EUROPEAN SOCIETY OF RADIOLOGY

eBook for Undergraduate Education in Radiology

CHAPTER: Paediatric Imaging

Preface

Undergraduate teaching of radiology in Europe is provided according to national schemes and may vary considerably from one academic institution to another. Sometimes, the field of radiology is considered as a "cross-cutting discipline" or taught within the context of other clinical disciplines, e.g., internal medicine or surgery.

This e-book has been created in order to serve medical students and academic teachers throughout Europe to understand and teach radiology as a whole coherent discipline, respectively. Its contents are based on the *Undergraduate Level of the ESR European Training Curriculum for Radiology* and summarize the so-called ***core elements*** that may be considered as the basics that every medical student should be familiar with. Although specific radiologic diagnostic skills for image interpretation cannot be acquired by all students and rather belong to the learning objectives of the *Postgraduate Levels of the ESR Training Curricula*, the present e-book also contains some ***further insights*** related to modern imaging in the form of examples of key pathologies, as seen by the different imaging modalities. These are intended to give the interested undergraduate student an understanding of modern radiology, reflecting its multidisciplinary character as an organ-based specialty.

We would like to extend our special thanks to the authors and members of the ESR Education Committee who have contributed to this eBook, to Carlo Catalano, Andrea Laghi and András Palkó who initiated this project, and to the ESR Office, in particular Bettina Leimberger and Danijel Lepir, for all their support in realising this project.

We hope that this e-book may fulfil its purpose as a useful tool for undergraduate academic radiology teaching.

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ESR Education Committee Chair

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Chapter Outline

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eBook for Undergraduate Education in Radiology

Based on the ESR Curriculum for Undergraduate Radiological Education

Chapter: **Paediatric Imaging**

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Chapter Outline

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Chapter Outline

Paediatric Radiology

Paediatric Radiology is the **art** and the **science** of working with children, imaging children, choosing the most appropriate imaging modality to answer clinical questions depending on the situation, interpreting imaging findings related to growth, congenital or acquired abnormalities and finally, treating children using imaging-guided techniques.

Paediatric Radiologists are specialists who interpret such imaging, discuss with clinical colleagues and recommend the next steps in the child's care.

Paediatric Radiology is a **challenging**, and **exciting** radiological **subspecialty**, due to the wide range of imaging techniques, the different developmental stages of children from foetal life to adolescence, and the diversity and uniqueness of diseases that are encountered at this stage of life.

Paediatric Radiology can be extremely **rewarding** given the significant and appropriate solutions to daily medical inquiries which can be provided efficiently for vulnerable children and their families.

Chapter Outline

Definitions

FOETUS

- A foetus (related to the Latin 'offspring' or 'bring forth', and the Greek 'to plant') refers to the developing young in the uterus, specifically the unborn offspring in the postembryonic period from the third month (11th week) after fertilisation until birth
- The 'full term' gestational period in humans ranges from 37 to 42 weeks

NEONATE

- A neonate (literally from the Latin, 'new-born') is a newly born human in their first 28 days of life
- A term neonate is one who is born at over 37 weeks of gestation; a premature neonate is one who is born before 37 weeks of gestation; a post-dates or post-term neonate is one who is born after 42 weeks of gestation

INFANT

- An infant (from the Latin infans, meaning 'unable to speak' or 'speechless') generally refers to a young child from the age of 1 to 12 months
- Baby, a more informal term meaning very young offspring, may be used by parents/caregivers

TODDLER

- The term toddler is used for those who are walking unsteadily or 'toddling' from the age of 12 to 36 months, including those who are newly ambulant to those with more developed gross motor skills

CHILD

- Childhood is the period of life from the developmental stage of infancy to puberty
- After toddler, the terms young and older child can be used; a 'school-aged child' is usually one from the age of 5 years onwards
- Legally, child refers to an individual who has not reached the 'age of majority'

ADOLESCENT

- A young person who has undergone puberty but who has not yet reached full 'adult' maturity (from the Latin, adolescere, meaning 'to grow up')

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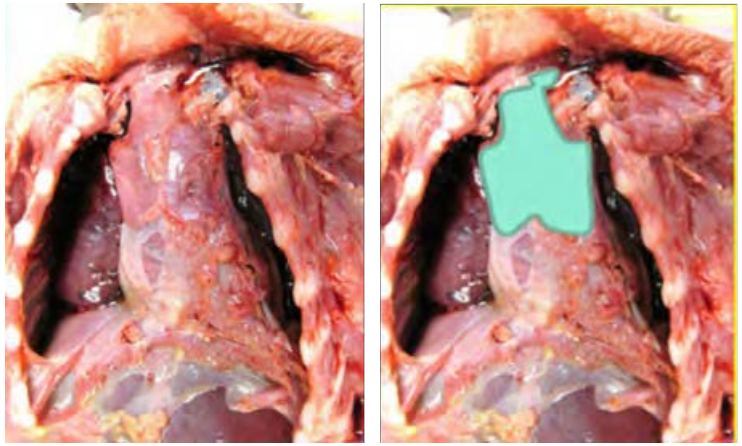
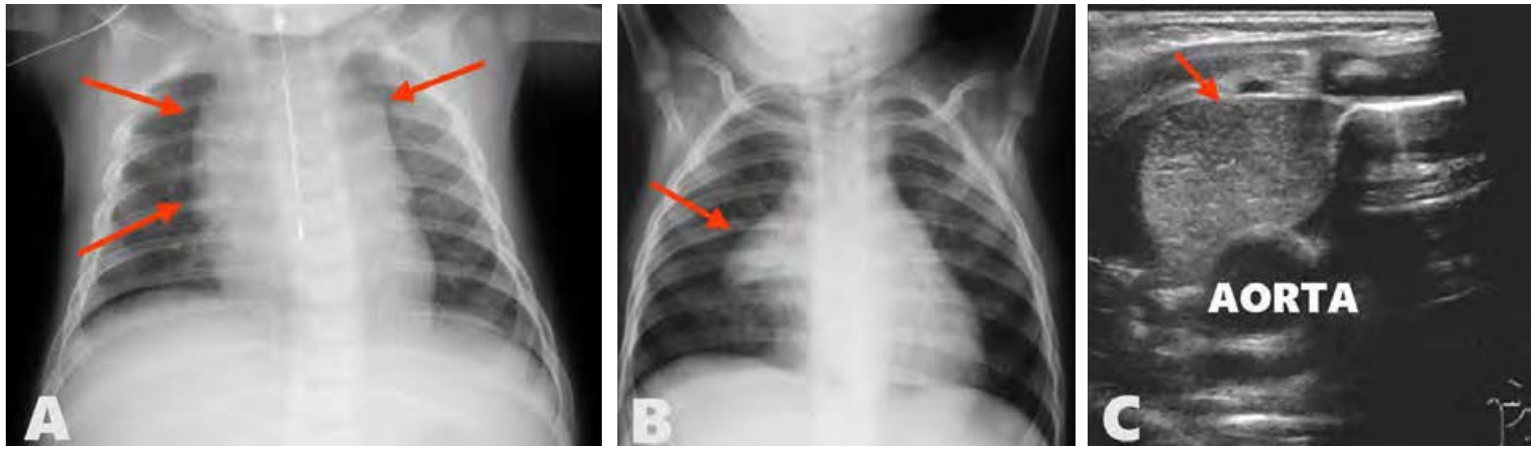
Differences between Children and Adults
Normal Paediatric Anatomy – Chest Radiographs



The thymus gland can be seen in the anterior mediastinum (overlaid in green on the right-sided image). Image courtesy of A. Patterson, MD, Royal Belfast Hospital for Sick Children, UK

The **thymus gland** is prominent in **infants**. It has variable size and shape, sharp contour, and causes anterior mediastinal widening. It is soft and its contour is indented by the ribs and often has a 'wavy' appearance (arrows in A). It may extend to the minor fissure exhibiting the "sail" sign (arrow in B), overlie the heart, and can mimic a mediastinal mass or cardiomegaly. It never displaces or compresses adjacent structures. If in doubt, ultrasound can demonstrate the "starry sky" pattern of the thymus (arrow in image C).

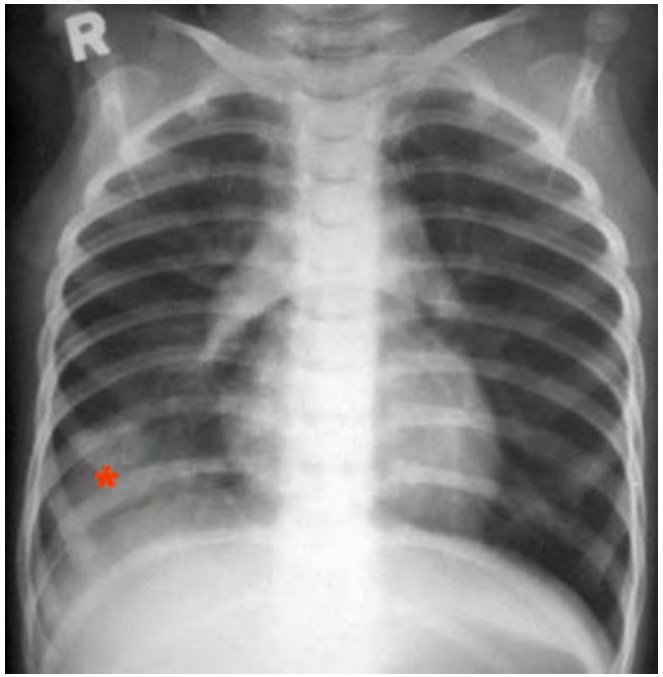
The **transverse diameter of the heart** is young infants may measure up to 60% of the transverse thoracic diameter, compared to 50% in older children and adults. Note too, how **the ribs** on these conventional radiographs lie more horizontally compared to those of older children. Given that the transverse diameter of the barrel-shaped paediatric chest is wider than the anteroposterior diameter, and abnormalities are mostly seen on AP radiographers, lateral chest radiographs are rarely performed in children.in green)



Chapter Outline

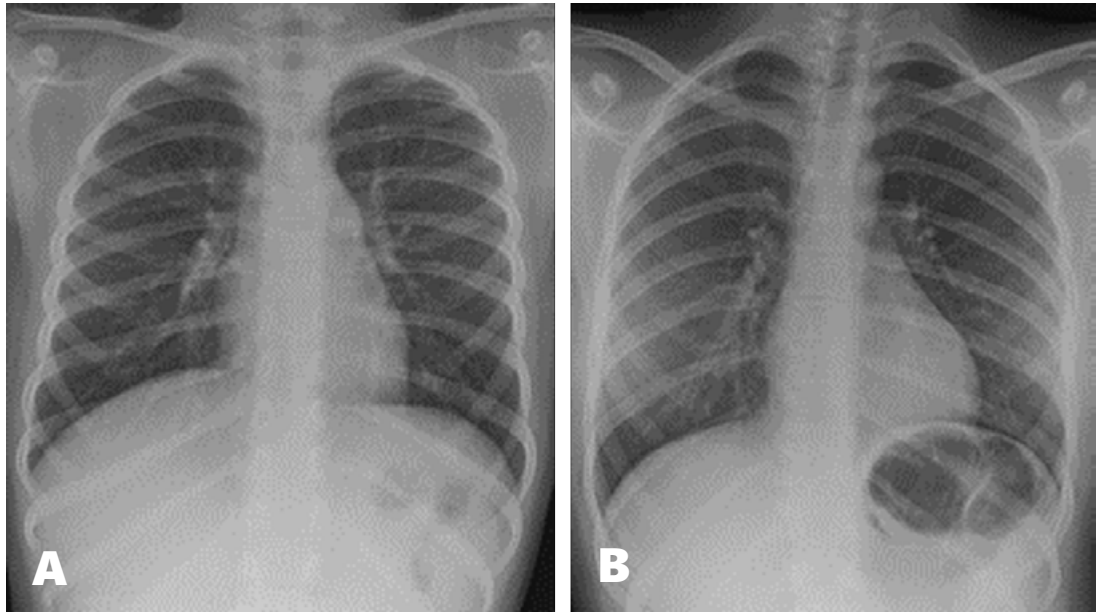
Differences between Children and Adults

Normal Paediatric Anatomy – Chest Radiographs



Pneumomediastinum following blunt chest trauma. The two lobes of the thymus are elevated and outlined by air (and thus easy to visualise) - this is known as the 'Angel Wing' sign. Also note the opacity at right lung base (*) which in this context is consistent with lung contusion.

The thymus grows throughout childhood reaching maximal volume in adolescence. It then involutes during adulthood. The gland regresses in unwell neonates and it may not be visible on chest radiographs.



6-year-old (A) and 13-year-old (B). The thymus is present but proportionately smaller when compared to younger children and consequently is no longer visible. Note the developing breast shadows in the adolescent patient (densities over lower chest)

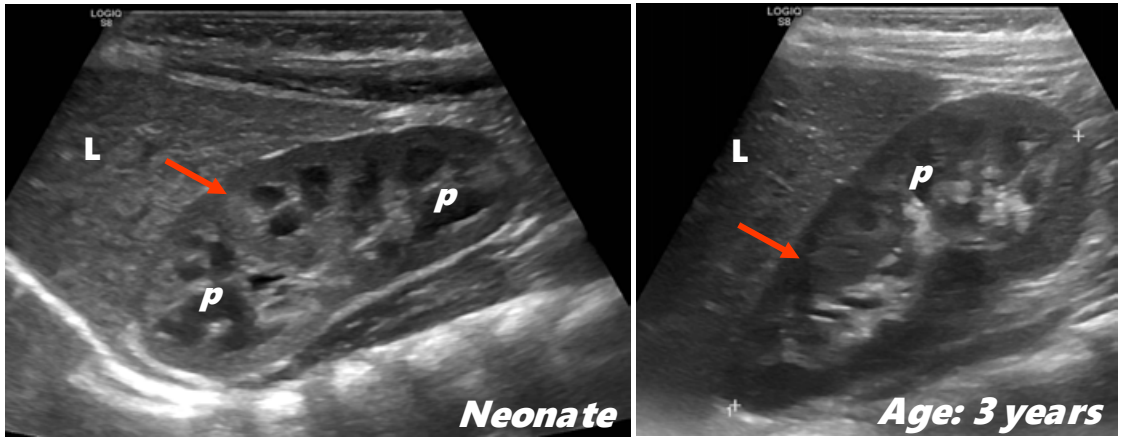
Chapter Outline

Differences between Children and Adults

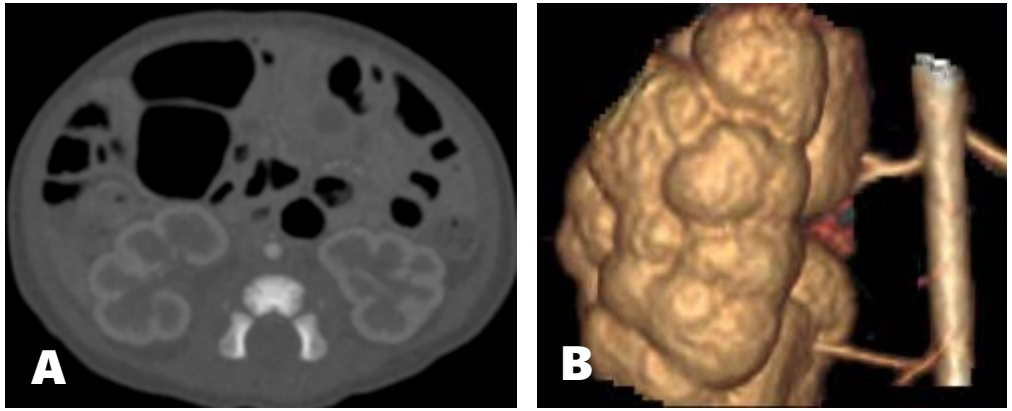
Normal Paediatric Anatomy – Kidneys

Ultrasonography in children can be extremely rewarding and may reveal details in anatomy due to the smaller patient size and lack of fat.

In neonatal kidneys, the cortex may appear equally echogenic ("bright") compared to the liver, making pyramids prominent and less echoic (black): these should not be mistaken for cysts or dilatation. Persistent fetal lobulation is normal in neonates.



Compare the appearances of a neonatal and paediatric kidney to the liver (L). The renal cortex (arrows) is more echogenic in the neonatal kidney and pyramids (p) stand out.



Incidental foetal lobulation, here seen on axial CT (A) and 3D reconstruction from CT images (B) should not be mistaken for acquired scars.

Knowledge of normal values and morphological features during development is important to appreciate normality from pathology.

The Radiology Assistant : Normal Values in Pediatric Ultrasound

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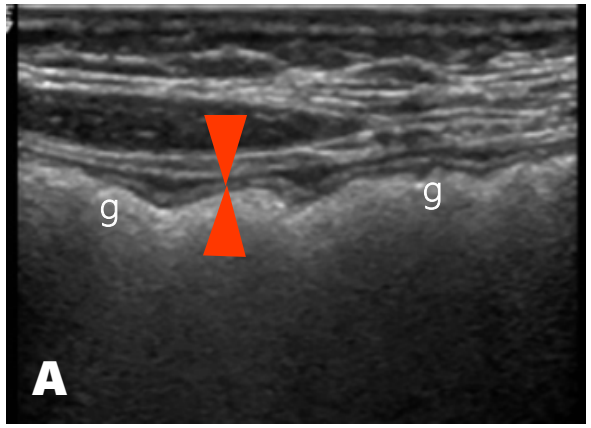
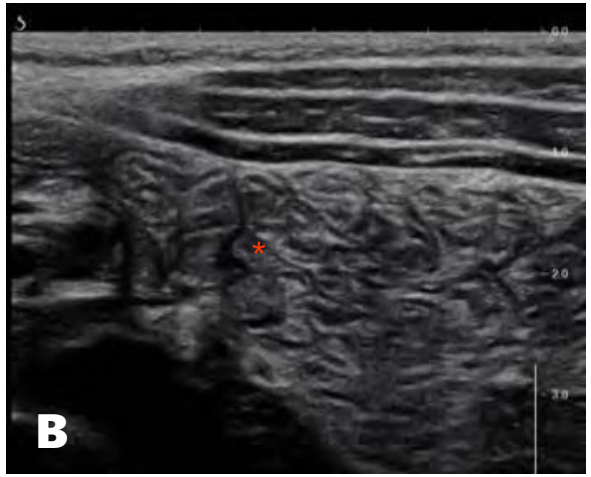
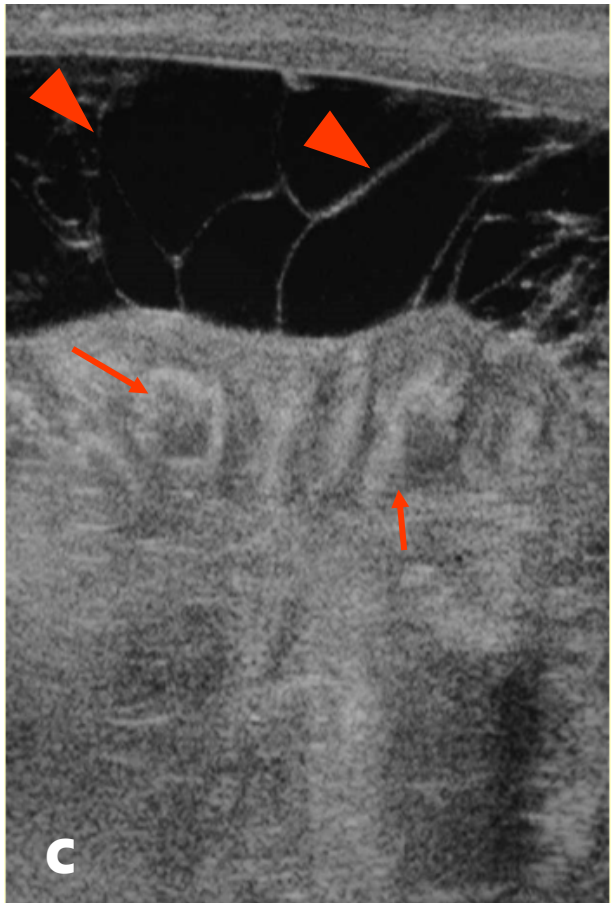
Differences between Children and Adults
Normal Paediatric Anatomy – Kidneys

At ultrasonography, the bowel wall is clearly visible with the 5-layered pattern called "the gut signature"







A. Normal colonic wall is visualised as alternating white and black lines (between arrowheads) forming curves. Intraluminal gas (g) casts an artefactual echogenicity with "dirty" shadowing. B. US appearances of normal collapsed small bowel loops (*) known as the mucus pattern. C. US image of a neonate with perforated necrotizing enterocolitis. Fluid with fibrin strands (arrowheads) should not be mistaken as bowel. Collapsed bowel exhibits the "gut signature" and echogenic mucosa (arrows)..

Chapter Outline

Differences between Children and Adults
Normal Paediatric Anatomy – Paediatric Brain

Brain imaging in children: indications

- Brain imaging in children depends on age and clinical indication:
  - In neonates, sonography (ultrasound) is mainly performed through the anterior fontanelle as the first imaging modality.
  - In older children and in emergency settings, CT is recommended ,mainly for traumatic brain injuries and when MRI is unavailable for the exclusion of space occupying lesions.
  - Due to radiation exposure with CT and the increased sensitivity of MRI, MRI is the test of choice to depict brain abnormalities in most circumstances, when available.

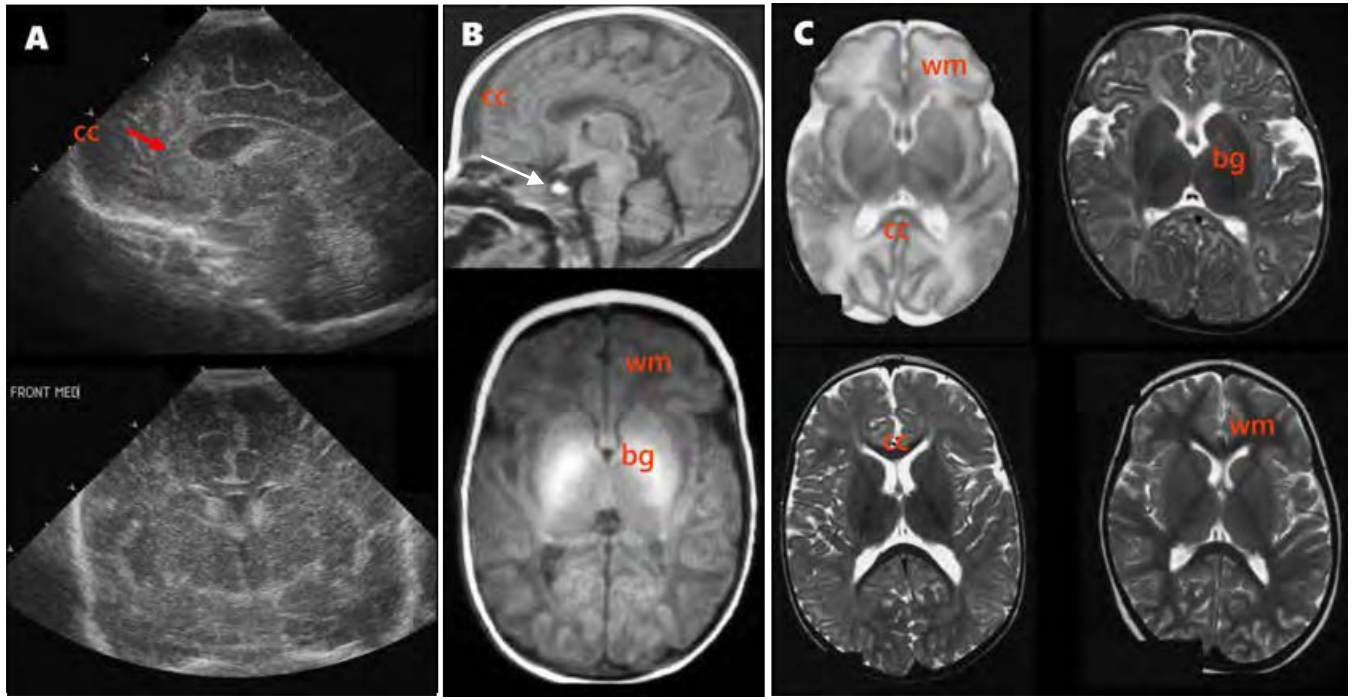
Brain imaging in children: anatomy

- During foetal and neonatal development, the evolution of migration, sulcation and myelination can be appreciated with MRI.
- In relation to myelin maturation, grey-white matter differentiation is progressively accentuated on CT in older children and on MRI appears inverted on T1-weighted (T1W) and T2-weighted (T2W) MRI sequences.

Chapter Outline

Differences between Children and Adults

Normal Paediatric Anatomy – Paediatric Brain



A. Cranial sonography, sagittal (top) and coronal (bottom) views. Corpus callosum (cc).
B. T1W sagittal image (top) in a neonate demonstrating a hyperintense anterior pituitary gland (arrow), which does not occur in older children and adults. Axial (bottom) view in a 3-month-old infant showing unmyelinated white matter (wm) and hyperintense basal ganglia (bg).
C. T2W axial images in a premature neonate: 5 months-old (top left), 10 months-old (top right) and 3 years-old (bottom) showing progression of myelination.

Compare the aspects of corpus callosum (cc) and white matter (wm), turning from hyperintense (unmyelinated) to hypointense (myelinated) on T2W images.

Also compare the relatively stable signal intensity of the grey matter within the cortex and basal ganglia (bg) with age, and the evolution of cortical folding from blunt in the premature brain, to complete in an older brain.

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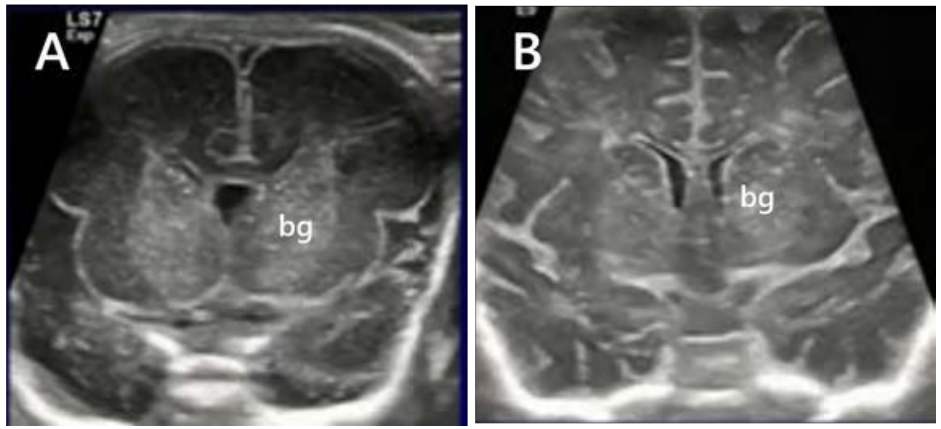
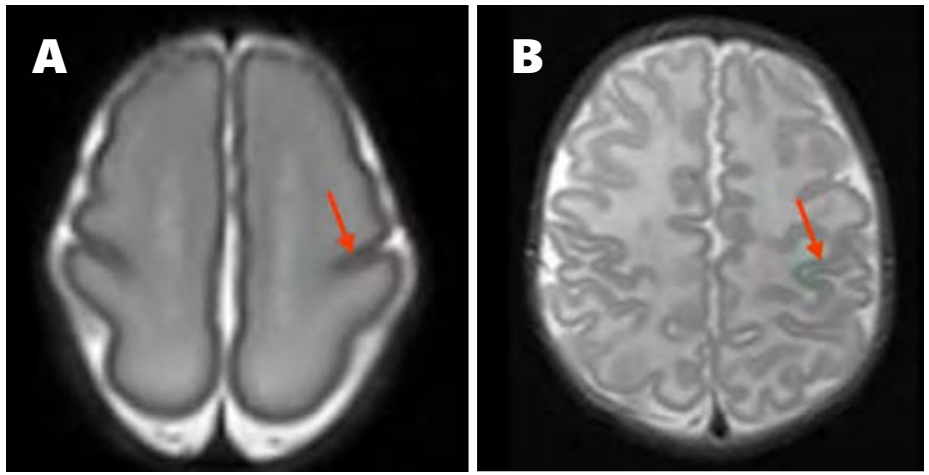
Differences between Children and Adults
Normal Paediatric Anatomy – Paediatric Brain

Evolution of sulcation: Sulci appear in a predictable fashion and can be appreciated on sonography and MRI. Awareness of normal appearances for age is important to enable differentiation from pathology/abnormality (examples below).



Normal cranial ultrasound examinations, coronal views. A 26-week gestational age premature neonate (A) and a 40-week gestational age term neonate (B). The simplified gyral pattern and the echogenic basal ganglia (bg) are normal only in A.



MRI, T2W sequences, axial views in two different neonates. In the 26-week gestational age neonatal (A), there is a normal simplified gyral pattern with a prominent central sulcus (arrow) and shallow remaining sulci. In the term 40-week neonate (B), the central sulcus (arrow) and all other sulci have now developed and a simplified gyral pattern would be considered abnormal.

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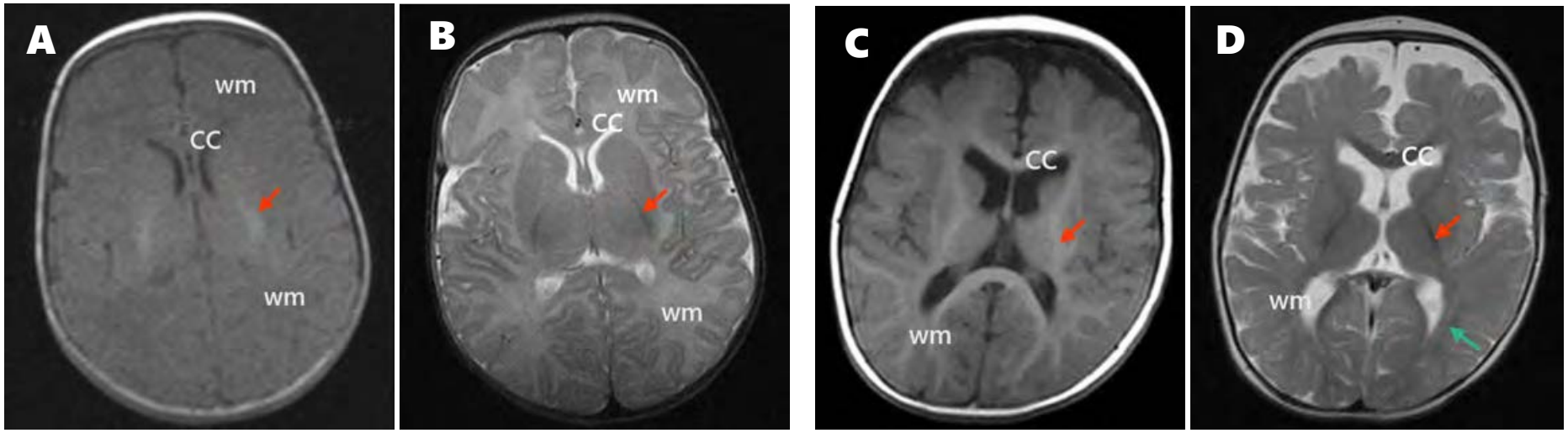
Differences between Children and Adults
Normal Paediatric Anatomy – Paediatric Brain

Evolution of myelination: Myelin is a lipid-rich glycoprotein that wraps around oligodendrocytes eliminating water (hydrophobic). Thus, it appears hyperintense on T1W (A, C) and hypointense on T2W (B, D) sequences.

Compare the myelinated white matter at the posterior limbs of the internal capsules (PLIC), corpus callosum (CC) and periventricular white matter (wm) on T1W and T2W sequences between the neonatal and the 11-month-old brain. Myelinated wm in the new-born is visible mostly in the PLIC (orange arrows). At age 11 months, it is seen around the ventricles and in the subcortical white matter, reaching the adult pattern on T1W sequence and exhibiting spared areas around the trigones (green arrow) on T2W sequence.



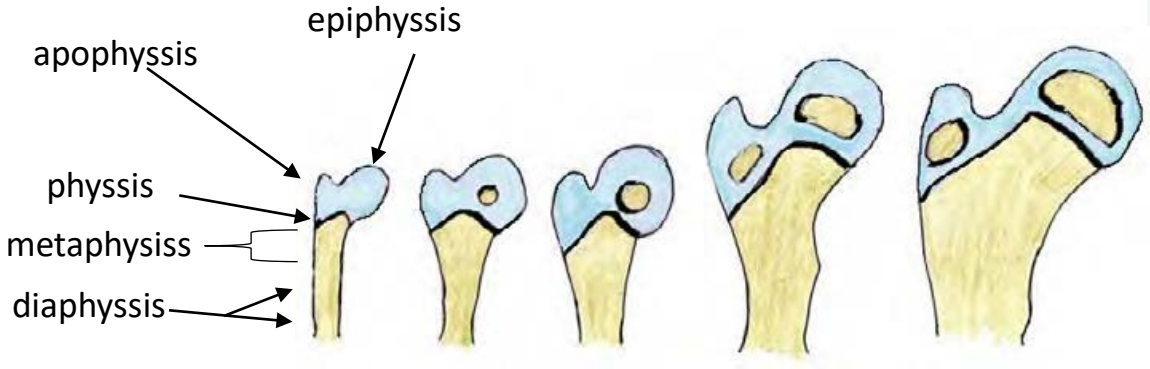
Term neonate (40 weeks gestational age)

Age 11 months

Chapter Outline

Differences between Children and Adults
Normal Paediatric Anatomy – Bones

- As children grow and develop, their bones undergo changes that are seen on imaging.
- An understanding of this helps us to understand what is normal and abnormal.
- Growth plates (called physes) at the ends of long bones start to 'fuse' with age (see hand radiographs on next slide).
- Cartilage around the joints is initially more than bone but reduces in volume (see also knee MRI on next slide).

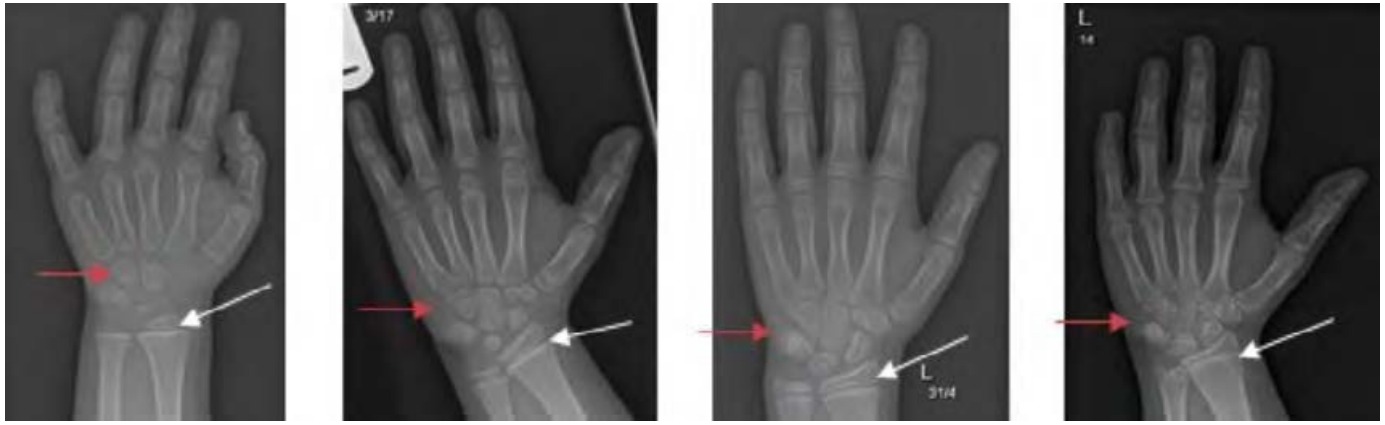


Epiphyses are completely cartilaginous at birth and become gradually ossified. Ossification centers at epiphyses gradually enlarge as children grow.

Ossification centers at apophyses, where a muscle or tendon attaches, are separated by cartilage from the remaining bone during childhood, which makes them prone to avulsion fractures

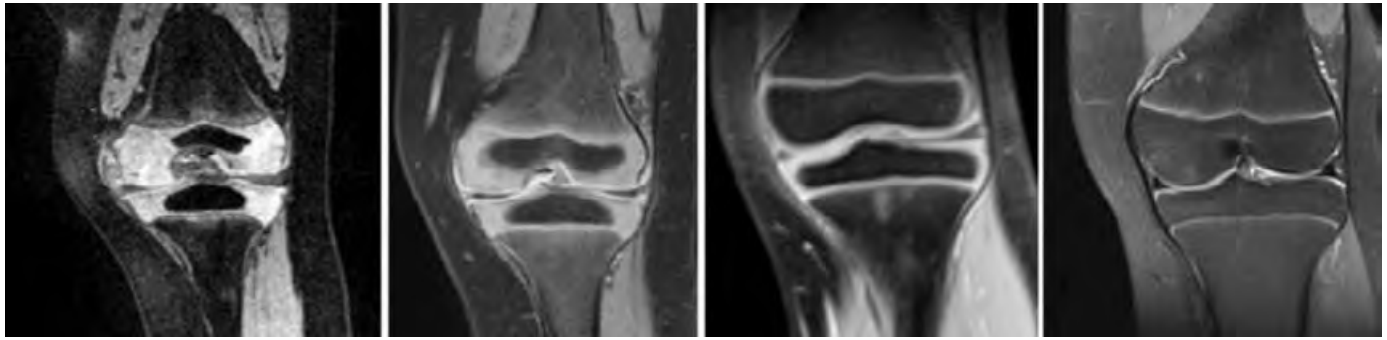
Chapter Outline

Differences between Children and Adults
Normal Paediatric Anatomy – Bones



3 years | 7 years | 10 years | 14 years

← In these hand radiographs in children of different ages, carpal bones (red arrows) are seen at different ages, and the growth plates at the wrist (white arrows) become narrower, until the metaphyses and epiphyses fuse with increasing age and eventually are not visible.



1 year | 2.5 years | 7 years | 13 years

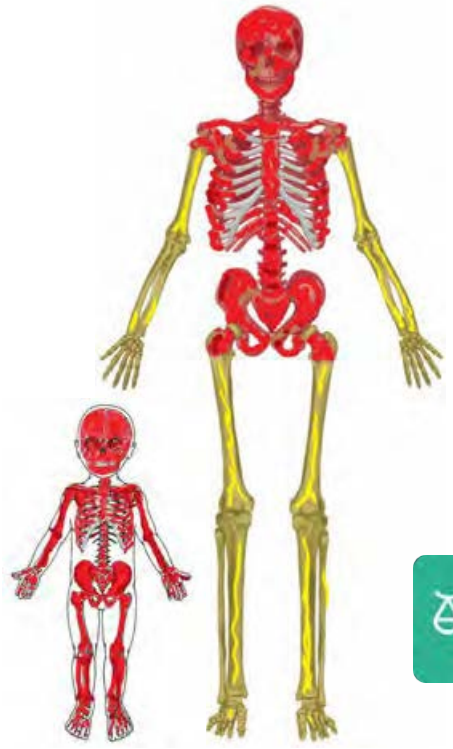
← In these knee MRIs of different children at different ages, you can see the 'white area' representing cartilage becoming less prominent with increasing age.

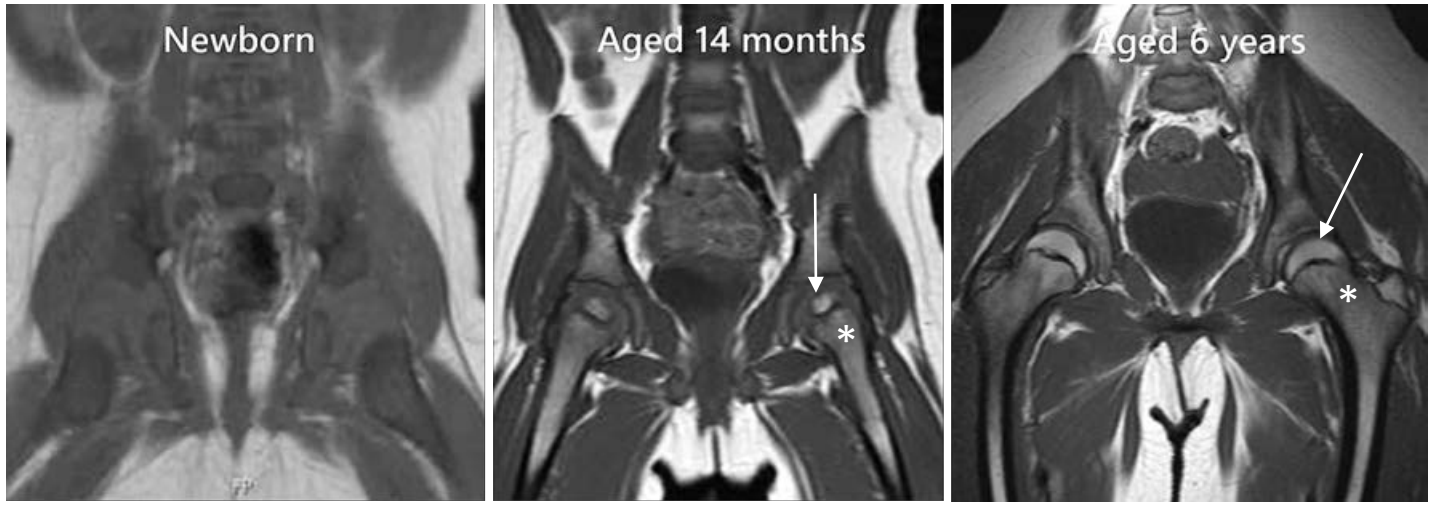
Chapter Outline

Differences between Children and Adults

Normal Paediatric Anatomy – Bone Marrow

- Children are born with red marrow. As they grow, their bone marrow undergoes transition from red (containing mostly haematopoietic cells) to yellow (containing mostly adipocytes), until only few flat bones remain with red marrow.
- These changes occur in a predictable pattern in long bones from peripheral to central, from diaphysis to metaphysis and from central to endosteal, symmetrically on both sides.
- Red marrow distribution can be appreciated on MRI. On T1W sequences, fatty marrow is hyperintense and red marrow is relatively hypointense but never more hypointense compared to muscle in children older than 2 years





Compare the bone marrow appearance of the pelvis and proximal femur on T1W sequences. In the new-born, the red marrow is extremely cellular and more hypointense than muscle. In older children, the red marrow predominates at the proximal femoral metaphyses (*) and exhibits higher signal intensity compared to cartilaginous discs and to muscle, due to progressive loss of cellularity. Epiphyses are fatty and hyperintense (arrows).

Chapter Outline

Differences between Children and Adults
Effects of Ionising Radiation

Stochastic (or probabilistic) effects

- Where the severity of the result is the same, but the *probability* of occurrence increases with radiation dose, e.g., development of cancer.
- **There is no threshold** for stochastic effects (all or nothing effect of ionizing radiation - **any** amount **may** cause an effect and is cumulative).
- Example: cancer.
- There is a small risk for stochastic effects following diagnostic procedures that involve radiation exposure making radiation protection measures mandatory.
- This risk is not individual but applies to a population.

Deterministic effects

- Where the severity depends upon the radiation dose, e.g., skin burns.
- The higher the dose, the greater the effect.
- **There is a threshold** for deterministic (i.e., can be determined) effects which varies by individual.
- Examples: skin burns, cataract, infertility following irradiation of gonads.
- There is no risk for deterministic effects following diagnostic procedures that involve radiation exposure provided that radiation protection measures have been applied.

"Stochastic" comes from the Greek word "στόχος" which means aim or target

Paediatric Radiology		
Risk of	**Staff**	**Patient**
Death	x	x
Skin burn	x	x
Infertility	x	x
Cataract	x	x
Cancer	small	small
Genetic effect	very small	very small

The effects of ionizing radiation are not a child-only issue. They apply to both children and adults; they are emphasized in this section due to the relatively increased radiosensitivity of children.

Chapter Outline

Differences between Children and Adults

Radiosensitivity of Children

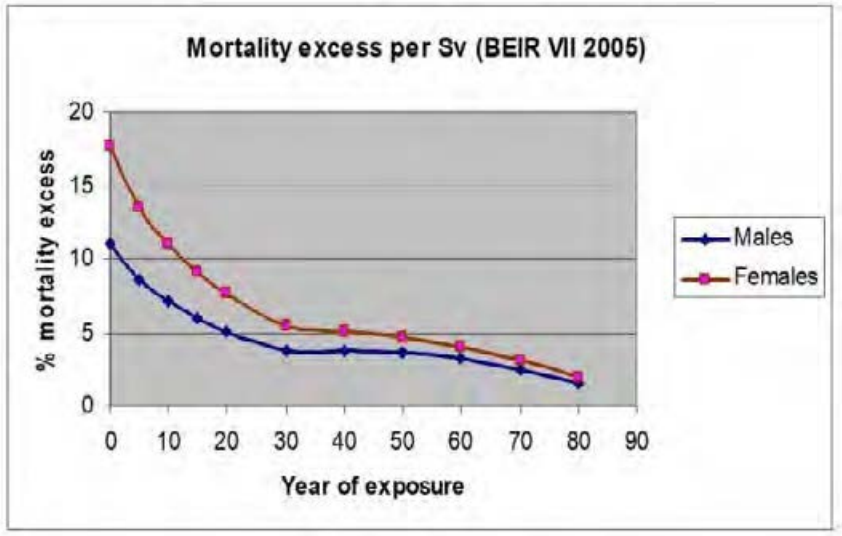
Children are more radiosensitive than a middle-aged adult by a factor of 2-5 to 10 due to:

- Increased mitotic activity (more vulnerable tissue).
- Longer life expectancy (enough time to develop cancer).
- Radiation is cumulative (increased possibility of repeated tests).

Girls are considered more radiosensitive than boys.

Radiosensitivity is greater in younger children:

- Neonates are more radiosensitive than infants.
- Infants are more radiosensitive than children.
- Children are more radiosensitive than adolescents.



- Children are 2-3 times more susceptible to radiation in the development of leukaemia.
- Adults exposed to radiation during childhood have an increased probability of developing breast, thyroid and brain cancer, with a clear dose-response relationship for the development of both leukaemia and brain tumours: the risk increases with increasing cumulative radiation dose.
- Consequently, the overall benefit to an individual from the diagnostic capabilities of an indicated test should be much greater than the potential risk from the associated ionising radiation - the smallest radiation dose for size should be meticulously applied in children (see ALARA in later slides).

Pierce DA, Preston DL. Radiation-related cancer risks at low doses among atomic bomb survivors. Radiat Res. 2000;154:178-186

Raissaki MT. Pediatric radiation protection. European Radiology Supplements March 2004 DOI: 10.1007/s10406-004-0011-7

Pearce MS, Salotti JA, Little MP, et al. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. The Lancet 2012

Chapter Outline

Differences between Children and Adults

Paediatric-friendly Environment

Very young children or those with developmental delay may have difficulty understanding what is going to happen during a scan and they can be scared by large machinery. This means that they may struggle to sit still for their scan, leading to non-diagnostic image quality.

Distraction tactics (e.g., cartoons, songs, pictures on the wall), bribery tactics (e.g., with candies, stickers, certificates) can be helpful. In some hospitals a '**play therapist**' may be employed to help calm and settle patients. Sedation and anesthesia do carry some small associated risks (e.g., drug allergy) and are performed only when necessary.

Demonstrating how an image will be taken using dolls and pictures helps children to understand what is going to be done in a less intimidating manner.

Having colorful lights (arrows), cartoons on the wall, or on the side of the scanning machines help to create a calm and inviting environment.

Images kindly provided by :S. Shelmerdine, GOSH Children's Hospital, London, and J. Jürgens, Pediatric UKE, Hamburg, DE

A ceiling- mounted television (arrow) (or iPad/ Phone) with cartoons and toys in the department help distract nervous patients.

Chapter Outline

Differences between Children and Adults
Communication Skills and Attitudes

- Each child is not a single patient. Children come with parents/carers and a referring physician who may all be stressed about the urgency for imaging, the procedure, and the results of imaging tests. Consequently, communication skills are paramount.
- Discussion of tests before and after imaging **between the referring physician and the radiologist** results in mutual decisions on whether to image, on the best imaging modality, and is vital for appropriately tailoring the examination to each individual patient. The choice of imaging test may also be influenced by the patient's ability to cooperate. After an examination, prompt feedback from the radiologist on unexpected or urgent findings ensures proper and **safe** care.
- The **parent or carers'** understanding, cooperation and consent, are vital for success. Parent and children's anxieties should be alleviated, and family should remain as relaxed, comfortable and reassured as possible, through proper information and a confident attitude by the radiologists and technicians (also known as radiographers/sonographers).
- Communication with **the child** is modified depending on the child's age and abilities. Compromises are required. Protocols are tailored to deliver the relevant information using the shortest possible time and the lowest possible radiation dose. The most exciting part of the daily routine is turning a frightened child into a co-operative smiling patient.
- **The delivery of results** to patients and families by radiologists is a delicate matter and requires collaboration with referring physicians, a clear understanding of the results and their significance, appreciation of what the family already know of their child's condition, appreciation of the environment and support available to the child and family, appreciation of confidentiality issues in older children and adolescents, empathy and sensitivity.
- The paediatric radiologist carries an important and often pivotal role in **multidisciplinary meetings** where results are delivered, limitations and certainties are highlighted, and therapeutic decisions can be made based on imaging findings.

"The paediatric radiologist has an intensely varied and stimulating role. Each day is different to the last and we are continually tested and stretched in terms of scientific knowledge, communication skills and time management. Energy, pragmatism, humility, empathy and a sense of humour are vital characteristics for this job, but if you have these and enjoy a challenge, the rewards are immense."
Kath Halliday, Consultant Paediatric Radiologist, Nottingham, UK

Katharine Kalliday, What does a paediatric radiologist do? P 8-11, IDoR2015 Paediatric Imaging Book FINAL | PDF | Medical Imaging | Radiology (scribd.com)

Chapter Outline

Indications, Strengths and Weaknesses of Imaging Techniques

Conventional Radiographs (CXR)

Indications:

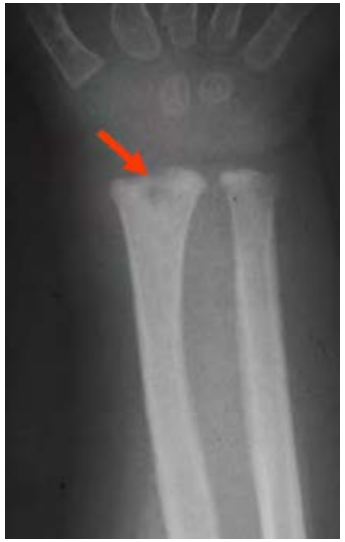
- Initial examination of chest, abdomen and bones.
- Particularly important in skeletal trauma (accidental and inflicted injury), infection, dysplasia
- A mainstay of paediatric practice.

Advantages:

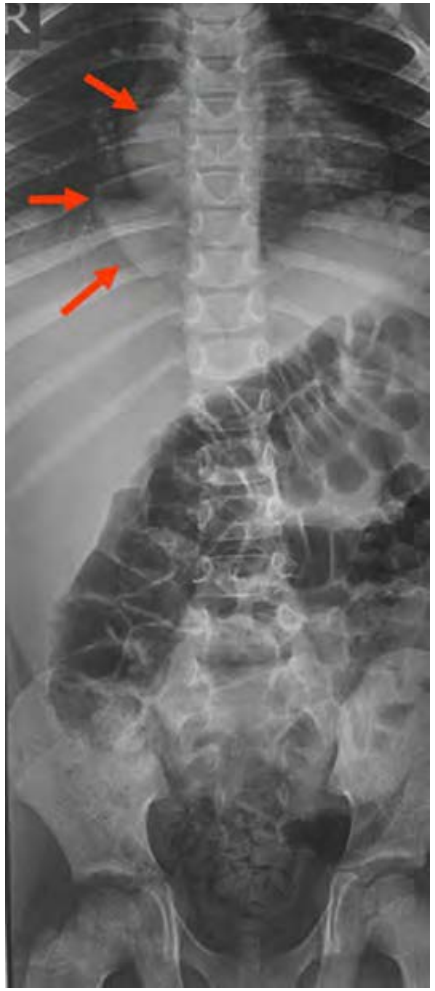
- Widely available, inexpensive.
- Often the 'starter' (first line modality) for other tests.

Disadvantages:

- Limited demonstration of soft tissue.
- Less detail than CT.
- Exposes the patient to ionising radiation



▲ Radiograph of the hand in a child with fever, local pain and tenderness. There is a lytic focus (arrow) at the metaphysis, a typical location of hematogenous spread of infection in children.



AP radiograph of the spine in a child with low back pain obtained to look for spondylolysis. A posterior mediastinal mass (arrows) was identified. Subsequent MRI confirmed metastatic neuroblastoma. ▶

Chapter Outline

Indications, Strengths and Weaknesses of Imaging Techniques

Ultrasonography (US)

Indications:

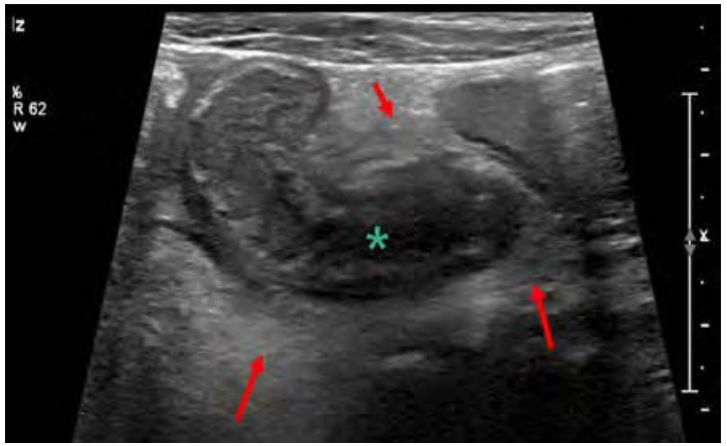
- Foetal pathology
- Neonatal brain and spinal cord
- Palpable lumps including neck lesions
- Suspected abnormalities of lungs
- Suspected abdominal anomalies including pelvis and bowel
- Musculoskeletal system abnormalities including neonatal hips
- Vascular anomalies – Doppler applications
- Guidance for interventional procedures

Advantages:

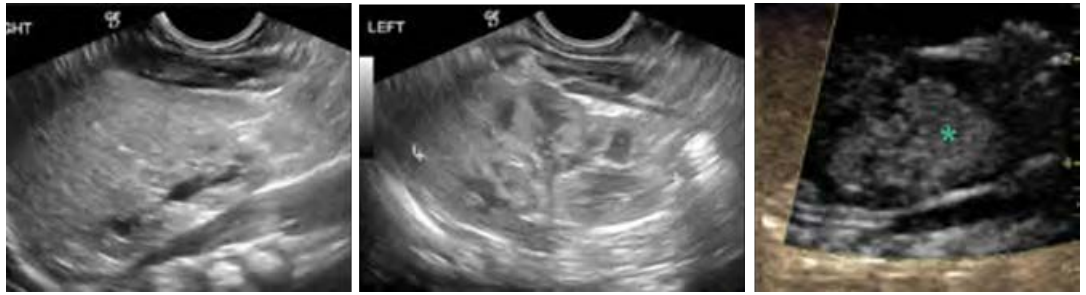
- Efficient and the test of choice for many indications.
- Readily available, inexpensive.
- Can deliver exquisite detail in children.
- Can appreciate movement e.g., bowel peristalsis
- Portable.
- No ionising radiation.
- Potential of advanced applications (power doppler, elastography, contrast-enhanced US & voiding US.

Disadvantages:

- Can be challenging in non-cooperative children.
- Deep structures may be obscured by bowel gas.
- Less easy to standardise, requires training, skill and experience.



Appendicitis – swollen non-compressible appendix with a dilated lumen (*) surrounded by oedematous echogenic fat (arrows). ▶



▲ Reflux nephropathy. The right kidney is smaller compared to the left with loss of corticomedullary differentiation. Contrast-enhanced voiding ultrasonography (VUS, third image) following instillation of echogenic microbubbles into the bladder via a nasogastric tube shows an echogenic dilated pelvis (*) indicating gross reflux.

Chapter Outline

Indications, Strengths and Weaknesses of Imaging Techniques

Fluoroscopy

Indications:

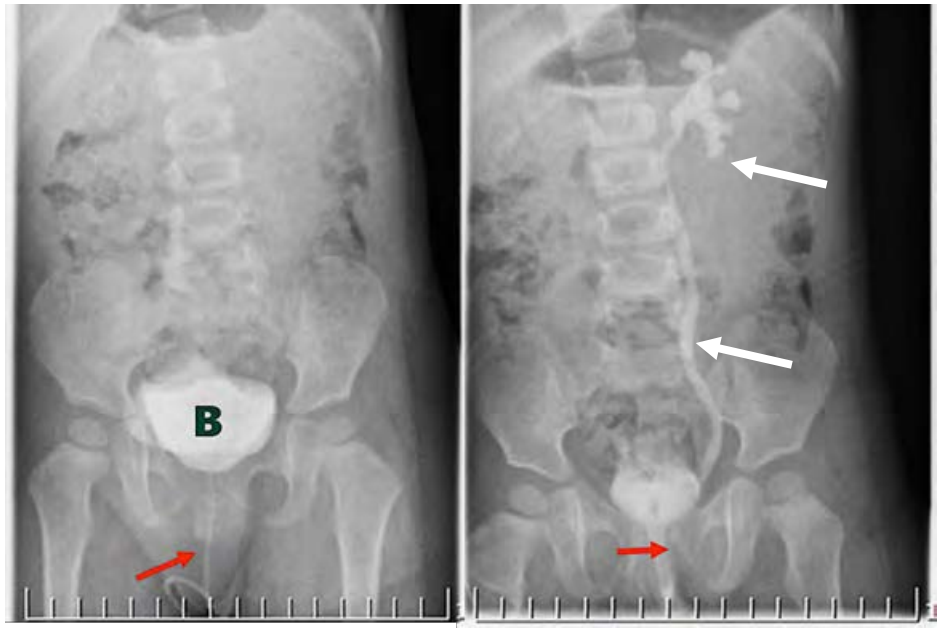
- Acute neonatal conditions manifesting as (bilious) vomiting and failure to pass meconium.
- Real-time contrast examinations of the gastro-intestinal (GI) tract, for example GI stenoses.
- Real time contrast examinations of the urinary tract, for example voiding cystourethrography, including critical diagnoses such as posterior urethral valves (PUV).

Advantages:

- Widely available.
- Classic features in some acute/critical diagnoses.
- Useful post operatively e.g., leaking viscus.
- Can be used therapeutically e.g., meconium ileus.
- Can be used as a guide e.g., contrast or air enema for intussusception reduction

Disadvantages:

- Operator dependent.
- Exposes patient to ionising radiation.
- No information on 'surrounding structures'.

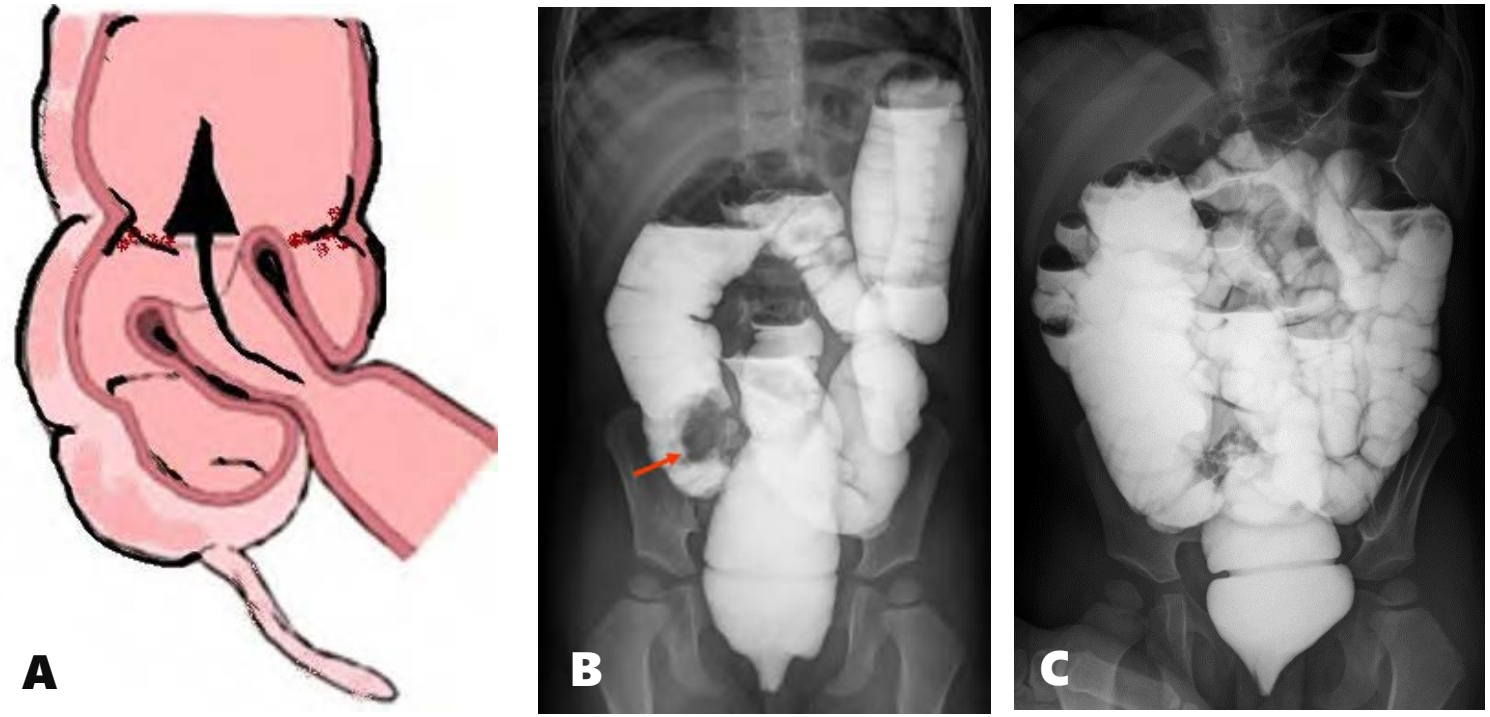


Micturating cystourethrography (MCUG) in an 11-month-old female with previous febrile UTI. Freeze-frame digital fluoroscopic image of the abdomen during bladder filling (left image) shows contrast in the bladder (B) and the catheter used for contrast infusion (arrow). During voiding (right image), left-sided vesicoureteric reflux (VUR, white arrows) is demonstrated. Note the normally short female urethra (arrow).

Chapter Outline

Indications, Strengths and Weaknesses of Imaging Techniques

Fluoroscopy - Guided Intussusception Reduction



Intussusception is the telescoping of bowel into adjacent bowel with resulting compression of trapped mesenteric vessels and ischemia of the telescoped bowel, if not reduced in a timely fashion. Most cases are ileocolic (A). Reduction of the intussusception under fluoroscopic guidance can be done using contrast enema (B and C) or air. The intussusception was diagnosed with US and is seen here (B) as a filling defect at the ileocecal valve area (arrow). Further administration of contrast resulted in reflux into the small bowel, a finding indicative of successful reduction (C). Intussusception reduction may be performed under ultrasonographic guidance using water or air enema in many European centres.

Chapter Outline

Indications, Strengths and Weaknesses of Imaging Techniques
Computed Tomography (CT)

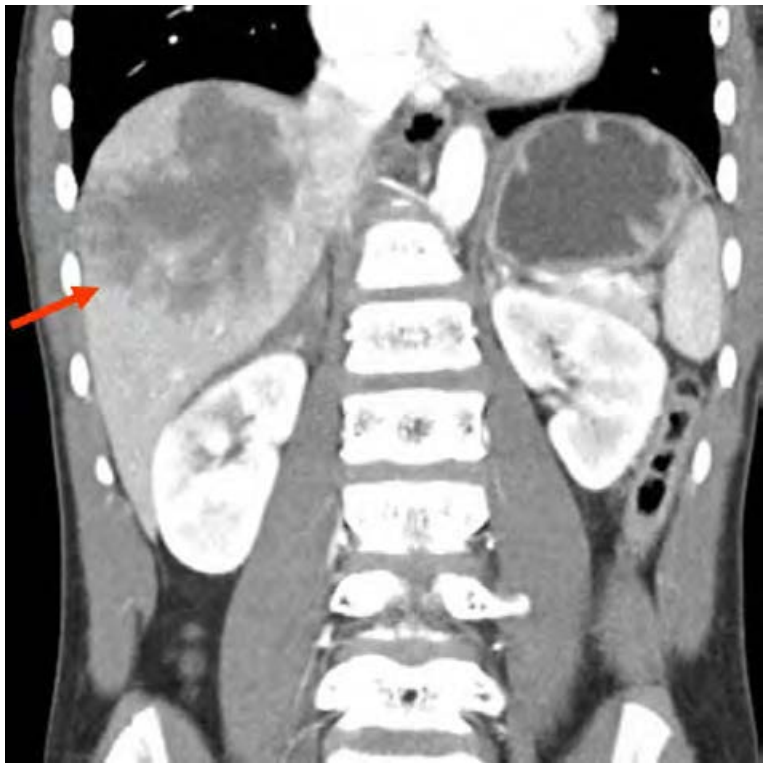
Indications:
- Trauma and acute presentations in any area of the body.
- Neurological, chest and cardiac disease.
- Oncological diagnosis and staging when MRI are not available or when lung staging is necessary.
- Detailed imaging of cortical bone.

Advantages:
- Greater detail than radiographs, information separately for each plane.
- Deep structures well visualised (compared to US).
- Quick – reducing the need for sedation or anaesthesia.
- Guidance for interventional procedures.
- Multiplanar 'reproducible' images.

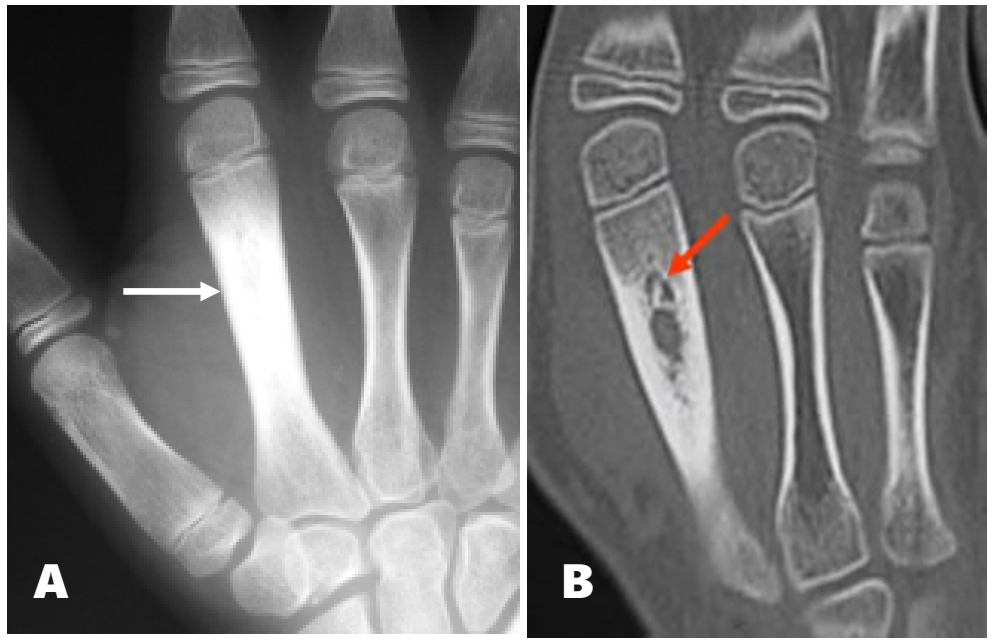
Disadvantages:
- Radiation dose more than radiography.
- Sedation occasionally needed.
- May require intravenous ionising contrast material which carries the risk of nephrotoxicity and allergic reaction.
- Less soft tissue contrast than MRI.

Chapter Outline

Indications, Strengths and Weaknesses of Imaging Techniques
Computed Tomography (CT) - Illustrative Examples



Post contrast CT (coronal plane) showing an extensive liver laceration as an area of diminished contrast enhancement (arrow).



Compare the radiograph and the CT scan of an 11-year-old child with chronic pain and swelling of the hand. The radiograph (A) shows sclerosis and thickening of the left index finger metacarpal diaphysis (white arrow). CT scan, coronal reconstruction image (B) shows evidence of chronic osteomyelitis with cortical thickening, a contained cavity with a small sequestrum (which is a necrotic piece of bone, shown by the orange arrow).

Chapter Outline

Indications, Strengths and weaknesses of Imaging Techniques

Magnetic Resonance Imaging (MRI)

Indications:

- The first line tool for all paediatric cross-sectional imaging e.g., CNS, MSK, abdomen, pelvic, cardiac, vascular pathologies. Used for lung assessment as a second-line tool in some centres
- Antenatal imaging of the foetus in selected cases

Advantages:

- Excellent soft tissue differentiation and detail, even without intravenous contrast administration
- No radiation. Good if multiple follow up examinations e.g., oncology
- Very sensitive for early or subtle changes
- Provides unique information with different sequences and specialized techniques, e.g., diffusion weighted imaging (DWI), spectroscopy, perfusion studies, etc.
- Multiplanar 'reproducible' images

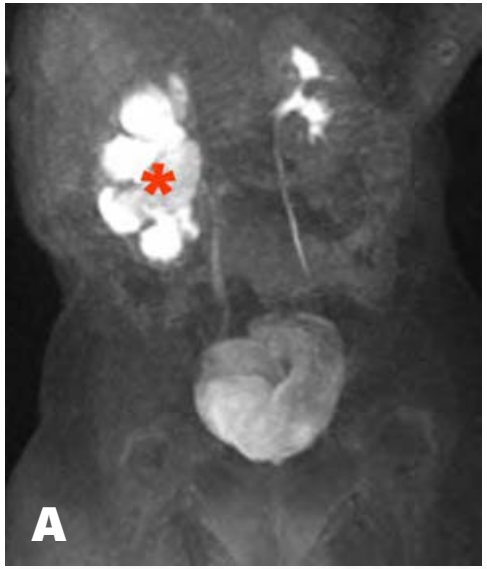
Disadvantages:

- Less widely available
- Young children usually require sedation or anaesthesia
- Cannot be performed in operated children having implanted MR-non-compatible devices or in claustrophobic children

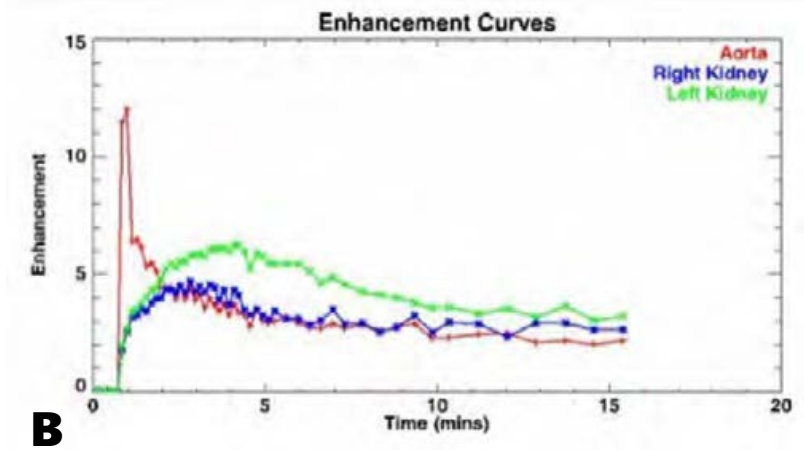
Chapter Outline

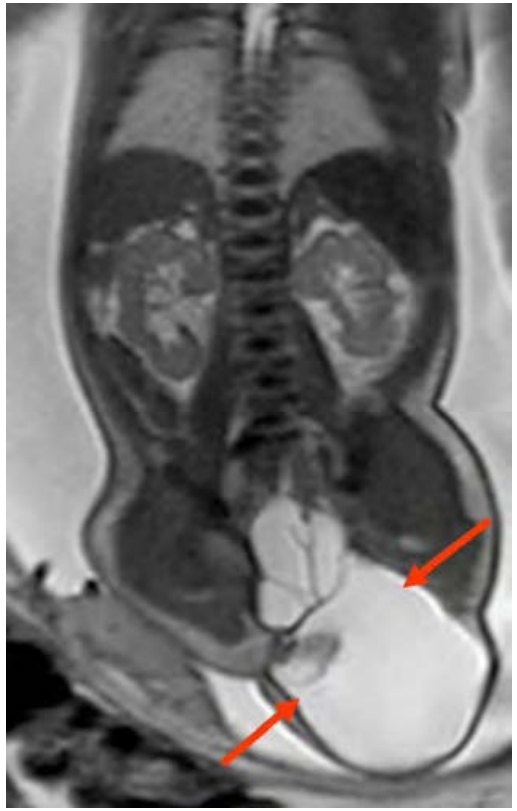
Indications, Strengths and Weaknesses of Imaging Techniques

Magnetic Resonance Imaging (MRI) – Illustrative Examples



MR Urography, post-contrast T1W sequence, multiplanar reconstruction in the coronal plane (A), shows dilated right pelvicalyceal system (*). Following a perfusion study, image postprocessing (B) shows a descending right excretory curve, indicating dilatation without obstruction





Foetal MRI, T2W sequence, coronal plane of a 28-week-old foetus. There is a huge, mostly cystic, pelvic and exophytic mass (arrows), indicative of a sacro-coccygeal teratoma

Chapter Outline

Indications, Strengths and Weaknesses of Imaging Techniques

Nuclear Medicine

Indications:

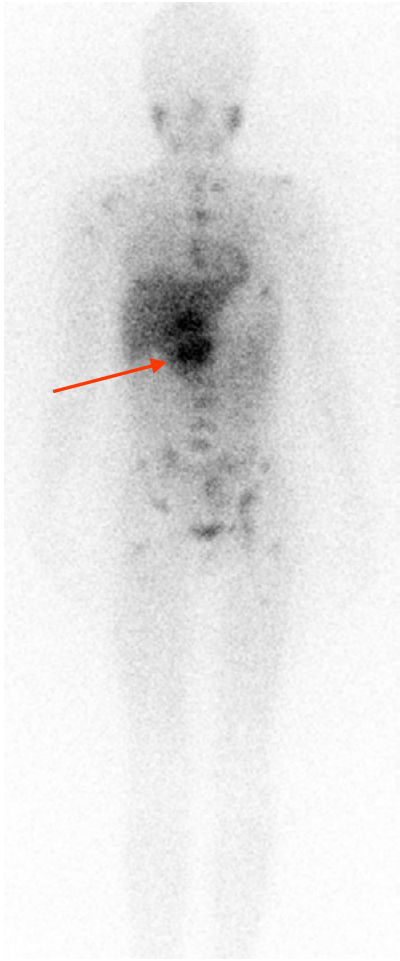
- Functional studies of the urinary and GI tracts, skeletal and endocrine system.
- Tumour staging, e.g., MIBG in neuroblastoma.
- Investigation of pain (MSK) and occult fractures.

Advantages:

- High Sensitivity.
- Multiplanar potential e.g., SPECT.
- Functional information can be fused with anatomical studies – hybrid imaging (e.g., PET-CT).
- No need for sedation for scintigraphy for most tests.

Disadvantages:

- Specificity may be low.
- Lesser anatomical detail with non-hybrid techniques.
- Hybrid imaging not universally available.
- PET-CT technically challenging in young children requiring anaesthesia.
- Radiation penalty.



MIBG (meta-iodobenzylguanidine) scan showing neuroblastoma (arrow)

Radiation Protection
The Justification Principle in Paediatric Radiology

- An imaging procedure should only be carried out if it provides a net benefit greater than the potential harm it might cause.
- The radiology request is a key document that must be filled in with the greatest care and diligence by the referring physician.
- Every request for an imaging procedure that involves exposure to ionising radiation should follow the conviction that the test is indicated and will result in a net benefit for the patient by considering the following questions:
    - **Has the scan/test already been performed?** Scans performed in the same or other institutions should be retrieved and reviewed, particularly if they have been performed recently. On many occasions, the answer to the clinical problem is available already.
    - **Do I need the scan?** Only scans that are expected to alter patient treatment and care (I.e., clinical management) should be performed
    - **Is the requested investigation the appropriate test done at the appropriate time?** Institutional, national and international practical guidelines are important in the investigation of specific conditions. Knowledge of the relevant clinical, laboratory and imaging findings should be considered within the relevant clinical context. Practices should be audited and revised regularly.
    - **Have I explained the problem? Have I discussed my thoughts?** Close co-operation and common language between referring physicians and radiologists constitutes essential steps in the elimination of unnecessary radiation exposures and facilitates the optimisation of techniques, particularly for complex, non-standard examinations.
    - **Are there any alternatives?** Alternatives should always be considered, such as ultrasound and MRI that do not involve exposure to ionising radiation, or fluoroscopic studies and radiographs (lower dose) over CT.

The risk of omitting of a radiograph and/or CT examination should not be underestimated given that omitting an indicated necessary examination may endanger the patient.

Chapter Outline

Radiation Protection
The ALARA Principle in Paediatric Radiology

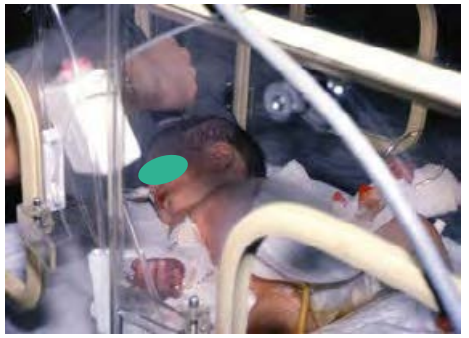
- Optimisation in radiology means that doses should be kept 'As Low As Reasonably Achievable' (the ALARA principle) whilst maintaining the minimum image quality necessary for accurate diagnosis.
- In practice, this means that paediatric radiologists accept 'noisy' (i.e., of lower quality) images to minimise dose in order to make a diagnosis.
- Minimising radiation exposure is a multifactorial exercise and is a shared responsibility between referring physicians, radiologists, technologists, medical physicists, the industry - this varies amongst institutions.
- Technology provides us with options to reduce radiation exposure whilst maintaining image quality.
- European Dose Reference Levels (*DRLs*) for the most common paediatric radiologic examinations, known as PiDRLs, are available in RP185, a document published by the European Commission.
- These values should not be consistently exceeded in clinical practice and facilitate implementation of the ALARA principle. PiDRLs are extremely important when considering high burden radiation investigations like CT and fluoroscopy-guided procedures.

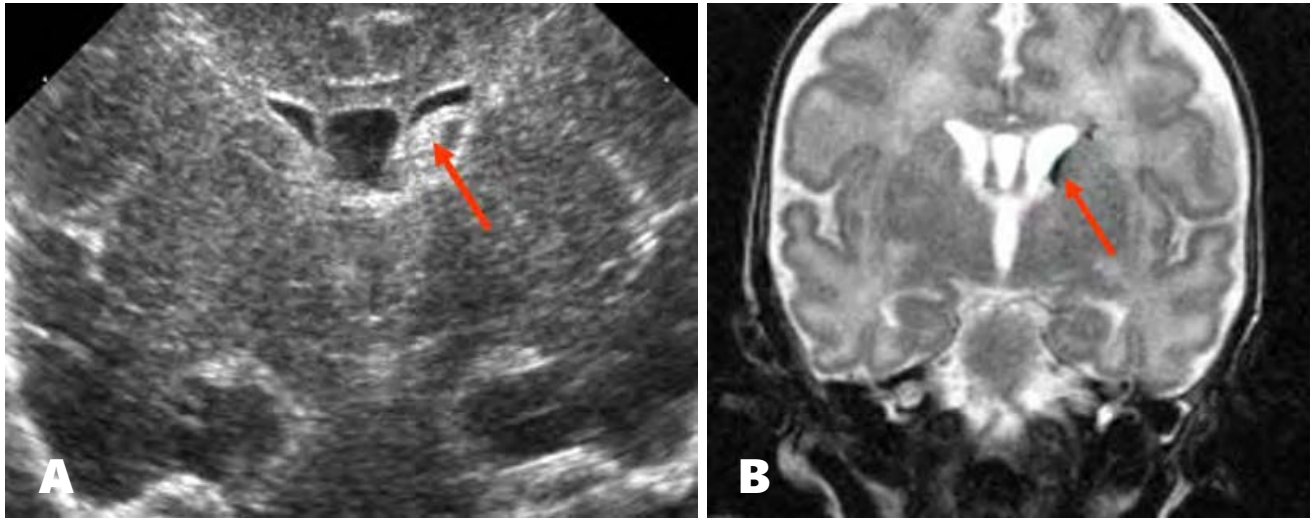
Chapter Outline

Disorders in Children

Brain Diseases: Neonatal Encephalopathy – Premature Baby

- Brain haemorrhagic disease and periventricular leukomalacia are the most common central nervous system (CNS) complications of prematurity.
- Brain sonography performed in the intensive care unit in the incubator (right image) is the first imaging tool and grading of haemorrhage is associated with prognosis.
- MRI may confirm the diagnosis and look for other lesions.



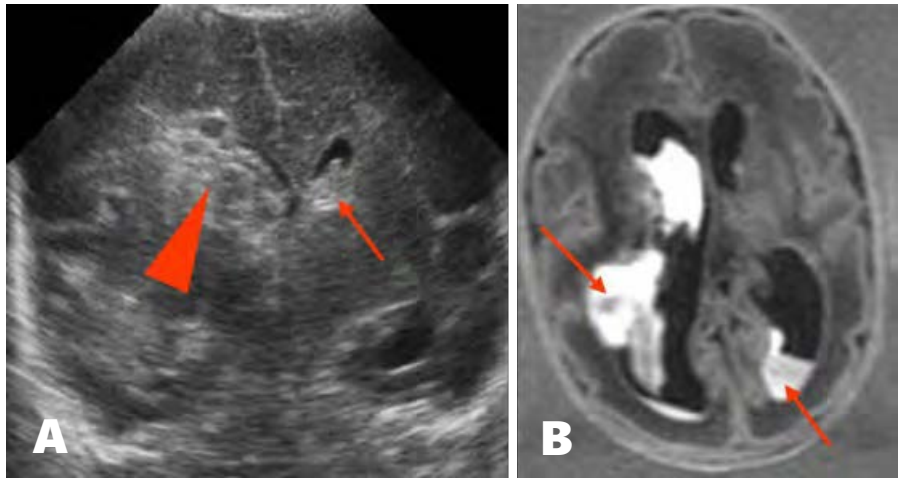


Hemorrhage at the vulnerable subependymal lining of the ventricles, called the germinal matrix. A germinal matrix haemorrhage grade 1 is seen in the left caudothalamic groove as an echogenic spot (arrow) on the coronal US view, (A) and as hypointensity (black area , arrow in B) on the coronal T2W MRI sequence.

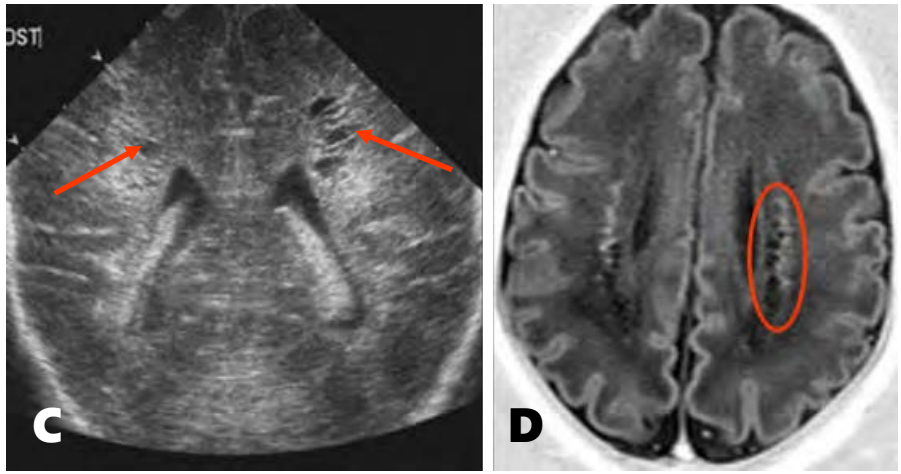
Chapter Outline

Disorders in Children

Brain Diseases: Neonatal Encephalopathy – Premature Baby



Bilateral germinal matrix hemorrhage with intraventricular hemorrhage (arrows) and associated haemorrhagic venous cerebral infarct (arrowhead) seen as space occupying echogenicities on coronal US (A) and as hyperintensities with ventriculomegaly on axial T1W MRI (B).

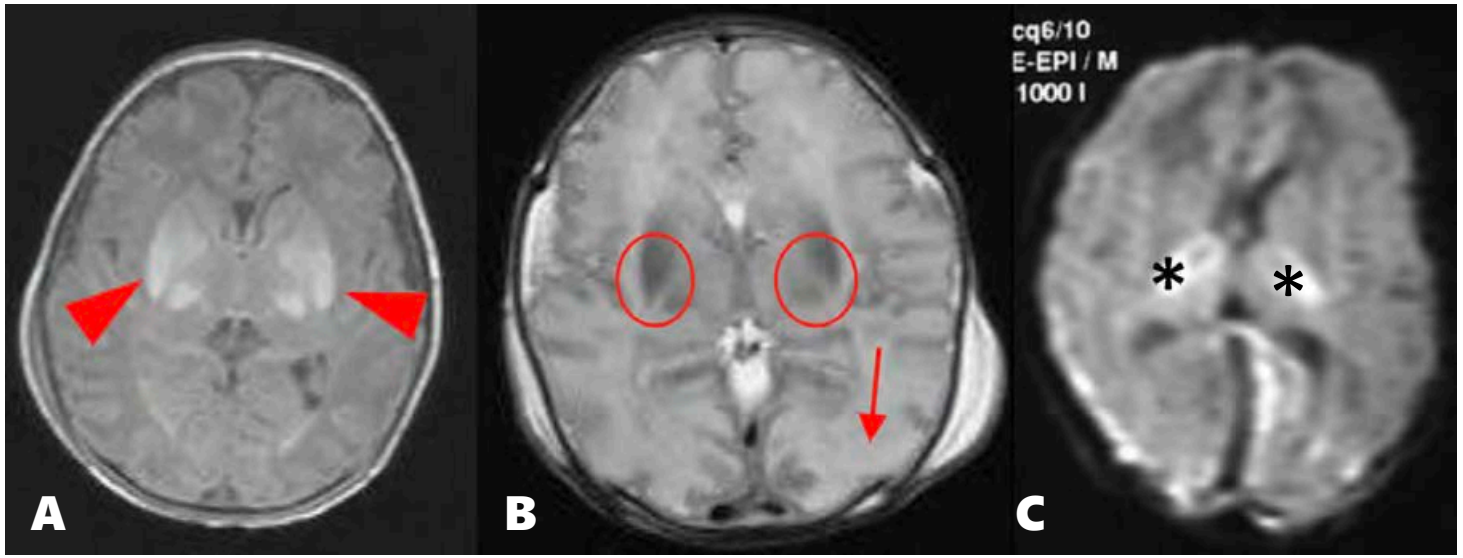


Compare the US (A, C) to the MRI (B,D) appearance of periventricular leukomalacia which is ischaemia with secondary cyst formation. It is visualised as multiple anechoic cysts (arrows in C) within echogenic periventricular white matter on US images, and as alternating hypointense cysts and hyperintense petechial haemorrhagic spots on MRI (within the red oval).

Chapter Outline

Disorders in Children
Brain Diseases: Neonatal Encephalopathy – Term Baby

- Hypoxic ischaemic injury in term babies typically results in lesions of basal ganglia and thalami. Initial diagnosis is difficult with sonography; MRI with diffusion is very helpful in this regard.
- Neonatal stroke occurs mainly after transient occlusion of the middle cerebral artery.
- Traumatic delivery could lead to subdural haemorrhage, or less frequently epidural haemorrhage

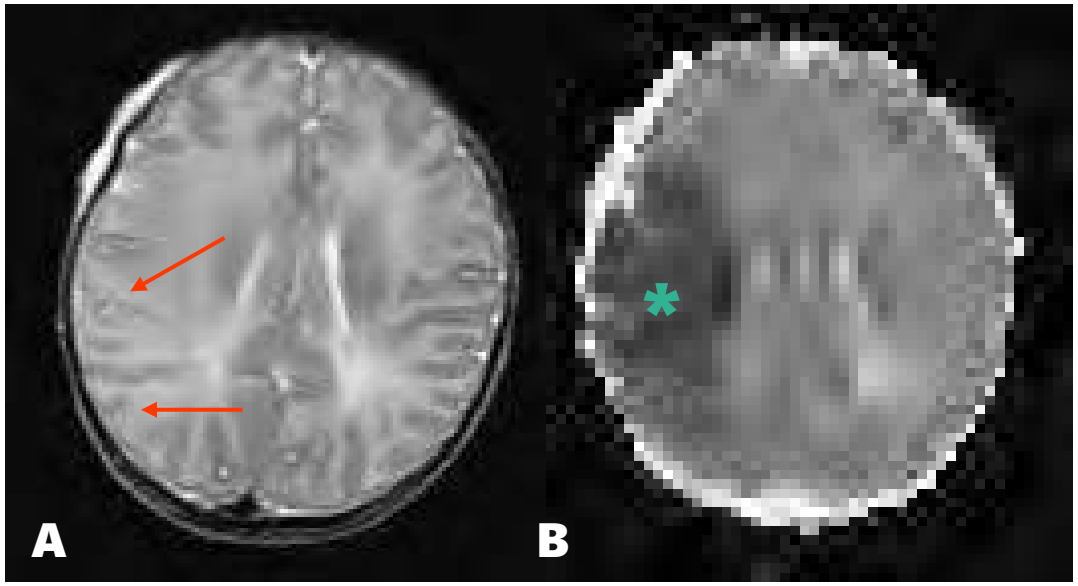


◀ Severe hypoxic neonatal encephalopathy on T1W (A), T2W (B) and diffusion-weighted MRI sequences (C): hyperintense deep grey matter (arrowheads), loss of PLIC alongside white mater oedema (arrow), restriction of diffusion in both thalami (*).

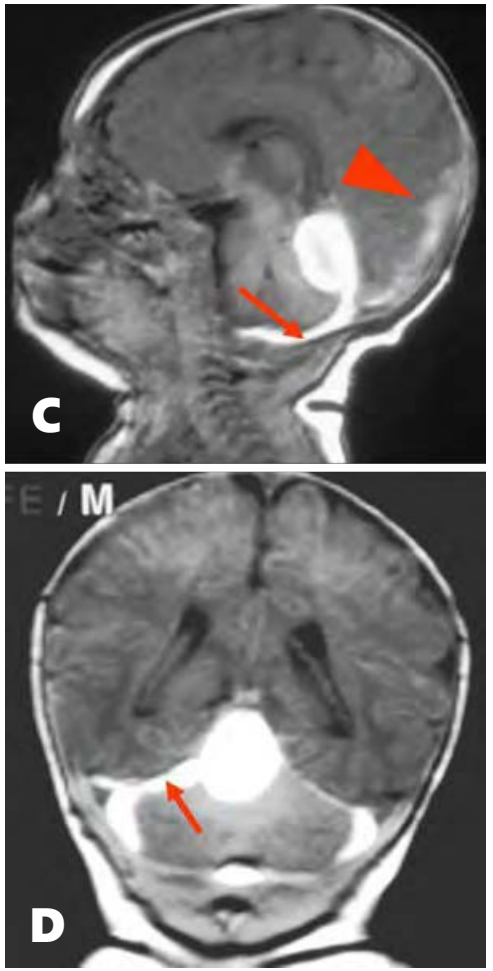
Chapter Outline

Disorders in Children

Brain Diseases: Neonatal Encephalopathy – Term Baby



Acute stroke in the right middle cerebral artery territory. On the T2W sequence, there is loss of the hypointense cortical ribbon (A, arrow), and the ADC map (B) exhibits restricted diffusion (*).



Subdural haematoma in the posterior fossa after breech delivery on T1W sequences, sagittal (C, arrow) and coronal planes (D, arrow); supratentorial subarachnoid hemorrhage is also seen (C, arrowhead).

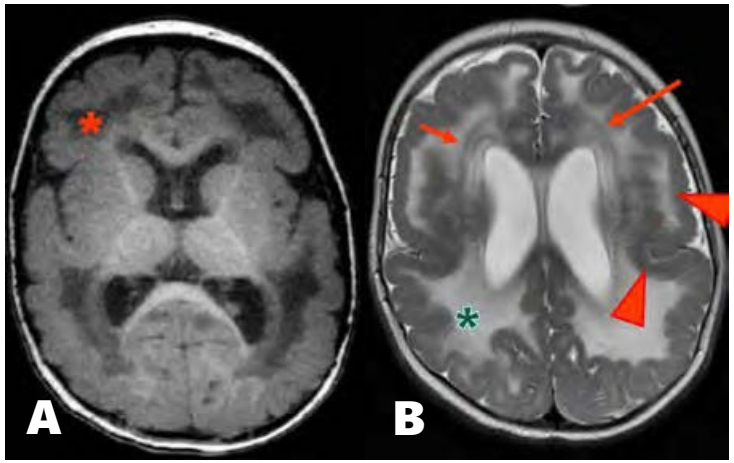
Chapter Outline

Disorders in Children
Brain Diseases: TORCH Infections

- **TORCH** is the acronym for congenital infections caused by transplacental transmission of pathogens:
- **T**oxoplasmosis,
- **O**ther (e.g., syphilis, Zika virus, HIV),
- **R**ubella,
- **C**ytomegalovirus (CMV),
- **H**erpes

CNS manifestations depend upon the age of the foetus at time of infection.

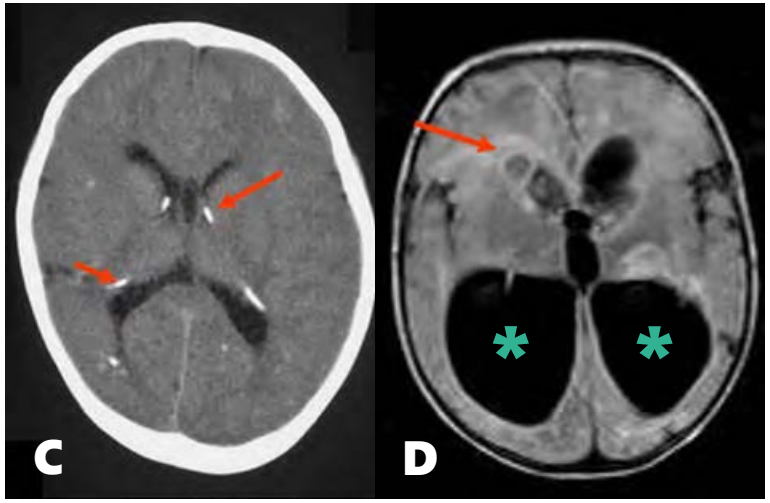
Disorders in Children
Brain Diseases: TORCH Infections & Imaging Features



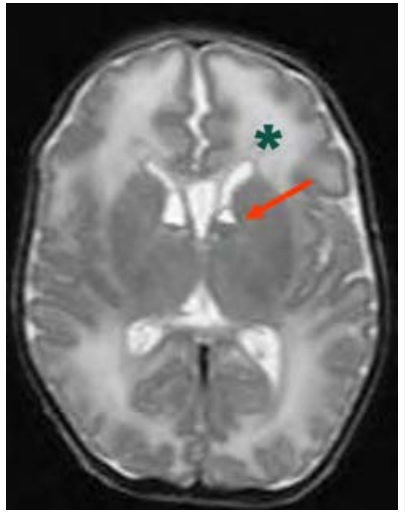
Early foetus infection with CMV results in white matter signal abnormality (* in A and B) and migration disorders: heterotopia (arrows) and pachygyria (arrowheads).

Grey matter heterotopia = grey matter is present in inappropriate locations in the brain due to interruption of cortical cell migration to the correct location

Pachygyria = (from the Greek "pachy" meaning "thick" or "fat" gyri) is a congenital malformation of the cerebral hemisphere. It results in unusually thick convolutions of the cerebral cortex



Two cases of congenital toxoplasmosis. C: the mild form with periventricular calcification (arrows). D: severe form with parenchymal lesions (arrow) and ventriculomegaly (asterisks).



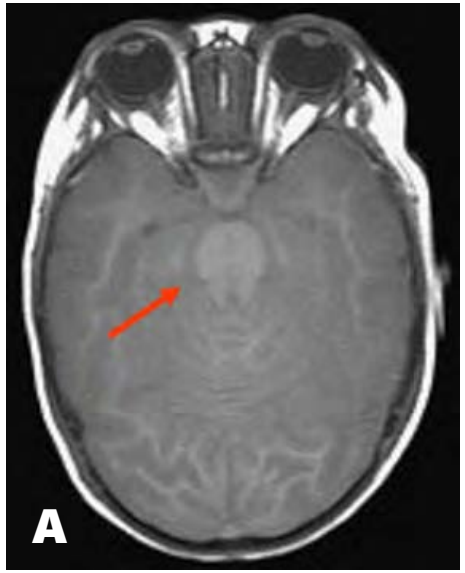
Rubella (E): subependymal haemorrhagic cysts (arrow) and white matter hyperintensity (*).

Chapter Outline

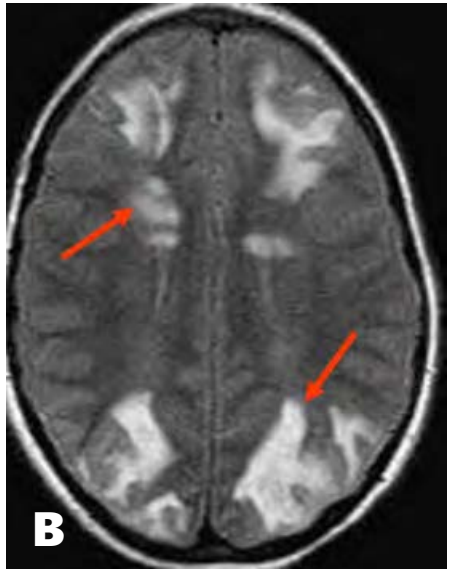
Disorders in Children
Brain Diseases: Post-natal CNS Infection

- Bacterial meningitis is frequent in childhood, including the neonatal period. Emergency treatment is mandatory, and treatment **should not** be delayed in order to undertake imaging.
- In neonates, US is the first line imaging modality. MRI is also useful in suspected complications which include ventriculitis, hydrocephalus, venous thrombosis, cerebral abscesses, and empyema.
- Acute encephalopathy may be directly related to the viral infection/load but also with an inflammatory auto-immune postinfectious disease, called Acute Disseminated Encephalomyelitis (ADEM).

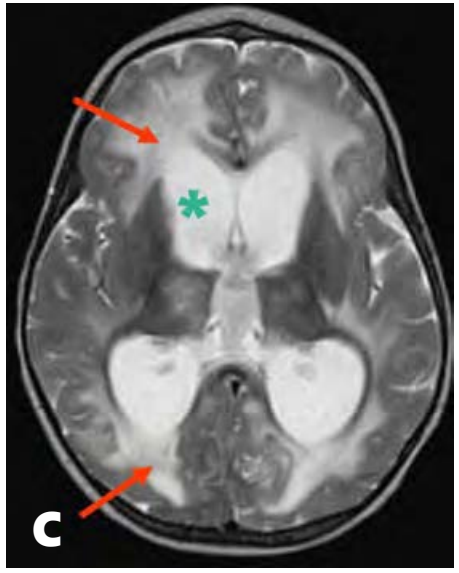
Disorders in Children
Brain Diseases: Post-natal CNS Infection
Illustrative Examples



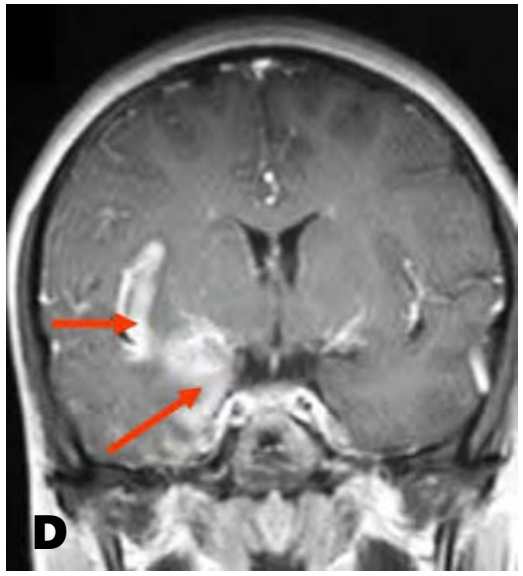
Meningococcal meningitis in a comatose patient (A). MRI T1W sequence after lumbosacral tap showing excessive brain edema, effaced peripheral sulci and basal cistern (arrow).



Pneumococcus meningitis in a 7-year-old (B), causing vasculitis and resulting in ischaemic lesions within junctional vascular territories (arrows)



T2W image obtained one week after bacterial meningitis in a 5-year-old (C): hydrocephalus with ventriculomegaly (*) and trans-ependymal CSF migration shown as periventricular hyperintensities (arrows).



Coronal T1W post contrast image in a child with partial seizures, fever and acute Herpes Virus HSV1 encephalitis. There is a characteristic right temporal and insula involvement with gyral enhancement (arrows).

Chapter Outline

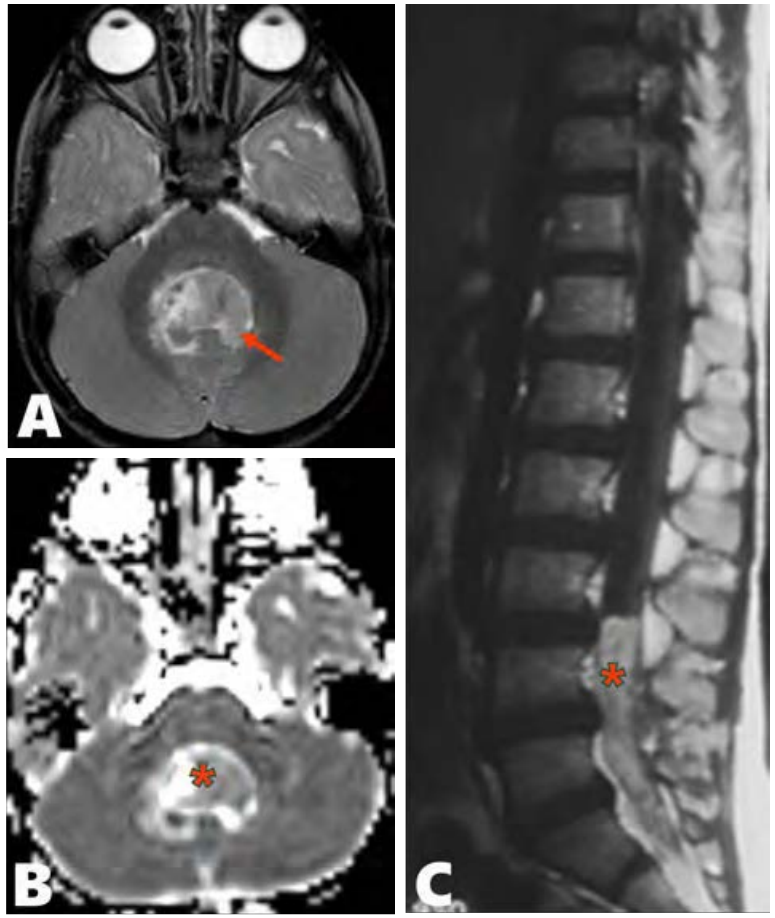
Disorders in Children
Brain Diseases: Posterior Fossa Tumours

- In children, tumours of the posterior fossa comprise more than 50% of all brain tumours.
- Headaches and vomiting are related to elevated intracranial pressure.
- Cerebellar tumours include medulloblastoma and pilocytic astrocytoma.
- Ependymoma and brainstem glioma are also frequent.

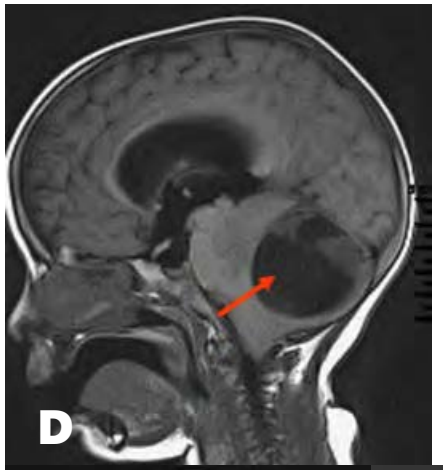
Disorders in Children

Brain Diseases: Posterior Fossa Tumours

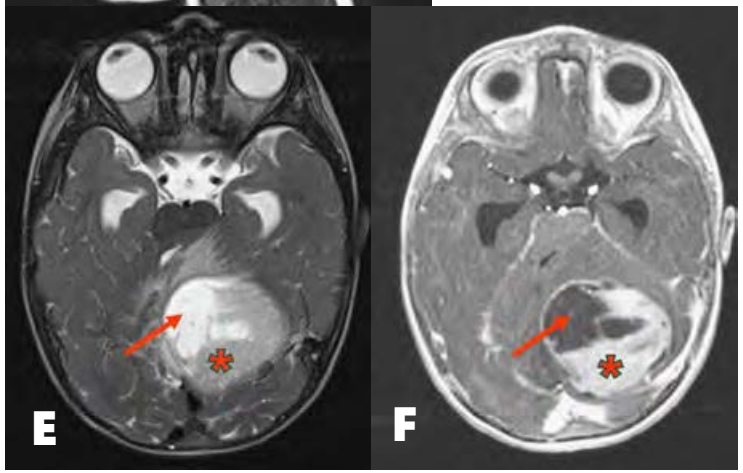
Illustrative Examples



◀ Tumour arising from the anterior part of the vermis (arrow), shows inhomogeneous signal intensity on T2W axial image (A), restricted diffusion as low intensity signal on the ACD map (* in B). Enhancing cauda equina masses (* in C) compatible with metastases within the thecal sac from anaplastic medulloblastoma.



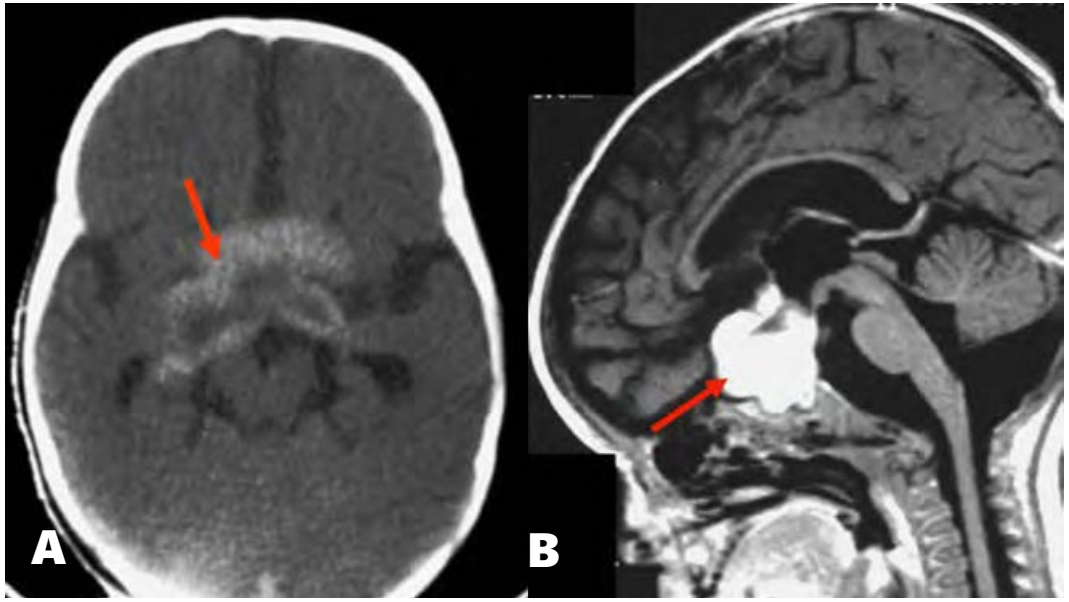
◀ Sagittal T1W (D), axial T2W (E) and axial contrast-enhanced T1W (F) images showing a tumour within the left cerebellar hemisphere with cystic (arrows) and enhancing solid portions (*) in a patient with a pilocytic astrocytoma.



Chapter Outline

Disorders in Children
Brain Diseases: Suprasellar Tumours

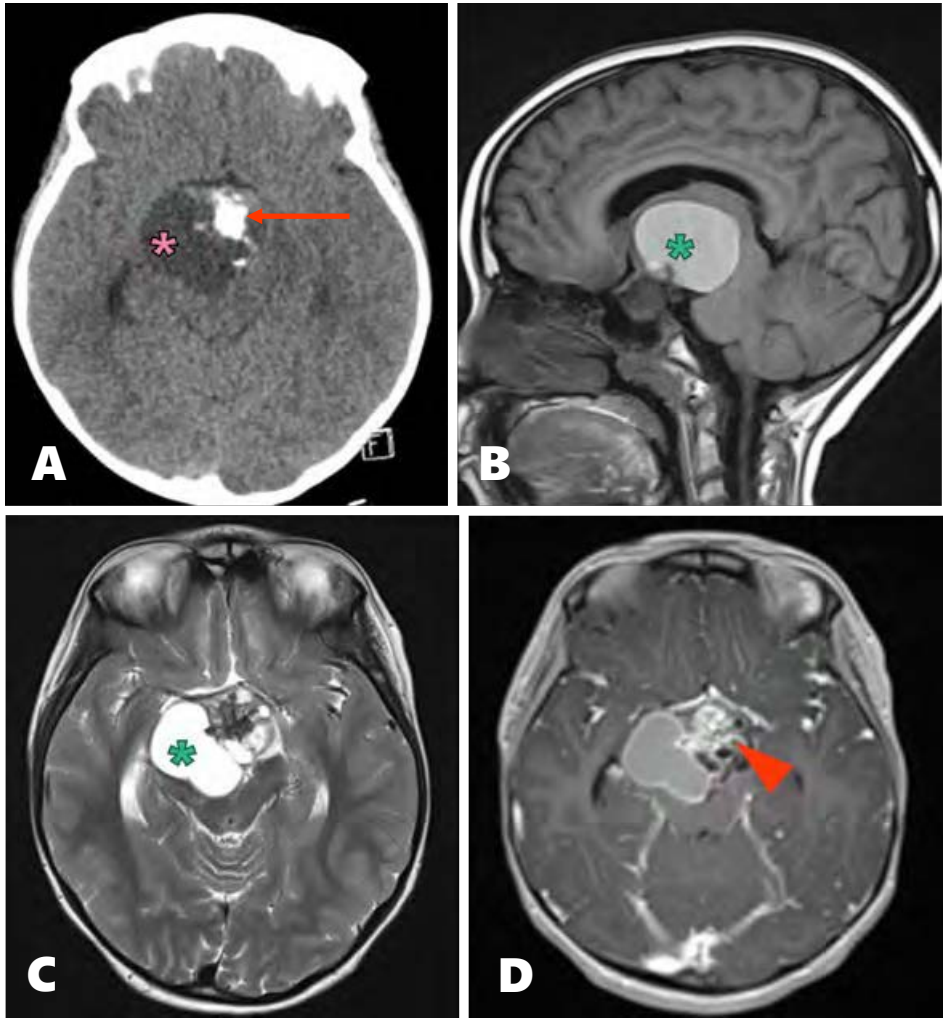
- The most frequent suprasellar tumours in children are craniopharyngioma and optic nerve glioma.
- Craniopharyngioma may present with endocrine symptoms (Growth Hormone [GH] deficiency) or elevated intracranial pressure. A cystic component, calcification and solid portions are characteristic.
- Optic nerve and chiasmatic gliomas can be isolated or associated with neurofibromatosis type 1 (NF1).



◀ **Axial** CT image (A) and sagittal contrast-enhanced T1W image (B) of a suprasellar tumour in the region of the visual pathways which exhibits enhancement following contrast injection (arrows).

Chapter Outline

Disorders in Children
Brain Diseases: Suprasellar Tumours



◀ Non-enhanced axial CT (A) and sagittal T1W (B), axial T2W (C) and axial T1W post contrast (D) images of a suprasellar tumour which is partly cystic (*). The cystic tumour part has a high signal intensity on T1W images (* in B). Calcification is seen on the left side of the lesion (arrow). Contrast enhancement is present in the solid part (arrowhead) of the tumour. Imaging findings are characteristic for craniopharyngioma.

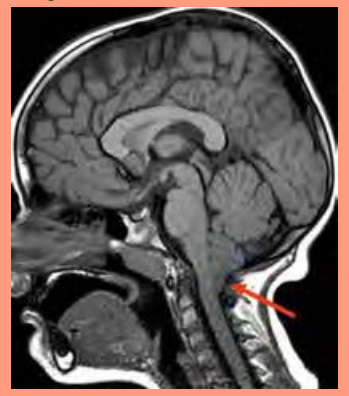
Chapter Outline

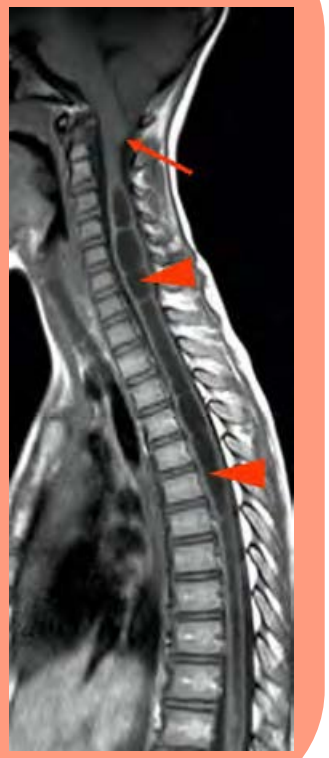
Disorders in Children
Congenital Malformations of Brain and Spine

Chiari Malformations are a heterogeneous group of malformations characterised by downward hindbrain displacement. Unlike Chiari II and III malformations, Chiari I is usually asymptomatic unless the descent of the cerebellar tonsils exceeds 5 mm, there is brain stem compression, syringomyelia, or scoliosis.

Chiari I

▼ Ectopia of the cerebellar tonsils (arrow) into the foramen magnum.



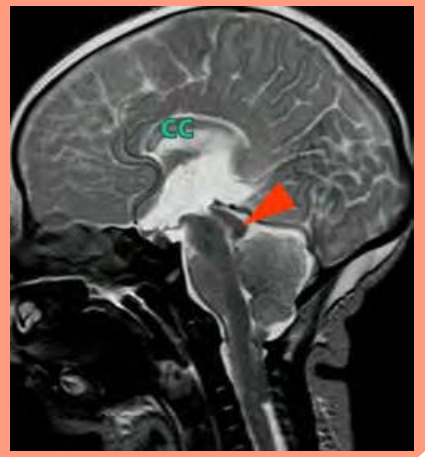


▶Subtype of Chiari I malformation. Chiari 1.5 is characterized by caudal displacement of brain stem and a cervicomedullary kink (arrow). Note the hydrosyringomyelia which is a frequent association with Chiari I malformations (arrowheads).

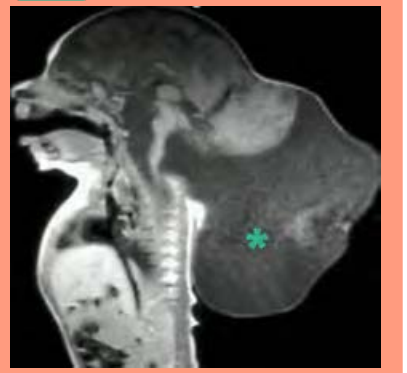
Chiari II

Small posterior fossa with herniation of the hindbrain, a beaked tectum (arrowhead), an elongated 4th ventricle, a dysplastic corpus callosum (cc) in a patient with open spinal dysraphism and a myelomeningocele (arrow).

Chiari II malformations can be reversed with prenatal surgical correction of the spinal defect.



Chiari III



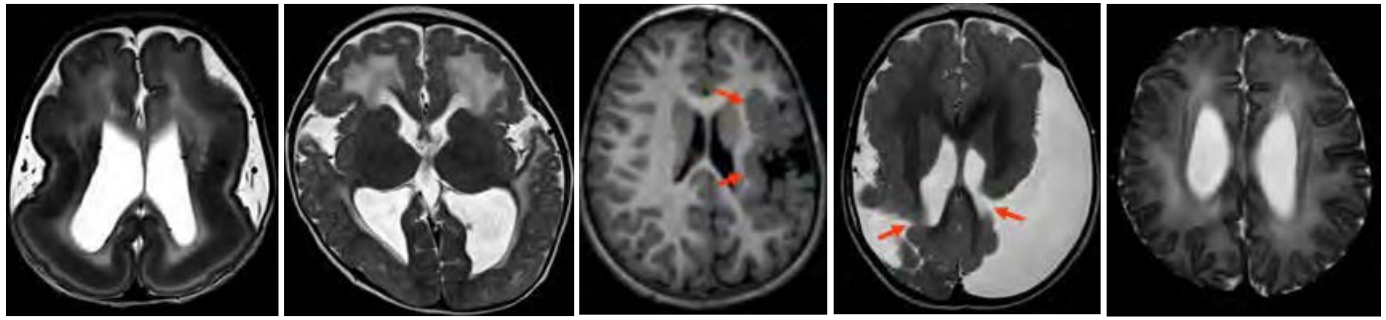
Herniation of the hindbrain into an occipito-cervical cephalocele (*).

The brain should be carefully inspected for tumours and other causes/evidence of intracranial hypertension to ensure that there is not secondary cerebellar tonsillar ectopia (and therefore not a Chiari I malformation).

Chapter Outline

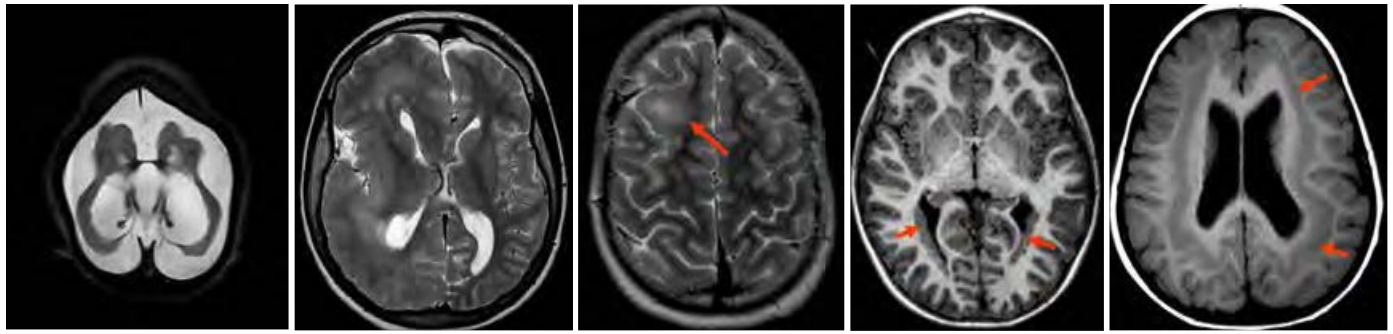
Disorders in Children
Congenital Malformations of Brain and Spine

- **Malformations of cortical development** are a major cause of intellectual disability, autism, epilepsy and cerebral palsy. They exist in **3%** of intellectual disabilities, **25%** of paediatric partial seizures, **5-15%** of adult epilepsy and **20-40%** of therapy-resistant epilepsy.
- There are **3 main categories**: disorders of cell proliferation and apoptosis (Group I), disorders of neuronal migration (Group II) and post-migrational (cortical organisational) disorders (Group III).
- The neurological outcome is extremely variable depending on the type, extent and severity of the malformation and the involved genetic pathways of brain development. Examples of the *ten main malformation patterns* are shown below:



Group II: Lissencephaly | Group II: Cobblestone Malformation | Group II: Polymicrogyria | Group III: Schizencephaly | Group III: Dysgyria

Barkovich AJ, Guerrini R, Kuzniecky RI, Jackson GD, Dobyns WB. A developmental and genetic classification for malformations of cortical development: update 2012. Brain 2012; 135: 1348-1369 [PMID: 22427329 DOI: 10.1093/brain/aws019]



Group I: Microcephaly | Group I: Hemimegalencephaly | Group I: Focal Cortical Dysplasia | Group II: Subependymal Heterotopia | Group II: Subcortical Band Heterotopia

Severino M, Geraldo AF, Utz N, Tortora D, Pogledic I, Klonowski W, Triulzi F, Arrigoni F, Mankad K, Leventer RJ, Mancini GMS, Barkovich JA, Lequin MH, Rossi A. Definitions and classification of malformations of cortical development: practical guidelines. Brain. 2020 Aug 10:awaa174. doi: 10.1093/brain/awaa174.

Chapter Outline

Disorders in Children
Spinal Dysraphism

Spine and spinal cord malformations result from abnormal development occurring during the early stages of embryonic development:

- gastrulation (weeks 2-3).
- primary neurulation (weeks 3-4).
- secondary neurulation (weeks 5-6).

Spinal dysraphism is categorised into:

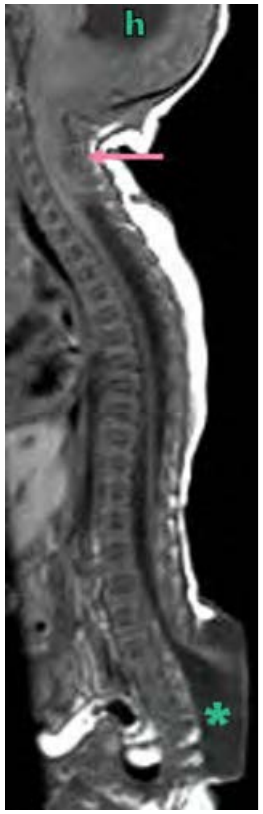
- **open spinal dysraphism** (abnormal neural tissue protruding through a posterior skin defect; myelomeningocele is the most frequent; associated with Chiari II malformation).
- **closed spinal dysraphism** (abnormal neural tissue covered by the integuments).

Closed spinal dysraphism is further subcategorised:

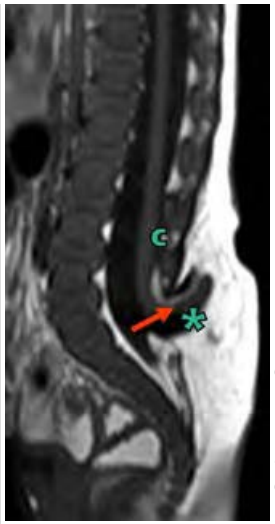
- With tumefaction (subcutaneous mass indicating underlying malformation; lipomyelocele, lipomyelomeningocele, meningocele, myelocystocele, and limited dorsal myeloschisis).
- Without tumefaction (no subcutaneous mass but often other stigmata such as hairy tuft, capillary malformations, dimple/holes, and dyschromia).

Clinical features:

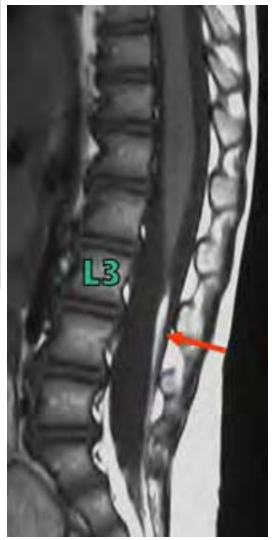
- Open spinal dysraphism presents at birth with an open defect that must be corrected urgently to avoid infection; variable impairment of gait, scoliosis, and urinary incontinence may develop.
- Closed spinal dysraphism often presents with a tethered cord syndrome and a low-lying (below L2) conus.



Sagittal spine T1-w image of a new-born with lumbosacral myelomeningocele (*) and an associated Chiari II malformation (arrow) with hydrocephalus (h).

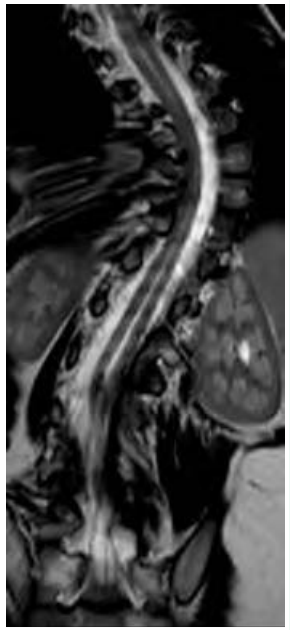


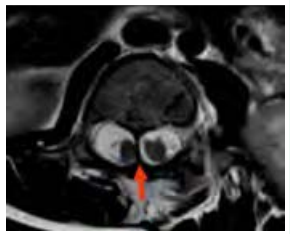
◀ New-born with a lumbosacral lipomyelomeningocele producing a skin-covered tumefaction. Note the low-lying conus (c), c-shaped fat (arrow) and CSF (*) protruding outside the canal.



◀ 5-year-old boy with a hyperintense (white) lipoma of the filum terminale (arrow). The conus is stretched into a low position at the level of L3.

▼ 6-year-old girl with scoliosis seen on coronal T2W imaging and a diastematomyelia with intervening bony spur (arrow), best appreciated on the axial image (bottom).

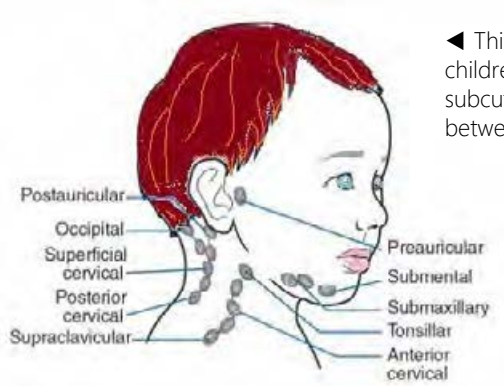




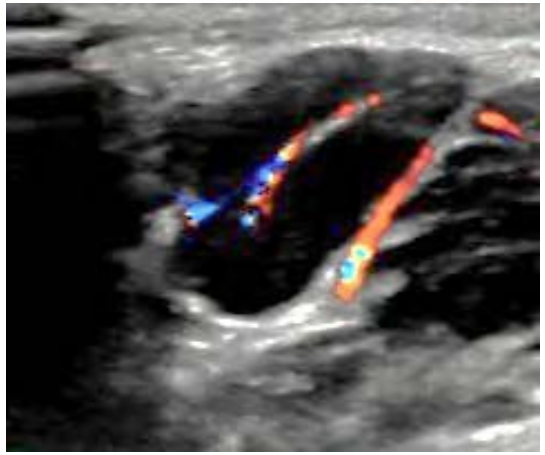
Chapter Outline

Disorders in Children
Cervical Lymph Nodes and Lymphadenopathy

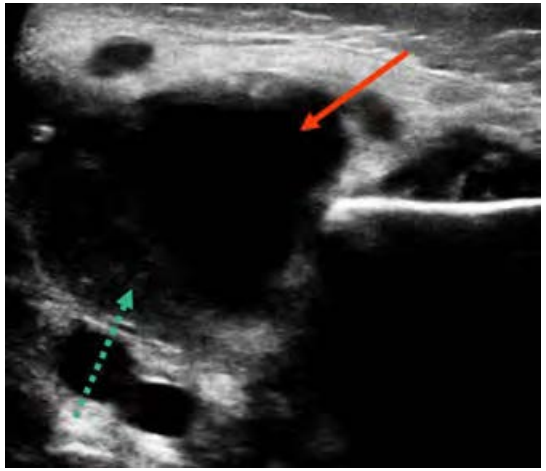
- Palpable cervical lymph nodes (CLNs) are common and found in nearly up to 60% of otherwise healthy children.
- Lymphadenopathy is defined as abnormal lymph nodes in terms of size (enlarged), number (widespread) and/or consistency (firm, hard, rubbery, non-mobile).
- Palpable CLNs <1 cm (short-axis) are considered physiological, even if persistent for many months.
- Cervical lymphadenopathy is also common and is reported in up to 90% of children between 4 and 8 years of age.
- CLNs >2 cm persisting for >6 weeks warrant referral for assessment: cervical lymphadenopathy, particularly supraclavicular, with associated splenomegaly, night sweats, weight loss, bone pain, symptoms/signs of a mediastinal mass, are all concerning for malignancy.
- Ultrasound is best suited to assessing CLN, but no single feature can determine the nature of an enlarged CLN – the combination of features and clinical context are key.
- Ultrasound cannot reliably differentiate between the changes from benign (e.g., reactive or infection) and malignant (lymphoma) causes.
- As such, ultrasound **should not** be used as a screening tool to 'exclude malignancy'.
- Ultrasound is occasionally used to show liquefaction requiring drainage in suppurative lymphadenitis (bottom image, right).



◀ This image illustrates the normal distribution of CLNs in children which are easily palpated due to relative lack of subcutaneous fat. The distinction should be made between normal palpable CLN and lymphadenopathy.



▲ Normal cervical lymph node on ultrasound in a well 20-month-old male with normal shape, size, visible hilum and blood flow. This child had normal palpable CLN but was mislabelled as "lymphadenopathy" for which this ultrasound was performed.



▲ Lymph node abscess on ultrasound in a 20-month-old male. He presented with fever and a right-sided neck swelling. The necrosis (orange arrow) is arising from an infected right submandibular lymph node (turquoise arrow). He proceeded to an incision and drainage (I&D).

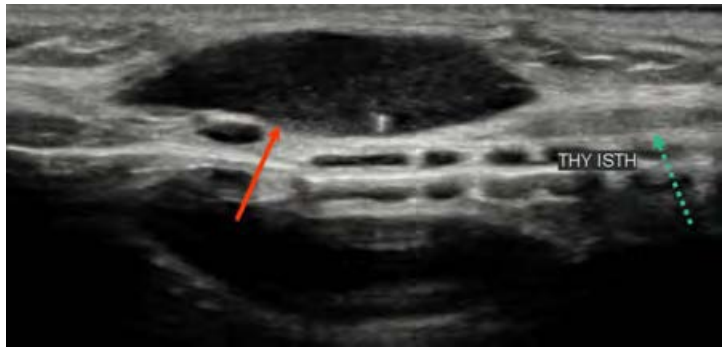
- Paddock M, et al. Do otherwise well, healthy children with palpable cervical lymph nodes require investigation with neck ultrasound? Arch Dis Child 2020. DOI: 10.1136/archdischild-2020-319648
- https://connect.springerpub.com/content/book/978-0-8261-5021-9/part/part02/part/section02/chapter/ch13

Chapter Outline

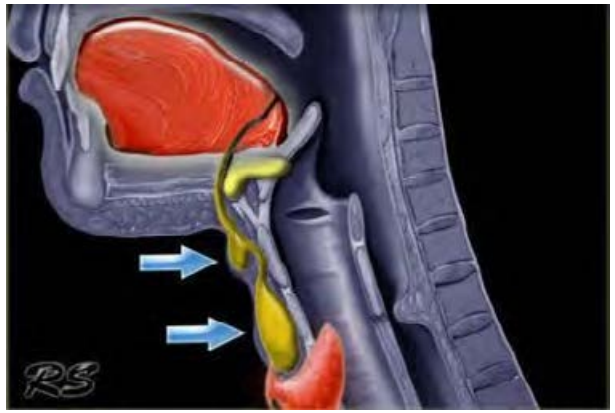
Disorders in Children
Thyroglossal Duct Cyst

- As the most common congenital neck cyst in children, it is usually midline or adjacent to the midline i.e., paramedian (within 2 cm).
- They may occur anywhere along the course of the thyroglossal duct which runs from the foramen caecum at the base of the tongue to the thyroid gland (illustration).
- As such, these cysts move upward with swallowing and on tongue protrusion which can help to distinguish it from other entities (mainly dermoid cysts and nodes).
- The majority (90%) typically present before the age of 10 years and are usually non-tender, fluctuant masses which may only be noticed as they gradually increase in size.
- They often remain asymptomatic unless they become infected (see grey box), prompting treatment.
- Ultrasound is the ideal modality to assess these cysts (top image), but they can also be seen on CT and MRI.
- Complete resection of the cyst and the thyroglossal duct up to the foramen caecum is curative, with only a small recurrence rate (<3%).
- The presence of the normal thyroid gland should be sought, as should the presence of any ectopic thyroid tissue which may be associated with these cysts.

Do not forget the cardinal signs of inflammation, defined by the 1st century AD Roman scholar Celsus (in Latin):
Calor - heat
Dolor - pain
Rubor - redness (also known as erythema, from the Greek, erythros, meaning 'red')
tumour - swelling



▲ Thyroglossal duct cyst (orange arrow) in a 9-year-old girl who presented with a midline swelling which moved on swallowing and tongue protrusion. US, longitudinal image shows that it lies just above the thyroid isthmus (turquoise arrow).



▲ The potential locations of thyroglossal duct cysts, indicated by the blue arrows, may occur anywhere along the path of the thyroglossal duct from the base of the tongue to the thyroid gland.

Image from https://radiologyassistant.nl/head-neck/neck-masses/neck-masses-in-children

Chapter Outline

'Branchial' is Greek for gill, so named for the externally visible 'gills' in the developing embryo.

Disorders in Children
Branchial Cleft Anomalies

- The branchial (or pharyngeal) apparatus is a complex embryological structure comprised of several paired symmetrical arches, pouches, clefts, and membranes which are precursors to several important structures in the head and neck.
- Anomalies of the branchial clefts usually result in **cysts**.
- **Fistulas** and **sinuses** may also occur but are less common.
- The 2nd to 4th branchial clefts, form the cervical sinus (transient depression in the embryonic neck) which obliterates when these clefts fuse.
- The commonest abnormalities are remnant 2nd branchial cleft cysts which may present following minor trauma or infection, and can be visualized with ultrasound, CT and MRI.

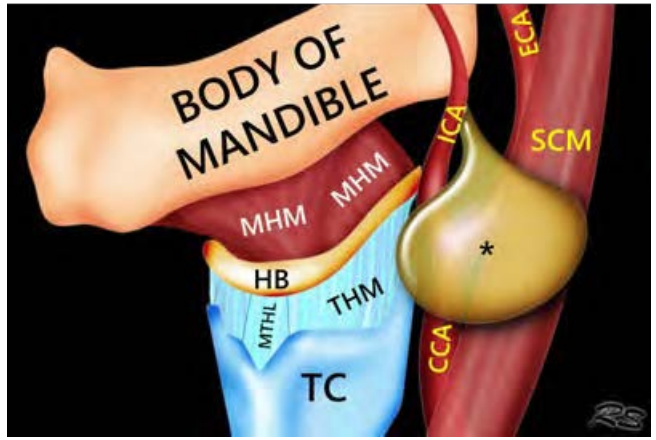
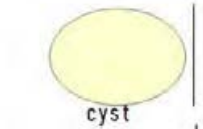


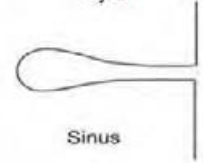
Image from https://radiologyassistant.nl/head-neck/neck-masses/neck-masses-in-children

◀ **ANATOMY REVIEW**: Branchial cleft cyst (BCC, *); CCA, common carotid artery; ECA, external carotid artery; HB, hyoid bone; ICA, internal carotid artery; MHM, mylohyoid muscle; MTHL, median thyrohyoid ligament; SCM, sternocleidomastoid muscle; TC, thyroid cartilage; THM, thyrohyoid membrane.

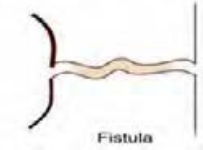
Definitions:



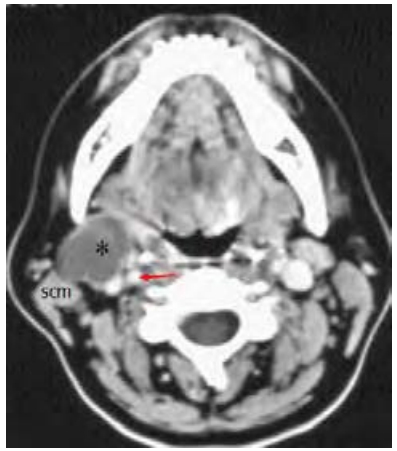
Cyst - an abnormal thin-walled membranous sac or cavity which contains fluid.



Sinus - a hollow space or cavity in the body, or blind track passing between epithelial surfaces and organs or tissue.



Fistula - an abnormal connection between the lumen of one viscus to the lumen of another (internal), or to the exterior (external).



◀ Note the typical location of the 2nd BCC (*) in the above illustration and the CT scan (left). It lies just below/posterior to the angle of the mandible, anterior to the SCM and lateral to the CCA (red arrow). The tail of the cyst can lie in between the ICA and ECA, as can the body of the cyst if it lies more superiorly.

Common associations with branchial arch anomalies:
1st - Treacher Collins syndrome; Pierre Robin sequence.
3rd - DiGeorge syndrome.

Chapter Outline

Disorders in Children
Vascular Anomalies - Classification

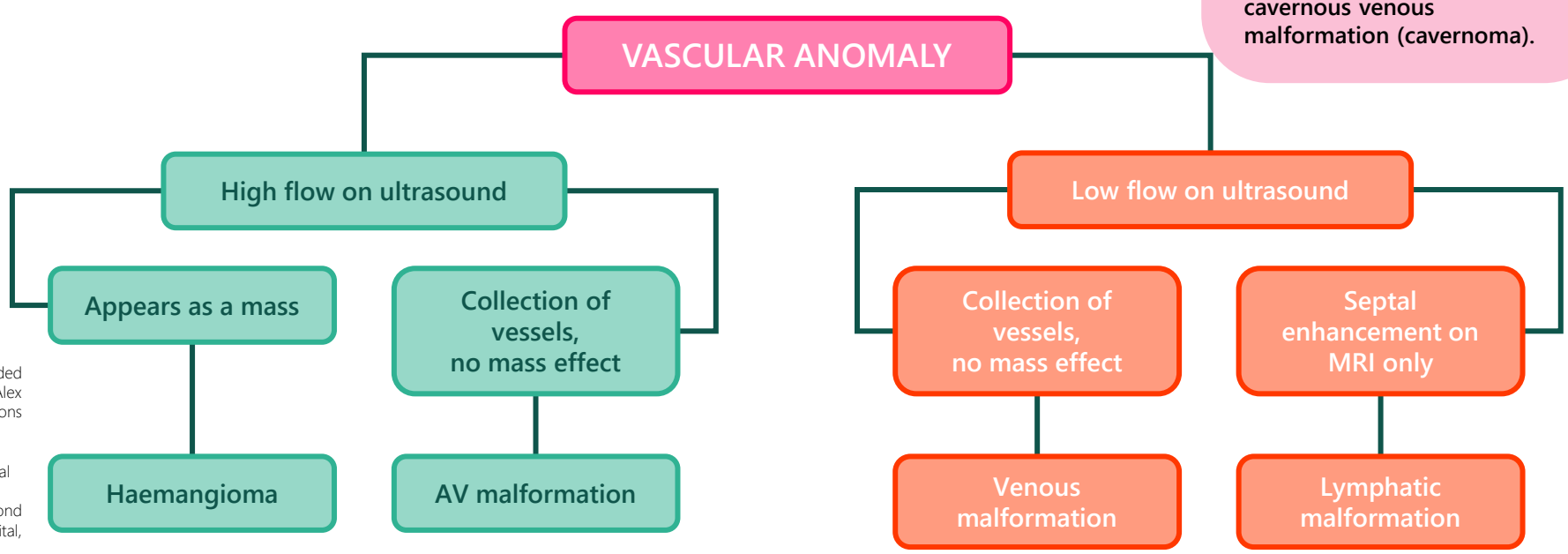
Vascular Malformations:
- Venous
- Lymphatic } slow flow lesions
- Capillary
- Arterial*
- Arteriovenous (AV)*
- Mixed

Haemangiomas & other Vascular Tumours:
- Common infantile haemangiomas*
- Congenital haemangiomas*:
  - Rapidly involuting (RICH)
  - Non-involuting (NICH)
- Other vascular tumours:
  - Kaposiform haemangioendothelioma (KHE)
  - Tufted angioma*

** = high flow lesions*

The International Society for the Study of Vascular Anomalies (ISSVA) has standardized the international nomenclature of vascular anomalies. Given the ubiquity of older terminology and misnomers ingrained in clinical practice, the convention is to now state the ISSVA term followed by "traditional" term in parentheses, e.g. cerebral cavernous venous malformation (cavernoma).

Pathway for vascular anomalies on imaging

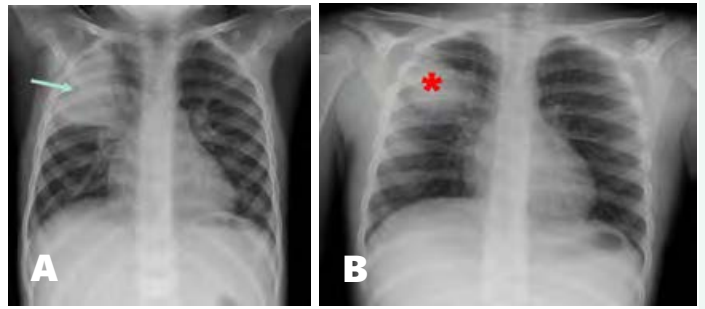


Diagrams kindly provided by Dr Alex Barnacle, Consultant Paediatric Interventional Radiologist, Great Ormond Street Hospital, UK

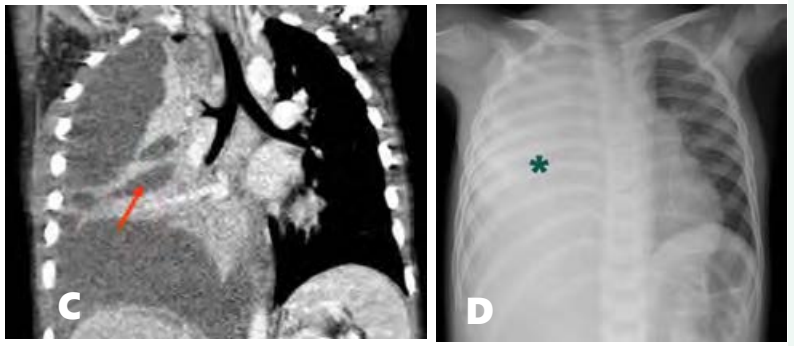
Chapter Outline

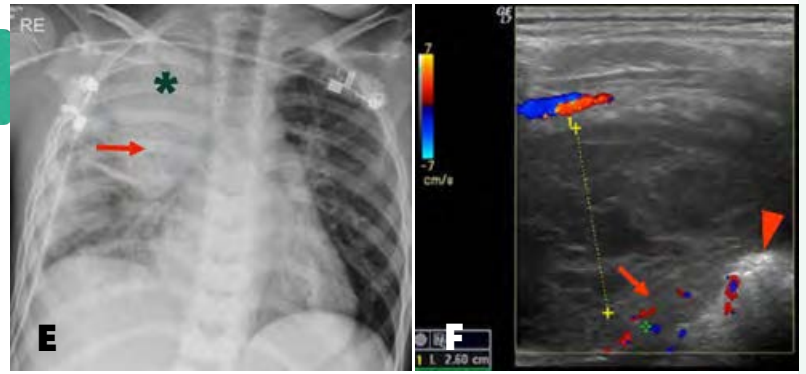
Disorders in Children
Respiratory Tract Infection

- A wheezy child (asthma or viral bronchiolitis) does not routinely require imaging with chest radiography. The radiograph is typically normal or may show hyperinflation, peribronchial cuffing or minor atelectasis which will not influence treatment choices. Most paediatric respiratory tract infections are viral in aetiology, especially in younger children.
- Imaging is only indicated if there is fever, localised chest signs/symptoms, a persistent cough or a severe illness which may indicate bacterial pneumonia or a complication (e.g., pneumothorax) and may require hospitalisation for intravenous antibiotic treatment.



- With bacterial pneumonia, alveolar air is displaced by inflammatory infiltrate/pus and appears dense (white) on the radiograph, obliterating mediastinal, vascular, diaphragmatic contours.
- Pneumonia may opacify an entire segment or lobe (right upper lobe pneumonia, blue arrow in A). Less common pneumonia in younger children may look circular, known as a round pneumonia (red * in B)
- A CT scan (coronal soft tissue window, C) may reveal areas of non-enhancing pulmonary parenchyma in keeping with necrotising pneumonia (red arrow in C). A parapneumonic effusion in the pleural space combined with pneumonia and atelectasis may result in complete opacification (white-out, green * in D) of the hemithorax with deviation of the mediastinum away from the side of the effusion.
- US delineates the amount of simple (clear=black) or complex (echogenic=thick or with lines= fibrin strands) pleural effusion while consolidated lung has a "hepatisation"/liver-like appearance.



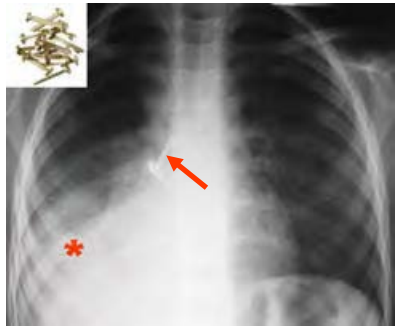


Compare the radiograph (E) and targeted US image (F) in a child with fever. There is a right apical density (*) which exhibits an air-bronchogram at its lower part only (arrow). US shows a mixed anechoic/hypoechoic area with multiple septae and debris, consistent with a complex apical effusion (between yellow crosses). Note the hepatisation of adjacent consolidated lung (arrow) and echogenic air-containing lung (arrowhead). A parapneumonic effusion complicating an apical pneumonia was diagnosed.

Chapter Outline

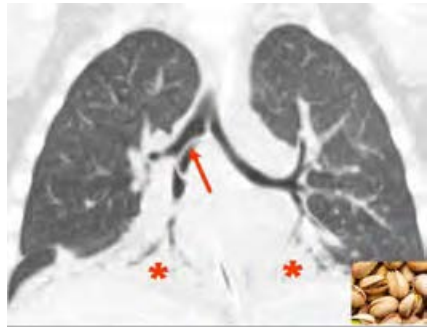
Disorders in Children
Foreign Bodies (FB)

- Young children may ingest, aspirate or insert a foreign body in other orifices like the ears, nose, vagina or urethra.
- Fluoroscopy images can identify radiopaque FB (e.g., metal, bone, glass) using a very low dose. Non-radiopaque FB, like food particles, paper, wood, wax, gems are not directly visible on radiographs or fluoroscopy.
- Aspirated FB manifest with a choking episode which can range from mild coughing to severe respiratory arrest due to airway obstruction. If choking goes unnoticed, the child may present following an asymptomatic interval with respiratory complications like chronic wheezing, recurrent respiratory tract infection, "asthma-like" manifestations, and/or airway obstruction.
- Aspirated FB can be indirectly identified because they can cause incomplete bronchial obstruction with air trapping, bronchial obstruction with atelectasis or even nothing. If a suggestive history and auscultation are present, even when radiographs are negative, bronchoscopy or CT may be undertaken.
- Ingested FB usually come out naturally and uneventfully unless sharp, or large. Imaging should also rule out button batteries that are corrosive and should be removed immediately, alongside multiple magnets because they can cause fistulas, perforation and peritonitis.



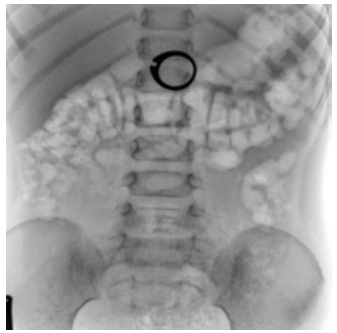
4-year-old boy who presented with fever. Note that besides a right middle and lower lobe pneumonia (*), the FB (arrow) is radiopaque.

2-year-old boy with paroxysmal coughing. Paucity/thin vessels and increased left lung volume, indicated air-trapping which was due to aspirated nuts.

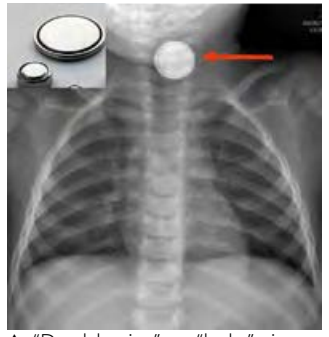


7-year-old boy who developed ARDS. The pistachio shell (arrow) was first seen with CT. Note the basal atelectasis bilaterally (*).

Any "double rim" or "halo" sign in a circular opacity differentiates a button battery from a coin (the latter appearing solid) and should prompt removal from the oesophagus within 2 hours.



▲ 5-year-old girl who ingested her mother's engagement ring. Note that the stone is not radiopaque (invisible).



▲ "Double rim" or "halo" sign (arrow) consistent with a button battery: **EMERGENCY SITUATION!**

Chapter Outline

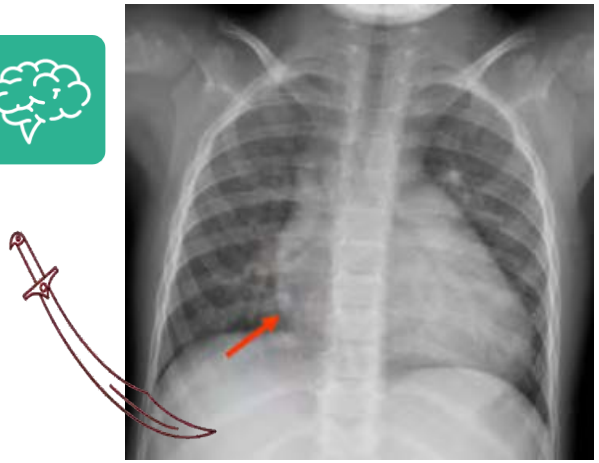
Disorders in Children
Congenital Heart Disease (CHD)

- CHD is the *most frequent malformation at birth* (1 per 100 live births).
- Most CHD patients will now *survive to adulthood* thanks to current treatment.

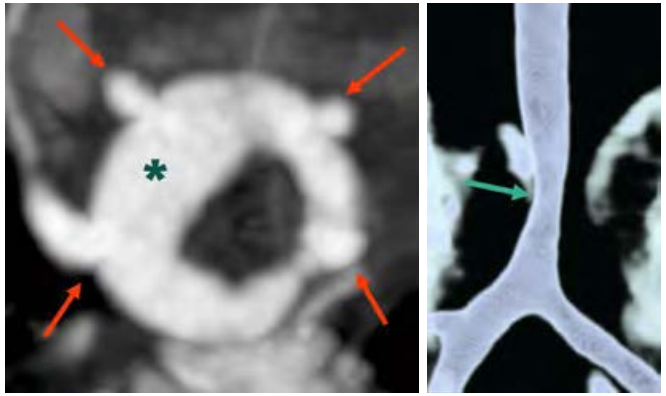
CHD evaluation requires a *multi-disciplinary and multi-modality imaging approach*

- **Non-invasive imaging**
  - *Echocardiography (Echo)*
    - *First-line* exam in the *initial evaluation and follow-up.*
    - May be *limited by poor acoustic window/operator-dependency* and *for extracardiac/complex anatomical/functional evaluation.*
  - *Chest Radiography (CXR)*
    - *Complementary* examination.
    - Information on *heart size, pulmonary vasculature and parenchyma.*
  - *Cardiac Computed Tomography (CCT)*
    - *Second-line* examination for *extracardiac/complex and coronary anatomy.*
  - *Cardiac Magnetic Resonance (CMR)*
    - *Second-line* examination *for intracardiac and extracardiac/complex anatomical/functional evaluation.*
    - *Gold-standard* for *ventricular volumes/function and flow/shunt quantification.*
- **Invasive imaging**
  - *Cardiac Catheterization (Cath)*
    - Mainly reserved for *hemodynamic measurements* and *intervention.*

The correct execution, post-processing and interpretation of all imaging modalities require direct involvement of specialised physicians with knowledge of relevant technical and clinical aspects related to CHD.



◀ 4-year-old boy with scimitar syndrome (scimitar = curved sword). CXR shows a smaller (hypoplastic) right lung with ipsilateral mediastinal shift, right heart enlargement and shunt vascularity. A tubular structure parallel to the right heart (arrow) can be seen (scimitar sign) which represents partial anomalous pulmonary venous return to the inferior vena cava. This is one of the few CHDs where CXR can be diagnostic, otherwise it is usually a complementary examination.



6-month-old girl with a vascular ring presenting with stridor. Cardiac CT imaging reconstructed so that the, vessels can be seen from above in an axial plane. There is a double aortic arch with right dominance (*) and left hypoplasia, as is usually the case. The epiaortic vessels (red arrows) have a characteristic pattern, each with their origin from each carotid and subclavian artery from the respective ipsilateral arch. Coronal reconstructed image demonstrates air-filled structures: the trachea is stenotic with malacia at the same level (turquoise arrow).

Chapter Outline

Disorders in Children
Congenital Heart Disease (CHD)

Cardiac Computed Tomography (CCT)

- **Extracardiac/complex and coronary anatomy**
  - *Superior to CMR* for imaging *small blood vessels* due to the higher spatial resolution.
- **Concurrent airway/pulmonary parenchyma evaluation**
- **Uncooperative patients**
  - *Neonates/infants and younger children.*
  - *Critically ill patients.*
- **Metallic devices and calcifications** (e.g., stents)
  - Superior to CMR due to lower susceptibility to artefacts.
- **CMR contraindications** (e.g., non-compatible devices)
  - Inferior to CMR for ventricular volumes/function quantification due to lower temporal resolution, no flow information, and increased radiation exposure.

CCT Indications

- **Coronary artery anomalies**
- **Vascular rings/slings**
- **Tetralogy of Fallot with pulmonary atresia ± major aorto-pulmonary collateral arteries (TOF/PA/MAPCAs)**
- **Aortic anomalies**
- **Anomalies of systemic and pulmonary veins**

Cardiac Magnetic Resonance (CMR)

- **Ventricular volumes/function quantification**
  - *Superior to Echo for the right ventricle.*
- **Flow/shunt quantification**
  - *Superior to Echo for pulmonary regurgitation.*
  - *Inferior to Echo for stenosis.*
  - *Equal to Cath for QP/QS.*
  - *Right/left lung perfusion.*
- **Intracardiac and extracardiac anatomical/functional evaluation** (if Echo is insufficient)
- **Co-operative patients**
  - *Older children/adolescents and adults.*
  - *Sedation/anaesthesia for uncooperative patients.*
- **Serial follow-up** due to no radiation exposure.

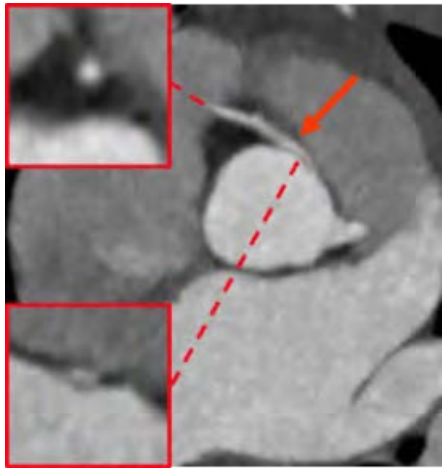
Main Clinical Settings for CMR

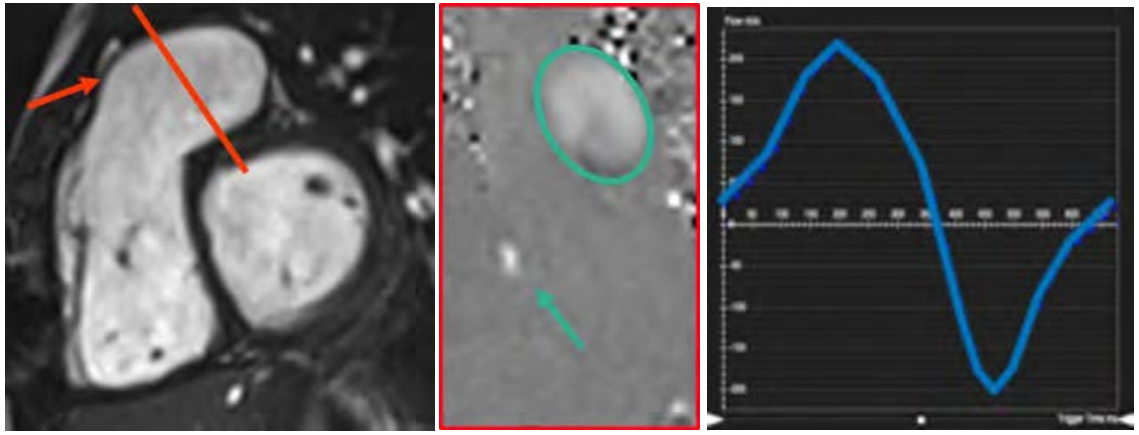
- **Repaired Tetralogy of Fallot (rTOF)**
- **Systemic right ventricle**
- **Single ventricle (Fontan)**
- **Shunts of uncertain haemodynamic significance**
- **Aortic anomalies**
- **Anomalies of systemic and pulmonary veins**

Chapter Outline

Disorders in Children
Congenital Heart Disease (CHD)

▶ CCT in a 6-year-old boy with a coronary artery anomaly. Maximum-intensity projection (MIP) axial image (with embedded vessel cross-section insets): anomalous origin of the right coronary artery (arrow) from the left aortic sinus with iuxta-junctional and juxta-commisural ostium. The vessel has a proximal interarterial and intramural course (the latter suspected by the acute take-off angle, slit-like orifice, and elliptical lumen). This is considered a malignant variant at risk for sudden cardiac death, especially during exercise.



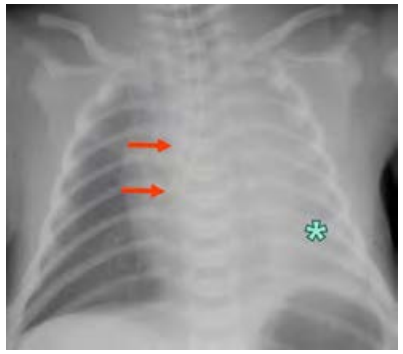


◀ CMR in a 14-year-old boy with rTOF (transannular patch and ventricular septal defect closure). **Left:** Cine-SSFP image shows dilation of the right ventricle (RV) with right ventricular outflow tract (RVOT) aneurysm (orange arrow). **Centre:** Velocity-encoded phase-contrast image perpendicular to the RVOT is acquired to quantify pulmonary flow (turquoise circle). Tricuspid regurgitation (turquoise arrow) is also seen. **Right:** Pulmonary flow/time curve, obtained through post-processing reveals severe pulmonary regurgitation (regurgitant fraction 54%). These are typical findings in rTOF and are usually monitored with CMR to decide on pulmonary valve replacement.

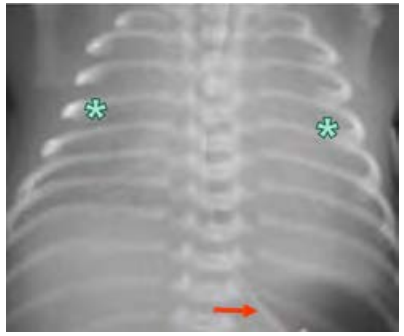
Chapter Outline

Disorders in Children
Lines and Tubes in Neonates

- Neonates may be supported via endotracheal tubes (ETT), umbilical venous catheters (UVC) and umbilical arterial catheters (UAC), amongst others.
- The optimal range for the ETT tip is between the thoracic inlet to one vertebral body above the carina.
- The UVC can be misplaced and lie within the portal venous system, superior vena cava or it can cross the foramen ovale to lie in the left heart and pulmonary veins.
- UAC characteristically course inferiorly within the umbilical artery before turning superiorly to cross the internal iliac artery and reach the aorta. The tip of UAC should lie away from the aortic branch vessels (ideally above T10 or below L3 vertebral levels) to prevent thrombosis/emboli.

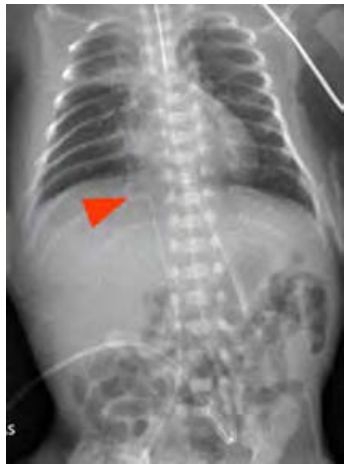


◀ The **endotracheal tube (ETT)** has been advanced down the right bronchus and there is consequent collapse of the left lung (*) which has lost volume and appears dense (white).

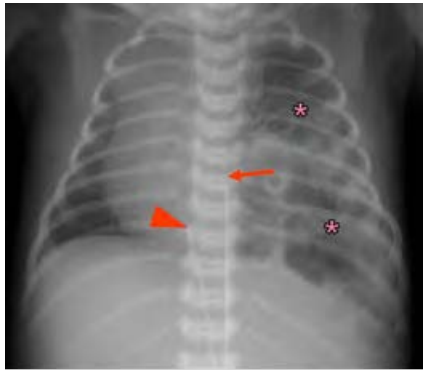


◀ **Respiratory distress syndrome** in a premature neonate due to surfactant deficiency. The lungs (*) are dense, exhibit small volume and are usually treated with surfactant delivered via the ETT. Note the nasogastric tube (arrow).

The ETT tip mirrors chin movement: The tip moves down (towards feet) with neck flexion and up (towards head) with head extension.



◀ **Umbilical venous catheters (UVC)** traverse the left portal vein and patent ductus venosus to reach their optimal position within the IVC near the right atrium (arrowhead).

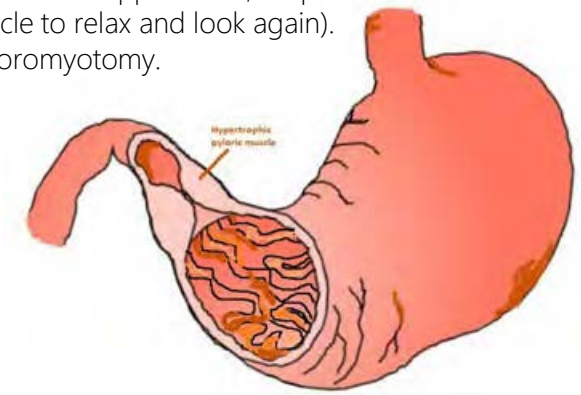


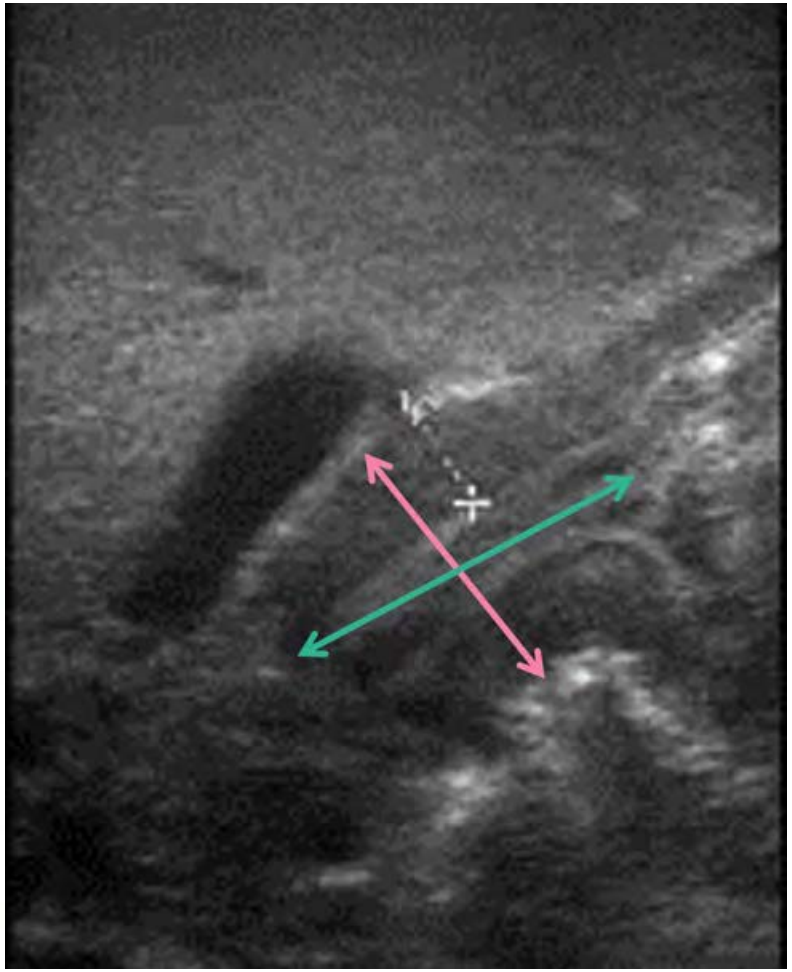
◀ **Congenital diaphragmatic hernia** with hypoplasia of the left lung, bubbly appearance of air-filled bowel loops into the chest (*) and shift of the mediastinum to the right. Diaphragmatic defects in CDH are usually posterior and left-sided, requiring surgical repair. Prognosis is influenced by the degree of pulmonary hypoplasia. Note the tips of UAC (arrow) and UVC (arrowhead).

Chapter Outline

Disorders in Children
Hypertrophic Pyloric Stenosis (HPS)

- Hypertrophy of circular muscle causing gastric outlet obstruction.
- The aetiology is uncertain.
- Risk factors: male 4:1, first born and positive family history, 13%.
- Symptoms: projectile non-bilious vomiting at 2-12 weeks of age, palpable "olive" at epigastrium, visible gastric hyperperistalsis. In late stages, electrolyte imbalance and weight loss/emaciation.
- Imaging method of choice: ultrasound before and during feeding.
- US findings: thickness of the muscle > 3 mm (between cursors shown in this longitudinal US view of the pylorus) and lack of passage of gastric contents through the pylorus typifies HPS making the diagnosis. A distended stomach in a vomiting unfed child is an indirect sign of delayed gastric emptying.
- Additional findings (coloured arrows seen on the adjacent US image): **Antero-posterior pyloric diameter** > 15 mm, **elongated channel (pyloric canal)** >18 mm.
- Pitfalls: pylorospasm (transient abnormal appearance, important for the US operator to wait for the pyloric muscle to relax and look again).
- Treatment: surgery with Haller's pyloromyotomy.

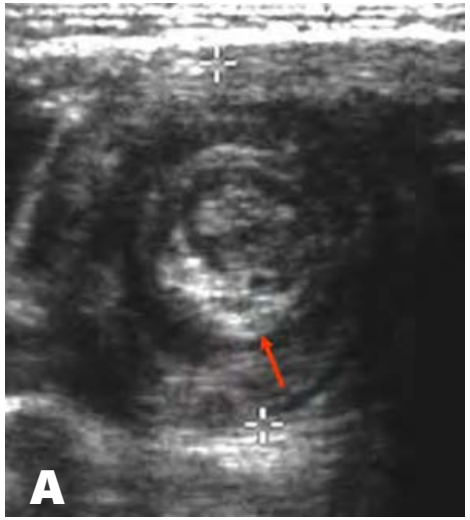


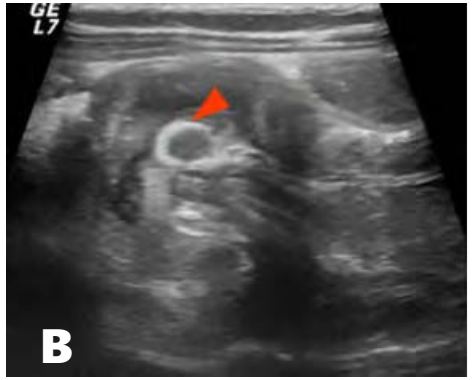


Chapter Outline

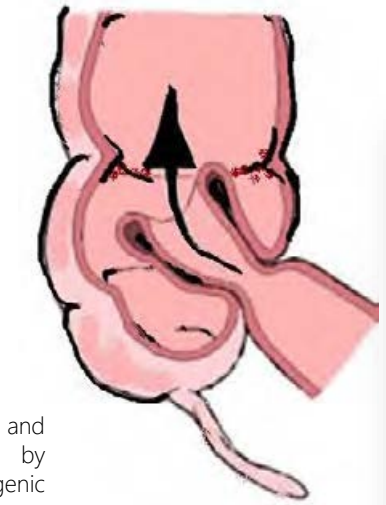
Disorders in Children
Intussusception

- This is a common condition seen in young children, usually between 5-9 months (with range between, 3 months and 3 years).
- The majority are idiopathic (90%) and preceded by viral infection. The commonest subtype is ileo-colic intussusception.
- Secondary intussusception due to pathological lead points, including Meckel's diverticulum, lymphoma, duplication cyst, polyp, and haematoma should be excluded in children younger than 2 months and older than 3-4 years of age.
- Traditionally children present with irritability, abdominal pain, pulling the legs up to the abdomen and 'red currant jelly' type stools. Since many children present with non-specific symptoms, this diagnosis **must be excluded** in acute abdominal pain in certain age groups.
- There is a risk of bowel infarction if not managed quickly by prompt reduction. If this cannot be managed radiologically the child may need surgical reduction.
- Emergency US establishes the diagnosis by showing a target sign, typically in the right side of the abdomen. Abdominal radiographs are subsequently not indicated but if performed, they may demonstrate a soft tissue density, relative paucity of gas within the right abdomen and possibly upstream small bowel obstruction.
- Radiological management is undertaken by reduction that can be done by an air enema or a fluid enema, under fluoroscopy or ultrasound guidance – this depends on local expertise and availability. Recurrent post reduction may occur. The main risk of the reduction procedure is perforation (low in expert hands).





US scan showing intussusception. Transverse (A) and oblique/longitudinal (B) views reveal the "donut" formed by concentric rings of oedematous bowel. Note a trapped echogenic crescent of fat (arrow) and a trapped lymph node (arrowhead).



▶ Red currant jelly

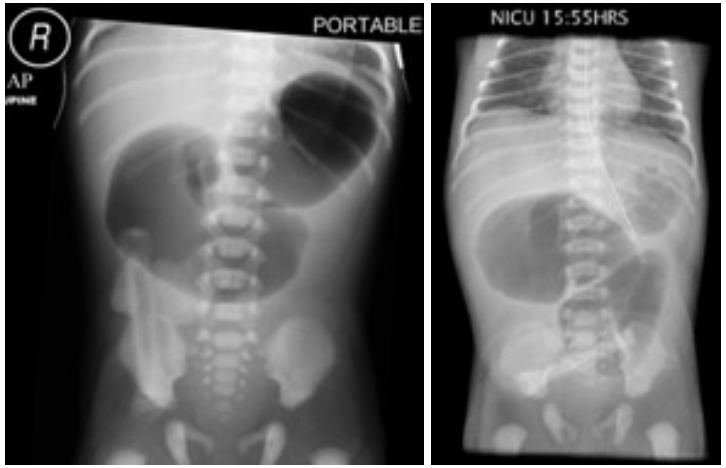
Chapter Outline

Disorders in Children
Neonatal Proximal GI Obstruction

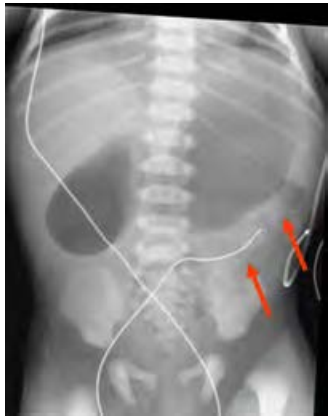
- Obstruction of the gastrointestinal (GI) tract in neonates can be detected antenatally with abnormally distended loops of bowel on foetal US/MRI or postnatally in babies who do not follow the normal feeding expectations, e.g., they aspirate and vomit or fail to pass meconium.
- A plain radiograph is the initial imaging test. Normally, gas fills the stomach and proximal small bowel by 6 hours, the entire small bowel by 12 hours and reaches the rectum by 24 hours.
- Radiographs help neonatologists decide if an obstruction is present, where it is likely to be, give a differential and guide what to do next....
- It is difficult to differentiate small and large bowel on radiographs of small children and dilated loops differentiate "upper" vs. "lower" obstruction.
- Upper obstruction is commonly due to an atresia (complete congenital occlusion) or a stenosis (fixed narrowing) in the proximal bowel (most commonly involving the duodenum, jejunum and less so the stomach outlet in that order)
- In congenital upper obstruction radiographs demonstrate a limited number of significantly distended loops of bowel (depending on which of the above segments are involved), usually less than four.
- If no gas is seen beyond these dilated loops of bowel then an atresia is likely. If some distal gas is appreciated, then a stenosis is more likely.
- When appearances are those of complete obstruction then the surgical team often proceeds directly to the operating room without requiring further imaging. If appearances are not classical and the course is uncertain, an upper GI study may be performed.

Differential diagnosis for the "double bubble" with distal gas:

- Duodenal stenosis
- Duodenal web
- Annular pancreas
- Preduodenal portal vein
- Ladd's bands in malrotation (see specific slide on malrotation)



Plain films in 2 neonates demonstrating abnormal dilated loops of bowel with no distal bowel gas compatible with atresia – the baby on the left has a 'double bubble sign ' and duodenal atresia was confirmed at surgery. The neonate on the right demonstrates a triple bubble and jejunal atresia was found at surgery.



◀ Similar scenario with a proximal obstruction in a neonate with a dilated stomach and duodenum. In this case distal gas can be appreciated (arrows). This is secondary to incomplete obstruction from a duodenal stenosis.

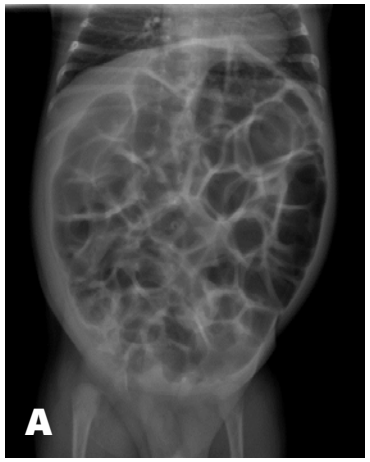
- Berrocal et al. GI emergencies in the Neonate. Chapter in: Radiological imaging of the digestive tract in infants and children. 2nd edition. (2016)
- Stafrace & Blickman Editors Springer publishers

Chapter Outline

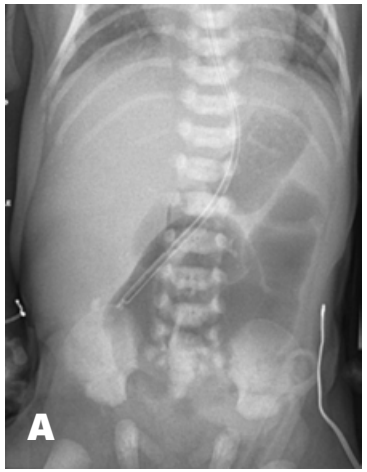
Disorders in Children
Neonatal Obstruction - Distal Obstruction

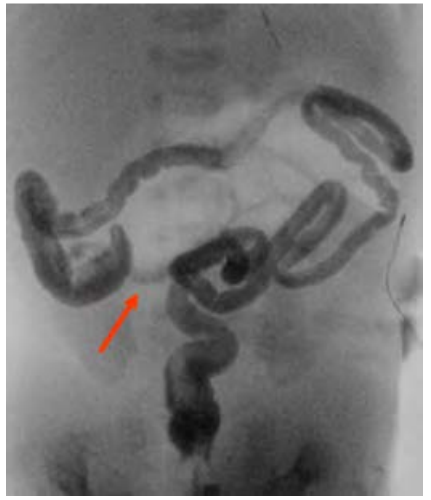
- Obstruction that involves the bowel from the **distal** ileum onwards is referred to as distal obstruction
- In simple terms, this means that there are too many dilated loops of bowel to count on the radiograph!
- Obstruction can again be due to atresia or stenosis of the distal bowel (more commonly the ileum). Other considerations include:
- Inspissated abnormal meconium causing obstruction in the distal small bowel termed '**meconium ileus**'; the latter is a presentation of **cystic fibrosis**.
- Congenital anorectal malformations (ARM).
- Abnormalities with the innervation of the bowel resulting in abnormal or absent peristalsis, i.e., Hirschsprung disease.
- Functional immaturity of the colon.
- In neonates with a distended abdomen, delayed passage of meconium and distal obstruction on radiographs, anal atresia should be excluded clinically first which will allow a fluoroscopic retrograde contrast enema to be performed. In some centres, this is replaced or preceded by an ultrasound-guided saline enema.
- In the above scenario, the enema is diagnostic but may also be therapeutic, e.g., in meconium ileus and functional immaturity of the colon.

When neonates undergo an enema investigation or any fluoroscopic investigation, care must be taken to keep them warm. Neonates get cold very quickly!



◀ First abdominal radiograph (A) of a neonate with delayed passage of meconium, demonstrating multiple dilated gas-filled loops of bowel in all four quadrants; these appearances are not specific but are sufficient to identify distal obstruction.





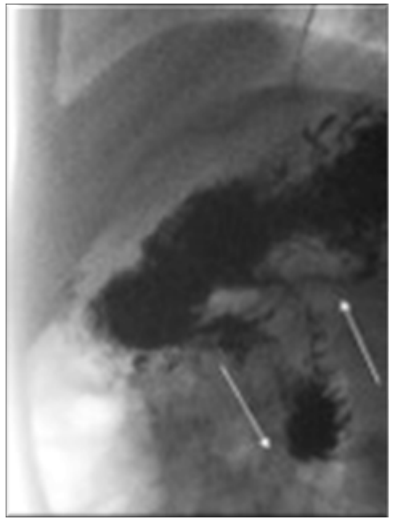
Neonate with abdominal distension and failure to pass meconium. The abdominal radiograph (left image) demonstrates multiple dilated bowel loops consistent with distal obstruction. The enema (fluoroscopic image on the right) demonstrates a 'microcolon/unused colon' of small calibre. Some contrast also retrogradely fills collapsed distal small bowel (red arrow) with dilated gas-filled bowel more proximally. The diagnosis was ileal atresia.

Berrocal et al. GI emergencies in the Neonate. Chapter in Radiological imaging of the digestive tract in infants and children. Stafrace & Blickman Editors. 2nd edition (2016) Springer publishers

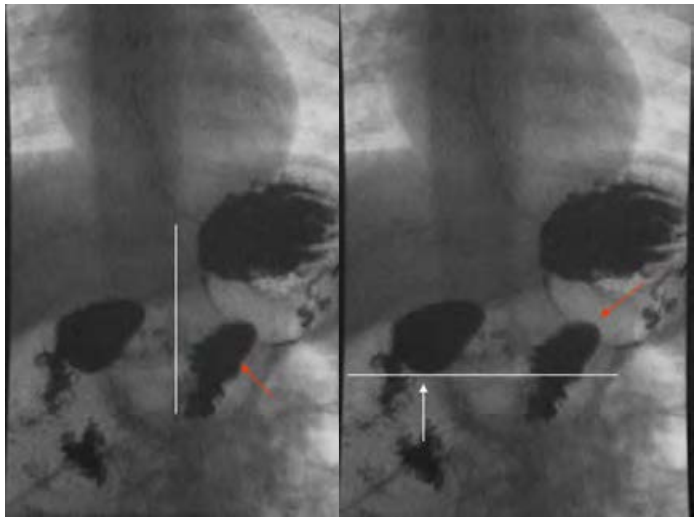
Chapter Outline

Disorders in Children
Malrotation - Midgut Volvulus

- Normal rotation and fixation of the bowel results in a long mesentery between the duodenal-jejunal (DJ) flexure in the left upper quadrant and the caecum in the right lower quadrant of the abdomen.
- When this developmental process is abnormal, the mesentery is short, and the bowel is prone to twisting on itself around the mesenteric vessels causing acute obstruction and potentially fatal bowel ischaemia.
- Congenital bowel obstruction may also result from abnormal peritoneal bands (Ladd's bands) that cross over the duodenum.
- Malrotation can present at any age and is a **clinical emergency**.
- Infants with malrotation and volvulus present early in life, classically with bilious (green) vomiting (90% in the first 3 months).
- An emergency, targeted ultrasound may demonstrate the "whirlpool sign" of small bowel and mesentery with swirling vessels wrapped around the superior mesenteric artery. If US is inconclusive, an upper GI contrast study, the gold standard examination, **must** be done which evaluates the position of the DJ flexure and assesses for secondary volvulus.
- On a fluoroscopic AP image, the DJ flexure should be positioned to the left of the adjacent vertebral pedicle, with its upper aspect at least at the level of the lower margin of the pylorus.
- On a lateral fluoroscopic image, the 2nd, 3rd and 4rth part of the duodenum are situated retroperitoneally, with the 3rd part more caudally and posteriorly to the 2nd and 4rth parts.

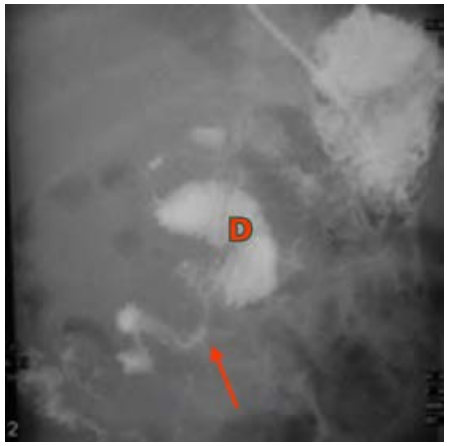


▲ Normal retroperitoneal course of the duodenum on the lateral projection which proceeds posteriorly before descending.



▲ Normal position of the DJ flexure (red arrows) on the AP fluoroscopic images from an upper GI examination which lies to the left of the left pedicles (vertical line) and above the lower margin of the pylorus (horizontal line).

- When malrotation is complicated with volvulus the DJ flexure is abnormally positioned and a "corkscrew sign" is classically demonstrated. Alternatively, there may be a complete cut off at the level of the 2nd part of the duodenum.

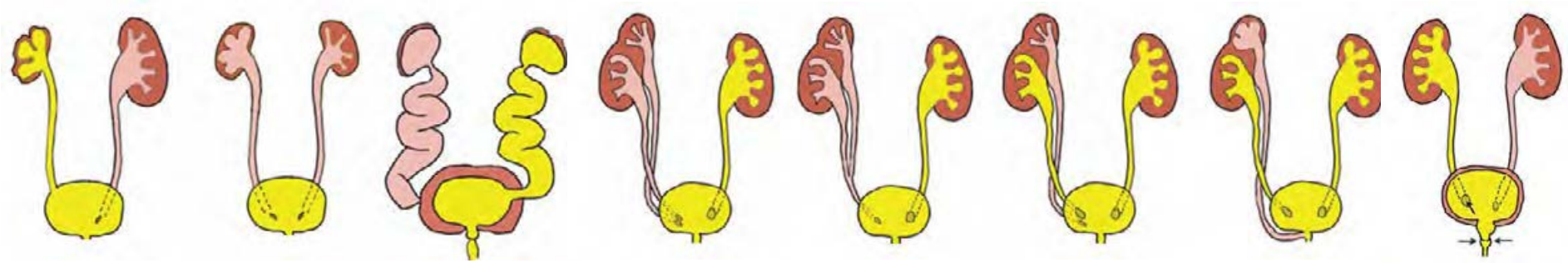


◀ Classical malrotation and volvulus with dilated proximal duodenum (D) leading to the "corkscrew sign" (red arrow).

Chapter Outline

Disorders in Children
Congenital Anomalies of Kidney and Urinary Tract (CAKUT)

- These result from failure of the normal development of nephrons and the urinary collecting system (nephropathy and uropathy):
  - **Malformation of the renal parenchyma**: renal agenesis, renal dysplasia, multicystic dysplasia.
  - **Abnormalities of embryonic migration of the kidneys**: renal ectopia, fusion anomalies (horseshoe kidney).
  - **Abnormalities of the developing urinary collecting system**: duplicate collecting systems, posterior urethral valves (PUV), pelvi-ureteric junction obstruction (PUJO), vesico-ureteric junction (VUJ) obstruction.
- Most may be accompanied by vesicoureteral reflux (VUR) and predispose to urinary tract infection (UTI).
- Most CAKUT manifest with some degree of dilatation of the collecting system and/or ureter with or without parenchymal anomalies.
- Dilatation and gross reflux that result in deterioration of renal function are treated operatively and with endoscopic sclerotherapy.



Reflux nephropathy | Dysplasia | Hypoplasia Obstruction VUR | Duplex systems, variable ureteric insertions and ureterocele | PUV with VUR

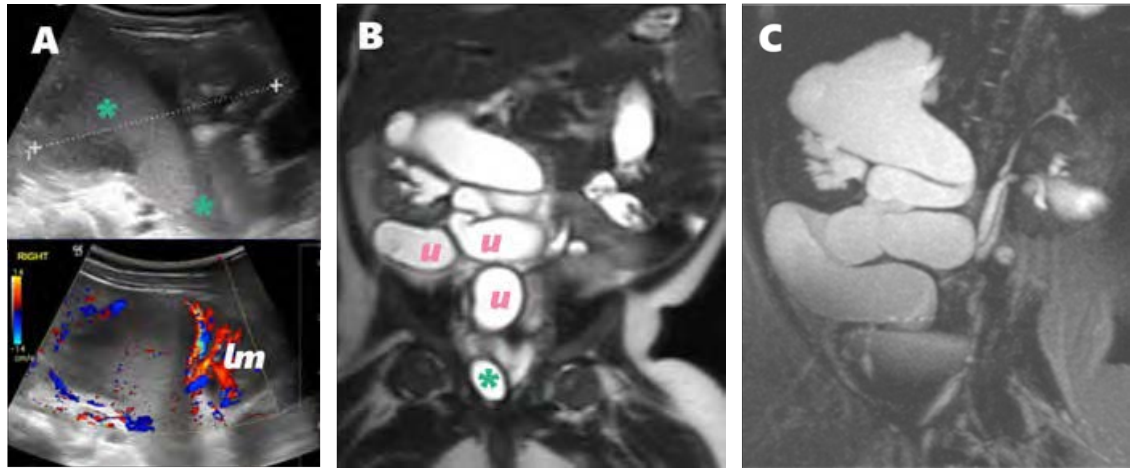
Images above modified from Dr. Pieter Dik, paediatric urologist, UMC Utrecht

Chapter Outline

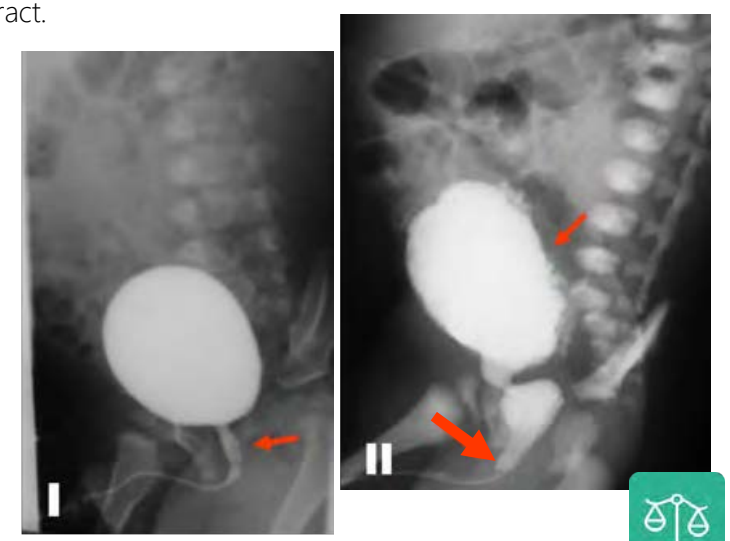
Disorders in Children

Congenital Anomalies of Kidney and Urinary Tract (CAKUT)

- US of bladder, ureters, kidneys on a well hydrated child, with emphasis on parenchyma, and excretory system (measurements of anteroposterior diameter of pelvis, ureters, pre and post void) is used for antenatal and postnatal diagnosis and follow-up.
- Micturating cystourethrography (MCUG) is used for the diagnosis of VUR and PUV by retrograde instillation of contrast into the bladder via a catheter, with images obtained during filling and voiding using fluoroscopy, US or scintigraphy.
- Morphological and functional images, including split renal function, can be performed by MR urography.
- Functional images and split renal function can also be obtained by renography.
- Intravenous urography has no routine place in imaging of the paediatric renal tract.



A. Longitudinal US scan of the right kidney in a febrile child with urinary tract infection. The lower renal moiety is normal and well-perfused (lm). The upper renal moiety exhibits parenchymal thinning and gross dilatation of pelvis and ureter with echogenic content suggestive of pyonephrosis (*).
B. MRI coronal T2-w sequence shows tortuous upper moiety ureter (u) ending in an ectopic position (*).
C. MRI multiplanar reconstruction oblique coronal plane demonstrates a dilated duplex system on the right and an uncomplicated duplex system on the left.



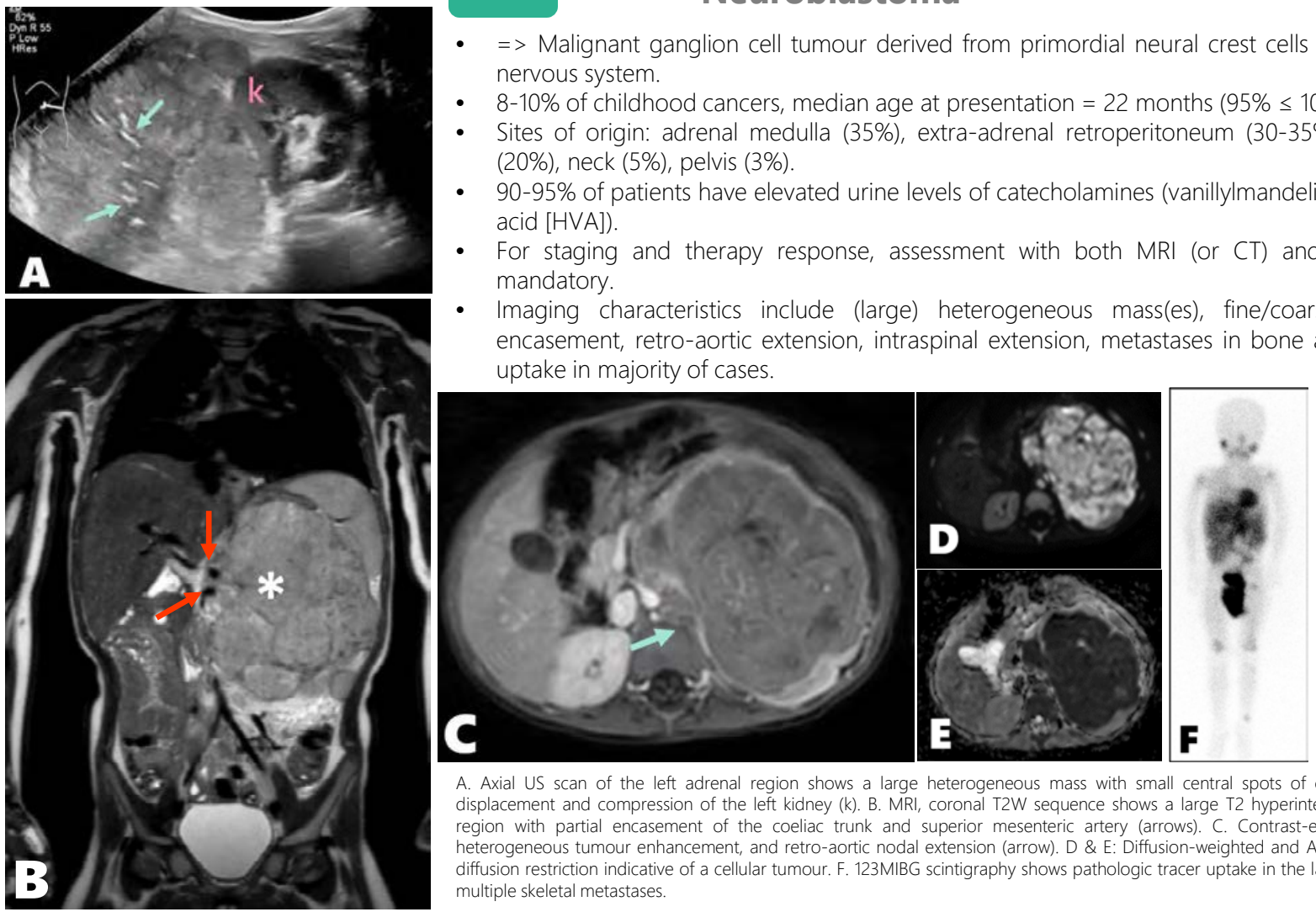
Compare the MCUG images during micturition of contrast in a normal male (I) and male with posterior urethral valves (II). Normally the bladder is smooth, and the posterior urethra (arrow) is slightly wider than the anterior urethra (I). In (II), there is a trabeculated bladder (arrow) and a dilated posterior urethra with a thin shelf-like filling defect (thick arrow) at the site of posterior urethral valves (PUV).

Chapter Outline

Disorders in Children

Neuroblastoma

- => Malignant ganglion cell tumour derived from primordial neural crest cells that form the sympathetic nervous system.
- 8-10% of childhood cancers, median age at presentation = 22 months (95% ≤ 10 y).
- Sites of origin: adrenal medulla (35%), extra-adrenal retroperitoneum (30-35%), posterior mediastinum (20%), neck (5%), pelvis (3%).
- 90-95% of patients have elevated urine levels of catecholamines (vanillylmandelic acid [VMA], homovanillic acid [HVA]).
- For staging and therapy response, assessment with both MRI (or CT) and 123MIBG scintigraphy is mandatory.
- Imaging characteristics include (large) heterogeneous mass(es), fine/coarse calcifications, vascular encasement, retro-aortic extension, intraspinal extension, metastases in bone and liver with MIBG tracer uptake in majority of cases.

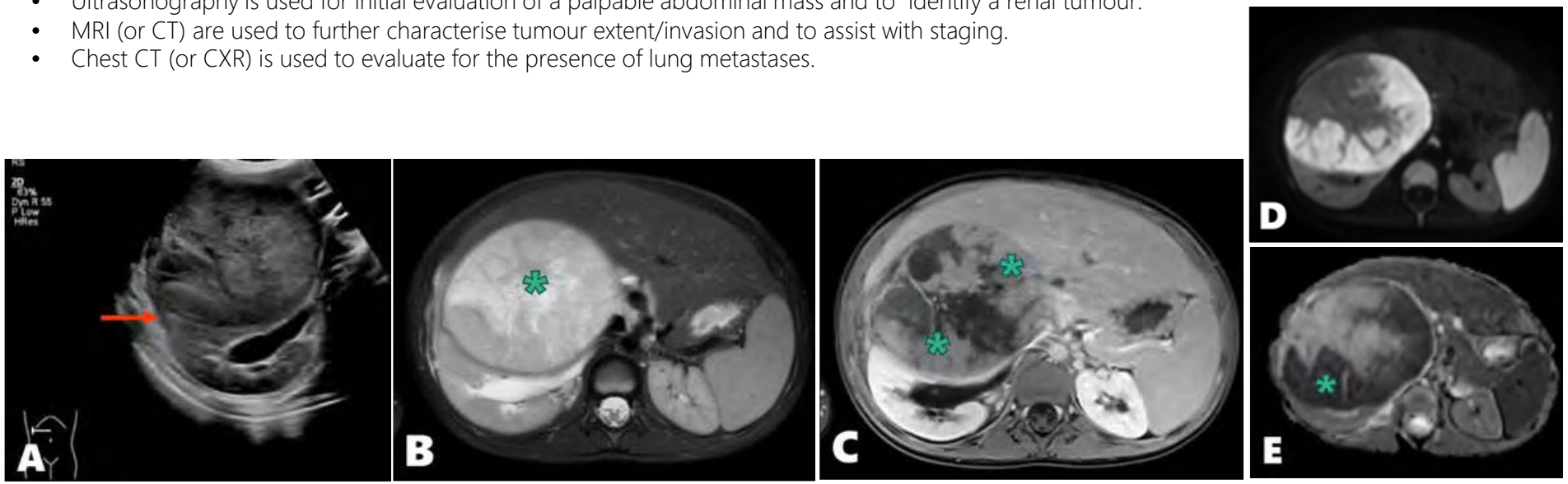


A. Axial US scan of the left adrenal region shows a large heterogeneous mass with small central spots of calcifications (arrows). There is displacement and compression of the left kidney (k). B. MRI, coronal T2W sequence shows a large T2 hyperintense mass (*) in the left adrenal region with partial encasement of the coeliac trunk and superior mesenteric artery (arrows). C. Contrast-enhanced T1W sequence shows heterogeneous tumour enhancement, and retro-aortic nodal extension (arrow). D & E: Diffusion-weighted and ADC map images show extensive diffusion restriction indicative of a cellular tumour. F. 123MIBG scintigraphy shows pathologic tracer uptake in the large retroperitoneal mass and in multiple skeletal metastases.

Chapter Outline

Disorders in children
Wilms Tumour (Nephroblastoma)

- Most common renal malignancy in children with peak incidence at 3 years of age (80%, 1-5 years of age).
- Usually asymptomatic but the patient may present with a palpable abdominal mass.
- It can be bilateral (5%), may be associated with overgrowth disorders (e.g., Beckwith-Wiedemann syndrome) and other genetic disorders (e.g., DICER1 mutations).
- Imaging characteristics include large (usually well-defined) mass, "claw sign" from the involved kidney, solid-cystic components with either homogeneous or heterogeneous enhancement (indicating haemorrhage, and/or necrosis), diffusion restriction of solid parts (increased signal at DWI, reduced ADC values), invasion of the renal vein and inferior vena cava, lymph node involvement, lung metastases (20%), and liver metastases.
- Ultrasonography is used for initial evaluation of a palpable abdominal mass and to identify a renal tumour.
- MRI (or CT) are used to further characterise tumour extent/invasion and to assist with staging.
- Chest CT (or CXR) is used to evaluate for the presence of lung metastases.

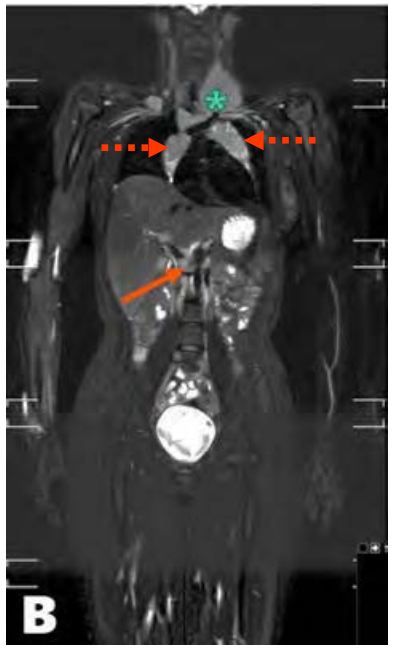


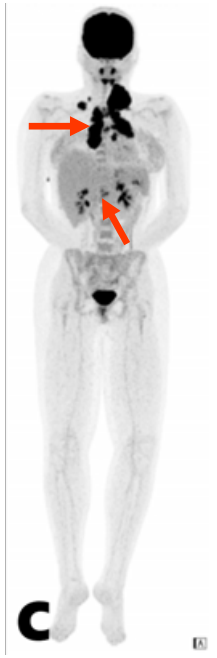
A. Axial US image of the right kidney shows a large slightly heterogeneous mass with a neighbouring "beak" of kidney (arrow) indicating intrarenal origin.
B. MRI axial T2W sequence shows a large hyperintense mass (*) in the right abdomen, arising from the right kidney.
C. Axial contrast-enhanced T1W sequence shows heterogeneous enhancement (*).
D and E. Diffusion-weighted images show extensive diffusion restriction in the solid enhancing parts of the mass (*) arising from the right kidney

Chapter Outline

Disorders in Children
Lymphoma

- Lymphoreticular malignancy: third most common malignancy in children (most common malignancy in adolescents).
- Main groups: Hodgkin Lymphoma (HL), Non-Hodgkin Lymphoma (NHL), Post-Transplant Lymphoproliferative Disease (PTLD):
- HL: teenagers/adolescents, 4 histological subtypes, >90% survival, cervical/mediastinal masses (75-80%).
- NHL: younger age group, >40 histological subtypes, survival variable, abdominal presentation (>50%).
- Staging mainly based on disease involvement above/below diaphragm and presence/absence of extranodal involvement:
- HL: Ann Arbor/Cotswold (1989) or Lugano classification (2014).
- NHL: St. Jude/Murphy (1980) or IPNHLSS (2015).
- Imaging characteristics include lymphadenopathy anywhere in the body, splenic involvement (diffuse/focal), extranodal involvement (most commonly lungs, liver, kidneys, gastrointestinal tract and bone marrow).
- Ultrasonography and CXR are often the first line modalities utilised at presentation/diagnosis.
- MRI (or CT) and/or 18FDG-PET are mandatory for staging and therapy response assessment (depending on subtype).





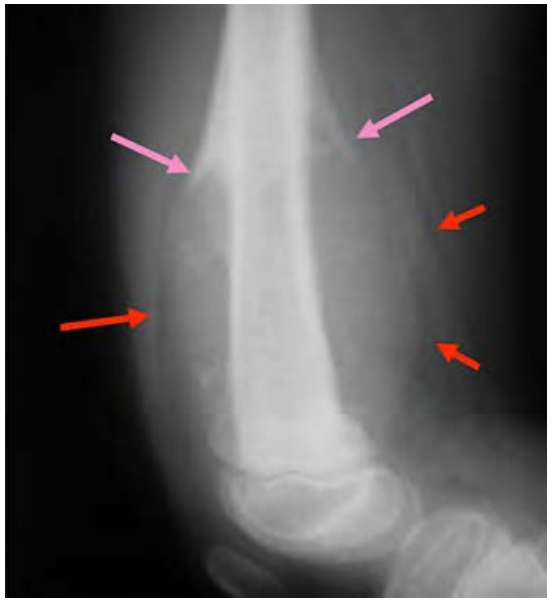
A. Axial US scan of the left cervical region shows enlarged hypoechoic lymph nodes (*) in the left cervical region in a patient with Hodgkin lymphoma.
B. MRI coronal T2W STIR sequence shows bulky hyperintense lymphadenopathy in the lower cervical region (*) on both sides as well as in the mediastinum (dashed arrows). Smaller pathologic lymph nodes are seen in the porta hepatis below the diaphragm (arrow).
C. 18FDG-PET scan shows extensive tracer uptake in the cervical lymph node masses on both sides of the diaphragm, i.e., in the mediastinum and in the porta hepatis and splenic hilum (arrows).

Chapter Outline

Disorders in Children

Osteosarcoma

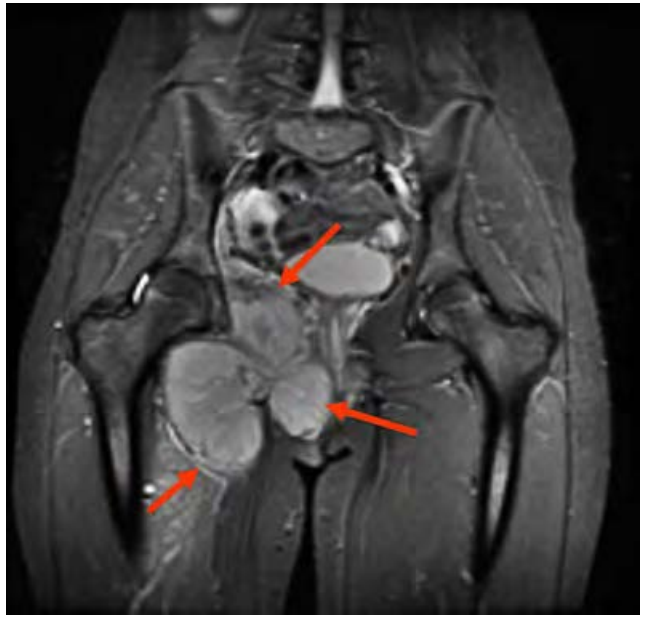
- Accounts for 20% of all bone tumours.
- Typically in patients under the age of 20 years (usually at puberty).
- Presents with bone pain, soft tissue mass and swelling or with a (pathological) fracture through the lesion.
- Mostly located at the metaphysis of femur or tibia.
- On imaging, it is associated with bone destruction, aggressive periosteal reaction and a soft tissue mass.
- Osteosarcomas commonly metastasize to the lungs and adjacent bones.
- Curative treatment requires aggressive resection of the lesion (amputation or limb-salvage excision) with chemotherapy.



◀ This lateral radiograph of the distal femur in a child with osteosarcoma demonstrates the aggressive periosteal reaction of the bone (pink arrows) and soft tissue swelling (orange arrows) representing the mass associated with this aggressive tumour.

Ewing Sarcoma

- Second most common malignant bone tumour in children (after osteosarcoma).
- Typically in children aged 10-20 years old, on average, slightly younger than osteosarcoma.
- Presenting symptoms and signs include pain, soft tissue mass, fracture and sometimes fever.
- Commonly located in the lower limbs or pelvis.
- On imaging they appear destructive, aggressive with a soft tissue mass.
- They can also metastasize to lung and other bones.
- Chemotherapy +/- surgery and radiotherapy are used for treatment.

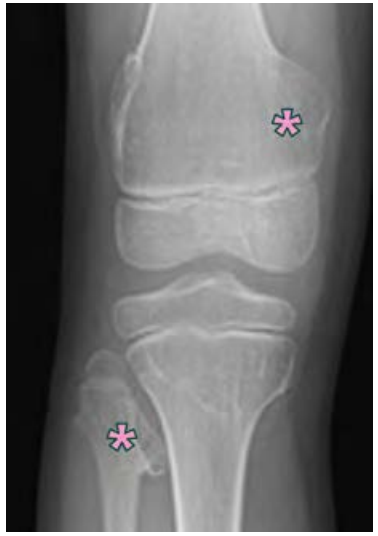


◀ In this contrast enhanced MRI of the pelvis in a 13-year-old boy, a large mass (arrows) is seen cantered over the right pubic bone and iliac crest. This was found to be Ewing sarcoma.

Chapter Outline

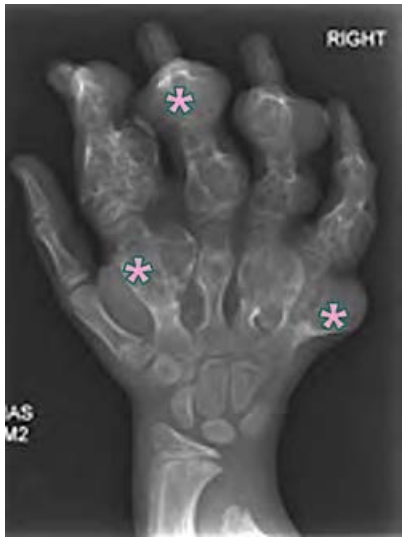
Disorders in Children

Benign bone lesions can sometimes look aggressive; however, knowledge of these and how they present on imaging can be very useful as the diagnosis does not usually require a biopsy or excision unless for cosmetic or functional reasons. They are therefore known as "**do not touch**" lesions. Whilst many benign bone lesions exist, a few have been included here to demonstrate their varied appearances.



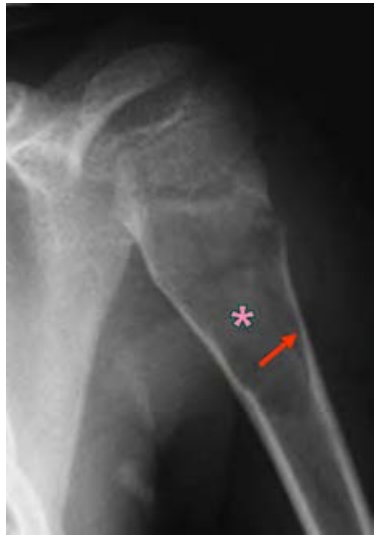
Exostoses (Osteochondromas)

These are benign outgrowths of bone (*) covered by a cartilaginous cap. They can be solitary or multiple and part of an underlying syndrome. They are mostly asymptomatic. They become of occasional significance when they fracture, cause pain or nerve/adjacent bone compression. Malignant transformation may occur, mainly after the age of 20 and is suspected if they enlarge and become painful.



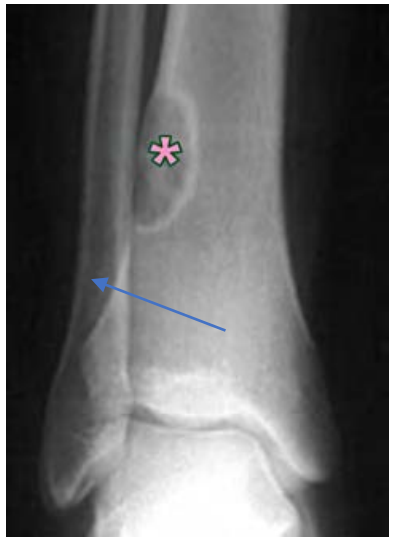
Enchondromas

Benign cartilaginous tumours (*), peak incidence at 10-30 years of age. Usually an incidental finding, do not require treatment but can predispose to fractures. Commonly seen at hands and feet. Typical sharply demarcated lesions with cartilaginous stroma (rings and arches).



Bone cysts

These are fluid-filled cavities, usually incidental and asymptomatic. They can cause focal weakness, making the bone prone to pathological fracture. Commonly seen at the meta-diaphyseal proximal humerus and other long bones, causing radio-lucent lesions (*) with internal cortical scalloping (arrow).



Fibrous Cortical Defects (FCD) Non-ossifying Fibroma (NOF)

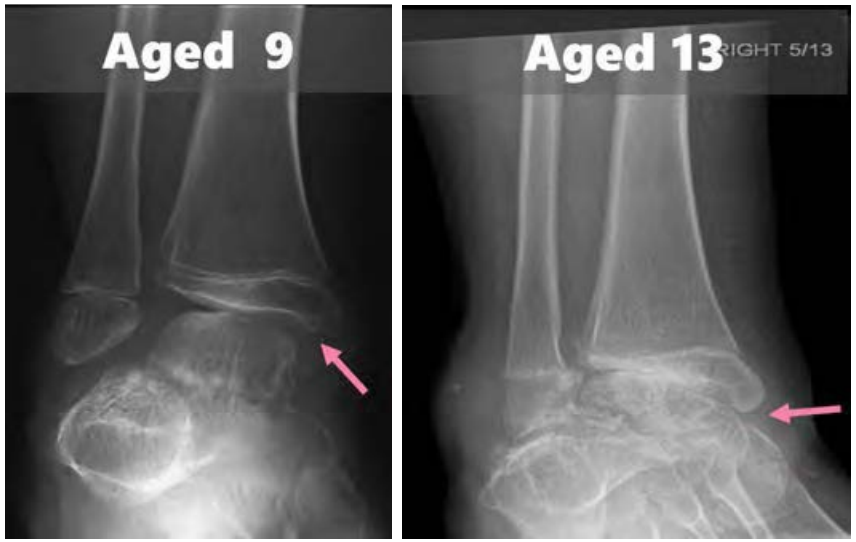
Both lesions are similar in histology; however, those measuring >3cm are referred to as NOFs. They predispose to bone fractures, are common in children 2-15 years and normally heal spontaneously. Usually asymptomatic, they cause cortical lucency (*) with sharp and sclerotic (during healing) borders.

Chapter Outline

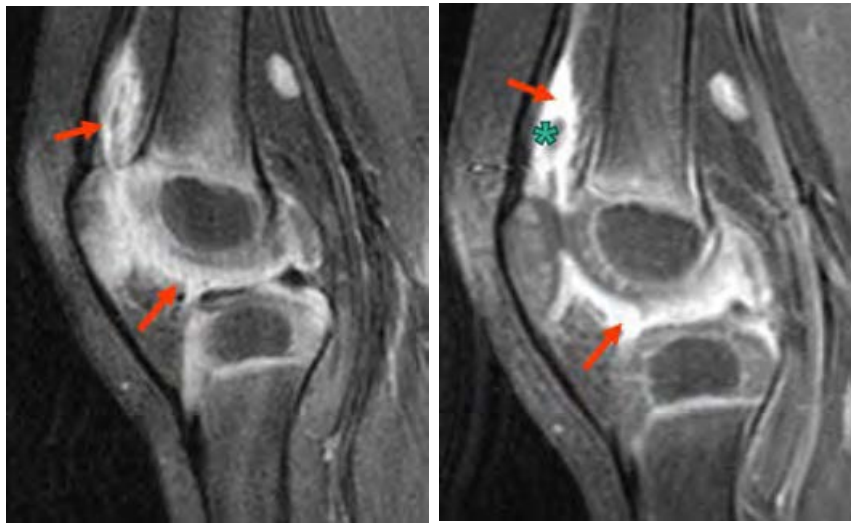
Disorders in Children

Juvenile Idiopathic Arthritis (JIA)

- Autoimmune disease of unknown origin, characterized by joint swelling and synovial inflammation.
- Onset < 16 years, lasting for > 6 weeks.
- Classified into 7 subtypes according to ILAR; of which the oligoarticular form (up to 4 joints), is the most common.
- Diagnosis is based on history, clinical examination and laboratory tests, in addition to imaging findings.
- Radiographs of the joints are taken to exclude other causes (e.g. developmental issues, bone tumours etc.).
- Typical imaging findings include effusion/synovial thickening with increased contrast enhancement (US, MRI) and later growth abnormalities / destructive changes (XR).
- Anti-inflammatory medication, corticosteroids (including joint injections), disease modifying drugs (e.g. methotrexate) and 'biologic agents' (e.g. infliximab) can be helpful in slowing down the destructive process.



In these radiographs over 4 years, a young girl with JIA affecting her ankle shows progressive loss of joint space height (pink arrows) and destructive change, leading to leg length discrepancy and long-term disability – highlighting the importance of early treatment and follow-up

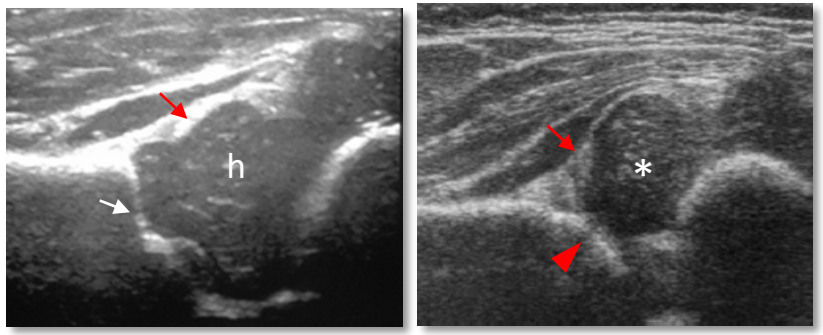


MRI scan of a 2-year-old female with a joint swelling over 7 weeks. T2W sequence with fat saturation (left) shows increased signal intensity at the area of the joint (arrows). Post-contrast T1W sequence with fat saturation (right) shows synovial inflammation as enhancement of thickened synovium (arrows) with a small effusion (*).

Chapter Outline

Disorders in Children
Developmental Dysplasia of the Hip (DDH)

- Most common musculoskeletal disorder in children, with a reported prevalence of 1-3% in new-borns, according to definitions and method of ascertainment used. Around 1-3 per 1000 children is detected at a late stage (after one month of age).
- In new-borns, the dysplastic hip is characterized by a steep acetabulum with or without an unstable/dislocatable/dislocated femoral head. Clinical diagnosis with the Barlow/Ortolani tests in new-borns has poor sensitivity and specificity, thus, universal or selective screening (of the "at risk" group, including a significant family history of DDH, breech delivery, oligohydramnios, high birth weight) has been introduced (for details/recommendations, see www.espr.org, MSK task force).
- Ultrasound in the new-born period reveals that 84% of the babies have normal hips, of which 0.1% are dislocatable; 13% have immature (0.6% dislocatable), 2.4% have mildly dysplastic (60% dislocatable/dislocated) and 0.7% have severely dysplastic hips (100% dislocatable/dislocated) – see below.
- In children over the age of 4.5 months, radiography, with measurement of the acetabular index (AI) (a) remains the imaging modality of choice. Based on the AI, and the standards by Tönnis and Brunken, the hips are classified as normal (b), acetabular ossification delay (c) or dysplastic (d).

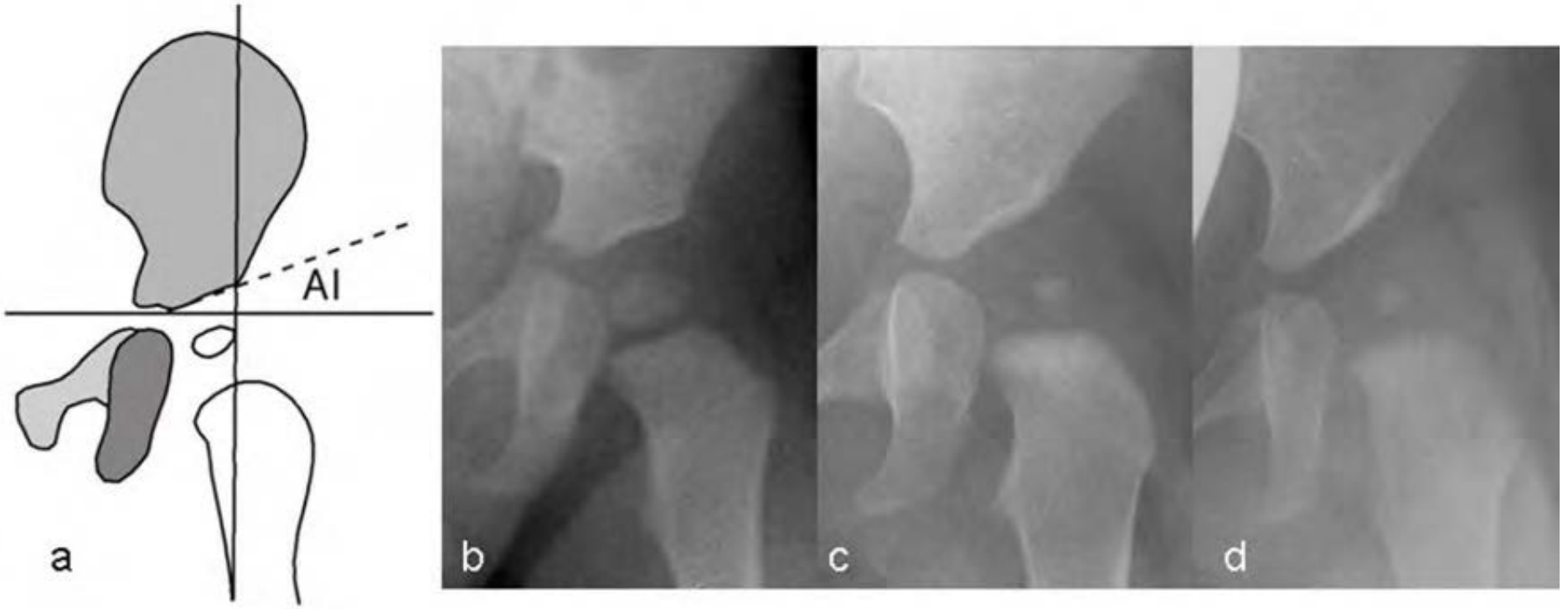


Left: Ultrasound image of a normal neonatal hip, shows the cartilaginous femoral head (h) covered by the labrum (red arrow) and by the deep bony roof of the acetabulum (white arrow). Right: Ultrasound image of a de-centered dysplastic hip shows lateralization of the femoral head (*), incomplete coverage by the superiorly displaced labrum (arrow) and incomplete coverage by the shallow bony roof (arrowhead).

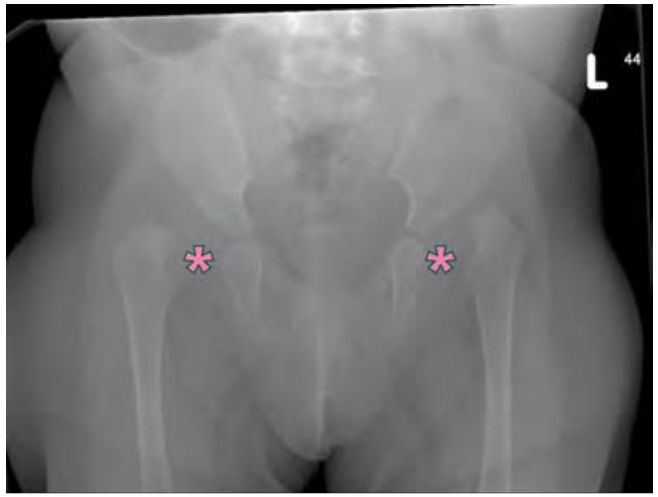
Rosendahl K, Markestad T, Lie RT. Developmental dysplasia of the hip: prevalence based on ultrasound diagnosis. Pediatr Radiol 1996;26:635-9.

Chapter Outline

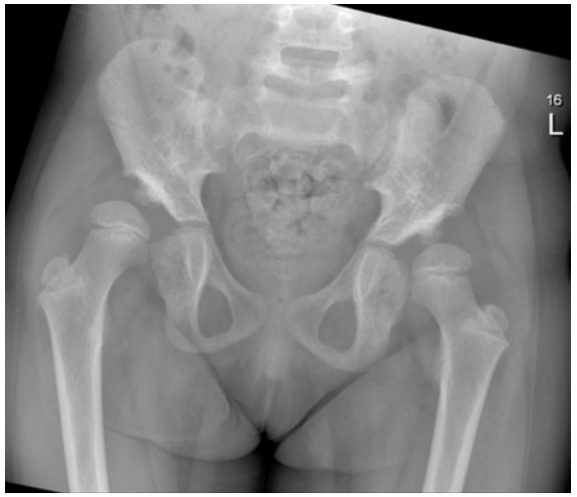
In children over the age of 4.5 months, radiography, with measurement of the acetabular index (AI) (a) remains the imaging modality of choice. Based on the AI, and the standards by Tönnis and Brunken, the hips are classified as normal (b), acetabular ossification delay (c) or dysplastic (d).



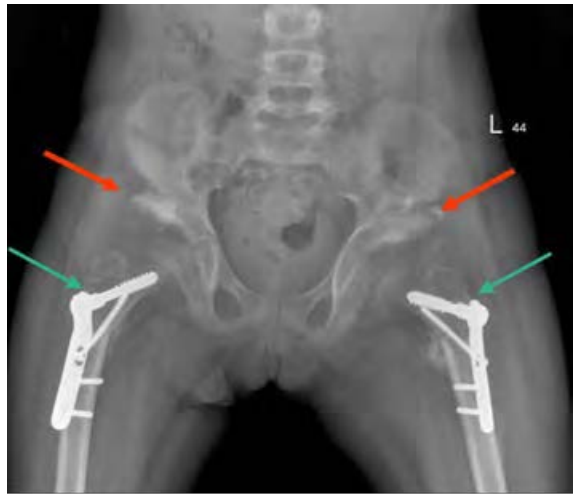
Tönnis D, Brunken D. Eine Abgrenzung normaler und pathologischer Hüftpfannendachwinkel zur Diagnose der Hüftdysplasie. Arch Orthop Trauma Surg 1968;64:197-228.



Aged 9 months



Aged 4 years



Aged 6 years

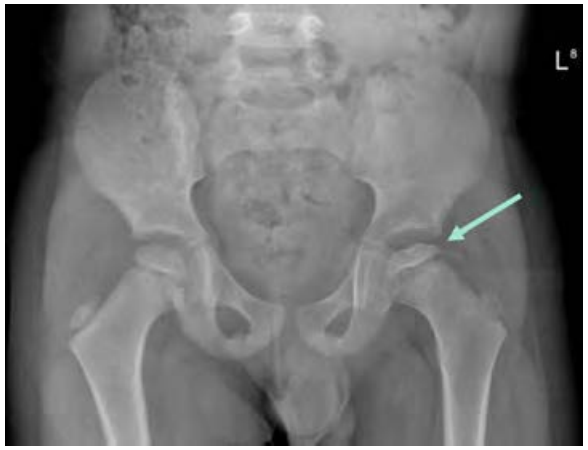
Severe DDH in a female, diagnosed at 9 months of age (first radiograph) with follow-up radiographs at 4 and 6 years of age. At 9 months, there are dysplastic acetabulae, and both proximal femora (unossified) are dislocated. The location within the joint at where they should have been cantered is marked with asterisks. At 4 years of age, both acetabulae are still severely dysplastic, and the femoral heads are subluxed. By 6 years of age the patient has undergone surgical correction with periacetabular osteotomies (orange arrow) to correct the acetabular angles, and relocation of both proximal femurs to restore containment and normal joint alignment.

Chapter Outline

Disorders in Children

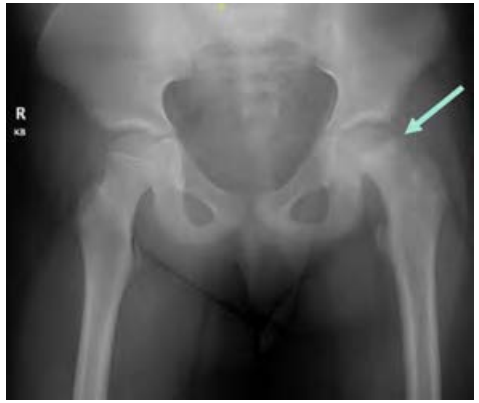
Perthes Disease

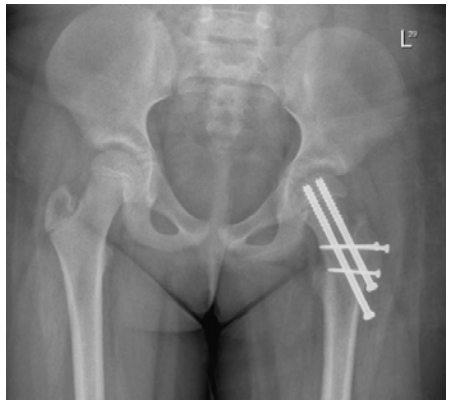
- This is an idiopathic osteonecrosis of the femoral epiphysis, most common in children 5-6 years old and which is more likely to occur in boys > girls.
- The femoral heads become radiographically sclerotic, collapsed (arrow), and fragmented with occasional metaphyseal changes. Radiographic findings might be delayed for up to 2-3 months. In these cases, MRI may be helpful.
- US may show fluid and deformity at later stages. MRI accurately depicts changes and joint congruity.
- Blood tests are typically normal.
- Alternative differential diagnoses need to be considered before assigning the diagnosis of Perthes (e.g., irritable hip, sickle cell, leukaemia, steroid administration).
- Treatment is largely supportive (self-limiting condition) but operative management may be undertaken for limb length discrepancies and to correct any structural abnormalities.



Slipped Upper Femoral Epiphysis, SUFE

- One of the commonest hip abnormalities in adolescents and is bilateral in 20% cases.
- The proximal femoral epiphysis 'slips' off the metaphysis due to repeated trauma and a background of mechanical/hormonal predisposing factors (e.g., obesity). (Image below left, white arrow)
- It is classified as a 'Salter Harris type 1' injury (see fracture section later).
- Surgical pinning (below, right image) is commonly used to fix the slipped femoral epiphysis in place.
- Sometimes prophylactic pinning of the other hip is also done given that asynchronous bilateral disease is relatively common.





Chapter Outline

Disorders in Children

- Musculoskeletal injuries are common in children.
- They account for 15-20% of emergency department presentations.

Fracture patterns:

- Complete fracture: spiral, transverse or oblique.
- Plastic deformity (bowing fractures).
- Buckle fractures.
- Greenstick fractures.
- Physeal fractures.
- Apohyseal avulsion injuries.

The mechanism varies depends on the child's age

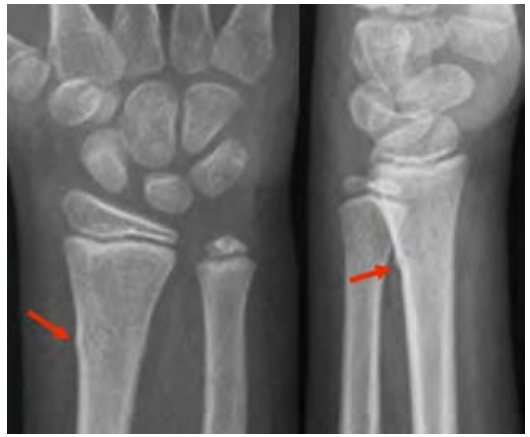
Clinical evaluation is paramount: Always image the "point of maximum tenderness"

How to image:

- Radiography: two orthogonal planes.
- Ultrasound: "second imaging technique" for cartilaginous immature skeleton.
- Computed tomography: complex pelvic fractures or Salter–Harris knee or ankle injuries. Contrast CT angiography for vascular injury.
- MRI: bone marrow and soft tissue.
- Nuclear Medicine: occult trauma, occasionally child abuse.

Buckle or "torus" fracture ▶

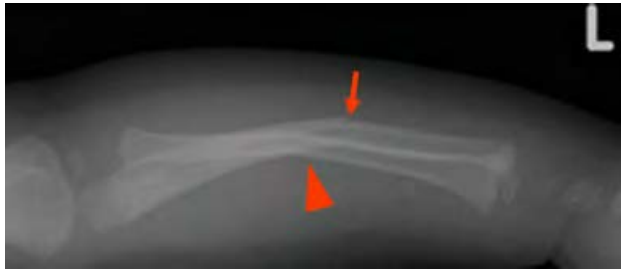
- The most common fracture in children due to compression when a child falls on outstretched hand.
- One of the most common recurrent diagnostic errors by radiology trainees.
- The angulated cortical outline = "little hill" = torus is easily missed.

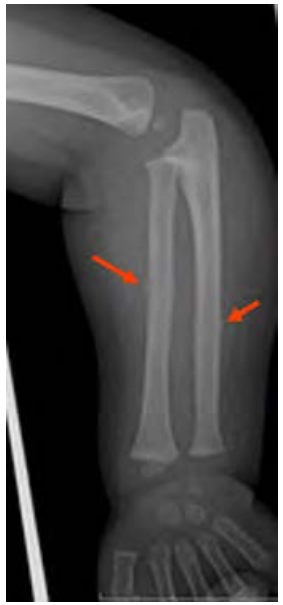


Value of two projections ▼ ▶

There is minimal contour deformity on the right radiograph (arrow).

Greenstick fracture of the ulna (arrow) and plastic deformity of the radius (arrowhead) is better depicted on the *orthogonal projection like the cross-table lateral view (left). Contralateral plain films may also be useful as a problem-solving tool if there is diagnostic uncertainty.*





Chapter Outline

Disorders in Children
Physeal Fractures

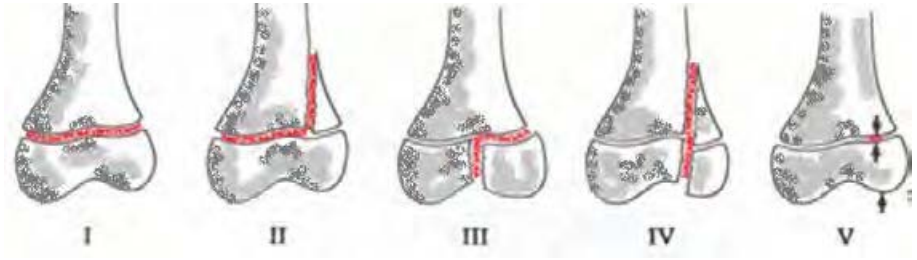
- They involve the "weak point", the growth plate.
- Account for approximately 15% of all fractures in children.
- The distal radial physis is the most frequent
- They may result in progressive angular deformity, limb-length discrepancy, or joint incongruity.

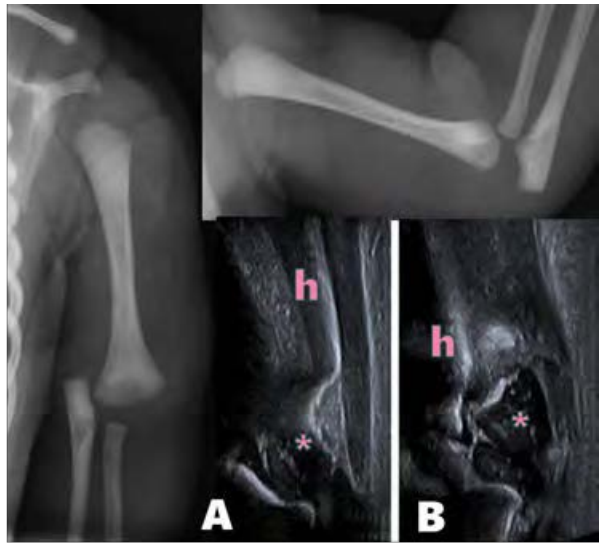
Salter-Harris (SH) classification

Mnemonic: SALTR

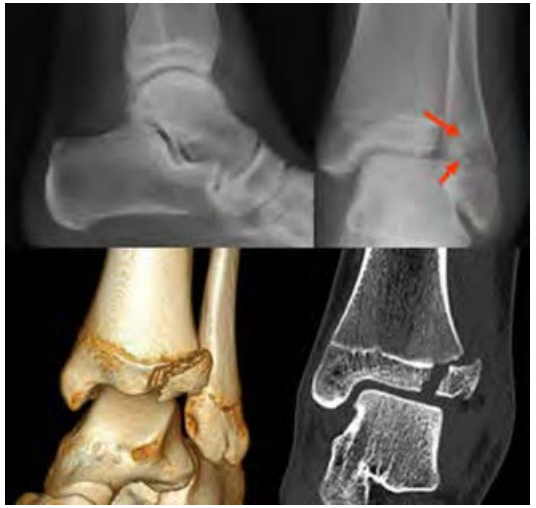
(**S**lip of physis or **S**ame=type 1; **A**bove physis=type 2; **L**ower than physis=type 3; **T**hrough the physis=type 4, **R**ammed/**R**uined =type 5).

- SH classification has prognostic value.
- US is useful in immature cartilaginous skeleton
- CT is useful for the evaluation of articular extension of physeal fractures.
- MRI is a "non-ionizing" alternative with much better contrast for soft tissue and bone marrow when evaluating physeal injuries.





◀ Distal humerus SH type I fracture in an infant with left elbow swelling and an apparent elbow malalignment and dislocation on radiographs.
A: posterior US view of the normal distal humerus (h) including the epiphysis (*).
B: posterior US view of the affected elbow showing post erior displacement of the distal epiphysis (*) related to the humerus (h).



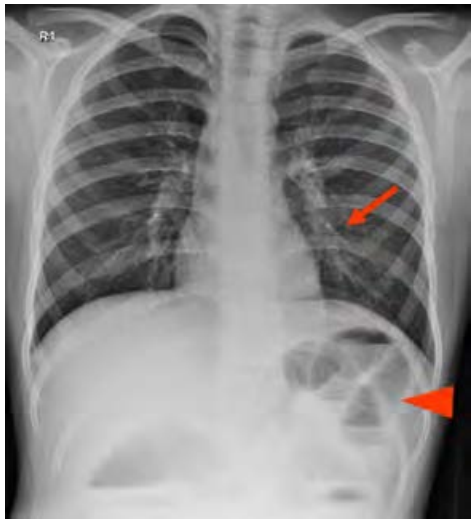
▶ Distal tibia SH type 3 fracture which is difficult to appreciate on radiographs as a gap (arrows). This is a "Tillaux" fracture in a 14-year-old child with almost obliterated physes and a "mature" skeleton.

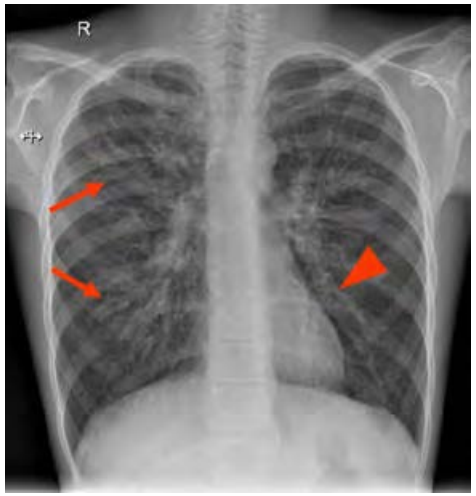
CT is useful to demonstrate extension of physis fracture to the joint surface.

Chapter Outline

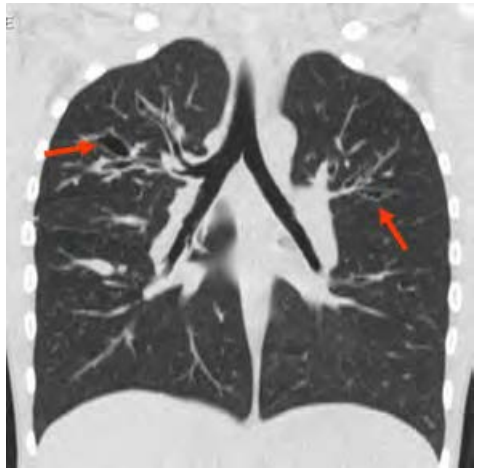
Disorders in Children
Cystic Fibrosis (CF)

- CF is an inherited disorder that affects cells producing mucus, digestive juices and sweat.
- A faulty gene alters a protein that regulates salt movement in and out of cells.
- The major organs affected are the lungs and digestive system, including the pancreas.
- Secretions become thick and sticky, blocking the airways and drainage ducts.
- The condition can be diagnosed at birth before symptoms develop ('heel prick test') and later with a sweat test.
- Clinical presentation is variable but includes:
    - Shortness of breath and wheeze with recurrent chest infections, leading to chronic lung disease with fibrosis and bronchiectasis.
    - Reduced endo- and exocrine pancreatic function, resulting in malabsorption and consequent growth disturbance. Lack of Insulin can cause diabetes in older patients.
    - Bowel obstruction due to thickened and sticky contents blocking the terminal ileum.
    - Liver disease secondary to blocked and inflamed bile ducts may ultimately cause cirrhosis and liver failure.





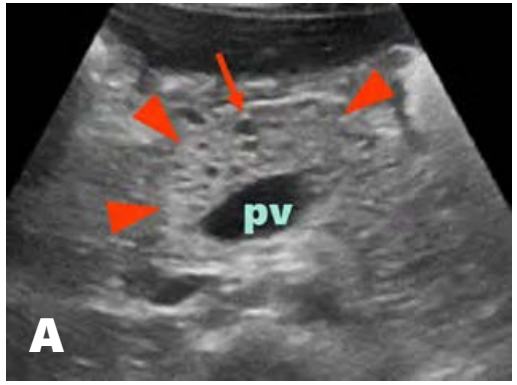
◀ Chest radiograph of a patient with CF: the airways have thickened walls making the lungs appear "streaky" (arrow). In cross section, the thick airway walls look like "donuts" – these are mostly seen near the lung hila.
In the upper abdomen there are dilated small bowel loops with air-fluid levels (arrowhead) due to bowel obstruction resulting from surgery earlier in this child's life.

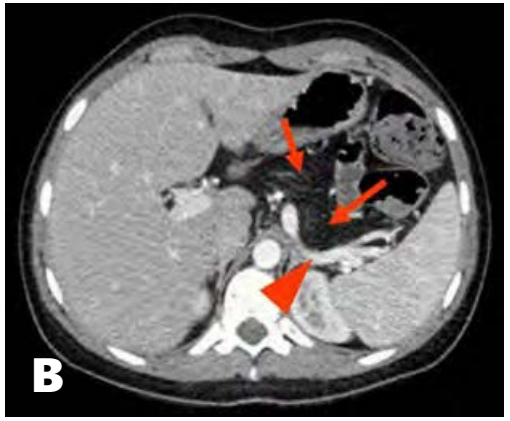


◀ ▲ Adolescent boy presenting with recurrent chest infections. The chest radiograph shows streaky opacity due to dilated bronchi (arrows). Mottled patches represent mucus blocking the airways (arrowhead). The CT image (above) demonstrates detail of the dilated bronchi (arrows). These do not taper towards the lung periphery as they normally should.

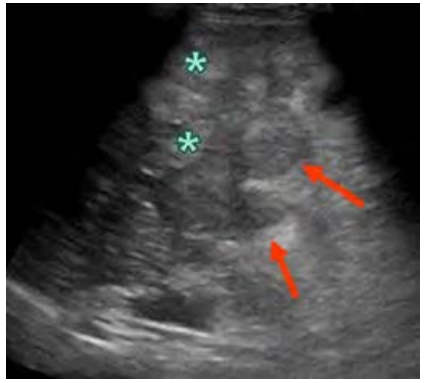
Chapter Outline

- CF is a life-limiting condition.
- Approximately half of patients will live longer than 40 years.
- Therapy is supportive with the aim of controlling symptoms, preventing and reducing complications.
- Some patients may require lung or liver transplantation.
- CF patients are cared for by a multi-disciplinary hospital team.

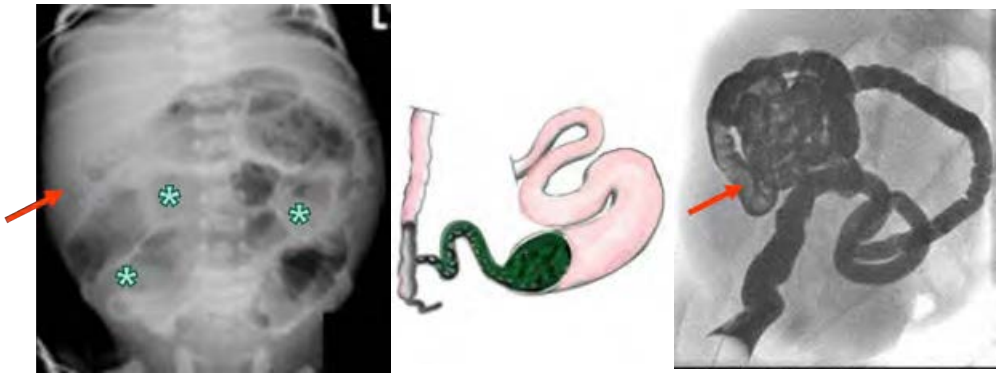




◀◀ CF and the pancreas: the ultrasound image (A) shows a bright (fatty) pancreatic head (arrowheads) with small cysts (arrow). The bright (white) 'tadpole' of the portal vein (pv) is the anatomic marker for level of the pancreas. The CT image (B) demonstrates an "absent" pancreas – the organ has been replaced by fat which is demonstrated with a low density ('black') comparable to subcutaneous fat.



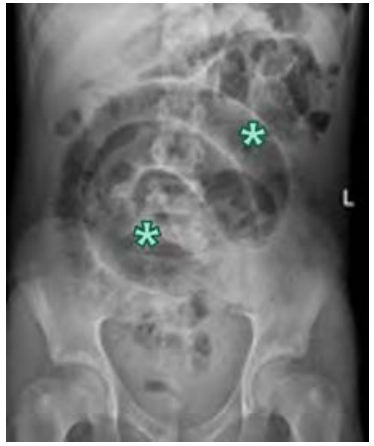
◀ Ultrasound image of the liver in a child with cirrhosis: the liver edge is lobulated (arrows), and the texture is heterogeneous with nodules(*).



▲▲▲ 2-day-old neonate with distended abdomen who did not pass meconium following birth: abdominal radiograph (left image) shows gassy, dilated bowel loops (*) and a 'bubbly' pattern of faeces (arrow). The central sketch illustrates pellets of sticky faeces blocking the terminal ileum resulting in upstream bowel dilatation. A contrast enema (right image) performed by the paediatric radiologist shows a small calibre (unused) colon with contrast refluxing back into the ileum, which has filling defects (red arrow). The diagnosis is meconium ileus, a presentation of CF in neonatal life.

DIOS: distal intestinal obstruction syndrome

▶ Abdominal radiograph in a child with abdominal pain and vomiting. Dilated central small bowel loops (*) indicate obstruction. There were inspissated faeces proximal to the ileo-caecal valve. This is DIOS in an older child with CF.



Chapter Outline

Disorders in Children
Child Abuse

- Child maltreatment, according to WHO, refers to all forms of physical and/or emotional or sexual abuse, deprivation and neglect of children, or commercial or other exploitation resulting in harm to the child's health, survival, development or dignity in the context of a relationship of responsibility, trust or power.
- Although the incidence of child abuse and neglect has been decreasing, almost 9.2 in every 1,000 children in the United States were abused in 2018 according to the Children's Bureau. Children of any age may be abused; it is the youngest children, smaller than two years of age, whom are the most vulnerable. It is estimated that 26.7 per 1,000 children are victims of child abuse and neglect in their first year of life. Approximately 25% of abused children are physically abused.
- Physically abused infants and children may present with unexplained skin marks (bruises, burns/scalds, bites), unexplained fractures, neurological and retinal injuries without a supporting history (abusive head trauma [AHT]), as well as with unexplained visceral (thoracic and abdominal) injuries
- Paediatric radiologists are important members of an interdisciplinary team that look for, identify and interpret subtle imaging findings in favour of abuse or in favour of alternative diagnoses through specific imaging protocols. Their role is extremely important in non-verbal and vulnerable children younger than 2 years of age.

A highly detailed complete radiographic skeletal survey with focused views, CT of brain, and MRI of brain and potentially the spine are performed in children younger than 2 years to identify and document clinically occult injuries, according to national and international guidelines.

Images kindly provided by Dr A. Patterson, UK. Right-hand image modified from Kleinman PK. Diagnostic imaging of child abuse. 2nd ed, St Louis, Mosby; 1998

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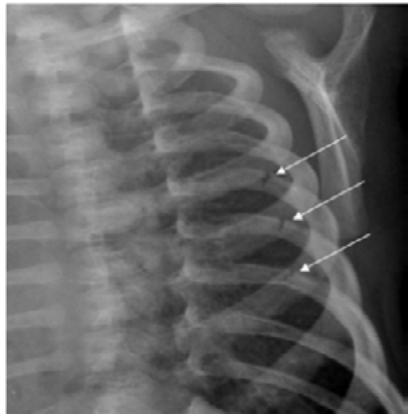
Chapter Outline

Disorders in Children
Abusive Skeletal Injuries

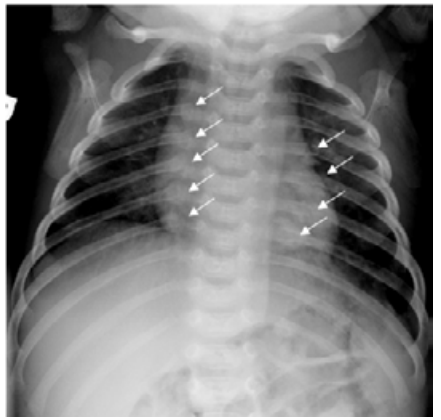
- Fractures are the second most common finding in physically abused children, following skin lesions (e.g., bruises).
- ***One in 3 physically abused infants have fractures.***
- Fractures resulting from physical violence can be found throughout the skeleton; they are likely to be multiple and can show diverse stages of consolidation and healing.
- Fractures may from result of accidental trauma. However, rib and metaphyseal fractures (classic metaphyseal lesions [CML]) are more frequently seen in abused infants provided that there is no accidental trauma or medical condition that result in fragile bones.
- Abused children may also be polytrauma patients.

"Children who do not cruise do not bruise"... or fracture. Up to 25% of fractures in children younger than 1 year-old are related to child abuse.

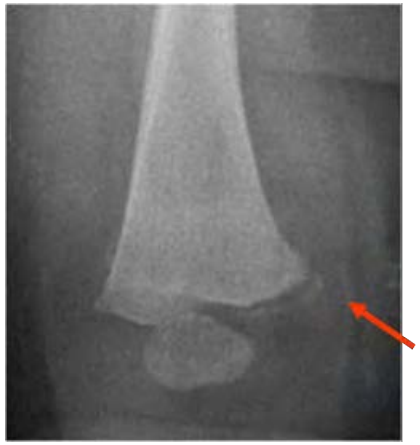


◀ Detail of an oblique chest radiograph of an infant with clinically suspected abuse showing 3 acute left posterior rib fractures (arrows).

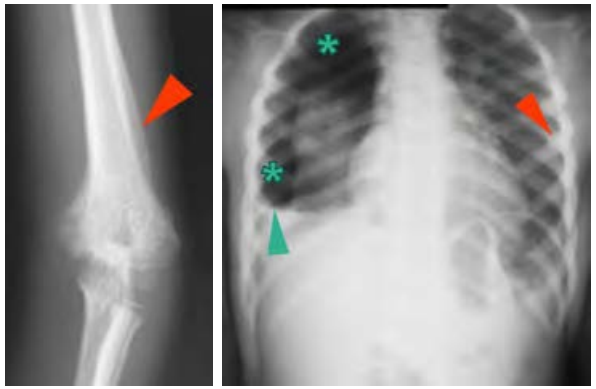
▼ 5 days later, a follow-up chest radiograph shows signs of healing on the 3 known rib injuries and additional healing fractures on the posterior arch of several other ribs (arrows).



▶ Detail of an AP radiograph of the distal femur of an infant with clinically suspected abuse showing a "bucket handle" fracture (a curved chip of bone detached from the metaphysis), highly specific for child abuse.



▶ Child with multi-system recent and old injuries: healing distal humerus and rib fractures (arrowheads), right hemopneumothorax (*) with air-fluid level (turquoise arrowhead). There was also a liver laceration (not shown).

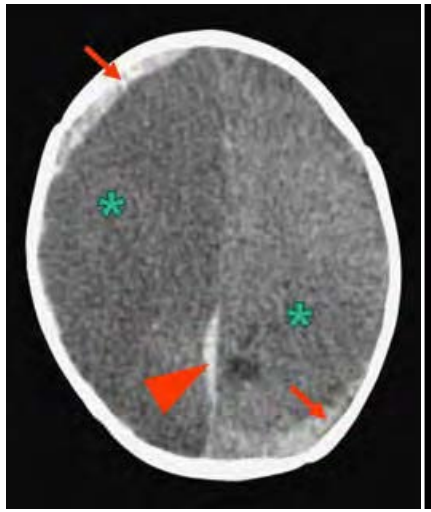


Up to 26% of skeletal surveys performed in infants <6 months demonstrate clinically unsuspected fractures.

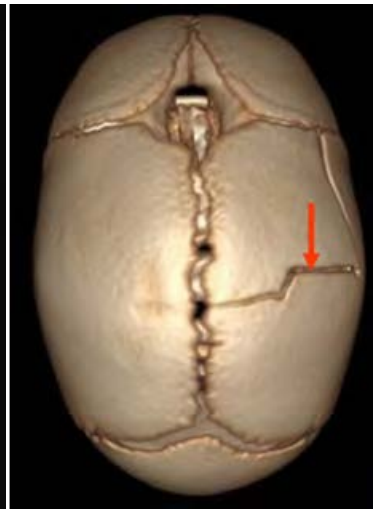
Chapter Outline

Disorders in Children
Abusive Head Trauma (AHT)

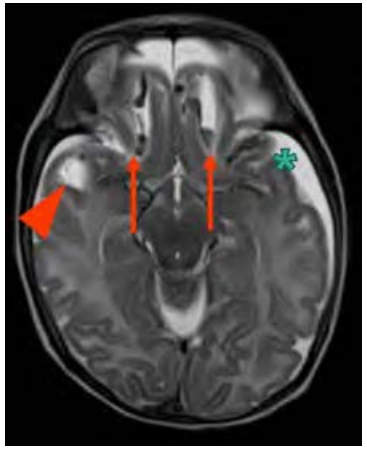
- AHT following ***shaking*** (violent "to and fro" head motion) and/or direct impact with or without skull fractures, may result in lethal or chronically debilitating injuries.
- Subdural hematomas (SDH) are seen at various sites and exhibit variable densities on CT as the first-line imaging test. They also exhibit variable signal intensities on MRI and are related to superficial vein rupture/thrombosis. Parenchymal injuries include brain contusions, shearing injuries and ischaemic lesions.
- Further investigations with fundoscopy to identify abuse-related retinal haemorrhages, radiographic skeletal survey for bone fractures and MRI of the spine for ligamentous injuries and subdural hematomas are advised, also.
- Children suspected of abuse should be protected during investigation and local child protection agencies notified.



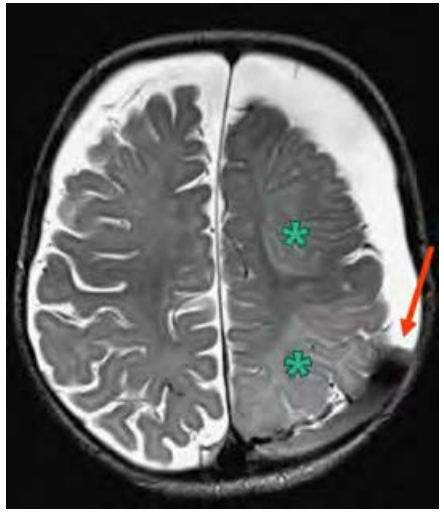
Axial CT. Hyperdense subdural haematomas of different densities (arrows), interhemispheric subdural haematoma (arrowhead), diffuse brain oedema-ischaemia (*) with hypodensity and obliteration of sulci.



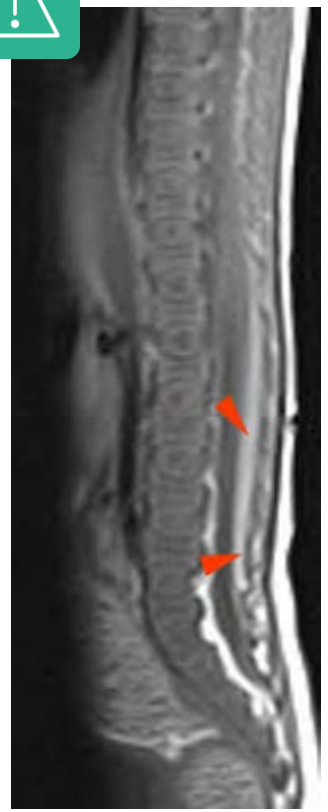
3D CT bone reconstruction of the skull shows a left parietal bone skull fracture (arrow).



T2W axial MRI in the same child as the 3D CT shows subdural haematoma (*), bilateral frontal shearing injuries (arrows) and right temporal lobe contusion (arrowhead).



T2W axial sequence shows bilateral subdural hematoma with blood-fluid level on left side (arrow) and parenchymal oedema with hyperintensity (*) in left hemisphere.



Abused infant with posterior fossa subdural haematoma (not shown). Sagittal T1W sequence shows an unsuspected hyperintense subdural haematoma in the lumbar area (arrowheads).

Chapter Outline

Paediatric radiology is much more... it is a world of ongoing information and collaboration!

ESPR
European Society of Paediatric Radiology

image gently®
The Image Gently Alliance

SPR The Society for Pediatric Radiology

Pediatric Radiology

American Society of Pediatric Neuroradiology

ESNR 52 1969 2021

Radiology Assistant

aoSPR
Asia-Oceanic Society of Paediatric Radiology

PiDRL EUROPEAN DIAGNOSTIC REFERENCE LEVELS FOR PAEDIATRIC IMAGING

Latin American Society of Pediatric Radiology

SLARP

WFPI The World Federation of Pediatric Imaging

Contact: your National Radiological Society and see if they have a paediatric radiology specialist interest group; the Paediatric Radiology society in your country; or the ESPR.

Further information on careers in radiology can be found here.

Chapter Outline

Take-Home Messages

- Paediatric Radiology is an exciting, stimulating and rewarding subspecialty in radiology
- Paediatric Radiologists master the art and skills of working with children and the knowledge regarding radiation protection principles and unique paediatric disease
- Knowledge of all imaging modalities and their role depending on the indication is important for appropriate patient care and management
- Being a paediatric Radiologist matters to children, families and society
- Being a paediatric radiologist builds solid and fruitful bridges with numerous specialties including geneticists, neonatologists, paediatricians, paediatric surgeons, paediatric oncologists, paediatric neurologists, paediatric rheumatologists, paediatric orthopaedic surgeons, and many more…
- Paediatric Radiologists are crucial and visible members of multidisciplinary teams

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Chapter Outline

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Chapter Outline

Test Your Knowledge

1. The angel wing sign is encountered in

- Pneumothorax
- Intussusception
- Hypertrophic pyloric stenosis
- Pneumomediastinum
- Ascites

Test Your Knowledge

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- Intussusception
- Hypertrophic pyloric stenosis
- ✓ Pneumomediastinum
- Ascites

Test Your Knowledge

2. TORCH is the acronym for

- Congenital CNS infections
- Congenital renal anomalies
- Congenital lung anomalies
- Types of growth plate fractures

Test Your Knowledge

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- Congenital renal anomalies
- Congenital lung anomalies
- Types of growth plate fractures

Test Your Knowledge

3. What is true for SALTER Harris classification?

- It has a prognostic significance
- In type 1 there is no fracture
- In type II there is extension of the fracture to the joint
- In type V there is extension of the fracture to the joint

Test Your Knowledge

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- In type II there is extension of the fracture to the joint
- In type V there is extension of the fracture to the joint

Test Your Knowledge

4. What is the most appropriate statement for CAKUT?

- It is an acronym for anomalies resulting in potential nephropathy
- It is an acronym for anomalies resulting in potential uropathy
- It is an acronym for anomalies resulting in potential nephropathy and uropathy

Test Your Knowledge

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- ✓ It is an acronym for anomalies resulting in potential nephropathy and uropathy

Test Your Knowledge

5. The thymus

- Is normally visible in radiographs of adolescents
- May cause a false impression of pneumomediastinum
- May cause a false impression of a mediastinal mass
- Cannot be appreciated on ultrasound

Test Your Knowledge

5. The thymus

- Is normally visible in radiographs of adolescents
- May cause a false impression of pneumomediastinum
- ✓ May cause a false impression of a mediastinal mass
- Cannot be appreciated on ultrasound

Test Your Knowledge

6. Which of the following is true regarding aspirated or ingested foreign bodies?

- They can be indirectly identified due to air trapping, or atelectasis
- They cannot be identified unless they are metallic and radiopaque
- Ingested metallic objects require an operation
- Button batteries in the oesophagus usually come out naturally and uneventfully and should be left alone

Test Your Knowledge

6. Which of the following is true regarding aspirated or ingested foreign bodies?

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- Button batteries in the oesophagus usually come out naturally and uneventfully and should be left alone

Test Your Knowledge

7. What is the most appropriate modality for the investigation of hypertrophic pyloric Stenosis (HPS)?

- Abdominal radiograph
- Ultrasonography
- Computed tomography
- Fluoroscopy

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Test Your Knowledge

8. What is the most common abnormal finding in physically abused children?

- bruises
- fractures
- Head trauma
- Spinal trauma

Test Your Knowledge

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- Spinal trauma

Test Your Knowledge

9. What kind of lesions can be attributed to hypoxic ischemic injury in term babies?

- lesions of basal ganglia and thalami
- Germinal matrix haemorrhage
- Periventricular leukomalacia

Test Your Knowledge

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- Periventricular leukomalacia

Test Your Knowledge

10. Which of the following is a frequent suprasellar tumor in children?

- Craniopharyngioma
- Pituitary adenoma
- Meduloblastoma
- Choroid plexus papilloma

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Chapter Outline