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Samuel Stafrace
Johan G. (Hans) Blickman *Editors*

Radiological Imaging of the Digestive Tract in Infants and Children

Second Edition

Springer

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Radiological Imaging of the Digestive Tract in Infants and Children

Second Edition

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Preface

As a pediatric radiologist, I often meet clinical colleagues who "just don't get it": who do not seem to see the cardinal differences involved when investigating and treating the next generation(s). This may be a fact of life that I have learnt to accept but as a pediatric radiologist brings the added responsibility of highlighting that children are different at every occasion possible: simply not small adults!

This second edition of *Diagnostic Imaging: Radiological Imaging of the Digestive Tract in Infants and Children* hopefully brings this across. It is targeted to generalists and specialists alike – although it is not exhaustive, it offers a broad practical approach to the clinical diagnostic issues encountered.

In the second edition, the number of chapters has been extended. After a brief chapter on modalities, the next couple of chapters target the emergency conditions encountered in infants and young children. The remaining chapters then follow a more traditional anatomical division. A practical chapter on interventional techniques completes the project.

Newer chapters brought along a good number of new authors: specifically picked from different parts of the world and of different professional stature. This surely adds to the variety offered and gives the completed book a more international reach. We have to thank each and every colleague and friend who have put in time to bring this together. I am very grateful especially for sharing the rare pathologies they encounter in their respective practices to broaden our knowledge base.

Chapters can now be acquired and downloaded individually. In view of this, we have tried our best to make each chapter a "stand alone." This surely resulted in some overlap – and occasionally some challenging ideas by different authors. We have chosen to leave this and see this as a strength of the project – allowing different experienced colleagues to share their interpretations of their personal experiences backed by the published literature.

Finally on a personal level:

When approached by my good friend Rick van Rijn to introduce me to Hans about this project, I have to admit I was delighted. I felt honored to the prospect of working with Hans and more so of being asked to lead this. Hans did warn that this is like building a new house or department – "twice as expensive and twice as long!" His experience in such projects had surely nailed this equation. Hans – it has been such a pleasure!

Finally, I cannot but thank my immediate family – Mandy, Maya, and Elena. The time opportunity cost of a book project is very large – and the family is the one who pays for this. Your understanding and sacrifice humbles me.

Enjoy the book.

Doha, Qatar Sam Stafrace

To me, the most important part of being the senior author of any academic writing endeavor is to have the distinct pleasure of seeing the next generations of pediatric imagers grow and mature. Throughout my career, I have relished the joy and satisfaction of sharing an idea, nurturing the project, mentoring the colleagues in question, and finally rejoicing in the final "product."

When I was asked to undertake a second edition of *Diagnostic Imaging: Radiological Imaging of the Digestive Tract in Infants and Children*, I must confess to a less than enthusiastic reaction. Especially as our jobs have gotten busier, our academic time has shrunk and it was difficult to conceive of once more marshaling the energy to set up, manage, and complete such a project.

As mentioned above, our wonderful colleague (and my mentoree) Prof. Rick van Rijn would not hear of such drivel and suggested I contact Dr. Sam Stafrace, whom he described as a young and energetic colleague who would "surely jump at the chance!"

The result is before you. Sam and the most wonderful and knowledgeable crew of contributors have done an outstanding job. Thank you all, you especially Sam, as well as the excellent team at Springer, for going above and beyond.

All you readers now need to do is do well by our pediatric patients (and their parents, and their doctors, etc.). What more satisfying "job" is there?

Rochester, NY, USA Johan G. (Hans) Blickman
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Imaging Techniques

Kids are not Small Adults: Techniques and Helpful Hints

Johan G. (Hans) Blickman

Contents

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Abstract

Imaging techniques utilized in pediatric children very much spreads across the whole spectrum of the modalities available. The 'devil lies in the detail' where the emphasis and focus lies in reducing the radiation burden on the child whilst still answering the clinical questions. This chapter outlines the different techniques utilized highlighting their relative strengths and weaknesses.

1 Conventional Radiography

In a child with abdominal symptoms, conventional radiographs of the abdomen are usually the initial imaging study performed today utilizing computed radiographic or digital radiographic technology.

Although many clinicians request ultrasound (US) or computed tomography (CT) as the first abdominal imaging examination, conventional radiographs are still recommended by the American College of Radiology (ACR) appropriateness guidelines.

Appropriateness guidelines may often provide useful information if tailored to the individual patient's problem. Abdominal radiographs in infants and neonates are typically obtained in supine position, but after the age 1–2 years (when the child has started to walk) are often combined with a horizontal beam examination, preferably upright if needed. The left side down decubitus view may be obtained in newborns and ill or uncooperative patients. Single supine examinations may

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be obtained when the clinical suspicion is constipation or foreign body ingestion or if the examination is being performed for tube or catheter localization hence keeping the overall dose down.

The cross-table lateral view is less useful as it may be difficult to differentiate intraluminal air from extraluminal air. This is however useful if the baby/child should rather not be moved.

There are pertinent points of difference between the abdominal radiograph of an adult and that of a child: the liver takes up a relatively larger space in the peritoneal cavity of a child; the spleen may not be visible and usually does not displace the gastric contour in a child and it is often hard to differentiate large from small bowel, particularly when the bowel is slightly dilated.

Likewise, the retroperitoneal fat "stripes" (psoas shadows) are frequently not seen on the abdominal radiograph of a child because of the relative paucity of fat in the infant's and small child's retroperitoneum. The lack of fat in the capsules of the solid organs also makes evaluation of their size nearly impossible on abdominal radiographs. In contrast, the pro-peritoneal fat stripes are visible from infancy. A soft tissue pseudo-mass in the abdomen may be the urinary bladder, the fluid-filled stomach or intestine, or an umbilical hernia (Fig. 1).

In the newborn there should be air in the stomach at birth. By 6 h at the latest, the stomach and greater portion of the small bowel should be filled with air, by 12 h air should fill most of the (small) bowel, and by 24 h of life air should appear in the rectum, the so-called "rule of 6's."

However, the appearance of air throughout the gastrointestinal (GI) tract is usually more rapid than the above sequence in normal newborns and, unlike adults, children up to the toddler age group typically have air throughout the entire GI tract most of the time.

A variation in this sequence, such as absence of air in the stomach at 1 h, should raise the possibility of an esophageal obstruction. On the other hand, no air in the rectum need not herald intestinal obstruction like in the adult patient and should not be used to suggest bowel obstruction.

The most common cause of a lack of intestinal air in the newborn results from crying and/or less swallowing in ill babies, especially those with newborn lung disease.

Fig. 1 Soft tissue density at L4 region: an "outy," umbilical hernia. There is also evidence of a descending duodenal stenosis

Likewise, the neonate in whom an orogastric (OG) or nasogastric (NG) tube has been placed may have a relatively gasless abdomen without other underlying pathology. Other causes of a gasless abdomen are vomiting, medication that decreases peristalsis, and obstruction of a fluid-filled viscus. Peritoneal irritation (peritonitis) or ascites may also displace abdominal air.

Absence of meconium passage by 24 h is abnormal, and abdominal distention or marked dilatation of any viscus in the first day of life should lead to further imaging evaluation. As noted above, in neonates and infants, it is often impossible to differentiate small from large bowel, especially if the bowel becomes dilated. A prone film sometimes may be helpful because air then "rises" into the rectum to illustrate that distal obstruction is not present.

1.1 Tube and Catheter Positions

Most tubes and catheters are placed by the clinical team, but radiographs are often used for confirmation of position.

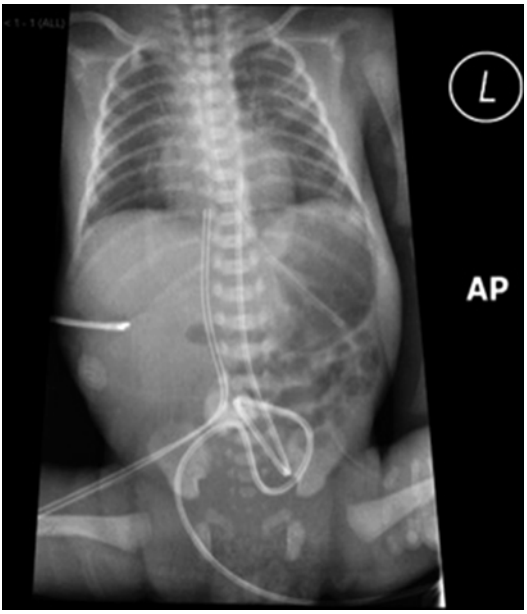

Fig. 2 Plain chest and abdomen radiograph in a neonate demonstrating the appropriate position of the arterial and venous umbilical catheters. The left-sided arterial umbilical catheter (UAC) courses caudal to its junction with the internal iliac artery following which it travels cephalad through the iliac system and the aorta. The right-sided umbilical venous catheter (UVC) travels cephalad from the umbilical vein through the ductus venosus into the inferior cavo-atrial junction (Image courtesy of Dr. Gurdeep Mann, Sidra Medical and Research Center, Qatar)

In the (premature) newborn, abdominal radiographs are commonly used to assess the positions of umbilical catheters, enteric tubes, and vascular access catheters.

Umbilical artery and vein catheters can be distinguished on the basis of their anatomic positions (Fig. 2).

The umbilical artery catheter (UAC) enters one of the umbilical arteries and courses caudal to its junction with the internal iliac artery. It then turns cephalad, coursing through the iliac system to the abdominal aorta.

The tip should be either in the thoracic descending aorta or, preferably, in the abdominal aorta below the origin of the great vessels and above the aortic bifurcation.

The preferred position in the former instance is between T7 and T11("T7 is 'heaven', T8 is great, T9 is fine"), in the latter, below the inferior endplate of L3(the renal arteries originate at L2).

The major complication of malposition of these lines is embolization of a great vessel or lower extremity artery by the thrombus that invariably forms at the tip of the umbilical artery catheter or simply due to vascular spasm.

The umbilical vein catheter (UVC) courses from the umbilicus cephalad through the umbilical vein and ductus venosus into the inferior cavo-atrial junction. Because the umbilical vein catheter shares sinusoids with the portal vein, it may enter the portal vein, the splenic vein, or the superior mesenteric vein (SMV) and in those cases should be replaced. The tip's optimal position is just within the right atrium, just above the confluent shadows of the RA and the right hemidiaphragm.

In older infants and children, venous access is often achieved through the iliac vein. The major complication is venous thrombosis with the risk of subsequent pulmonary embolism. Perforation by a vascular catheter is fortunately quite rare but potentially fatal. OG tubes are more commonly used in the newborn and NG tubes in older children. The tip of such a tube should project over the stomach. Common complications of the use of orogastric or NG tubes are tracheal intubation, coiling of the tube in the pharynx or esophagus, and, rarely, perforation of the esophagus or stomach.

1.2 Radiation Considerations

When imaging children, we have a choice among many modalities; the ones that do not use radiation include ultrasound and MRI. Modalities using ionizing to radiation include conventional radiographs (relatively low dose), fluoroscopy (mid-range dose), and computed tomography (CT) (possibly high dose although doses are reducing significantly with newer technologies).

An unfortunate by-product of the disappearance of hard copy (film) is that we are no longer able to tell inadvertent higher dose by tracking the repeat rate of images of lesser quality easily.

Post-processing algorithms make all the images appear "nice" and the repeat examinations may not be obvious as there is no excess film. For that reason a short review of the current understanding of radiation versus pediatric imaging also known as "imaging gently" or As Low As Reasonably Achievable(ALARA) follows.

The fetus and the young infant are at greatest risk for radiation-induced abnormalities as the effects of radiation are greatest on faster-growing organisms that are abundant in the fetus, infant, and young child. In addition, the effects of this radiation may not be obvious until later age. Evidence for carcinogenesis in the infant was first suggested in 1958 in a study of X-ray exposure during pregnancy. Subsequently, the survivors of the atomic bomb in Japan showed the age-related risk of radiation to be very much more obvious in children in the first decade of life. Thus, we know that ionizing radiation can be deleterious, but we do not know exactly how much and when. Pulse-fluoroscopy and digital imaging are two advances of the former decreasing exposure 30–50 % by changing from continuous to intermittent fluoroscopy. CT delivers the largest dose of ionizing radiation. Worrisome is that the use of CT examinations has increased at a rapid rate and in most non-pediatric radiology departments the technical factors are not adjusted for children. Fortunately the manufacturers are working diligently with us pediatric imagers to drastically lower the absorbed dose due to CT imaging and the rate of increase in CT utilization has slowed.

It is clear that we must reduce radiation dose to children as often as possible. We should actively screen the use of CT examinations as to whether the examination is really necessary in the clinical approach when making the diagnosis and question if another non-radiating modality could be used instead. We must always seek to use *that* protocol that gives the answer to the clinical question asked using the lowest dose.

1.3 Contrast Examinations

Indications for contrast examinations of the gastrointestinal tract are discussed subsequently in the appropriate chapters.

1.3.1 Barium Compounds

Guiding principles for contrast use should always include appropriate temperature and low or iso-osmolarity and always following ("watching with fluoroscopy") the administered contrast to reduce any possible complications.

There are two relative contraindications to using barium as a contrast agent: suspected bowel perforation and predisposition for pulmonary aspiration of barium. Neither one is an absolute contraindication. These compounds are inert thus they traverse the bowel lumen unaltered, flocculation being a thing of the past, as is the old-wives tale of barium "hardening to concrete" in an obstructed viscus.

Barium in the retroperitoneum, mediastinum, or peritoneal cavity that is removed shortly after entering these spaces holds only a minimal risk for sequelae such as granuloma formation, adhesions, and peritonitis. However, successful removal is not always possible and barium is generally contraindicated when the probability of perforation exists. Likewise, aspirated barium provokes a cough reflex. Thus, when routine care is taken, barium constitutes the most useful and safe contrast agent in the pediatric age group.

1.3.2 Water-Soluble Contrast Agents

The most commonly used water-soluble contrast agents are diatrizoate meglumine/sodium (Gastrografin or Gastroview), Iopamidol (Gastromiro), and, less commonly these days, diatrizoate meglumine (Hypaque), Iothalamate meglumine (Conray; Cysto-Conray) are also used.

These agents are hyperosmolar water-soluble media and should not be used routinely in the upper GI tract as there is a serious risk of pulmonary edema (or death) when these agents are aspirated. The aspirated contrast medium causes a release of histamine or histamine-like substances in the lung. In addition, hyperosmolar agents may be toxic to the bowel mucosa, and their hydrophilic nature can result in massive fluid shifts, especially in neonates.

Also these hyperosmolar contrast agents draw fluid into the GI lumen during their passage, often resulting in their marked dilution, sometimes as early as the third portion of the duodenum, thus severely limiting their diagnostic use for the rest of the GI tract.

In the large bowel, on the other hand, these agents are still used in an enema to exploit their hyperosmolar quality (e.g., to facilitate meconium plug evacuation by absorbing fluid into the bowel lumen, thus having a "lubricating" effect,