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Pediatrics

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This chapter briefly reviews pediatric imaging. Because of the nature of the diseases of children who come to see a primary practice physician (or a general pediatrician), the number of radiology exams is typically far lower on a per-patient basis than in the adult population. Children tend to have different diseases than adults and this chapter deals with a few of the most common clinical scenarios when children are sent for imaging. This chapter is only a brief overview of five of the most frequently encountered and/or clinically important situations in which imaging may be important in pediatrics. For more in-depth discussion, and for additional topics, two excellent books are Lane F. Donnelly's *Fundamentals of Pediatric Radiology*[1] (less expensive and short enough to read in its entirety) and Hilton and Edward's *Practical Pediatric Radiology*[2] (more expensive and considerably longer)[3]. The main points of this chapter are:

1. A two-view chest x-ray (CXR) may help in the evaluation of a child with cough and fever or in a child with a fever and no localizing signs or symptoms.
2. A barium study or abdominal ultrasound may be performed in a neonate with persistent vomiting.
3. In a young child with bloody stools, intermittent abdominal pain, and a palpable abdominal mass, emergency surgical consultation should be sought. Plain films and US of the abdomen may be followed by an attempt at intussusception reduction.
4. CT examination of the abdomen and pelvis may be obtained for a child with RLQ pain, loss of appetite, nausea and vomiting, fever, and an elevated white count.
5. CT examination of the sinuses and orbits may be obtained for a child with a runny nose, fever, and headache, if accompanied by visual symptoms.

A TWO-VIEW CHEST MAY HELP IN THE EVALUATION OF A CHILD WITH COUGH AND FEVER OR IN A CHILD WITH FEVER AND NO LOCALIZING SIGNS OR SYMPTOMS

Chest radiography is widely used in the evaluation of pediatric patients with lower respiratory tract infections, although there is some controversy regarding the routine use of the chest x-ray and some studies have shown that it does not affect the clinical outcome of outpatient children with pneumonia[4]. The value of chest radiography is based on the ability to help distinguish between the various causes of pneumonia, to diagnose complications, and to exclude other causes of pneumonia symptoms.

With respect to the cause of pneumonia, while most pneumonia is viral, there are important age differences: in patients from 3 months to one year of age, 95% of pneumonia is viral, whereas for patients one to five years of age respiratory syncytial virus (RSV) accounts for approximately 50% of pneumonias. For school aged children (ages five to eighteen), the atypical pneumonias Mycoplasma pneumonia and Chlamydia pneumonia predominate[5]. Chest radiographs may be broadly categorized as showing one of three "patterns":

interstitial (with linear strands of density radiating from the hila, peribronchial cuffing, and "fat" hila) (Figure 1), alveolar or "air-space" (with dense white parenchyma, air bronchograms, a segmental or lobar distribution, with an accompanying pleural effusion) (Figure 2), and mixed (some combination of the two) (Figure 3). As a generalization, the interstitial pattern predominates in viral pneumonia, the alveolar pattern is seen with infection from typical bacteria (for example, Staphylococcus aureus and Streptococcus pneumonia), and the mixed pattern is seen with atypical organisms (Mycoplasma and Chlamydia). While true as a generalization, the chest x-ray does not do as good a job at this distinction as many radiology textbooks would have you believe, secondary to a number of factors including inter- and intraobserver variability of interpretation, overlap between the radiographic findings and causes, and the fact that radiographic findings may lag behind disease because of dehydration[6]. Therefore, the chest radiograph cannot be used in isolation to make the determination of whether a given patient's pneumonia is caused by a virus, typical bacteria, or atypical bacteria.

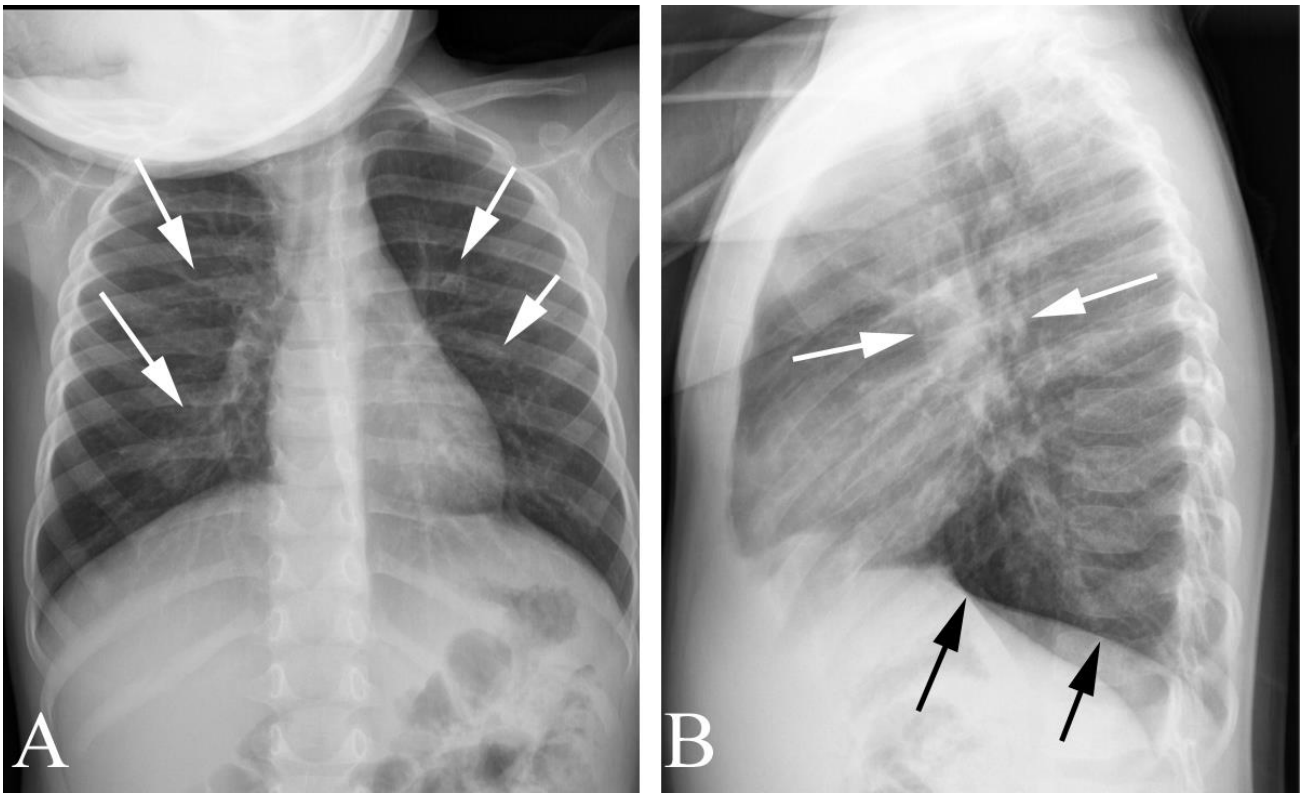

Figure 1. Interstitial pattern in a 2 year old with cough, shortness of breath, and likely viral pneumonia. A. Frontal chest radiograph shows streaky densities radiating from the hila (arrows). B. Lateral chest radiograph shows hyperinflation of the lungs with flattening of the diaphragm (black arrows) along with prominent hila (white arrows). The child's symptoms resolved without antibiotics.

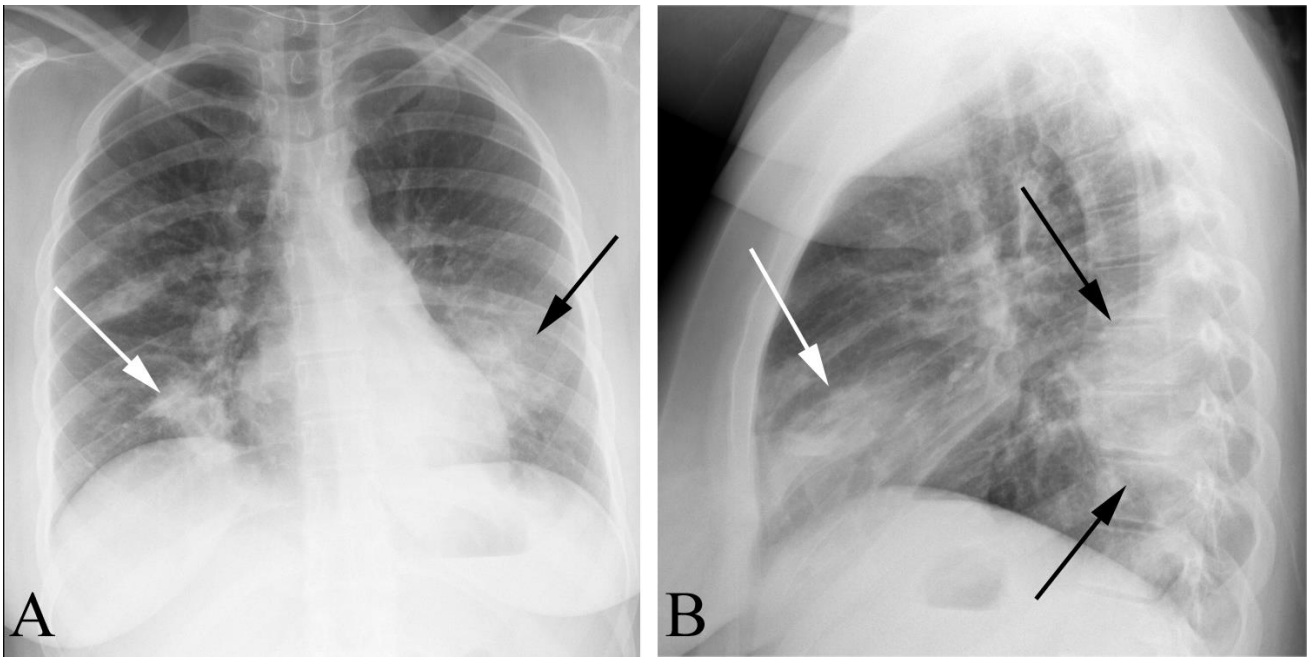

Figure 2. Alveolar pattern in a 15 year old with fever, cough, and bacterial pneumonia. A. PA chest radiograph shows focal abnormal densities in both the medial right base (white arrow) and along the heart border in the left base (black arrow). B. Lateral examination shows abnormal increased density overlying the heart (white arrow) and additional consolidation projecting over the mid thoracic spine (black arrows). Note that the vertebral bodies normally become more lucent from the apex to the base of the chest, whereas there is increased density of the mid-thoracic vertebrae in this patient.

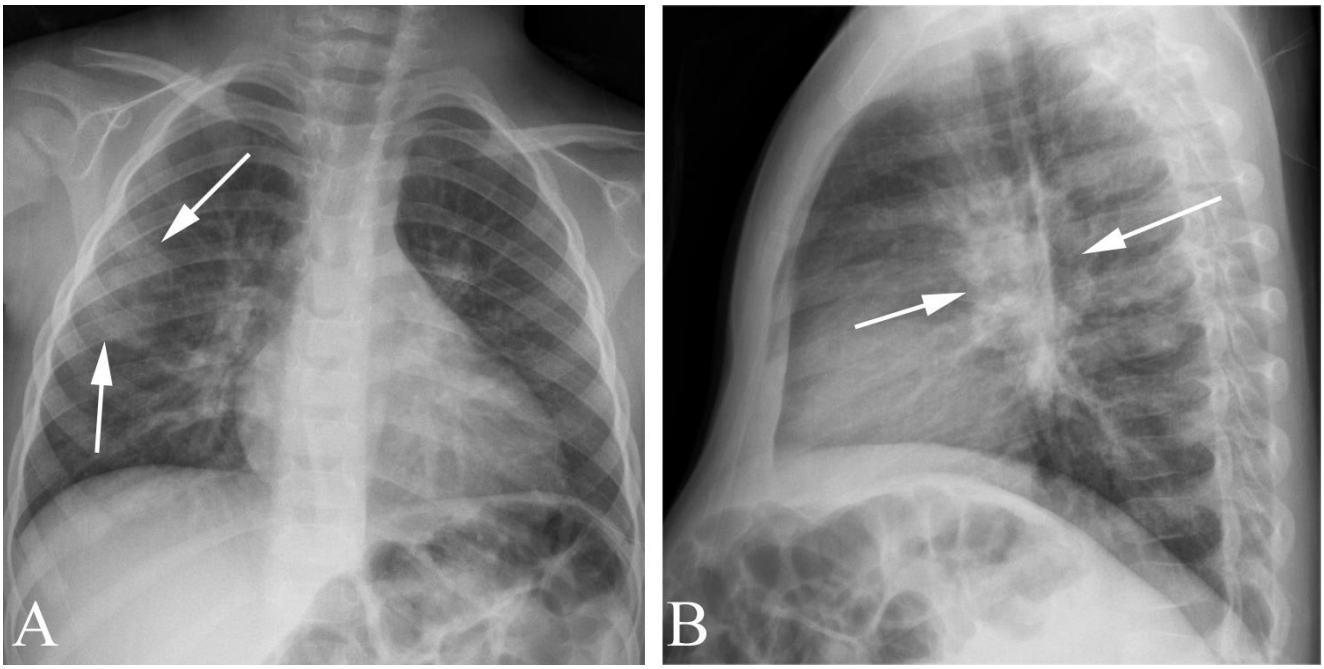

Figure 3. Mixed pattern in a 3 year old with fever, cough, and dyspnea. A. Frontal chest radiograph shows both prominent hila, streaky densities radiating from the hila, and abnormal opacity in the right mid-lung (arrows), only part of which may be accounted for by an overlying scapular shadow. B. Lateral exam confirms prominent hila (arrows). In such cases, it is difficult to tell if the vague pulmonary opacity represents atelectasis (which may accompany viral and/or atypical pneumonia) or a superimposed bacterial infection

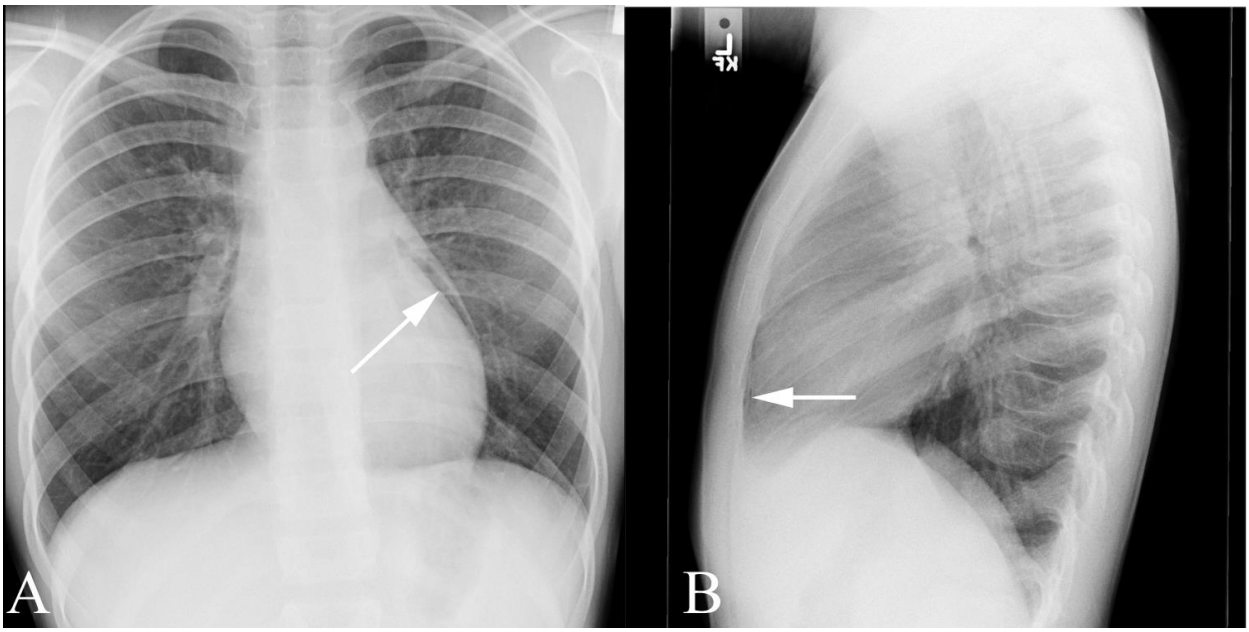

Figure 4. Pneumothorax in a 9 year old with asthma and cough. A. PA chest radiograph shows a lucency separating the normal thymus shadow from the heart border (arrow). B. Lateral chest radiograph shows a subtle lucency along the anterior chest wall (arrow) from pneumomediastinum.

The chest radiograph has more value in excluding such alternative explanations of cough and tachypnea as a retained foreign body (particularly when inspiration/expiration films are obtained) and congestive heart failure (for example, from viral myocardiopathy), and to diagnose complications of pneumonia such as development of a pneumothorax (from coughing) (Figure 4) pleural effusion, empyema, pneumatocele, necrotizing pneumonia, and lung abscess[5]. These performance features of the radiograph are particularly helpful in certain circumstances, such as when the child is severely ill and/or when the child is likely to be admitted to the hospital.

In those cases where the pediatric patient has a fever but no localizing signs or symptoms, a chest radiograph is helpful, since in one published report 26% of 146 children with fever and no clinical signs or symptoms of pneumonia (or other source of fever) with a white blood cell count of > 20,000/microL had radiographic evidence of pneumonia[7].

AN ABDOMINAL ULTRASOUND OR BARIUM STUDY MAY BE PERFORMED IN A NEONATE WITH PERSISTENT VOMITING

First, a few comments regarding vomiting in pediatric patients. As a generalization, it is best to involve the appropriate specialist (pediatric gastroenterologist, surgeon, or neurologist) earlier rather than later in cases where significant vomiting is occurring[8]. Features which merit particular concern include prolonged vomiting (greater than 12 hours in a neonate, greater than 24 hours in children under 2 years of age, and greater than 48 hours in older children); features of obstruction such as abdominal distension, visible bowel loops, marked change (increase or decrease) in bowel sounds, or bilious vomiting; features of a central nervous system cause such as vomiting without nausea particularly upon awakening or vomiting with a change in position; and features of adrenal crisis including hypotension out of proportion to the illness of the child or marked hyperkalemia[7].

In neonates with vomiting, the main considerations are normal spitting up, gastroesophageal reflux, idiopathic hypertrophic pyloric stenosis (IHPS), malrotation, and duodenal stenosis/atresia. The first two do not generally require imaging. If the child has most of the classic features for IHPS (presentation between 3 and 6 weeks of age, postprandial nonbilious projectile vomiting, desire to feed shortly following vomiting, and first-born male status) the best first step is probably ultrasound of the abdomen[9], performed in a fasting infant who is fed water or electrolyte-replacement solutions. The ultrasound study should demonstrate either a normal pylorus (Figure 5) or an abnormal pylorus (Figure 6) which may demonstrate abnormal wall thickness, length, or overall diameter or volume.

If the patient does not have the typical clinical features of IHPS, or if the ultrasound does not provide a satisfactory answer, then a UGI may be performed. This study should document prompt emptying of the stomach, presence or absence of gastroesophageal reflux, and (perhaps most importantly) the location of the ligament of Treitz (the transition from the duodenum to the jejunum). If the ligament of Treitz is not located in the left upper quadrant (to the left of the spine and superior to the duodenum), then malrotation (and associated risk for infarction of bowel), should be diagnosed.

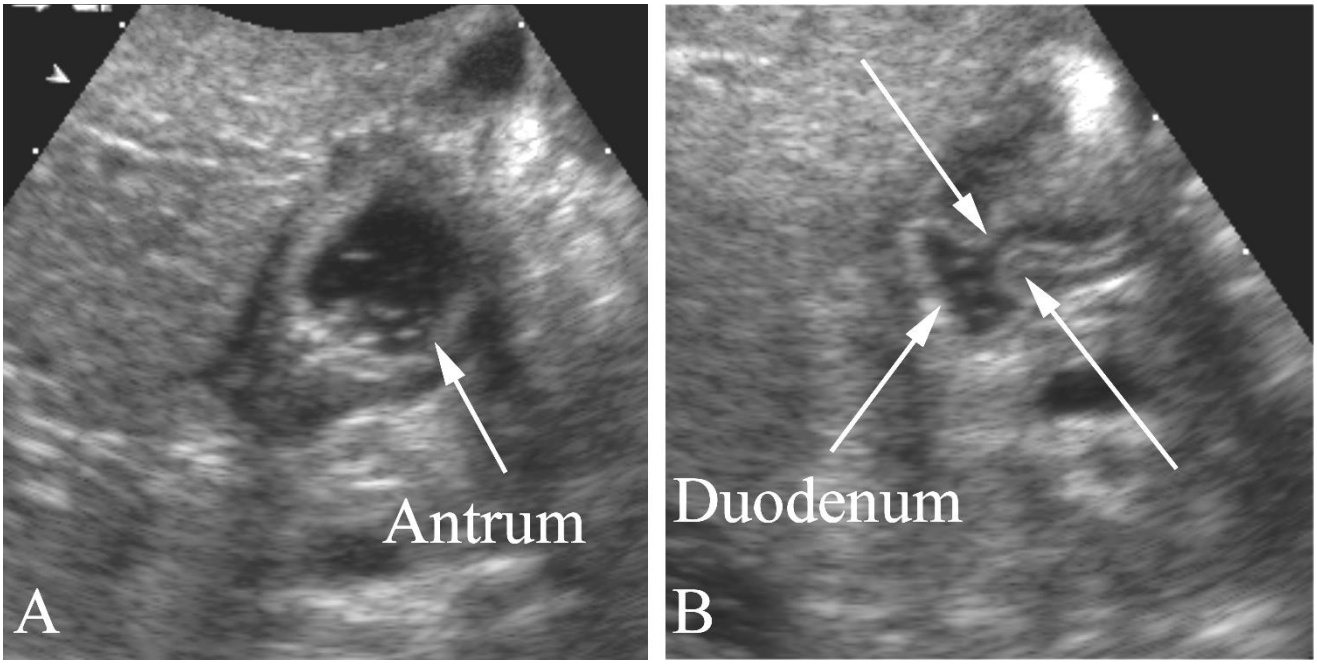

Figure 5. Normal pylorus in a 3 month old female infant with persistent projectile vomiting. A. Ultrasound examination through the mid-abdomen following oral administration of water/electrolyte solution shows the stomach antrum (arrow). B. Ultrasound examination obtained by constant observation of the antrum of the stomach following oral water demonstrates fluid in the distal antrum, pylorus, and duodenum. The arrows show the margins of the normal pylorus.

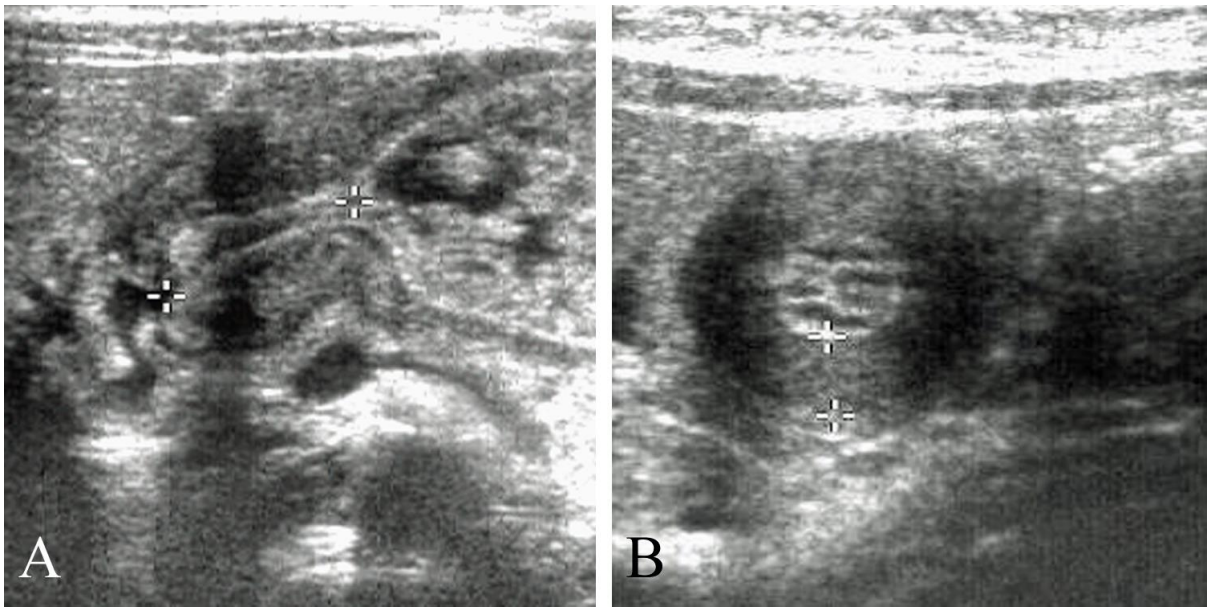

Figure 6. Idiopathic hypertrophic pyloric stenosis (IHPS) in a 2 month old child with vomiting and weight loss. A. Abdominal ultrasound with a longitudinal view of the pylorus (between calipers) shows an abnormally long and thick-walled pyloric channel. B. Abdominal ultrasound transverse view through the pylorus demonstrates an abnormally thick wall (calipers). Case courtesy of Dr. Jeffrey Zapolsky, Radiology Associates of the Fox Valley.

IN A YOUNG CHILD WITH BLOODY STOOLS, INTERMITTENT ABDOMINAL PAIN, AND A PALPABLE ABDOMINAL MASS, EMERGENCY SURGICAL CONSULTATION SHOULD BE SOUGHT PLAIN FILMS AND ULTRASOUND OF THE ABDOMEN MAY BE FOLLOWED BY AN ATTEMPT AT INTUSSUSCEPTION REDUCTION

Most (90%) of cases of intussusception will occur in the first two years of life, with the highest incidence between 5 and 9 months[10]. The classic presentation of pain, a palpable mass, and "currant jelly" stools[1] is seen less than 15% of the time[11]. Certainly, in cases where all of these features are present, and usually in cases where one or two of these features is evident in a child of the appropriate age, early surgical consultation is advised. Even if intussusception is diagnosed and treated in the radiology department, the child must be treated (prior to reduction) as if immediate surgery will be performed (with intravenous access and availability of a surgeon and operating room) because of the possibility of perforation during intussusception reduction[9].

In most cases, plain films and US (which may be ordered prior to surgical consultation in cases where there is a lower suspicion of intussusception) will be necessary for diagnosis. Plain films may document dilated small bowel loops from obstruction or even (usually indirectly) demonstrate a mass. Free air on the plain films is a contraindication to enema reduction, and typically patients with free air have a perforated viscus requiring operative intervention. Ultrasound usually shows a characteristic "bull's eye" or "coiled spring" appearance typical of intussusception. If there is no free air but there are ultrasound findings of intussusception, or if there is no free air but the clinical features are felt to be classic for intussusception, then enema reduction of the intussusception may be attempted. The method of reduction varies with local expertise and experience and may use either ultrasound guidance (with rectally administered air or saline) or fluoroscopic guidance (with rectally administered barium or water-soluble contrast material). As is

[1] This term applies to a bloody, mucus containing bowel movement which resembles currant jelly.

usually the case when many alternatives exist and one has not supplanted the others, there are advantages and disadvantages to each alternative, and there is likely a good reason (or several good reasons) that a particular radiology department chooses to treat intussusception in the manner that it does.

CT EXAMINATION OF THE ABDOMEN AND PELVIS MAY BE OBTAINED FOR A CHILD WITH RLQ PAIN, LOSS OF APPETITE, NAUSEA AND VOMITING, FEVER, AND/OR ELEVATED WHITE COUNT

For a discussion of appendicitis in adults, see pages 94-95 in Chapter 7. Many of the pediatric patients will be older than 5 years of age, and the diagnosis is often straightforward if all or most of the features of typical appendicitis are present, such as loss of appetite followed by nausea and vomiting, signs and symptoms of inflammation (peritoneal signs with an elevated white blood cell count), and pain localizing to the right lower quadrant. Imaging issues to consider in pediatric patients with possible appendicitis include a) whether to image; and b) if imaging is necessary, what modality to use. Some sources recommend early consultation with surgery[12], in which case the surgeons will make the decision of whether the clinical scenario is typical enough to proceed directly to surgery or if imaging needs to be performed.

In those cases where imaging is required, choices include ultrasound and CT. Ultrasound is recommended in those cases where local expertise is available in performance and interpretation of the exam. Ultrasound of the appendix is a demanding task, however, requiring considerable skill and extensive experience on the part of the ultrasound technologist and/or radiologist, and may not be available in all departments. As noted in Chapter 7, the exam is prone to false-negatives when performed by non-experts, and in this case a negative study cannot be relied upon to confidently exclude appendicitis. In these cases, CT needs to be performed anyway, and the US will only add time and money to the diagnostic evaluation. Furthermore, even in expert hands, if the ultrasound study is negative, or if the patient exhibits persistent features of appendicitis, repeat ultrasound or CT needs to be performed to confirm the apparent lack of appendicitis suggested by the initial ultrasound[13]. Ultrasound has a definite advantage in evaluation of female patients, however, in that it is the study of choice to evaluate gynecologic diseases (e.g., ovarian torsion, hemorrhagic ovarian cyst, pelvic inflammatory disease) which may mimic appendicitis.

When CT is chosen over ultrasound as the imaging method of choice, someone must decide how the examination should be performed. In all cases involving ionizing radiation, but particularly in pediatric cases involving ionizing radiation using CT, radiation dose becomes a factor in deciding how to perform imaging (see page 255). The technique should be optimized to use the lowest possible diagnostic dose of ionizing radiation (typically achieved by reduction in tube milliamperage and increased pitch with helical scanners). Of course, the more "passes" one takes through the abdomen and pelvis, and the larger area covered by those "passes" (covering both the abdomen and pelvis, versus covering only the pelvis), the more ionizing radiation is used for the study. Alternatives for scanning include:

1. Scan without any contrast material ("CT-KUB"). This alternative may be chosen when a ureteral calculus is a strong consideration (in addition to appendicitis). Advantages include an immediate scan without any oral, rectal, or IV contrast; disadvantages include possible lack of a fully diagnostic scan, sometimes necessitating a repeat scan (with more radiation exposure) after contrast has been given.

2. Scan with IV contrast only. The advantages of this alternative include rapidity and avoiding oral contrast. Disadvantages include that IV contrast may obscure small renal or ureteral stones (see Chapter 1) and that the distal small bowel is usually not well seen. With obstructing renal calculi, secondary signs (e.g., hydronephrosis and perinephric stranding) will usually indicate the diagnosis even if the stone itself is obscured.

3. Scan with oral and IV contrast. The disadvantages of this technique include that it takes longer (typically at least one hour, and often two, must pass before the terminal ileum and proximal colon contain enough contrast material for a diagnostic scan). Advantages include that it allows better evaluation of distal small bowel which may indicate an alternative diagnosis (gastroenteritis, Crohn's disease) to appendicitis as the cause of the patient's symptoms.

4. Scan with rectal contrast (with or without IV contrast). Advantages include high accuracy in diagnosis of appendicitis. Disadvantages to this alternative include lack of patient acceptance because of the necessity of performing a (water-soluble contrast) enema. In addition, while the large bowel (and frequently the appendix) is well seen and the technique is highly accurate in characterization of the appendix, contrast material may not freely reflux into the small bowel to evaluate for the alternative diagnoses mentioned in the previous paragraph.

As this brief review of scanning alternatives indicates, there are multiple considerations in play. Is it best to minimize radiation and maximize diagnostic yield, particularly when alternatives to appendicitis are under consideration? A single pass two hours after oral contrast administration with IV contrast will probably work best. Is it necessary to obtain an immediate diagnosis and is a ureteral calculus a strong consideration in addition to appendicitis? Immediate noncontrast scanning is the study of choice. Of course, such an immediate noncontrast study may be nondiagnostic and it may then require additional radiation, time, and expense to perform a study with oral or IV contrast. These considerations show why there is considerable variation in how radiology departments scan the patient suspected of appendicitis.

For patients with appendicitis, the imaging findings in pediatric patients are the same as those in adults: appendiceal swelling, a thick wall of the appendix which demonstrates abnormal contrast enhancement, and inflammatory changes in the surrounding periappendiceal fat (Figure 7). In patients where the process has progressed to the point where the appendix has ruptured, there is a disorganized appearance of the right lower quadrant because of leaked fluid and secondary inflammatory change (Figure 8).

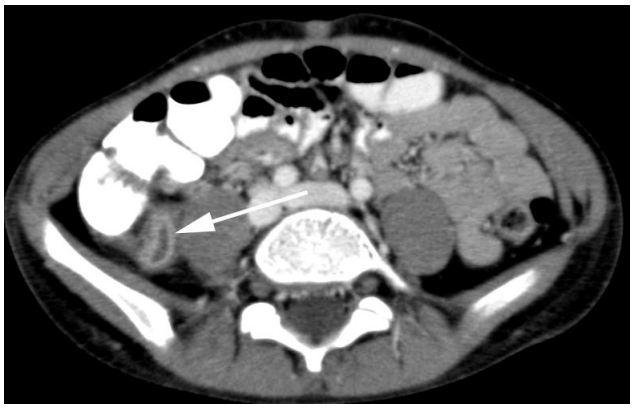

Figure 7. Appendicitis in a 6 year old boy with abdominal pain, nausea, and vomiting. Axial CT performed with oral and intravenous contrast material demonstrates a swollen, thick-walled appendix with marked contrast enhancement along the margins (arrow).

Figure 8. Ruptured appendix in a 16 year old male with abdominal pain for several days. Axial CT-KUB (CT performed without oral or intravenous contrast material) through the pelvis shows a disorganized appearance of the anatomy (between white arrows) in the right lower quadrant, with areas of inflammatory change within the peritoneum and focal areas of fluid representing abscesses/phlegmon, and no well-defined normal appearing bowel loops.

CT EXAMINATION OF THE SINUSES AND ORBITS MAY BE OBTAINED FOR A CHILD WITH A RUNNY NOSE, FEVER, AND HEADACHE IF ACCOMPANIED BY VISUAL SYMPTOMS

Sinusitis in pediatric patients generally manifests as a persistent runny nose, sinus congestion, sinus pain, and fever. Viruses cause most episodes of sinusitis, but approximately 10% of such viral infections are complicated by acute bacterial sinusitis[14]. When this occurs, the patient usually has either exacerbation of symptoms which were on the mend, or prolonged symptoms of between 10 and 30 days' duration. Since imaging (whether with plain films or CT) cannot distinguish between viral and bacterial sinusitis (both produce mucus membrane thickening and air-fluid levels), the American Academy of Pediatrics[15] and the American College of Radiology[16] do *not* recommend imaging.

There are, however, certain dreaded complications of sinusitis that require imaging. These complications involve spread of the infection from the sinuses to the orbits (orbital cellulitis) or cranial vault (septic cavernous thrombosis, meningitis, osteomyelitis of the frontal bone, epidural abscess, subdural empyema, and brain abscess)[13]. Such complications should be suspected in patients who develop orbital cellulitis, pain with eye movement, limitation of eye movement, double vision, vision loss, ptosis, proptosis, headaches, altered mental status, neurologic signs, or neck stiffness. In this case, a CT of the brain (including through the base of the maxillary sinus), performed using thin cuts (to allow multiplanar reconstruction) and contrast (to evaluate contrast-enhancing areas of inflammation) should be performed. MR of the brain (without and with contrast) is an alternative to CT in such cases. These cross-sectional exams will allow the distinction between, for example, preseptal (periorbital) cellulitis and orbital cellulitis. Such distinctions are critical to facilitate rapid treatment in patients with severe complications of sinusitis.

SUMMARY

This chapter briefly reviews a few of the more commonly encountered, or clinically important, scenarios in pediatric patients. For children with cough or fever, or with a fever and no localizing signs, a CXR may be helpful. In infants with persistent vomiting, abdominal US should probably be performed first if pyloric stenosis is suspected, with an oral contrast study if additional imaging is required. In a young child suspected to have intussusception, plain films and US may be followed at an attempt at reduction of the intussusception in the radiology department. For children with equivocal features of appendicitis, either US or CT may be used, although there are several variations in how to perform CT in these circumstances. In a patient with visual symptoms in addition to features of sinusitis, CT may be performed to exclude orbital extension of inflammation.

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