.

v. Abdominal imaging via contrast CT scan should be considered in children with suspected abuse who have signs or history of abdominal injury or otherwise unexplained elevated liver enzymes (aspartate transaminase and alanine transaminase >80 u/L).[46]

vi. The high risk of reinjury and death in victims of child abuse must be factored into the risk-benefit ratio when considering imaging of these children.

vii. Unless discharge from the ED is anticipated, the imaging evaluation for child abuse is best performed and interpreted at a hospital with a child protection team.

g. *Appendicitis*

i. Risk-stratification tools can be used to assist with determining which patients are unlikely to have appendicitis and do not need imaging.

ii. When imaging is indicated, ultrasonography is the preferred first-line imaging modality. If unavailable, physicians and physician assistants and nurse practitioners may incorporate shared decision making to determine whether immediate CT imaging, transfer for ultrasonography or MRI, or watchful waiting with admission or observation at home with next-day follow-up is the best plan.

h. *Pulmonary embolism*

i. Lower extremity Doppler ultrasound can be considered as a first-line test in patients with concern for a deep vein thrombosis or a pulmonary embolism (PE). A positive ultrasound may allow for presumptive diagnosis of PE in the appropriate clinical scenario. However, a negative ultrasound study is insufficient to exclude the diagnosis and depending on the pretest probability, CT would be appropriate.

ii. CT pulmonary angiogram is the diagnostic test of choice when there is high clinical suspicion for PE, and low-radiation dosing protocols are important to minimize radiation exposure. Clinicians should consider risk factors and clinical presentation to risk stratify patients, as decision tools, including the Wells Criteria,[47] and Pulmonary Embolism Rule-out Criteria (PERC),[48] have not been validated in children.

i. *Neck infections*

i. Ultrasonography, contrast-enhanced CT, and MRI are all considered appropriate for the diagnosis of neck lesions. Availability of resources, suspected location of pathology (eg, superficial versus deep neck), preference of surgical staff, test characteristics of each of the imaging modalities, risks of ionizing radiation, and need for sedation are important to consider when determining the optimal imaging approach. Lateral neck radiographs may be used as the initial test to evaluate for a retropharyngeal infection given the high sensitivity and specificity. However, given their limited ability to evaluate for other deep neck space infections, advanced imaging is typically indicated if there is continued clinical concern.

j. *Musculoskeletal infections*

i. Although radiographs are insensitive for the detection of acute bone infections, they may be considered as an initial examination to evaluate for other pathologies such as trauma or malignancy.

ii. If there is high clinical suspicion for osteomyelitis, MRI should be considered as the diagnostic test of choice, given its accuracy for diagnosis and ability to detect concomitant adjacent infections. It is best that such imaging is performed at the institution where definitive care will be delivered.

iii. Ultrasonography is an appropriate diagnostic modality to identify joint effusions; however, it cannot distinguish between sterile joint fluid and septic arthritis. Therefore, a definitive diagnosis requires synovial fluid analysis. MRI may be helpful in patients in whom there is clinical suspicion for concomitant osteomyelitis.

k. *Nephrolithiasis*
   i. The American Urological Association and the European Society for Pediatric Radiology recommended ultrasonography as first-line imaging for children with suspected nephrolithiasis.
   ii. CT should typically be reserved for indeterminate cases or if further clarification is needed, such as for surgical planning.
   iii. If CT is performed, a noncontrast, low-dose or ultra low-dose protocol will minimize radiation exposure.

SUMMARY

Important advances in imaging technology have resulted in increased use of advanced imaging to diagnose and manage pediatric patients in the ED. In order to optimize imaging, there are important considerations for the institution and for physicians and physician assistants and nurse practitioners who care for patients. These include adherence to the ALARA principle, using ultrasonography when appropriate and feasible as an alternative to CT, ensuring there are policies to facilitate consultation with pediatric subspecialists, including pediatric radiologists, and ensuring appropriate transfer to a pediatric center when necessary. For patients who will be transferred and for whom the imaging will not alter management prior to or during transport, it is optimal for imaging to be deferred to the receiving institution. Physicians and physician assistants and nurse practitioners should always weigh the benefits and risks of imaging and incorporate the recommendations, resources, and strategies in this policy statement and data in the accompanying technical report to optimize imaging in children.

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Table 1. Recommendations for Emergency Department Advanced Imaging Strategies for Common Pediatric Conditions

Clinical Problem	Risk Stratification Tools	Recommendations	First-line Imaging (if Available)[a]	Alternative/ Additional Imaging
Seizures				
Simple febrile		Neuroimaging is not necessary for children with a simple febrile seizure.[b]		
Complex febrile		Emergency neuroimaging is usually not indicated if the patient is back to baseline and without significant clinical findings.	MRI	CT
Afebrile		Do not order emergent imaging for children ≥6 mo with an unprovoked, generalized seizure who have returned to baseline mental status and have a normal neurologic examination.[b] Routine neuroimaging is not necessary after a breakthrough seizure in a patient with established epilepsy.[b]	MRI	CT
Headache (atraumatic)		Emergent neuroimaging is not necessary in patients with uncomplicated headache or those with stable headaches that meet criteria for migraine.[b]	MRI	CT
Ventricular shunt evaluation			MRI	CT
Stroke			MRI	CT
Trauma[c]		Routine whole-body CT should not be performed in pediatric trauma patients.[b] Whole-body CT is not used to screen asymptomatic children with a high-energy mechanism. When such imaging is used in children, venous-phase imaging of the chest and abdomen is often sufficient for screening.[44]		
Head	Kuppermann et al, 2009[29] Osmond et al, 2010[49] Dunning et al, 2006[50]	CT scans should not be routinely obtained for mild head injuries.[b]	CT	
Cervical spine	Leonard et al, 2019[51] Herman et al, 2019[52]	Routine advanced imaging is not warranted.[b]	XR	CT, MRI
Chest	American College of Surgery, Trauma Quality Improvement Program, 2018[44]	Chest CT is indicated if concern for blunt mediastinal vascular injury, wide mediastinum on chest XR, or	CT with IV contrast	

		for patients with penetrating thoracic trauma		
Abdomen/pelvis	American College of Surgery, Trauma Quality Improvement Program, 2018[44] Arbra et al, 2018[53] Holmes et al, 2013[30]		CT (with IV contrast)	
Child abuse				
Abusive head Trauma	Berger et al, 2016[45]		MRI CT if acute trauma or concern for skull fracture	CT
Cervical spine Injury		Immobilize cervical spine in cases of suspected abusive head trauma	MRI	
Abdominal Trauma		Imaging is warranted if signs of abdominal injury or unexplained elevated transaminases (>80 u/L)[46]	CT (with IV contrast)	
Appendicitis	Pediatric Appendicitis Score[54] Alvarado score[55] Pediatric Appendicitis Risk Calculator[31]		US [b]	MRI without contrast, CT with IV contrast, repeat US,[d] observation
Neck infections			US, CT with IV contrast), MRI	
Nephrolithiasis			US	Low-dose CT (stone protocol)

CATCH indicates Canadian Assessment of Topography for Childhood Head Injury; CHALICE, Children's Head Injury Algorithm for the prediction of Important Clinical Events; CT, computed tomography; IV, intravenous; MRI, magnetic resonance imaging; PECARN, Pediatric Emergency Care Applied Research Network; US, ultrasonography; XR, radiography.
All imaging is without contrast unless otherwise specified.

[a] When MRI is recommended, it should be performed only in a stable patient given the duration of obtaining and completing the examination.
[b] Indicates Choosing Wisely recommendation.
[c] Excludes patients with concern for child abuse.
[d] Patients with equivocal initial ultrasonography (eg, nonvisualized appendix) may undergo follow-up ultrasonography after a period of observation (eg, 6-12 hours).

Table 2. Imaging Decision Making Recommendations

Question to be Answered	Recommendation	Example
Will imaging assist with determining whether emergent intervention is needed?	Perform imaging	Patient with altered mental status and possible cerebral edema
Will imaging assist with determining whether transfer is needed?	Perform imaging	Patient with head trauma who is awake and alert but with signs/symptoms concerning for clinically important traumatic brain injury and could be discharged if imaging is negative
Will patient be transferred regardless of imaging findings?	Defer imaging to the receiving institution	Patient with significant abdominal pain and/or concern for acute abdomen, presenting to an emergency department without pediatric surgical capabilities

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