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ORIGINAL ARTICLE

Pediatric Imaging : Current Perspective.

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Abstract

Imaging forms the backbone of modern-day diagnostic and therapeutic procedures in both adults and children. But as children are not small adults, imaging in pediatric age-group is significantly different from adults which require special attention. The most crucial difference being dissimilar disease spectrum and the resulting clinical questions concerned with imaging. This article discusses different imaging modalities used in pediatric age-group with their merits and demerits.

Introduction

Imaging in children forms the backbone of modern day diagnostic and therapeutic procedures. Imaging in pediatric age group is significantly different from adults. The most crucial difference between adult and pediatric radiology is the dissimilar disease spectrum of children and the resulting clinical questions concerning imaging [1]. It is of extreme importance to restrict the use of imaging modalities using ionizing radiations. Imaging in children also needs to be quick in terms of time since they are usually not as co-operative as adults.

Exposure to ionizing radiation must be kept particularly low in children since their tissues are highly radiosensitive. They are more liable than adults to develop radiation - induced cancer because they have a lot of years left to live. As a prospective parents, they are at risk for transmitting radiation - induced genetic defects to the next generation. Radiological studies on children should be of a nature that does not involve ionizing radiation, like Ultrasound (US) or Magnetic Resonance Imaging (MRI) [1].

Due to their generally smaller size, children are perfect candidates for US evaluation. Pediatric US provides comprehensive anatomic information and has multiplanar capability. Doppler studies can add vital functional and physiological information [2].

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MRI with its higher sensitivity, better anatomical and spatial resolution, excellent soft tissue contrast, multiplanar imaging capability and lack of ionizing radiation has emerged as preferred modality of choice in the evaluation of children wherever possible [3].

Role of Positron Emission Tomography (PET) in children has been found in cases of pediatric epilepsy and for evaluation of functional development of the pediatric brain [4,5]. PET/CT and PET MRI have roles in evaluation of pediatric neoplasm and infections similar to that in adults.

Radiation Protection

Before starting about the various organ systems, it is imperative to know about the issue of radiation protection in children. Tissues with high mitosis rates are more vulnerable than inactive tissues since DNA metabolism is damaged by radiation [6]. The radiation risk is therefore highest in infancy and early childhood because of high mitotic rates in these age groups. The tissues of children also have a higher water content than adult tissues which absorbs radiation resulting in the need of a higher radiation dose to penetrate a layer of tissue of the same thickness [1].

It is important to strictly adhere to the concept of ALARA (As Low As Reasonably Acceptable) for pediatric radiography. This can be done by reducing the tube voltage, using appropriate tube filters and by collimating the images during an examination. Adequate gonad protection during radiography of abdomen and pelvis is a must. Proper positioning and use of appropriate pediatric specific grids is also extremely desirable.

For radiation dose management in pediatric CT, protocol optimization related to clinical indication is available [7]. An adjustment in the parameters that are mainly responsible for the dose delivered i.e. tube current, gantry cycle time, peak kilo voltage and pitch, based on the size of the child, examination indication, prior examinations and region examined should be done [8].

Planning examinations for individual patients need an accurate indication and close collaboration with the referring pediatricians. The most effective radiation protection be provided only when the question to be answered is clear. A CT scan can often be optimized or even avoided using a previous US or MRI examination [1].

Contrast Media in Children

Intravenous iodinated contrast media should be judiciously used in children. Although, the risk of contrast induced nephropathy remains the same as in adults, contrast media osmolality is of particular importance in neonates and small children. They are more vulnerable to fluid shifts and have a lower tolerance for intravascular osmotic loads as compared to adults. Intravascular administration of hyperosmolar contrast medium may result in migration of fluid from extravascular soft tissues into blood vessels, consequently expanding blood volume [9,10]. A large fluid shift may lead to cardiac failure and pulmonary edema in children with significant pre-existing cardiac dysfunction [11].

The guidelines for intravenous use of gadolinium-based contrast agents are similar in both the pediatric and adult populations [11].

Gastrointestinal contrast agents in children are most commonly barium-based. Iodinated contrast agents are usually preferred in suspected gastrointestinal tract perforation in which case osmolality should be considered as for intravascular contrast agents [11].

Unique Imaging Related Issues in Children

Patient movement during imaging distorts image acquisition causing difficulty in image interpretation. Young children are unable to remain motionless for extended periods of time, often necessitating the use of sedation or anesthesia during pediatric imaging, especially time taking procedures like MRI [12]. Whenever possible, children over the age of 7 years are scanned without sedation. Neonates under 2 months old are scanned during natural sleep induced by food, comfort and warmth, often after a period of forceful sleep deprivation. If this fails, then light oral sedation may be used. Majority of children require sedation or a general anaesthetic [13].

The American Academy of Pediatrics (AAP) defines the goals of sedation children for diagnostic and therapeutic procedures which are:

1) To protect the patient's safety and welfare;
2) To reduce physical discomfort and pain;
3) To control anxiety, minimize psychological trauma;
4) To control behavior and/or movement to allow for the safe completion of the procedure; and
5) To return the patient to a state in which safe discharge from medical supervision is possible [14].

Neuroimaging

Radiation dose being an important consideration in the pediatric age group, the indications of CT are limited in children, the most common indication being acute trauma. CT has the advantage of being fast and for showing excellent bony details (fractures), pneumocephalus and hematomas. Another less common indication of CT is evaluation of craniostenosis. In all other indications, MRI is preferred over CT.

MRI is important for the diagnosis of congenital anomalies of pediatric brain in patients presenting with developmental delay. Sagittal and coronal T1-W images are excellent for the evaluation of corpus callosum, cerebellum, anterior visual pathway, schizencephaly and holoprosencephaly [11]. Axial T2-W and Coronal FLAIR images have been shown to be complementary [15].

Children who have either multiple or focal seizures are investigated with MRI in accordance with NICE guidelines [16]. The aim is to detect focal cortical abnormalities which can be either mesial temporal in origin or extra temporal.

Other indications of MRI in children are pediatric tumors; pediatric stroke, non-accidental injury and Non-traumatic intraparenchymal hemorrhage wherein MRI is accompanied by MR Angiography.

MRI can detect patterns of regional brain injury in the neonatal period which can help to determine the time of injury, underlying mechanisms and eventually offer prognostic information. MRI is of use to detect hypoxic–ischemic injury and germinal matrix and intraventricular hemorrhage. It is also helpful to distinguish other differential diagnoses like venous infarction, metabolic disease, infection and congenital developmental abnormalities [11].

Contrast-enhanced MRI helps in detection and diagnosis of pediatric brain tumors and also improves the accuracy of differential diagnosis between CNS tumors and demyelinating disorders like multiple sclerosis and acute

disseminated encephalomyelitis and infective processes like abscesses. It is also a valuable tool in characterizing CNS infections; vascular anomalies and disorders [17].

The main indication for neonatal neurosonography is the detection of an intracranial hemorrhage in a preterm neonate. Other indications include revelation of congenital anomalies and intracranial vascular lesions and as a simple, cost effective screening tool to exclude gross intracranial pathology [18].

MRI is the modality of choice for imaging the intraspinal components of the pediatric spine, though ultrasound has also been shown to be an important screening tool before ossification of the posterior elements. Infants with a neurological abnormality on ultrasound still require MR imaging [19]. Other indications for which spinal MRI is indispensable included spinal infections, tumors and demyelination and contrast enhanced MRI is a must in these settings.

Head and Neck

CT is the preferred imaging modality to describe the intricate osseous anatomy and malformations of the inner ear, but MRI is increasingly being used to study the membranous labyrinth and eighth cranial nerve [20]. For infections of the middle ear and cholesteatoma, HRCT remains the imaging modality of choice whereas MRI is more useful to look for the intracranial complications of infectious processes.

Primary inflammatory processes in the pediatric neck are very common. Ultrasound is the initial imaging modality of choice because of their acute presentation. Contrast enhanced CT helps in detailed characterization, including involved spaces and complications which are important for determining appropriate clinical management [8].

For evaluation of pediatric head and neck tumors, Ultrasound with Doppler helps to distinguish cystic from solid lesions, detects vascularity and differentiates nodal from non-nodal masses. CT delineates bony changes and detects intralesional calcification. Multiplanar reformatted images with bone and soft tissue windows should be obtained. MRI demonstrates the soft tissue characteristics of the tumor [8].

Ultrasound is also the primary imaging modality for examining the thyroid and parathyroid glands, and for guiding aspiration and biopsy. Nuclear scintigraphy provides morphologic and functional information. CT and MRI are used as adjunctive tools [21].

Plain radiographs play no role in evaluation of a mass in the paranasal sinuses and in pre or post-operative evaluation of sinus surgery. They are also inappropriate for imaging complications of sinusitis [22]. CT and MRI are far superior to radiographs for evaluation of sinuses.

Upper airway disease is a common problem in the pediatric age group with many of them presenting as pediatric emergencies. Frontal and lateral radiographs of the airway and fluoroscopy have been mainstay in the evaluation of upper airway, though advances in cross-sectional imaging techniques like virtual endoscopy can more accurately depict airway anatomy [23].

Chest

Till date, chest radiography remains the most commonly performed radiologic study although there have been marvelous technological advances in thoracic imaging options including ultrasound, CT, MRI and PET.

Conventional radiographs are sufficient for making an accurate diagnosis of several lower large airway disorders like radiopaque foreign body aspiration. CT along with Virtual Bronchoscopy is usually necessary for a complete assessment, especially for surgical lesions [8]. Radiographs also play an important role in the initial detection and imaging of congenital lung anomalies. Cross sectional imaging such as CT with multiplanar reformatting is required for confirmation of diagnosis and further characterization of the anomaly[8]. Indications for chest radiography in infective pulmonary diseases are severe disease, confirmation or exclusion of the diagnosis of an atypical presentation, evaluation of complications, and ruling out other causes of respiratory distress [24]. CT can improve the diagnosis and management of symptomatic pulmonary tuberculosis, fungal infection and parasite infestation, particularly if an associated immune deficiency exists [8]. Pulmonary neoplasm and interstitial lung disease are often imaged similar to those in adults with CT.

Ultrasound has also been found to be effective and can be easily performed as an adjunct to chest radiography in the assessment of bewildering areas of increased opacity in the chest, to differentiate consolidation from lung masses and pleural and chest wall lesions. It also provides information about the nature of pleural fluid and allows guided aspiration [25].

Chest radiography now plays only an adjunctive role in the evaluation of heart disease in children with echocardiography serving as the major primary imaging modality after physical examination. However, the radiograph still may provide the first indication of cardiovascular disease and also offers an important overview of the heart and pulmonary circulation. CT Angiography has become a primary imaging modality for structural cardiovascular evaluation because it provides

the best global assessment of the lungs and airways and it can demonstrate associated primary abnormalities of the respiratory system in a shorter time at a lesser cost. With the rapid advances in MRI pulse sequences and quality of the scanners, cardiac MRI is also fast catching up with CT and Echocardiography for evaluation of the heart, especially in older children [8].

Abdomen and Pelvis

In a child with abdominal pain, history and physical examination are extremely valuable to help guide the subsequent imaging protocol. Plain radiographs have limited value for detection of urinary calculi, intestinal obstruction of perforation and abdominal calcifications. They are however, quite useful in the neonate as their pain localization and expression is very poor. They also wall-off infectious processes unsuccessfully, and frequently present with nonspecific signs and symptoms [26].

Ultrasound is particularly well suited to the child for the investigation of many of the etiologies for abdominal pain that are common in children and adults, such as renal disease, biliary disease, lymphadenopathy and suspected neoplasm. There are also several common entities unique to children that are diagnosed by ultrasound like Congenital Hypertrophic Pyloric Stenosis, intussusception and appendicitis [27].

Fluoroscopy with oral or rectal contrast is still carried out for problems of hollow viscera which are not evident on radiography or ultrasound like evaluation of esophageal problems (trachea esophageal fistulas), radiolucent foreign bodies, motility disorders, intestinal malrotation and for evaluation of constipation in children.

Contrast enhanced CT is especially useful in patients with diseases affecting multiple organ systems because evaluation of solid organ, hollow viscera and peritoneal cavity pathology is quickly obtained with great anatomic and physiologic detail [8]. It also gives complete comprehensive evaluation of abdominal masses and is particularly useful in diseases like pancreatitis, choledochal cysts and abdominal trauma. Limitation of radiation dose with the use of limited phases of scan and pediatric specific machine protocols are of utmost importance during CT examinations [28].

MRI of the abdomen is still evolving for practical use in pediatric age group because sedation limits the use of fast sequences that rely on breath hold, body sizes vary greatly necessitating the modification of coils and imaging parameters for different age ranges and also because diseases affecting children are unique. There is also the possibility that high specific absorption rate can lead to an increase in temperature especially in neonates. However, MRI is increasingly being used for evaluation of bowel abnormalities, like inflammatory bowel disease and appendicitis, hepatobiliary pathologies and for abdominal masses. Earlier, intravenous urography was the imaging modality of choice for evaluation of kidneys and collecting system, but it has now been surpassed by MRI and CT. Voiding cystourethrography has been the preferred examination for detailed anatomic evaluation of the urinary bladder and urethra as well as identification of vesicoureteric reflux.

Ultrasound is ideal method for examining the kidneys and bladder in infants and children. In young children urogenital ultrasound is started with the urinary bladder because it usually empties when the transducer is placed in the suprapubic region. Renal vessels can also be imaged using Doppler.

Contrast enhanced CT is required for the evaluation of renal lesions along with delayed imaging for assessing the integrity of the collecting system (such as after trauma), course of the ureter and evaluating renal and retroperitoneal masses [29].

MR urography is a major advancement in uroradiology, with hydronephrosis being the most common indication in children [30]. It is the method of choice for evaluation of congenital renal anomalies, ureteric pathologies and incontinence associated with ectopic insertion of the ureter.

For evaluation of genital system, ultrasound is used as initial investigation of choice followed by MRI, if needed.

Musculoskeletal System

Pediatric musculoskeletal radiology requires knowledge of normal growth and developmental variations, fracture patterns exclusive to the immature skeleton, skeletal dysplasia and knowledge of special tumor and tumor-like conditions [8].

Radiography remains the initial imaging modality for the evaluation of acute trauma, inflammatory arthritis, infection, bony neoplasm and skeletal dysplasia. The primary roles of musculoskeletal ultrasound are in evaluation of skeletal dysplasia, soft tissue masses and arthritis out of which evaluation of developmental dysplasia of hip deserves special mention. The main roles of CT are fracture assessment, including orthopedic hardware failure; assessment of alignment disorders, including physeal bar assessment; and evaluation of tumor matrix and tumor recurrence in case of an existing neoplasm or a resected neoplasm with hardware in place. MRI plays an important adjunctive role in oncologic, metabolic and sports medicine imaging [8].

Child Abuse

Child abuse, being unique to the pediatric age group deserves a special mention. Initial imaging is driven by the clinical presentation. Later a skeletal survey can be performed to look for occult injuries and evaluate for child abuse as a diagnosis. CT and MRI are used to evaluate suspected head trauma. CT of the abdomen and pelvis is indicated only in children with clinical and ultrasound suspicion of traumatic intra-abdominal injury [31].

Conclusion

It is very important to image the children with utmost finesse and try to reduce repeated imaging because of the various reasons cited above. A close communication with the treating clinician can bring out the best outcomes for the loveliest creatures on earth.

To summarize, pediatric imaging is significantly different from adult imaging and requires special consideration especially those related to radiation exposure and optimal sedation required for optimal scanning.

System	Clinical Condition	Preferred Imaging Modality
Central nervous system	Congenital anomalies, developmental delay	MRI
	Trauma	CT
	Neonatal Hypoxic Ischemic Encephalopathy	Cranial Ultrasound
	Infections, tumours	Contrast Enhanced MRI
	Spine	MRI
Head and neck	Temporal bone (middle ear)	HRCT
	Temporal bone (inner ear)	MRI
	Neck infections and tumors	Ultrasound followed by Contrast enhanced CT
	Thyroid	Ultrasound
	Paranasal sinuses	CT/MRI
	Upper airway disease	Radiography, CT if needed
Chest	Lower airway disease and congenital lung anomalies	Radiography followed by CT
	Pulmonary infections	Radiography
	Pleural fluid	Ultrasound
	Neoplasms	Contrast enhanced CT
	Heart disease	Echocardiography, CT / MR Angiography
Abdomen and pelvis	Pain abdomen	Ultrasound
	Multi organ disease, abdominal masses, trauma	Contrast enhanced CT
	Renal and ureteric pathologies	Ultrasound, followed by CT / MRI if needed
	Urinary bladder, urethra	Voiding Cystourethrogram
Musculoskeletal system	Trauma, infection, skeletal dysplasia, neoplasm	Radiography

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References

1. Gerhard Alzen, Gabriele Benz-Bohm. Radiation Protection in Pediatric Radiology. Dtsch Arztebl Int 2011; 108 (24): 407–414.
2. Brian D. Coley. Preface. Ultrasound Clin 1 2006; XI.
3. Venkatramana R. Vattipally, Richard A. Bronen. MR Imaging of Epilepsy: Strategies for Successful Interpretation. Radiol Clin N Am 2006; 44: 111–133.
4. Chugani HT, Phelps ME, Mazziotta JC. Positron emission tomography

study of human brain functional development. Ann Neurol 1987; 22: 487-497.

5. Lee DS, Lee SK, Chung J-K, et al. Predictive values of F-18-FDG PET and ictal SPECT to find epileptogenic zones in cryptogenic neocortical epilepsies (abstract). J Nucl Med 1997; 38: 272.
6. Brenner DJ, Elliston CD. Estimated radiation risks potentially associated with full-body CT screening. Radiology 2004; 232: 735–738.
7. Nievelstein RAJ, van Dam I, van der Molen A. Multidetector CT in children: current concepts and dose reduction strategies. Pediatr Radiol 2010; 40: 1324-1344.
8. Brian D. Coley. Caffey's Pediatric Diagnostic Imaging. 12th Edition.
9. Standen JR, Nogrady MB, Dunbar JS, Goldbloom RB. The Osmotic Effects of Methylglucamine Diatrizoate (Renografin 60) in Intravenous Urography in Infants. Am J Roentgenol Radium Ther Nucl Med. 1965; 93: 473-479.
10. Morris TW HP, Reece K, Katzberg RW. Tissue fluid shifts during renal arteriography with conventional and low osmolality agents. Invest Radiol 1983; 18: 335-340.
11. American College of Radiology Committee on Drugs and Contrast Media. ACR Manual on Contrast Media – Version 10.2, 2016.
12. Effect of Anesthesia and Sedation on Pediatric MR Imaging Patient Flow. Sonya A. Vanderby, Paul S. Babyn, Michael W. Carter, Susan M. Jewell, and Patricia D. McKeever. Radiology 2010; 256 (1): 229-237.
13. Saunders DE, Thompson C, Gunny R, Jones R, Cox T, Chong WK. Magnetic resonance imaging protocols for pediatric neuroradiology. Pediatric Radiology 2007; 37 (8): 789-797.
14. Coté CJ, Wilson S. American Academy of Pediatrics; American Academy of Pediatric Dentistry, Work Group on Sedation Guidelines for monitoring and management of pediatric patients during and after sedation for diagnostic and therapeutic procedures: an update. Pediatrics 2006; 118: 2587–602.
15. Barkovich AJ. Pediatric Neuroimaging, chapter 2, 2005 4th Ed. Lippincott Williams & Wilkins, Philadelphia.
16. The epilepsies: the diagnosis and management of the epilepsies in adults and children in primary and secondary care. National Institute for Health and Clinical Excellence Epilepsy 2007. National Institute for Health and Clinical Excellence,London. http://www.nice.org.uk/guidance/CG20/niceguidelines/pdf/English. Accessed 27 March 2007
17. Bhargava R, Hahn G, Hirsch W, et al. Contrast-Enhanced Magnetic Resonance Imaging in Pediatric Patients: Review and Recommendations for Current Practice. Magnetic Resonance Insights. 2013; 6: 95-111. doi:10.4137/MRI.S12561.
18. Bhat V, Bhat V. Neonatal neurosonography: A pictorial essay. The Indian Journal of Radiology & Imaging. 2014; 24 (4): 389-400.
19. Hughes JA, De Bruyn R, Patel K et al Three-dimensional sonographic evaluation of the infant spine: preliminary findings. J Clin Ultrasound 2003; 31: 9–20.
20. Joshi VM, Navlekar SK, Kishore GR, et al. CT and MR imaging of the inner ear and brain in children with congenital sensorineural hearing loss. Radiographics 2012; 32: 683–98.
21. Balon HR, Silberstein EB, Meier DA, et al. Society of Nuclear Medicine procedure guideline for thyroid scintigraphy. Reston, VA: Society of Nuclear Medicine 2006.
22. McAlister WH, Kronemer K. Imaging of sinusitis in children. Pediatr Infect Dis J 1999; 18: 1019-1020.
23. Wiett GJ, Long FR, Shiels II WE, et al. Advances in pediatric airway radiology. Otolaryngol Clin North Am. 2000; 33 (1): 15-28.
24. Swingler GH, Hussey GD, Zwarenstein M. Randomized controlled trial of clinical outcome after chest radiograph in ambulatory acute lower-respiratory infection in children. Lancet. 1998; 351: 404-408.
25. Kim OH, Kim WS, Kim MJ et al. US in the diagnosis of pediatric chest diseases. Radiographics 2000; 20: 653–671.
26. Meradji M, Van Herreweghe W. The plain film of the acute abdomen in the neonate and infant. J Belge Radiol 1980; 63: 33–42.
27. Manson D. Contemporary imaging of the child with abdominal pain or distress. Pediatrics & Child Health. 2004; 9 (2): 93-97.
28. Darge K, Anupindi SA, Jaramillo D. MR imaging of the abdomen and pelvis in infants, children, and adolescents. Radiology. 2011; 261:12–29.
29. Kokako E, BRATT S, Dora VS. Renal multidetector row CT. Radiol Clin North Am. 2005; 43: 1021-1047.
30. Lebowitz RL, Griscom NT. Neonatal hydronephrosis: 146 cases. Radiol Clin North Am 1977; 15:49-59.
31. Trout AT, Strouse PJ, Mohr BA, et al. Abdominal and pelvic CT in cases of suspected abuse: can clinical and laboratory findings guide its use? Pediatr Radiol 2011; 41: 92-98.