Imaging with Intention

Pediatric Fluoroscopy and Interventional Radiology for the Care Team

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Objectives

- **Part 1: Pediatric Diagnostic Fluoroscopy**
  1. Describe Fluoroscopy imaging and identify uses in the pediatric population.
  2. Discuss types of contrast agents.
  3. Review the most common fluoroscopy exams and their indications and contraindications.
  4. Discuss the common pediatric pathologies seen in the above exams.
- **Part 2: Pediatric Interventional Radiology**
  1. Describe Interventional Radiology and the various imaging modalities commonly used.
  2. Review common pediatric interventional radiology procedures.
  3. Review ordering indications for inpatient IR consults and pathways for outpatient IR referrals at Akron Children's hospital.

What is Fluoroscopy?

- A type of medical imaging that shows continuous X-ray images on a monitor.
- Radio-opaque contrast is administered by a variety of routes to image various organ systems (i.e. GI, GU) and/or medical devices in motion while capturing still pictures and/or video clips of what is occurring during the procedure.
- Used for both diagnostic and interventional purposes

Radiation Exposure in Fluoroscopy

- Radiation doses from fluoroscopic procedures vary, depending on the type of examination, length of exam and the patient's body habitus.
- Radiation exposure to the patient can be decreased with good technique, plan of care and modern equipment
  - pulsed fluoroscopy: "Pause and Pulse"
  - Utilizing "Last Image Hold"
  - Collimation – directing X-rays only to the area of the body being evaluated
  - Position of the patient in relation to radiation source and image intensifier (II)

Radiation Exposure in Pediatric Fluoroscopy

Non-medical radiation source	Radiation Dose Estimate	Equivalent Amount Background Radiation
Natural Background Radiation	3 mSv	1 year
Airline flight (cross country)	0.04 mSv	4 days
Medical radiation source	**Radiation Dose Estimate**	**Equivalent Amount Background Radiation**
Chest X-ray	0.01-0.05 mSv	1-5 days
VCUG	Average 0.2 mSv	20 days
UGI	Average 3 mSv	1 year
Contrast Enema	Average 4.5 mSv	1.5 years

The Fluoroscopy Suite

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Contrast Agents used in Fluoroscopy

- Non-water soluble
  - Barium Sulfate
  - Commonly used in evaluation of the GI tract
  - Not absorbed or metabolized in the GI tract; excreted unchanged in feces
  - Contraindicated if suspected perforated viscus
  - Chalky taste, but flavor additives make more palatable
  - Generally well-tolerated with minimal adverse effects; allergy rare

- Water soluble
  - Iodinated Contrast: Isovue®-200/250/300, Cystografin®, Gastrografin®
  - GI: post surgical patients, concern for perforated viscous, routine for contrast enemas; GU: routine exams
  - Safe if extravasation into the peritoneum
  - Varies in osmolality and in iodine concentration
  - Noxious, bitter taste – not as well-tolerated orally
  - Adverse effects more common than barium, but still rare with oral or rectal administration

- Air
  - Most common use is for Intussusception Reduction
  - May also be used in other GI fluoroscopy exams (Upper GI)

Common Fluoroscopy Exams in Pediatric Patients

- Videofluoroscopic Swallow Study
- Esophagram
- Upper GI
- Voiding Cystourethrogram
- Contrast enema
- Intussusception Reduction

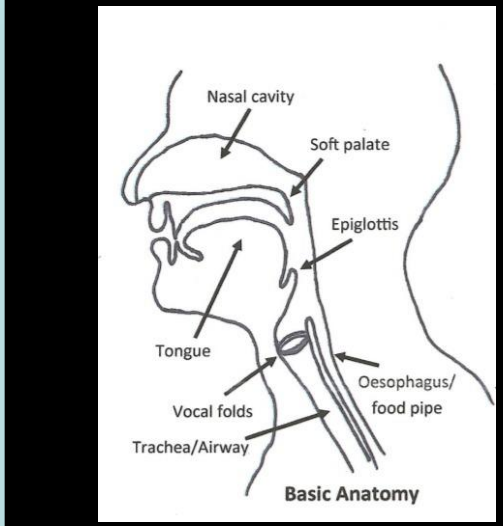
Videofluoroscopic Swallowing Study

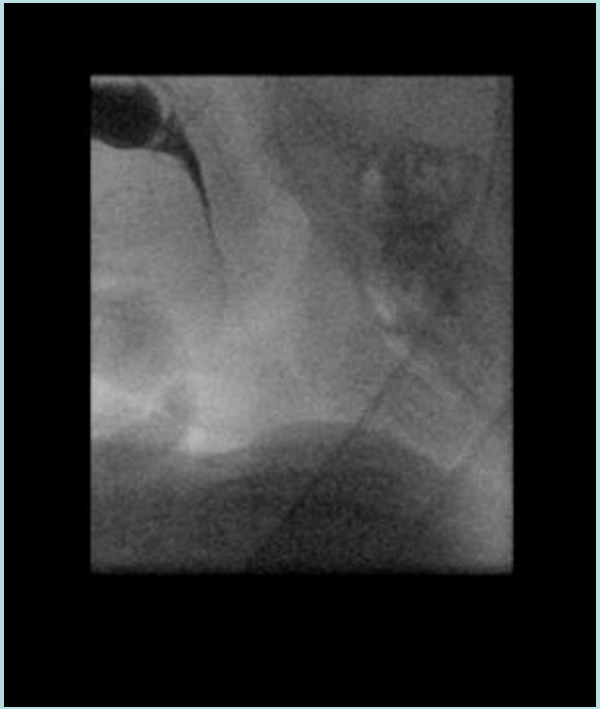
- AKA “Modified barium swallow study” or MBSS
- Evaluation for oropharyngeal dysphagia
- Performed in conjunction with a Speech Language Pathologist (SLP)
- “Modified” to the patient’s symptoms, age, ability to perform the exam, and the clinical question
- Common indications
  - Choking, coughing, or gagging with ingestion of liquids or foods
  - Concern for aspiration
  - Frequent URIs without clear cause
  - Feeding difficulties (especially in infants)

Videofluoroscopic Swallowing Study

- Relative Contraindications
  - Patient who does not eat/drink by mouth
  - Exclusively breastfed infant
- Contrast
  - Barium Sulfate of various consistencies
    - Thin, Nectar, Honey, Honey-Pudding, Pudding, Cookie
- Technique
  - Patient typically sits in an upright or semi-reclined position depending on age while ingesting various consistencies of barium
    - May use side-lying position for neonates and young infants
  - Lateral fluoroscopic images obtained of the oropharynx at 15 frames/second during swallowing

Videofluoroscopic Swallowing Study





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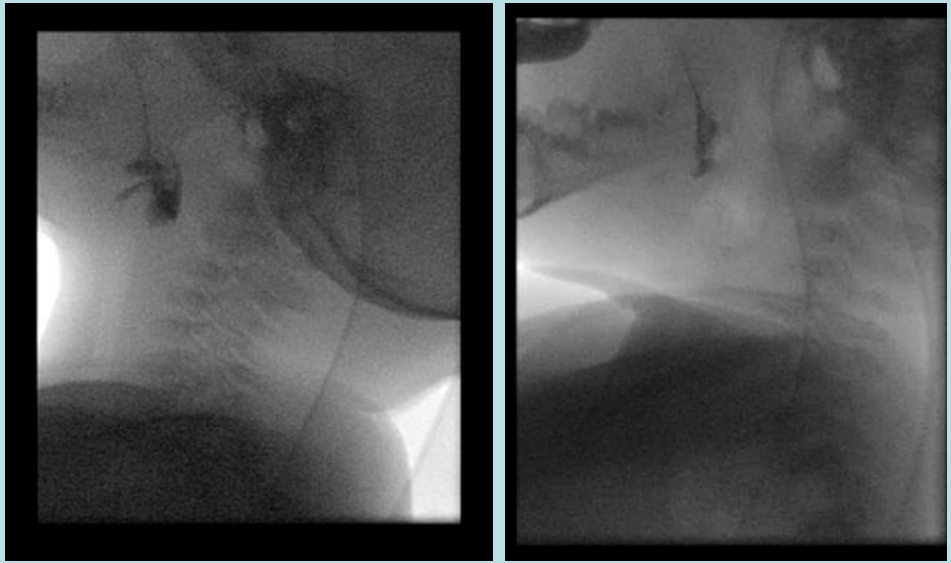
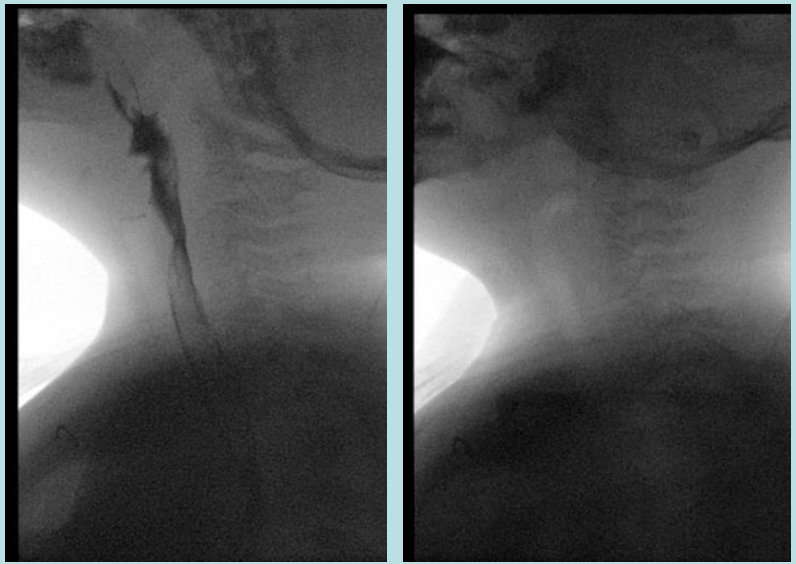
Videofluoroscopic Swallowing Study

Laryngeal Penetration



Aspiration



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Esophagram

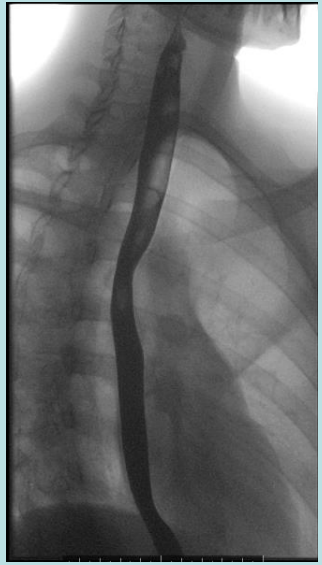
- AKA “Barium swallow”
- Evaluation of the esophagus in multiple views
- Common indications
  - Esophageal dysphagia “feels like food gets stuck,” globus sensation
  - Odynophagia
  - Concern for esophageal foreign body or food impaction (emergent)
  - Tracheoesophageal fistula
  - Vascular ring
  - Concern for esophageal stricture
- Relative contraindications/considerations
  - If patient not able to take p.o., NG may be placed in upper esophagus to administer contrast

Esophagram

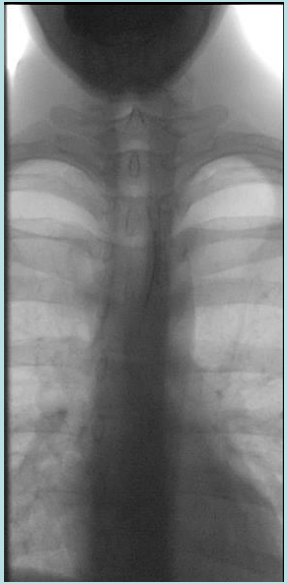
- Contrast
  - Barium sulfate most common
    - May administer pudding and/or cookie consistency for dysphagia to solids
  - Water soluble contrast used if concern for perforation (foreign body, post-op)
- Technique
  - Depending on patient age and ability, patient may be positioned supine/lateral on table or standing upright during administration of contrast and acquisition of images
  - Contrast administered p.o. by bottle, sippy, straw, open cup; syringe or via NG if necessary
  - Images obtained at 3 frames/second

Esophagram

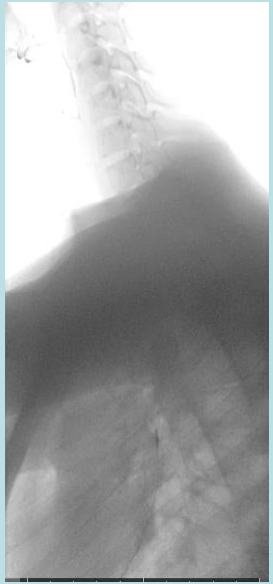
Upright Esophagram in a Teenager



oblique

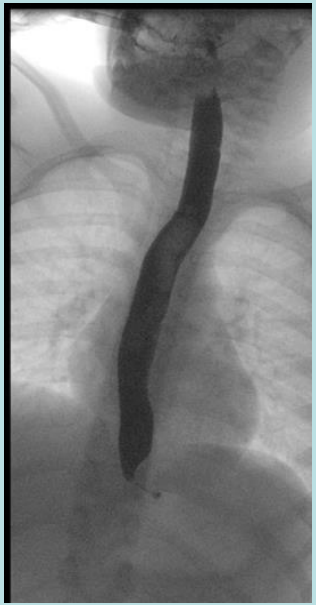


frontal

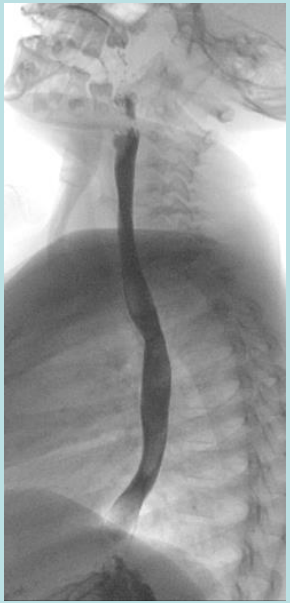


lateral

Recumbent Esophagram 6 y.o.



frontal



lateral

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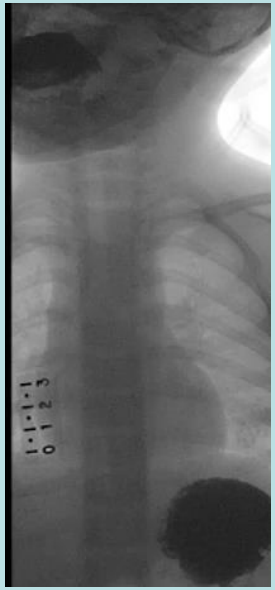
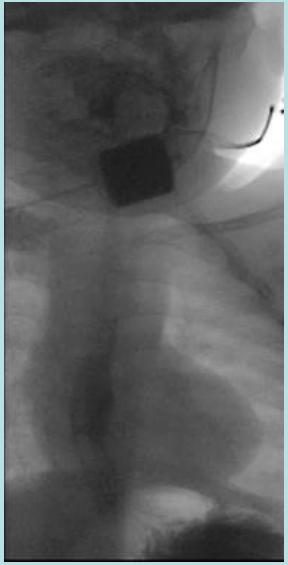
Esophagram

Stricture



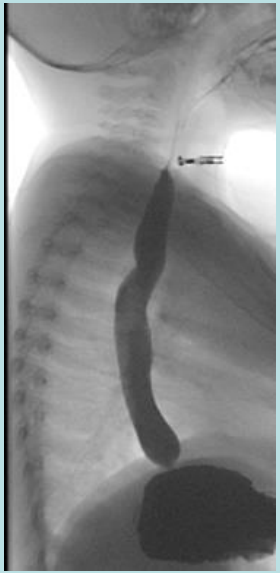
4 y.o. with h/o caustic ingestion

FB (blueberry)

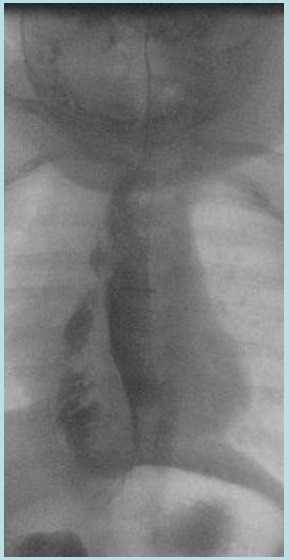


2 y.o. with h/o TEF/EA

Aberrant Subclavian Artery



Leak/perforation



h/o TEF & stricture s/p dilation

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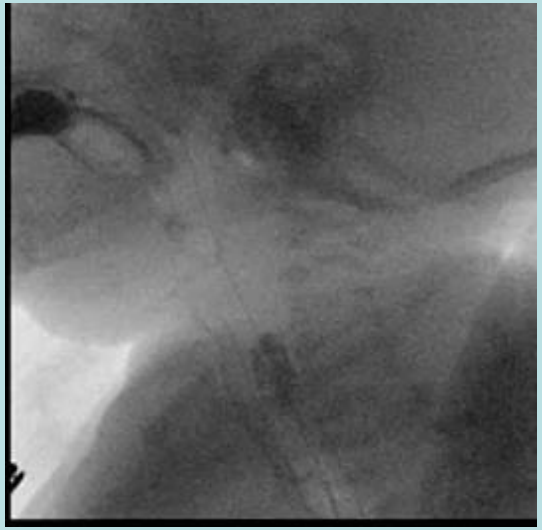
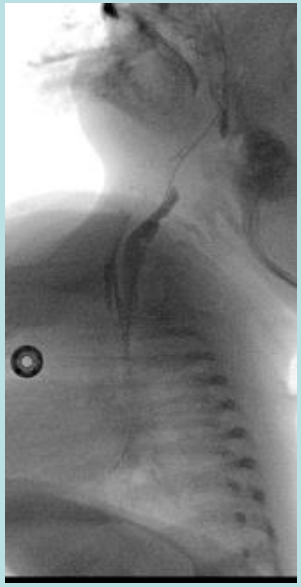
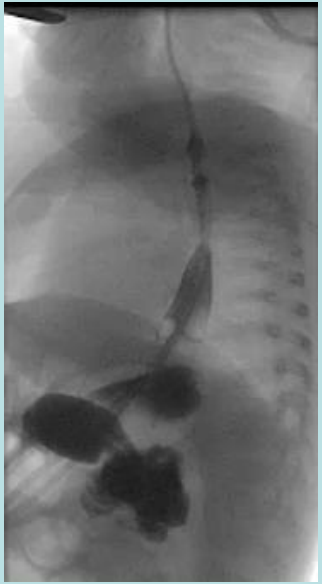
Esophagram

H-type TEF - VFSS



H-type TEF - Esophagram





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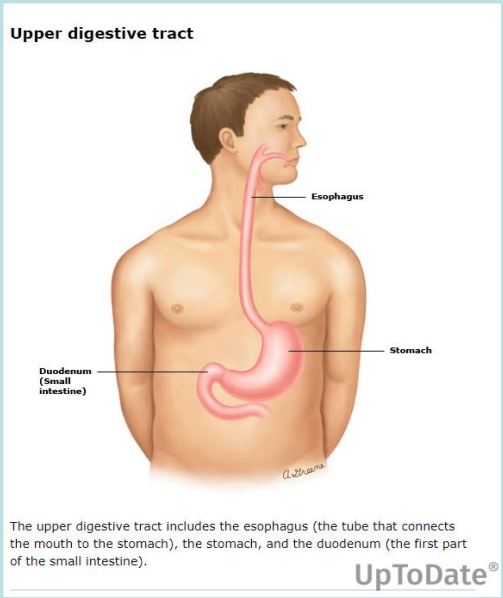
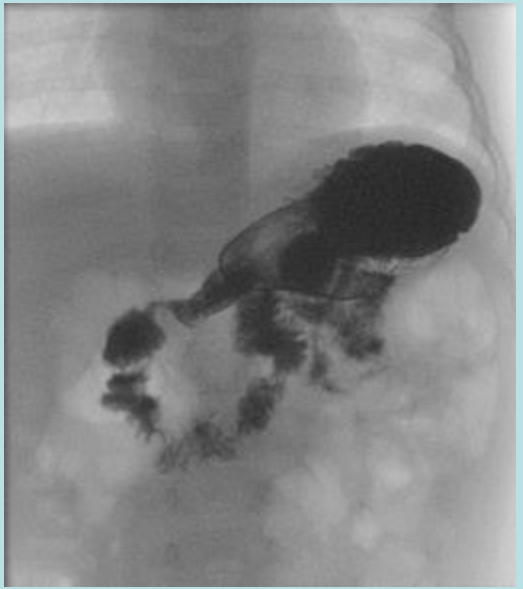
Upper GI

- Evaluation of the Esophagus, Stomach, and first portion of the small intestine (at least to the ligment of Treitz)





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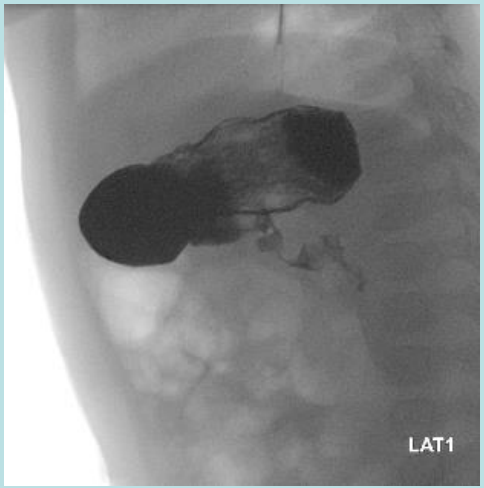
Upper GI

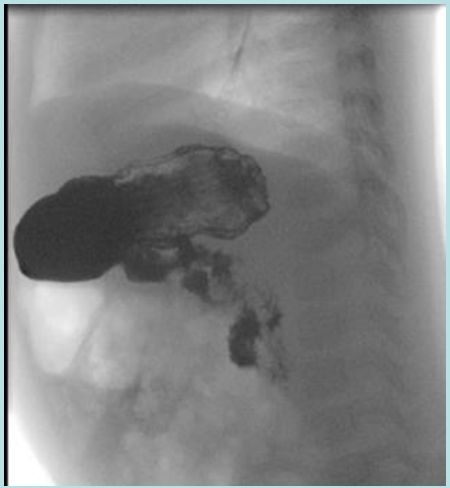
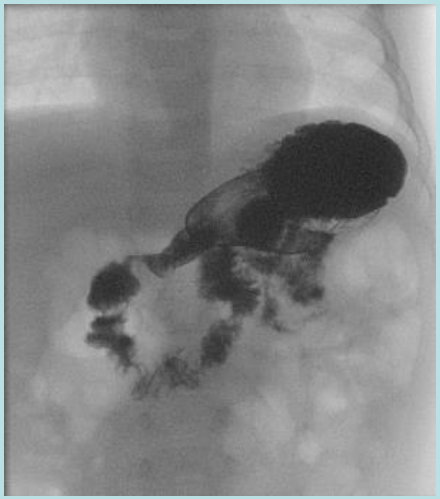
- Common indications:
  - Nausea/Vomiting
  - Abdominal Pain
  - Failure to thrive
  - r/o Malrotation
  - Gastroesophageal Reflux
  - Hiatal Hernia
  - Bilious Emesis
  - Concern for gastric outlet obstruction
  - Post-operative evaluation for stricture, leak, or other complication
- Relative contraindications
  - Inability to travel to fluoroscopy suite

Upper GI

- Considerations and Patient Preparation
  - NPO for 3 hours (age <1 year) or 8 hours (age >1 year)
  - Increased risk of aspiration in sedated patients (cannot protect airway), so generally not performed under sedation or anesthesia.
  - Timing and positioning is important for adequate evaluation.
  - Evaluation of reflux is limited.
  - If patient cannot/does not drink by mouth, safe administration of contrast may require administration via NG and/or G-tube if present.
- Technique
  - Esophageal images obtained as described for esophagram
  - Lateral and supine images of the anatomy of the duodenum
  - Supine image of abdomen showing proximal jejunal loops

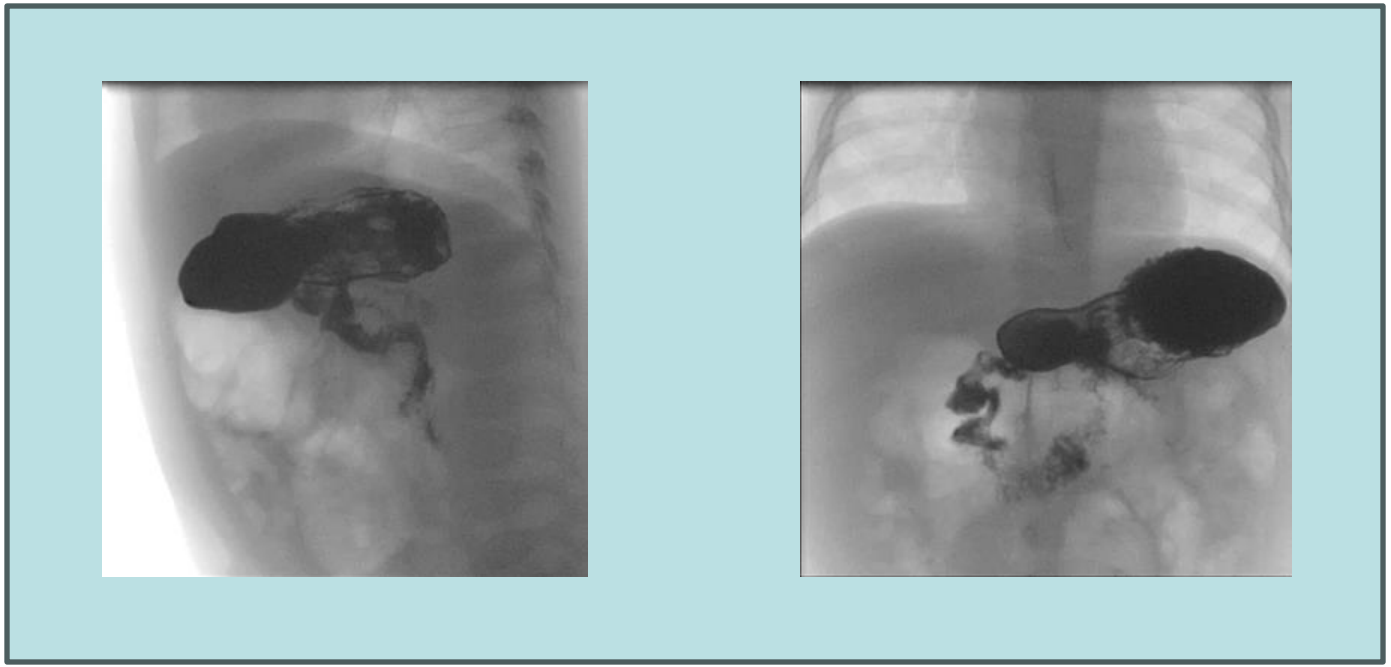
Upper GI



Normal UGI in a 4 m.o. with history of frequent NBNB emesis and reflux

Upper GI



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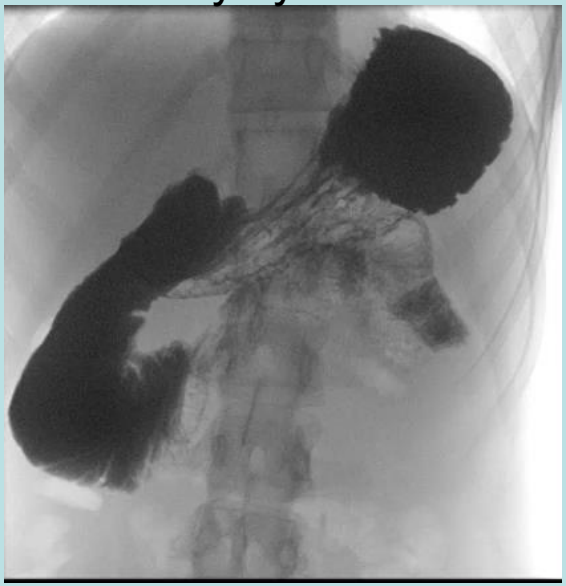
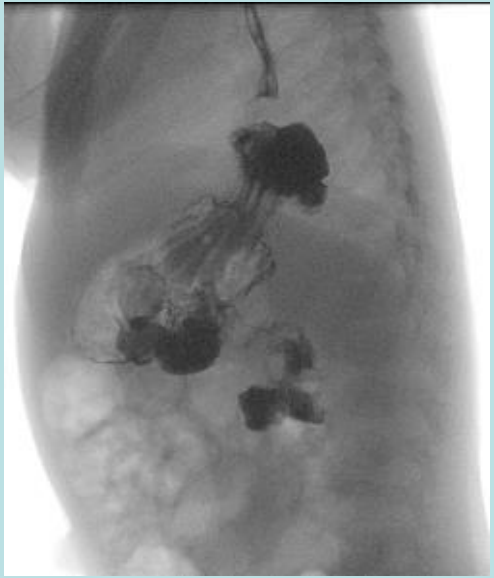
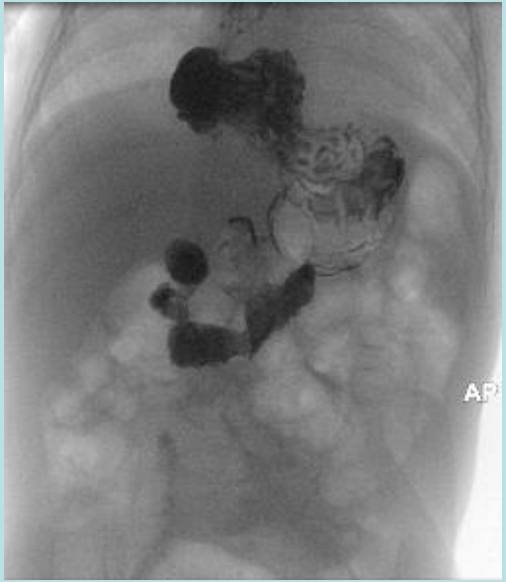
Upper GI

Superior Mesenteric Artery syndrome



Hiatal Hernia





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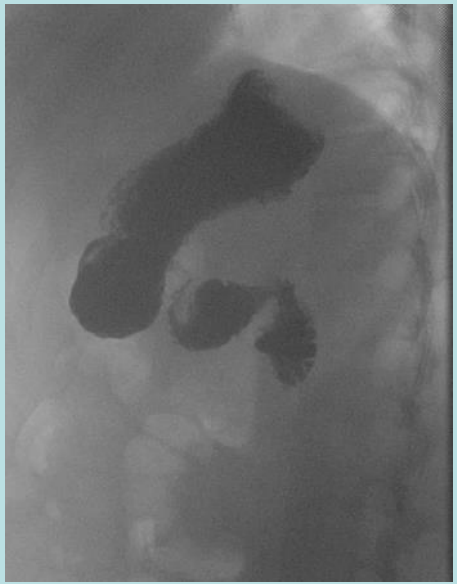
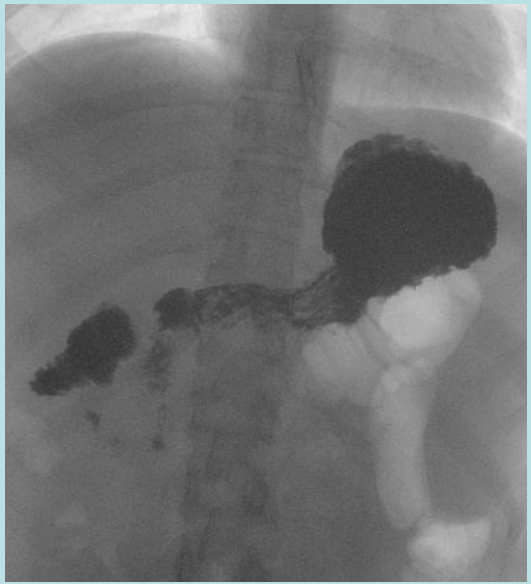
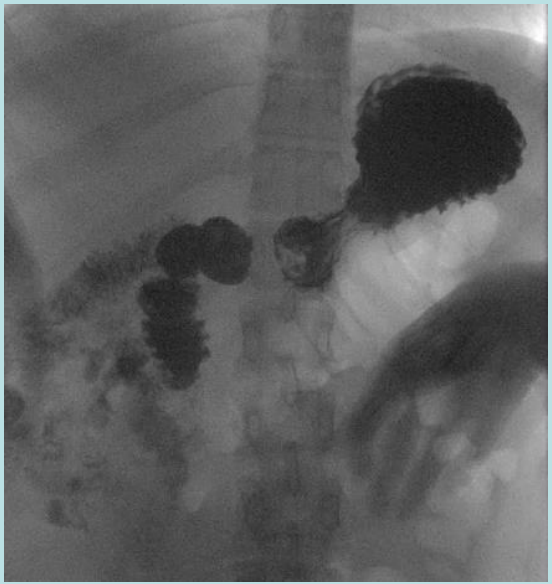
Upper GI

17 y.o. with incidental finding of malrotation (asymptomatic) on CT A/P for pancreatitis







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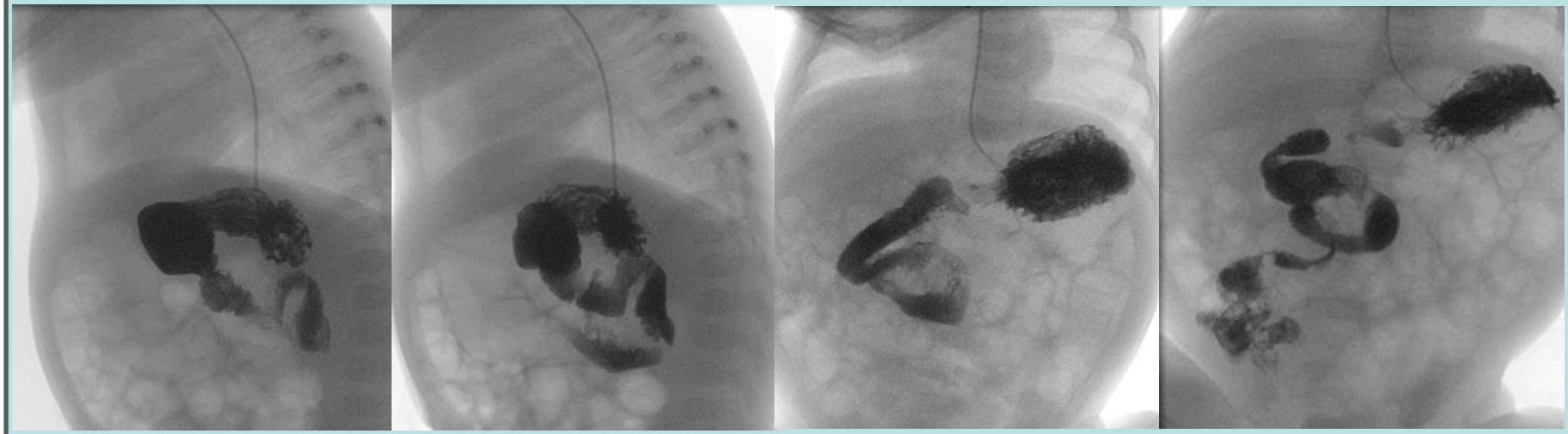
Upper GI

8 week old baby with emesis/frequent spitting up and poor weight gain



Malrotation with midgut volvulus

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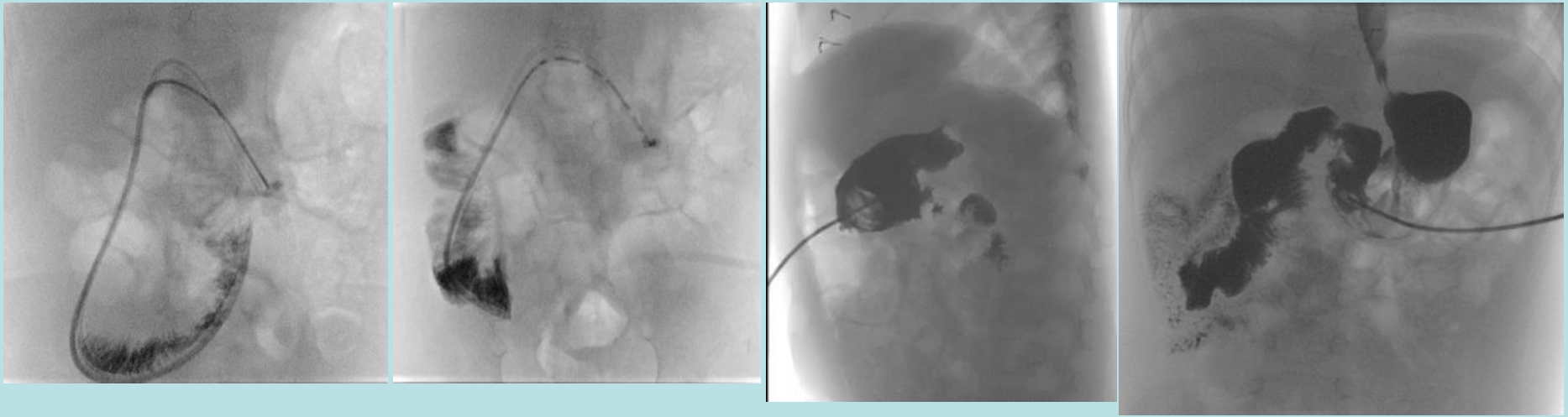
Upper GI

3 y.o. patient with GJ tube, concern for malrotation on GJ tube placement



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Small Bowel Follow Through

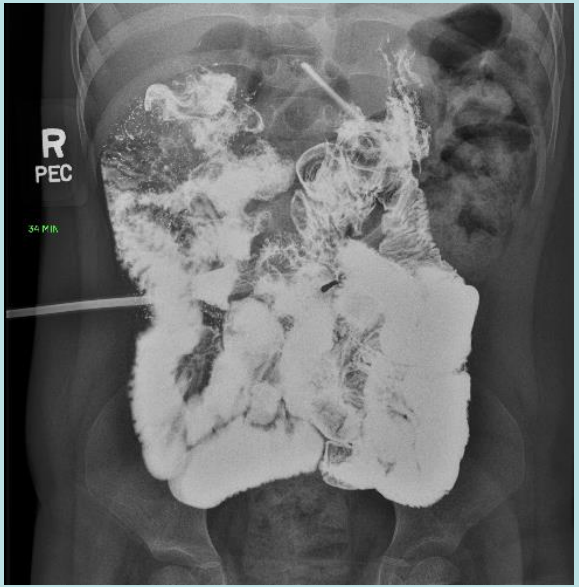
- Radiographic evaluation of the small intestine
- Typically, will follow an Upper GI exam
- Barium most often used, but may use water-soluble contrast
- Sequential abdominal radiographs are taken every 30-60 minutes until contrast reaches the colon, then spot images obtained with focused compression using a paddle to evaluate the terminal ileum or areas of concern.
- Time for contrast to reach the colon is documented.

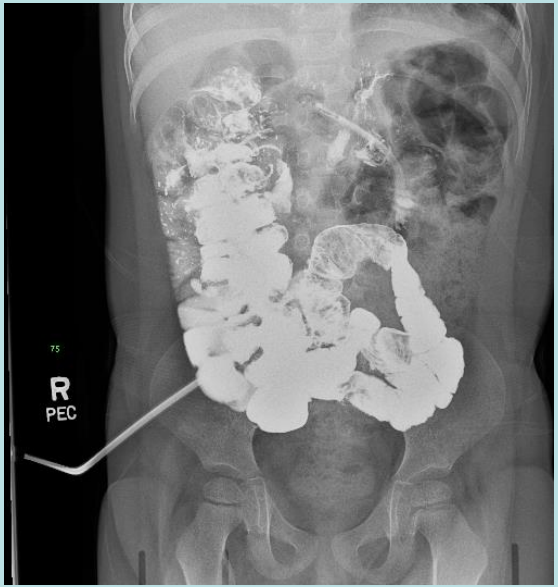
Small Bowel Follow Through

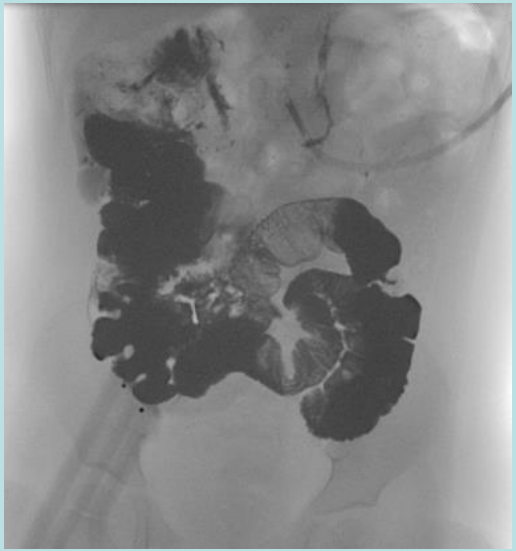
- Indications
  - Concern for small bowel obstruction or stricture
  - Concern for Crohn disease/Inflammatory Bowel Disease
  - History of Necrotizing Enterocolitis (NEC) or abdominal surgical history
  - To document position of the cecum in suspected malrotation
  - Evaluation of motility/transit time
- Relative Contraindications and Considerations
  - If suspected perforation is in ileum or jejunum, unlikely to be able to identify exact anatomic location of perforation/leak.
  - Suspected Perforation – water soluble contrast used
  - Exam may take several hours depending on transit time/motility
  - Increased radiation dose to the patient

Small Bowel Follow Through

3 y.o. patient with GJ tube, concern for malrotation on GJ tube placement







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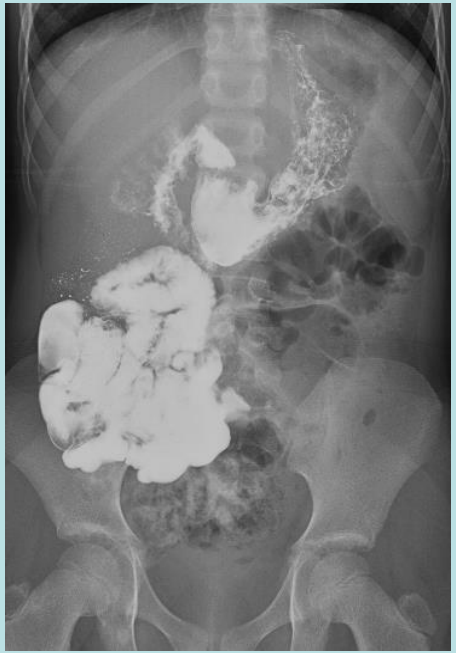
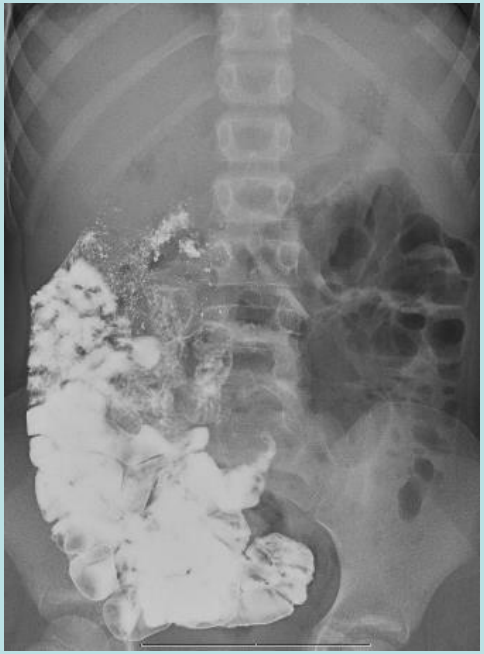
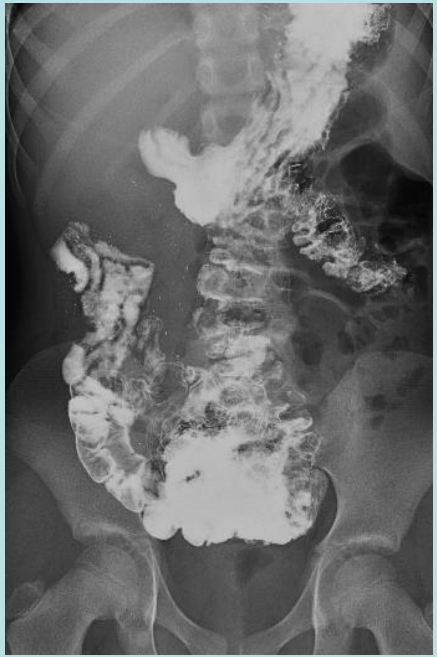
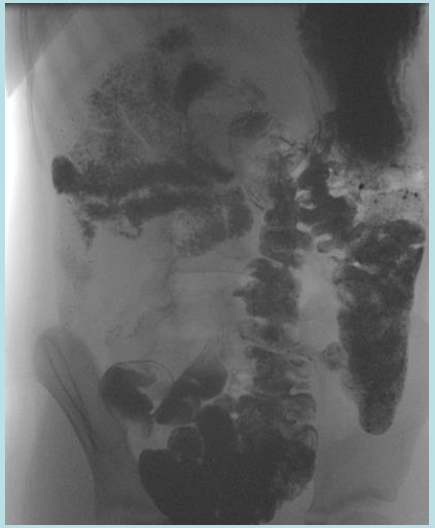
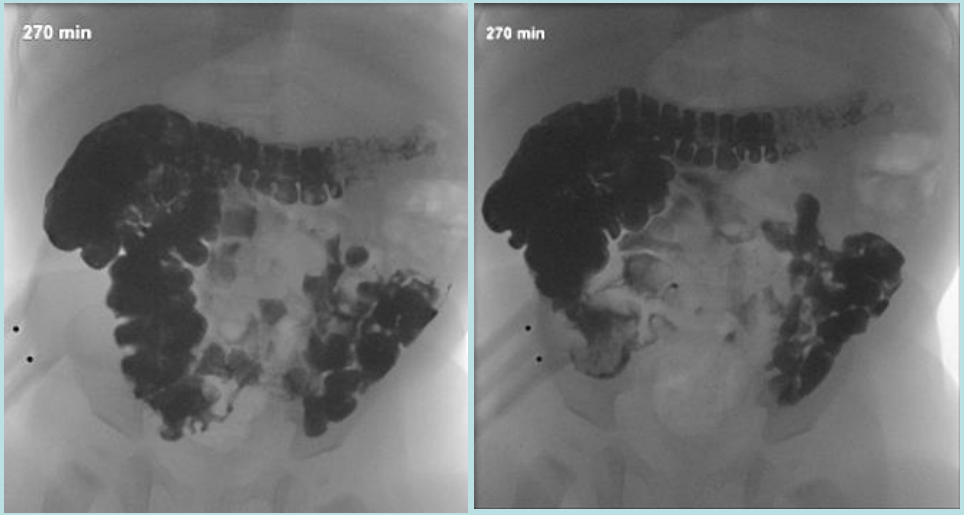
Small Bowel Follow Through

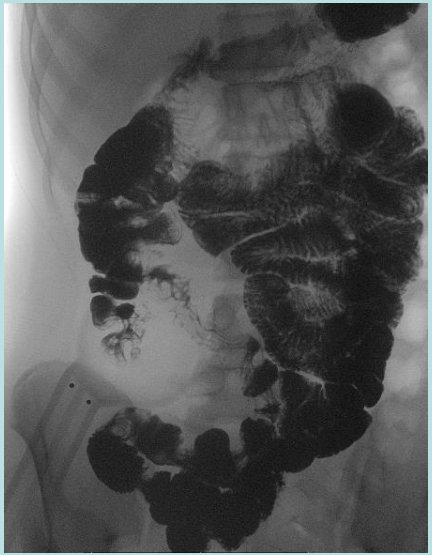
Malrotation with small bowel located on the right side of the abdomen and colon located on the left side of the abdomen

Small Bowel Follow Through

Spotting on SBFT



Normally located Cecum and TI



Chron's Disease of Terminal Ileum

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Contrast Enema

- Fluoroscopic evaluation of the colon
- Technique
  - A small catheter is placed in the rectum and secured in place with tape.
  - Contrast is administered by gravity via the rectal catheter and images are obtained while contrast is filling the colon in a retrograde fashion.
  - Begin in lateral position to obtain early fill images of the rectum and sigmoid colon to evaluate rectosigmoid ratio.
  - Obtain supine and oblique images as needed to image the entire colon.

Contrast Enema

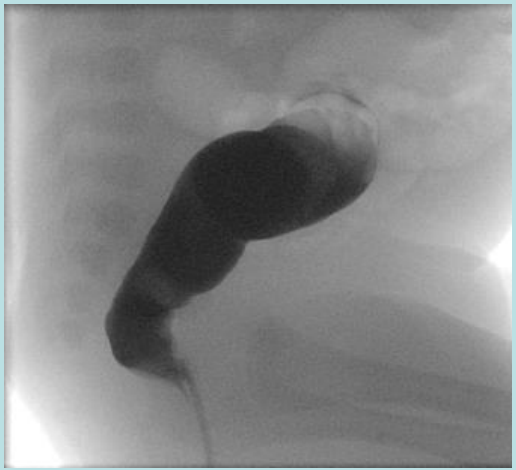
- Contrast
  - In pediatric patients, water-soluble contrast is most often used
  - At ACH, we use Isovue-200 in infants and Dilute Gastrografin in patients over age 1.
- Indications
  - Concern for distal intestinal obstruction
  - Failure to pass meconium
  - Concern for Hirschsprung Disease
  - Chronic Constipation, Estimated Colonic Volumes
  - Meconium Ileus
  - Distal Intestinal Obstruction Syndrome (DIOS)
  - Pre-surgical evaluation

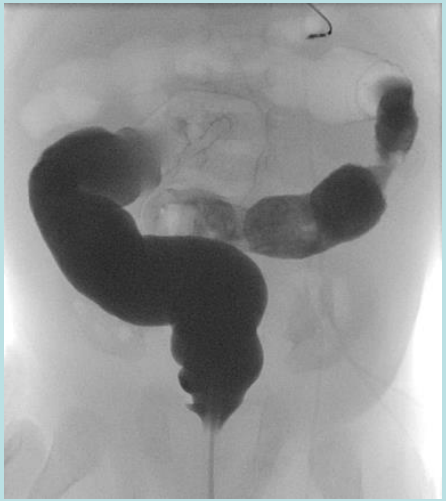
Contrast Enema

- Contraindications and Considerations
  - Active colitis
  - If severe abdominal distension, proceed with caution, monitor closely during exam.
  - Sedative medications decrease rectal tone making retention of contrast very difficult, which can lead to a non-diagnostic exam.
    - Sedation only considered in very specific scenarios/cases
  - Water-soluble contrast enema may be therapeutic as well as diagnostic
  - Contrast osmolality must be considered, especially in neonates, due to potential fluid shifts.

Contrast Enema

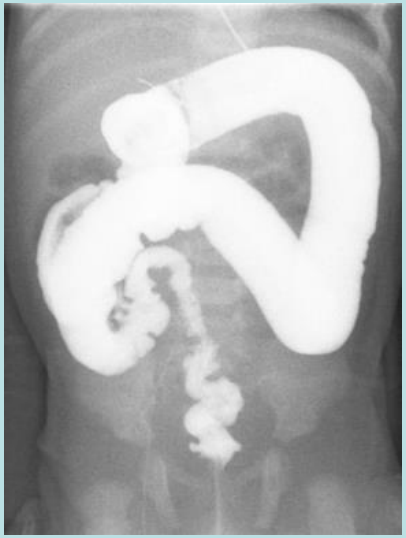
5 wk old premature infant with dilated bowel loops on AXR, rule out Hirschsprung's Disease





Hirschsprung's Disease

6 day old with Trisomy 21 and suction biopsy + for HD, evaluate for transition zone



Transition zone in mid to proximal sigmoid colon

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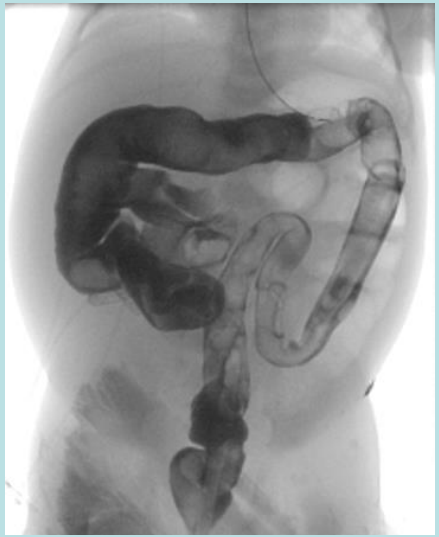
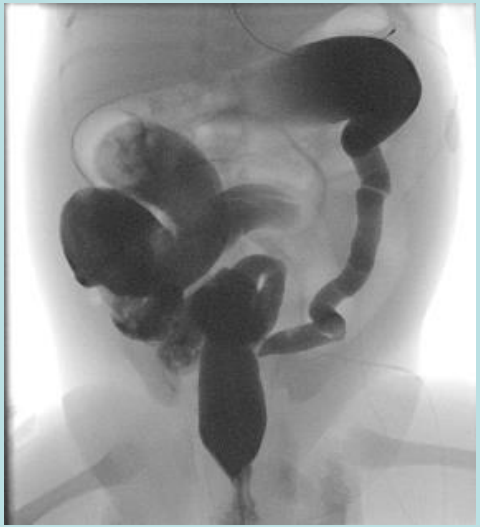
Contrast Enema

4 day old with no passage of meconium



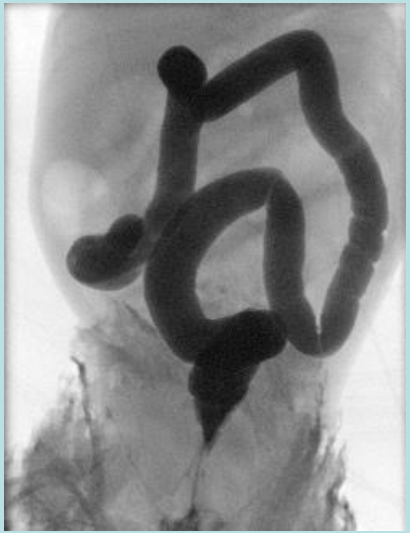
Meconium ileus

2 day old with no stool x 48 hours, abd distension, concern for distal bowel obstruction



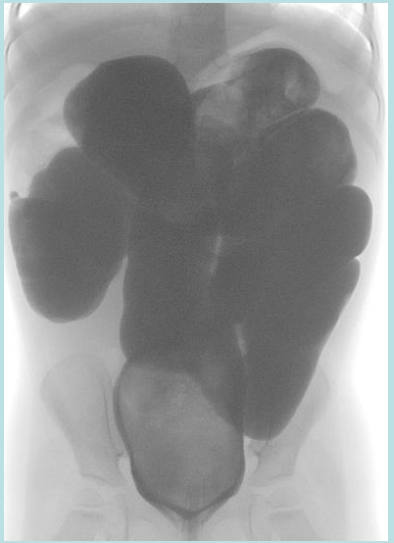
Small left colon syndrome/ functional immaturity of the colon/ meconium plug syndrome

25 week preemie with abdominal distension, concern for obstruction



Ileal atresia

2 y.o. with chronic constipation, r/o Hirschsprung's



Fecal Impaction

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Air Enema for Intussusception Reduction

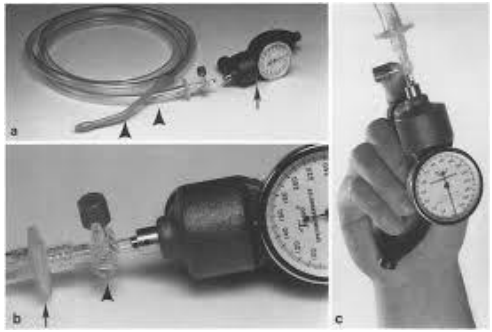
- Considerations
  - Decreased success of air enema reduction with long duration of symptoms (>24 h) and lethargy
- Contraindications
  - Peritonitis on physical exam
  - Pneumoperitoneum on radiograph

Air Enema for Intussusception Reduction

- Risk
  - Bowel perforation
  - Failure to reduce intussusception
  - Recurrence of intussusception
- Preparation
  - IV in place
  - Adequately hydrated (Fluid bolus given)
  - Surgical consult
  - Nurse present to monitor patient vitals

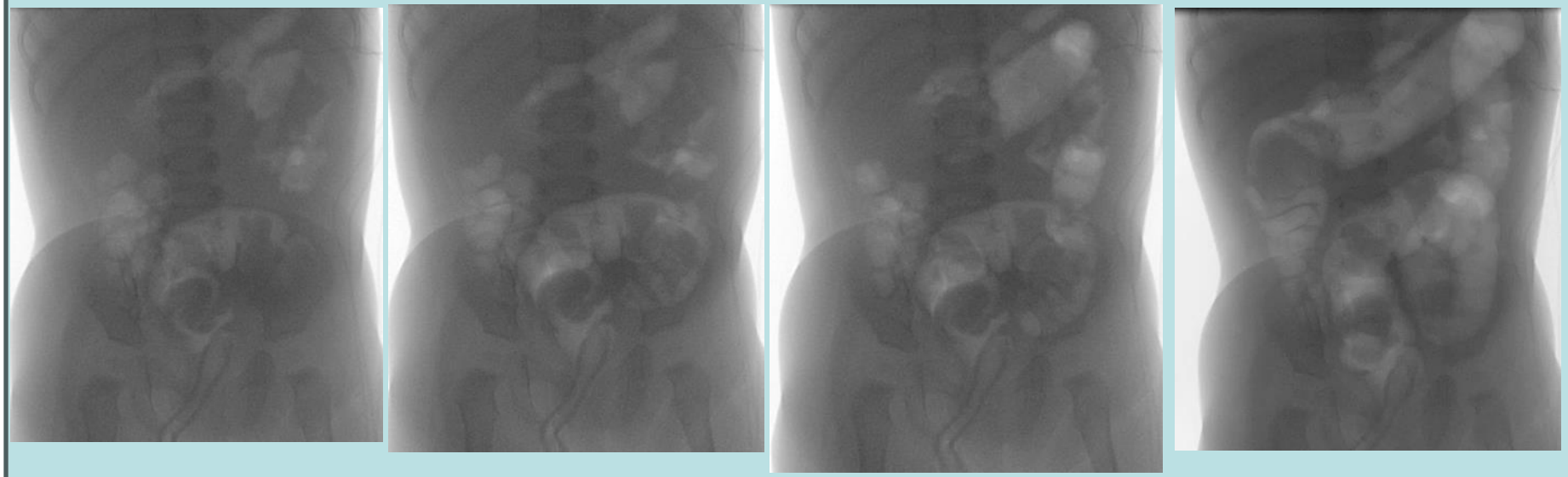
Air Enema for Intussusception Reduction

- Technique
  - Enema tip and tubing is connected to Shiels intussusception air reduction system.
  - Enema tip inserted into rectum and buttocks taped tightly together to maintain a good seal



  - Air insufflated into the colon, maintaining a pressure <120 mm Hg, while monitoring/following the intussusceptum under fluoroscopy until intussuscption is reduced and air is seen easily refluxing into the small bowel under fluouroscopy.

Air Enema for Intussusception Reduction



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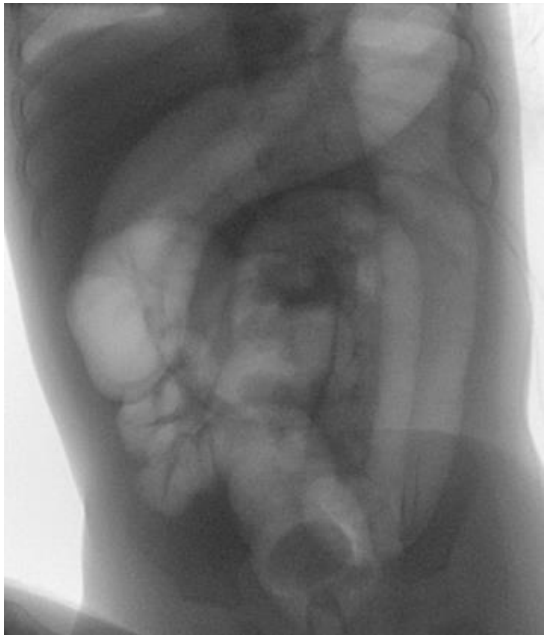
Air Enema for Intussusception Reduction



Successful reduction

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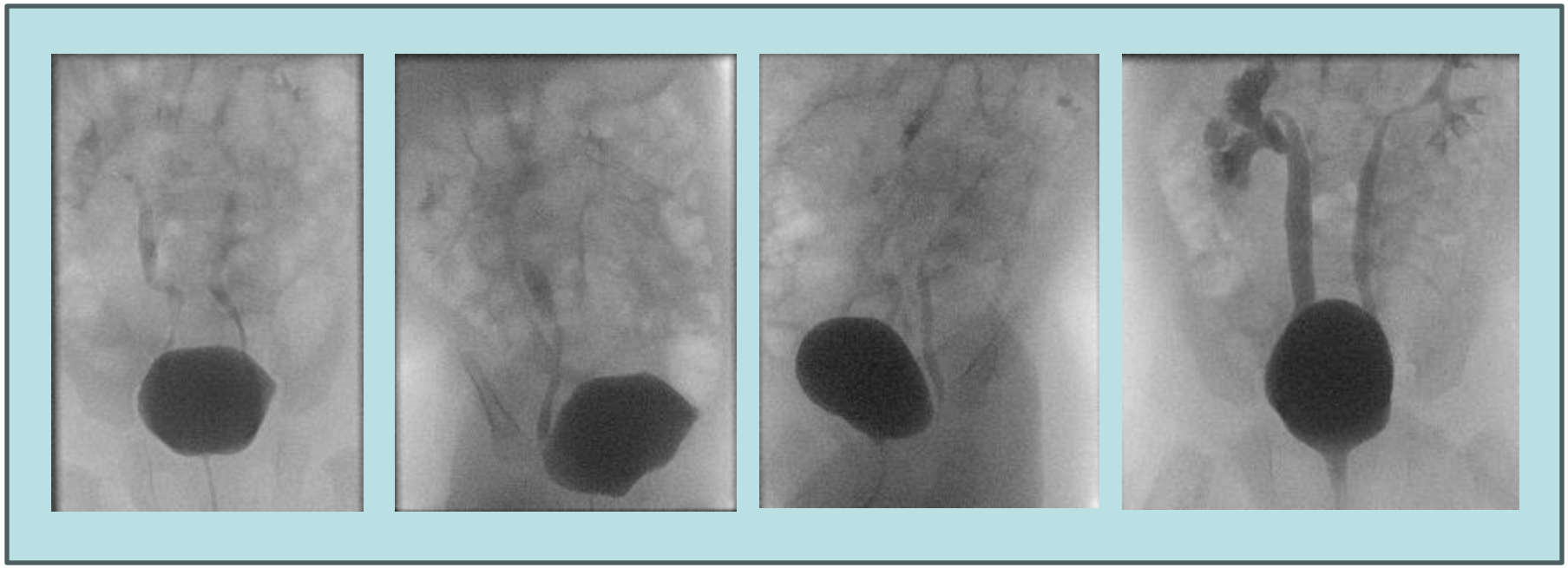
Voiding Cystourethrogram (VCUG)

- Indications
  - Febrile UTI/Recurrent UTI
  - Abnormal Renal Ultrasound (especially Hydronephrosis)
  - F/u of known Vesicoureteral reflux
  - Voiding dysfunction/Enuresis
  - Suspicion for Posterior Urethral Valves
- Contraindications
  - Active infection (fever within the last 24 hours)
  - Sedation that would impede normal voiding

Voiding Cystourethrogram (VCUG)

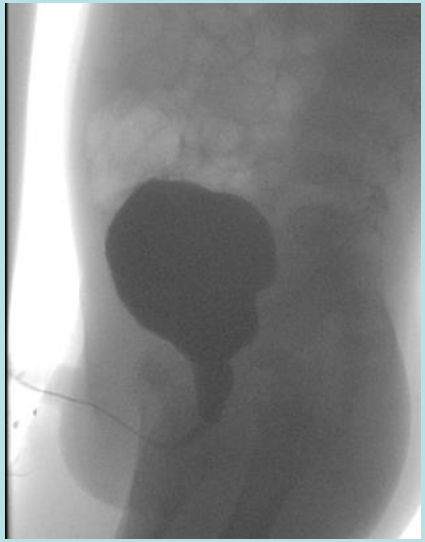
- Patient preparation
  - Patient will be catheterized.
  - Child life specialist very helpful.
  - In select patients, catheter can be placed under sedation (typically Nitrous Oxide)
- Technique
  - Water soluble contrast (Cystografin®) is administered by gravity into the bladder under pulsed fluouroscopy at 3 fps while observing for reflux and other pathophysiology. Filling continues until spontaneous voiding occurs.
  - Spot imaging performed over region of kidneys
  - Cyclic voiding study in patients < 1 year of age.

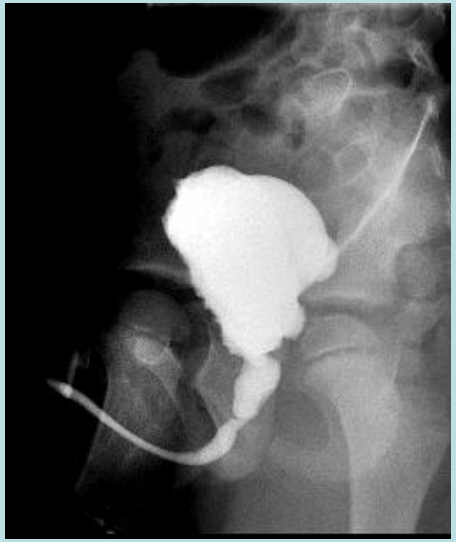
Voiding Cystourethrogram (VCUG)



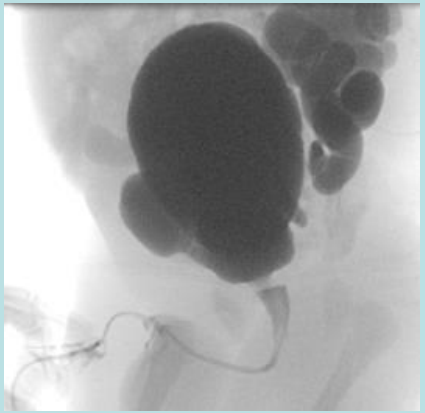
Vesicoureteral Reflux

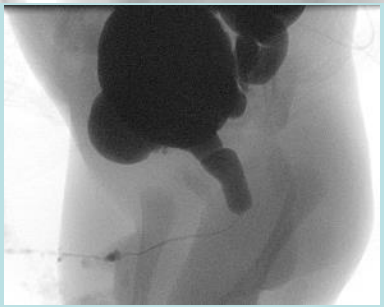
Voiding Cystourethrogram (VCUG)

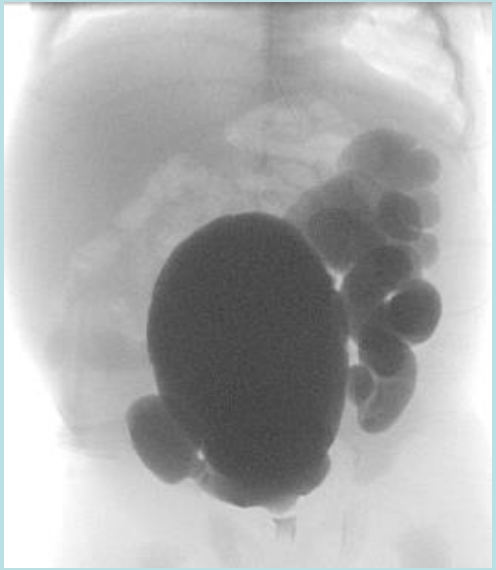




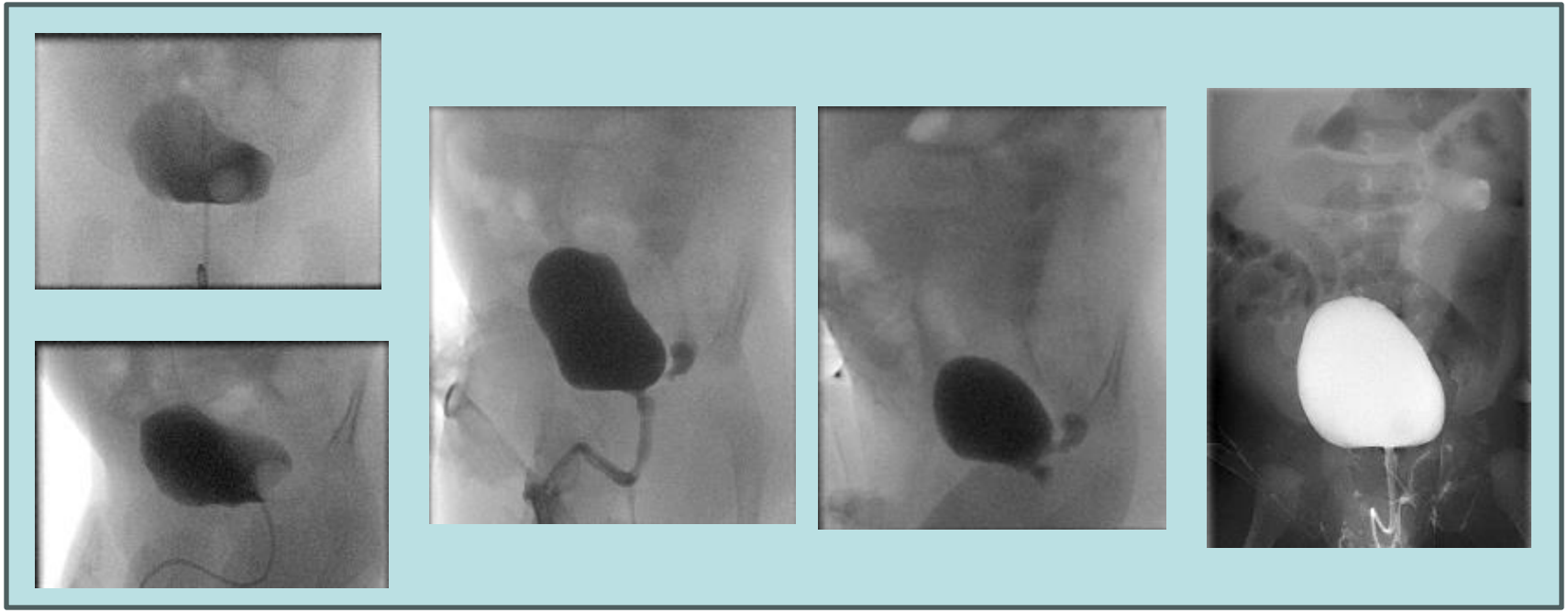
Posterior Urethral Valves







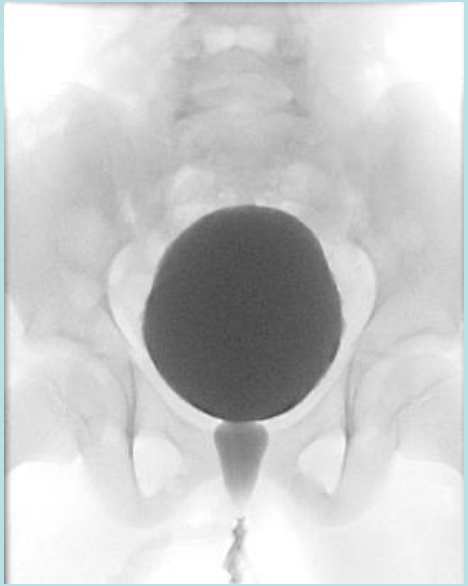
Voiding Cystourethrogram (VCUG)



Left ureterocele and left grade 4 vesicoureteral reflux

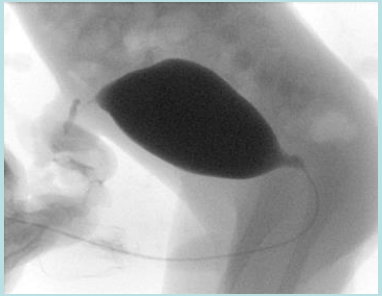
Voiding Cystourethrogram (VCUG)

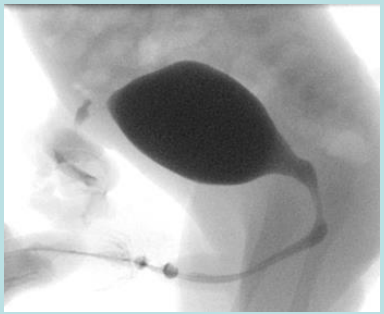
"Spinning top urethra"



Dysfunctional voiding

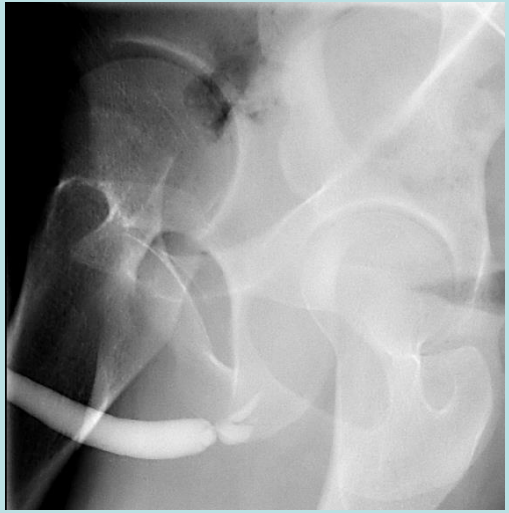
3 day old with umbilical defect





Patent urachus

17 y.o. with weak urine stream, unable to cath for VCUG



Retrograde Urethrogram (RUG) showing urethral stricture

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Considerations for Fluoroscopy

- Sedation is often not an option
  - Increased risks to patient
  - Nondiagnostic exams
- Why does the patient need to be NPO?
  - Increases patient participation in pediatric population
  - Recent food and/or liquid in the stomach may lead to non-diagnostic or poorer quality images for UGI

Considerations for Fluoroscopy

- Exam order matters!
  - Contrast from prior exams can make interpretation of other studies difficult or impossible
  - UGI prior to swallow study
  - UGI prior to Contrast Enema
  - Ultrasound exams prior to Fluoro exams

What is Interventional Radiology?

- The use of various imaging modalities to guide minimally invasive interventions/procedures
- Originated in the 1950s and 1960s with the development of catheterization techniques for cardiovascular angiography
- Specialty has evolved with the development of diagnostic radiologic techniques, especially cross-sectional imaging, and development of materials/devices used for intervention.
- Pediatric IR has grown in parallel with adult IR, but development of devices and procedures are often first targeted to adult populations.

Imaging Modalities in IR

- Fluoroscopy
- Ultrasound
- CT
- Cone-beam CT
- MRI

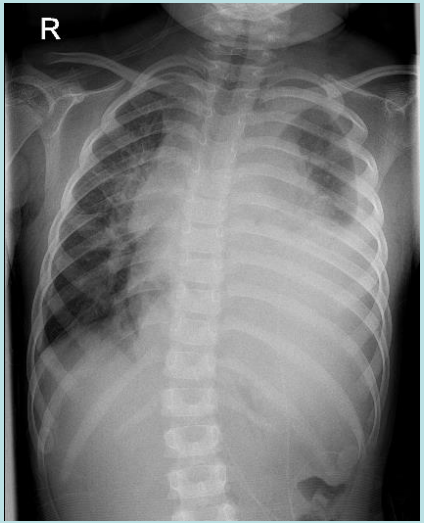
Equipment and Devices

- Generally:
  - Catheters
  - Guidewires
  - Needles
- Specialized devices and equipment required for complex cases

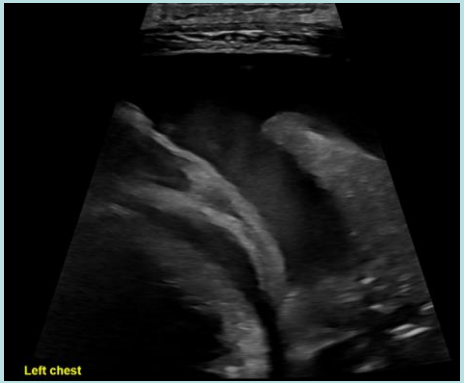
Contrast and Medications

- Water soluble iodinated contrast typically used
- Local Anesthetics
- Embolic Agents
- Thrombolytics
- Sclerosing Agents

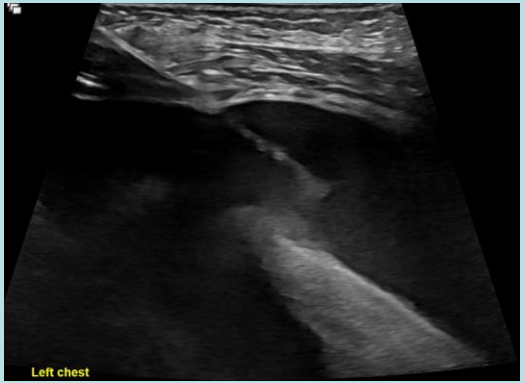
Example IR Procedure: Chest Tube Placement



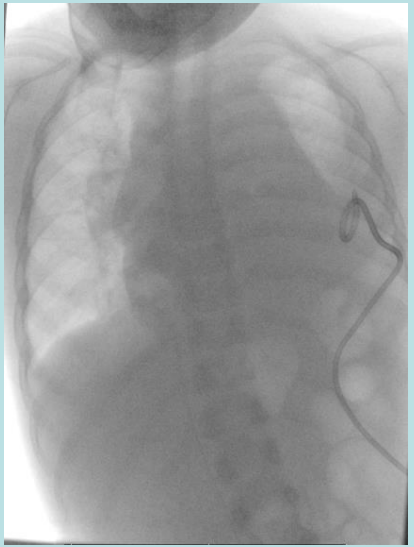
CXR with left pleural effusion



US chest showing pleural effusion



US chest with needle in effusion



Fluoro image with pigtail catheter

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The Interventional Radiology Suite

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Common Pediatric IR Procedures

- Fluoroscopic-guided placement of GJ tubes
- Joint injections/aspirations
- Fluid collection drainage/aspiration
- Biopsies
- Lumbar Puncture
- Thrombolysis/Thrombectomy
- Angiography +/- therapy
- Sclerotherapy
- Central Venous Access

Pediatric IR Procedures

- …and much more!
- Very wide breadth of procedures possible
- If you have a question of if something is possible or if/how IR can help, place a consult order.

How to Consult IR at Akron Children's

- Inpatient
  - Place IR consult order and include indication for the consult
  - Contact the IR provider on shift or on call.
    - APP first contact during regular business hours
  - For routine requests, Epic Secure Chat
  - For more complex cases or questions, a face to face or telephone discussion is ideal.
    - Interventional radiologist is happy to review imaging with consulting providers and discuss recommendations.

How to Consult IR at Akron Children's

- Outpatient
  - Place IR outpatient referral and/or IR procedure order
    - Including best way to reach consulting provider with any questions is preferred.
  - Referral is reviewed by Interventional Radiologist
  - Routine procedures may be scheduled from referral.
  - If questions remain about feasibility of procedure, or for complex cases, patient may first be seen in IR clinic.
  - Discussion or questions for referring provider via phone, Epic, or in person.

What to Expect from IR Consultation/Referral

- In depth review of patient's prior imaging
- Clinical evaluation of the patient by IR physician or APP
- Potential treatment options with risks and benefits
- Recommendations on need for anesthesia or sedation for procedure
- Follow-up post-procedural care

Questions?

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- Tracey Mehlman, MD, Pediatric Radiologist, Director of Fluoroscopy: tmehlman@akronchildrens.org
- Nathan Fagan, MD, Pediatric Interventional Radiologist: nfagan2@akronchildrens.org

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