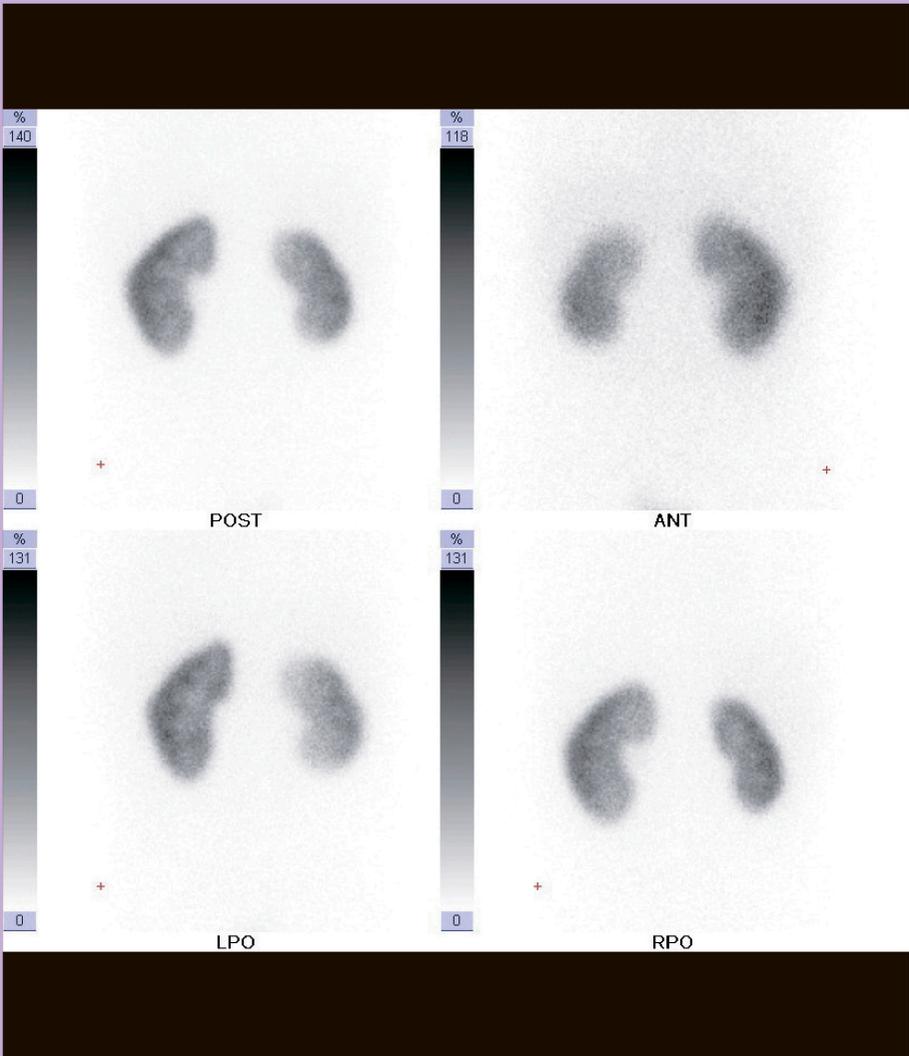
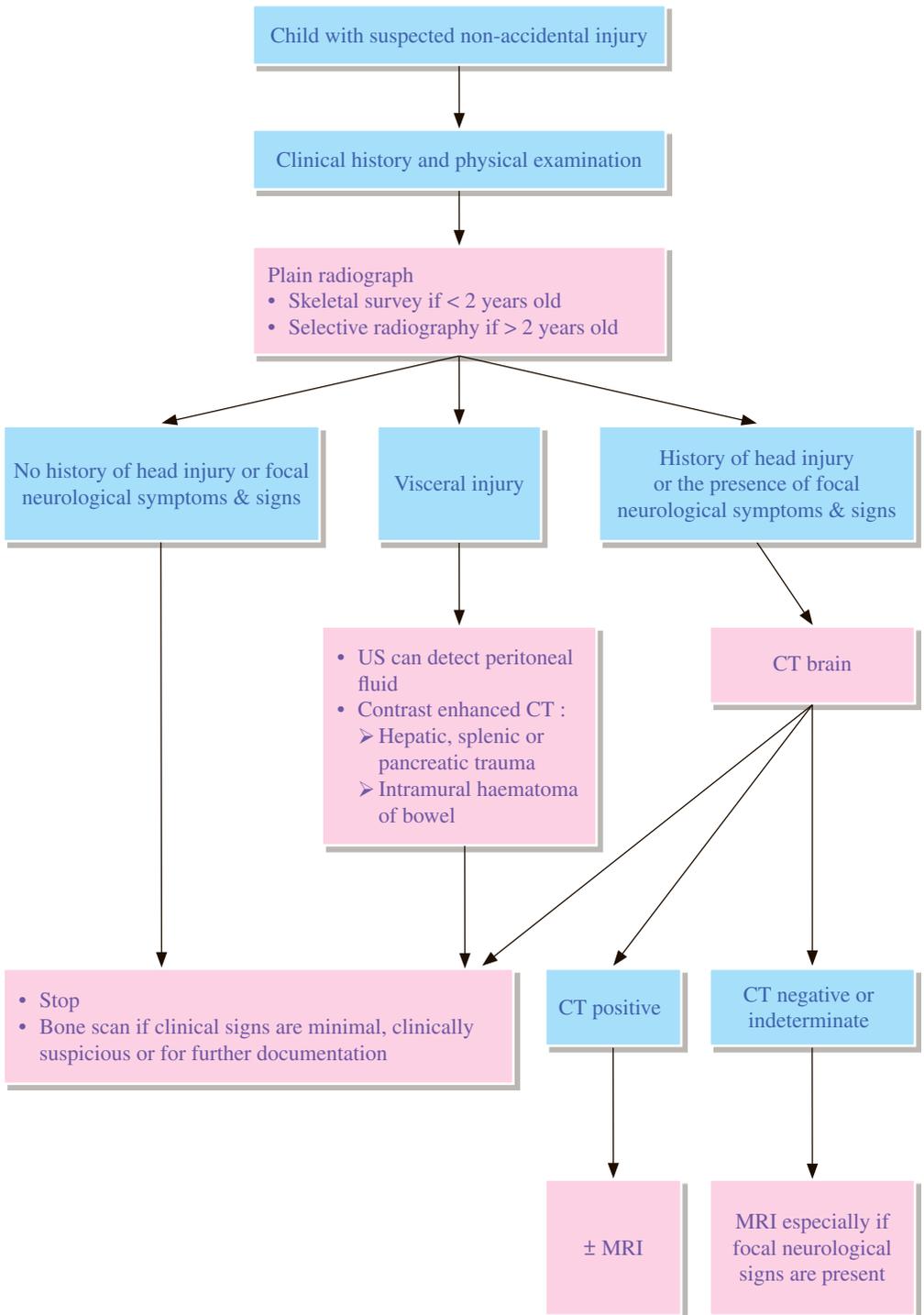


Paediatric Radiology



Hong Kong College of Radiologists

PD 1 Suspected non-accidental injury



REMARKS

1 General

- 1.1 Child abuse is not an imaging diagnosis. The role of imaging is to support the clinical diagnosis of child abuse in the proper clinical and social context and also to assist the evaluation of the severity and extent of injury.

2 Musculoskeletal trauma

- 2.1 Skeletal survey includes skull (frontal and lateral), spine (lateral cervical, thoracic and lumbar), chest (frontal including clavicles, and oblique views of bilateral ribs), abdomen (frontal, including pelvis and both hips), upper extremities (frontal humeri, forearms, and hands), and lower extremities (frontal femora, lower legs, and feet).
- 2.2 Conventional radiography is the primary imaging examination for musculoskeletal trauma.
- 2.3 Avoid 'babygram' as it is diagnostically inadequate.
- 2.4 Complete skeletal survey is normally indicated in children less than 2 years of age who have clinical evidence of child abuse, or in infants less than 1 year of age who show evidence of significant neglect and deprivation. In children between 2 years and 5 years of age, the skeletal survey may be tailored according to history and physical examination findings.
- 2.5 **For children more than 5 years old, skeletal survey is rarely indicated.**
- 2.6 Bone scans may be considered for children in whom skeletal survey is negative but clinical suspicion of non-accidental injury (NAI) is high. Bone scan is sensitive for the extent of bone injury, acute non-displaced and subtle healing fractures. Its pitfalls include normal uptake around the growth plates leading to difficult identification of metaphyseal-epiphyseal injuries, missed symmetrical fractures, inability to determine the age and type of fracture and relative insensitivity in detecting skull and vertebral body fractures. It should be used as a problem-solving study rather than first line.
- 2.7 Role of MRI and US for evaluating skeletal injury in NAI has not been established with reference to prevailing international guidelines and recommendations.

3 Skull trauma

- 3.1 Skull radiographs form part of the full skeletal survey for non-accidental injury.
- 3.2 In children with head trauma who are at increased risk of intracranial injury, CT is the preferred initial imaging modality and also improves definition of depressed and other complex fractures.
- 3.3 Bone scan is unreliable in identifying skull fractures.

4 Intracranial trauma

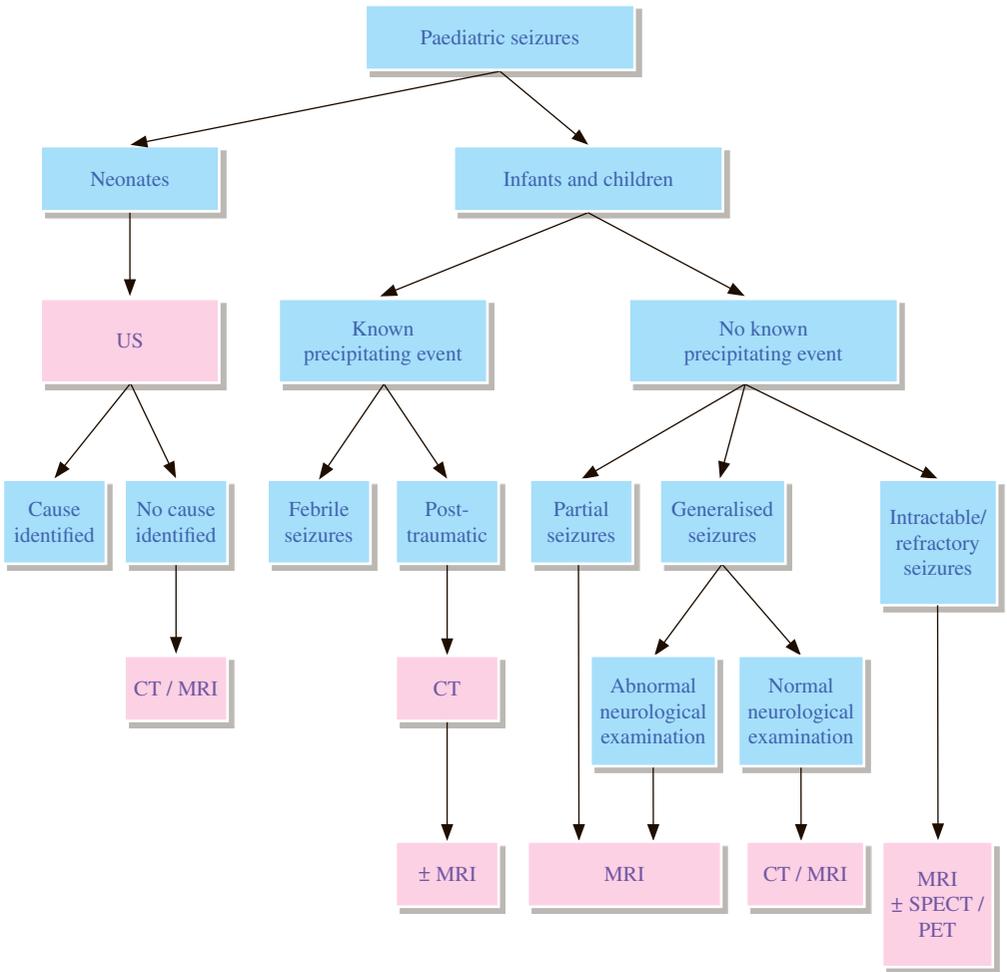
- 4.1 CT is both sensitive and specific in defining acute intra- and extra-cerebral injuries, especially subarachnoid haemorrhage.
- 4.2 MRI is useful in the subacute and chronic settings and is superior in detecting subdural haematomas, cortical contusions and shearing injuries. It can determine the age of extra-cerebral fluid collections and timing of intracranial haemorrhage.
- 4.3 MRI should be performed in patients whose clinical symptoms are disproportionate to the CT findings.

5 Visceral trauma

- 5.1 Imaging examinations should be tailored to specific clinical concern.
- 5.2 Abdominal US is useful to detect peritoneal fluid but is less sensitive than CT to detect solid organ injury.

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REMARKS

1 Indications

- 1.1 Structural neuroimaging is recommended for all children with recently diagnosed localization-related or generalized epilepsy who do not have the clinical and electroencephalogram (EEG) features characteristic of classical idiopathic focal or generalized epilepsy (benign epilepsy with centrotemporal spikes (BECTS), childhood absence epilepsy (CAE), juvenile absence epilepsy (JAE), or juvenile myoclonic epilepsy (JME)) and for any child younger than 2 years of age.
- 1.2 Imaging early in the course of epilepsy is directed at identifying an etiology for seizure that requires other medical or surgical attention¹:
 - 1.2.1 If there is any evidence to suggest the epilepsy is localization-related (e.g. focal), with the exception of typical benign idiopathic partial epilepsy.
 - 1.2.2 Abnormal neurologic examination, including focal deficits, stigmata of neurocutaneous syndrome, cerebral malformation syndrome, or a history of significant developmental delay, arrest, or regression.
 - 1.2.3 Children younger than 2 years, excluding those with simple febrile seizures.
 - 1.2.4 Children with characteristics of a symptomatic generalized epilepsy syndrome, including infantile spasms or early Lennox-Gastaut syndrome.
 - 1.2.5 Failure to control seizures, worsening seizures, changes in seizure manifestations, or developmental regression also merit neuroimaging if not previously performed.
 - 1.2.6 New-onset seizure/epilepsy presenting with evidence for a medical emergency such as increased intracranial pressure or status epilepticus always merit emergency imaging.
- 1.3 Imaging studies in CAE, JAE, JME, and BECTS do not identify significant structural abnormalities¹.

2 Plain radiograph

- 2.1 Skull radiographs are not routinely indicated in evaluation of seizures in children as it lacks both sensitivity and specificity.²

3. US

- 3.1 US is effective in evaluation of seizures in neonatal period and may adequately define treatable pathology to allow management in some cases.
- 3.2 An open fontanelle is necessary for US.
- 3.3 US Doppler evaluation of intracranial arteries is effective in assessing regional cerebral blood flow but its clinical value remains unclear.

4. Nuclear medicine

- 4.1 Single photon emission computed tomography (SPECT).
 - 4.1.1 Ictal SPECT has been useful in differentiating temporal lobe epilepsy from extra-temporal lobe foci and provides non-invasive imaging information used in planning treatment strategies.³
 - 4.1.2 Ictal SPECT optimization requires radiopharmaceutical injection (Tc-99m hexamethylpropyleneamine oxime [HMPAO] or Tc-99m ethyl cysteinate dimer [ECD]) within seconds of a seizure.

4.2 PET

- 4.2.1 PET offers a direct quantitative correlation with metabolic activities and therefore it is potentially more specific than SPECT.
- 4.2.2 Both SPECT and Fluorodeoxyglucose (FDG) PET have been used as a part of pre-surgical evaluation and planning.

5. CT

- 5.1 Non-contrast CT is effective in identifying some treatable causes of seizures or emergencies causing seizures.
- 5.2 CT confers some advantages with regard to identifying blood and calcification (as found in congenital infection).¹
- 5.3 Contrast enhancement in general does not improve the sensitivity in detecting focal intracranial lesions with the exception of brain metastases, which are rare causes of seizures in the paediatric population.
- 5.4 CT is more widely available than MRI, less expensive, and less likely to require sedation for younger children.
- 5.5 CT can detect all treatable lesions in the setting of acute mild trauma.³

6. MRI

- 6.1 MRI has the highest sensitivity in detecting focal intracranial lesions. It is considered the imaging modality of choice because of superior anatomic resolution and characterization of pathologic processes.¹
- 6.2 Routine administration of gadolinium contrast provides little advantage in children with epilepsy. Administration of gadolinium is of limited value in increasing the sensitivity of MRI examination of brain, although the specificity can be improved.⁴ It is reserved for circumstances where tumor, vascular malformations, inflammation, and infectious concerns arise or are suspected based on review of non-contrast studies.
- 6.3 There is no agreement on specific imaging protocols or MRI sequences, but there is general agreement that the following should be performed¹:
 - 6.3.1 Anatomic, thin-slice volumetric T1-weighted gradient-recalled-echo sequence,
 - 6.3.2 Axial and coronal T2-weighted sequence,
 - 6.3.3 Fluid attenuated inversion recovery (FLAIR) sequence (axial, and coronal if possible),
 - 6.3.4 High resolution oblique coronal T2-weighted imaging of the hippocampus (fast or turbo spin echo weighted sequence),
 - 6.3.5 There is debate, and there are limited data, about the utility of newer sequences such as magnetization transfer imaging and diffusion tensor imaging,
 - 6.3.6 When metabolic disorders are suspected, magnetic resonance spectroscopy (MRS) may be helpful,
 - 6.3.7 Functional MRI has been used as a part of pre-surgical evaluation and planning.

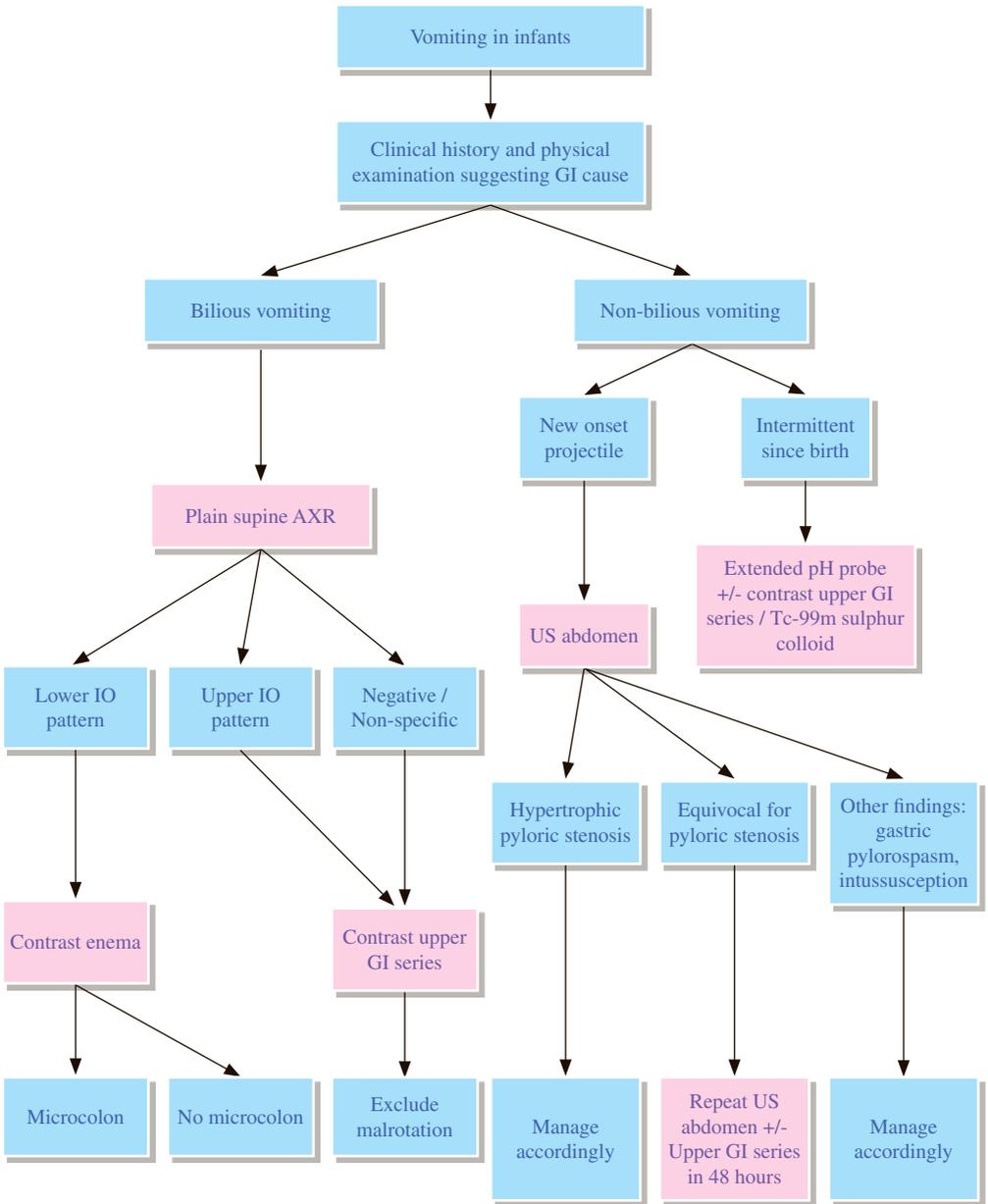
- 6.4 Children younger than 2 years require special sequences, as immature myelination affects the ability to identify common causes of epilepsy¹:
- 6.4.1 In addition to a 3D dataset, imaging in children younger than 2 years should include sagittal, axial, and coronal T1-weighted sequences.
 - 6.4.2 Volumetric T1-weighted sequences are less useful before one year of age due to incomplete myelination on T1 sequences.
 - 6.4.3 MR imaging (especially high-resolution T2 images) performed early in the first year of life in infants with epilepsy is important to identify areas of cortical or subcortical dysplasia, which can become difficult to identify after myelination.
 - 6.4.4 If MR imaging before the age of 2 years is normal, and seizures persist, then MRI may be repeated at 6-month intervals, and after age 24–30 months when more mature myelination can reveal otherwise unsuspected cortical dysplasia.

7. Angiography

- 7.1 Angiography should only be performed with prior imaging suggesting a vascular lesion.

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REMARKS

1 Malrotation / midgut volvulus

- 1.1 Midgut volvulus is an emergency situation. It should be considered in patients with bilious vomiting.
- 1.2 Contrast upper GI series is the preferred examination. Barium is usually used, except in suspected perforation or high risk of aspiration. Low-osmolarity contrast media are used in extremely ill or premature neonates.
- 1.3 US is limited by operator experience and incomplete examination due to overlying gas.

2 Gastroesophageal reflux (GER)

- 2.1 Extended pH probe is currently the gold standard for diagnosis. Preference for the other methods in the diagnostic work-up of GER varies among different centres depending on expertise and availability.
- 2.2 GER is the commonest cause of recurrent non-bilious vomiting. Abdominal X-ray (AXR) does not have a role in diagnosis of GER, and is indicated for additional clinical conditions, e.g. obstruction.
- 2.3 Contrast upper GI series or nuclear medicine examination are advocated only when failure of conservative treatment, development of complications or life threatening symptoms occur.
- 2.4 Upper GI series and nuclear medicine examination (Tc-99m-labelled sulphur colloid scan) show similar sensitivity, and upper GI series allows anatomical evaluation e.g. obstruction and structural abnormalities.
- 2.5 US can provide functional and morphologic information. However, its diagnostic performance on GER is variable.

3 Hypertrophic pyloric stenosis

- 3.1 AXR should not be routinely obtained when the diagnosis is strongly suspected.
- 3.2 US is the preferred method for diagnosis but it requires considerable experience. Repeat US in 48 hours is recommended in case of doubt. Contrast upper GI series is limited by its ionizing radiation, and should be used when other causes are suspected.

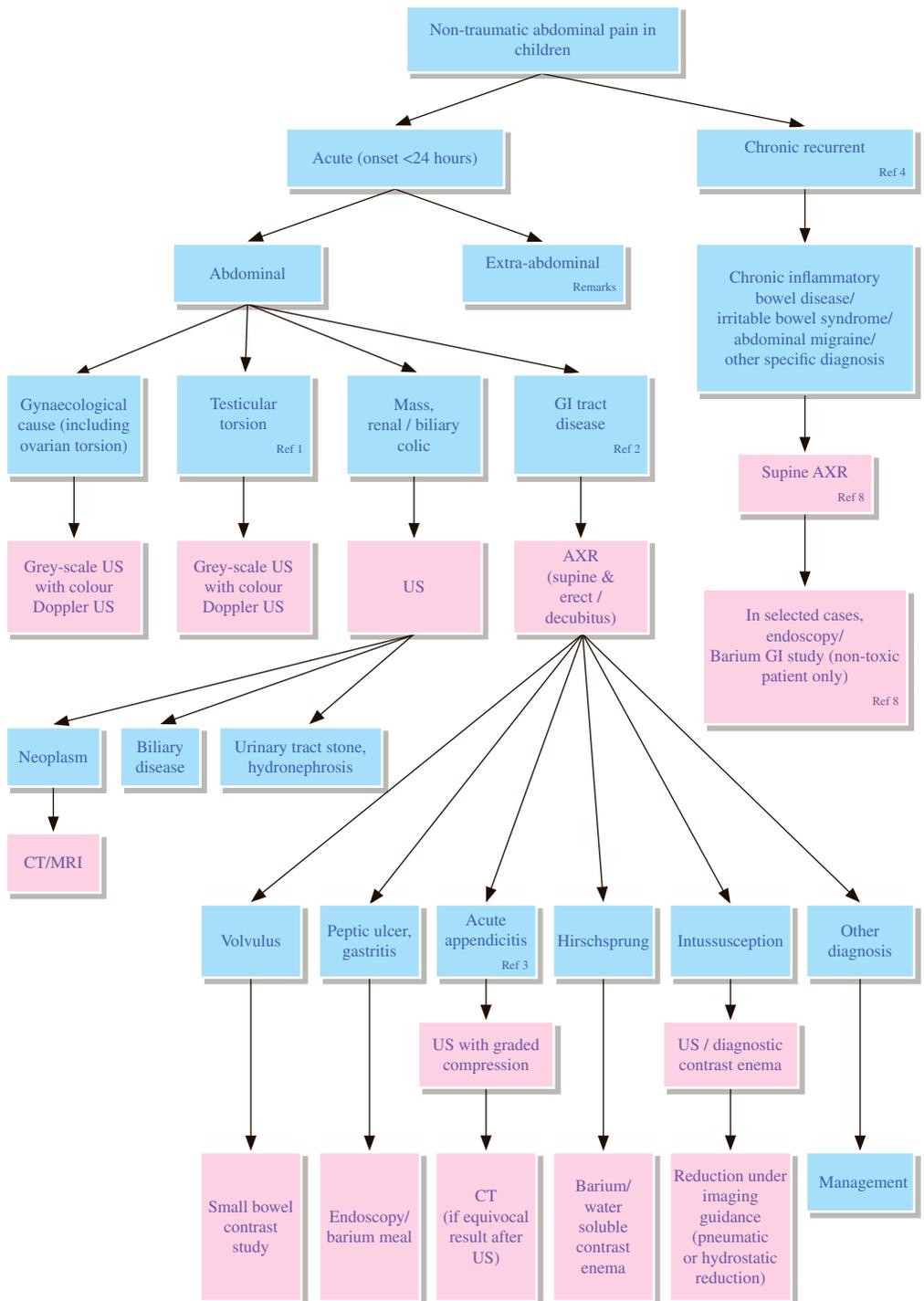
4 Intussusception

- 4.1 Intussusception is a frequent cause of crampy abdominal pain, which can be accompanied by vomiting in children.
- 4.2 The main reason for obtaining plain radiographs is to look for the presence of free intraperitoneal air and degree of small bowel obstruction. US is a sensitive diagnostic method.
- 4.3 Pneumatic reduction under fluoroscopic guidance is used to reduce intussusception, only where specialist equipment and expertise is available.

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PD 4 Non-traumatic abdominal pain



REMARKS

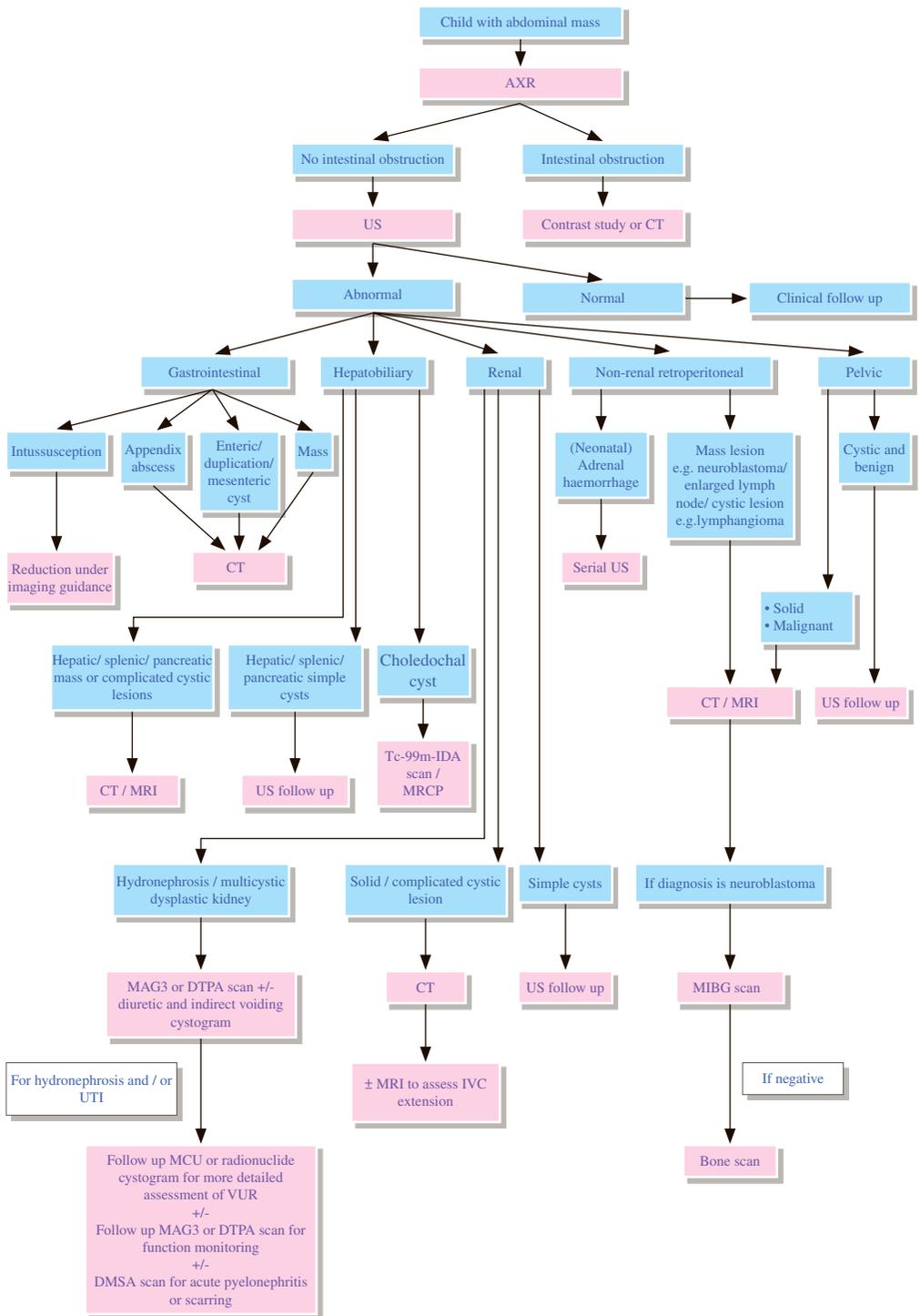
- 1 In all children presented with abdominal pain, history and physical examination should be carefully assessed for evidence of significant trauma (both accidental and non-accidental).
- 2 In significant abdominal trauma, further investigations with radiograph, US and sometimes CT are necessary to exclude pneumothorax, perforation of hollow viscus or contusion / laceration of solid organs.
- 3 In pre-school children, abdominal pain is rarely of psychogenic origin and an organic source should be carefully sought.⁷
- 4 A period of observation is important in those with non-specific symptoms and absent physical signs. Subsequent change in symptoms or development of specific signs may point to the diagnosis.
- 5 **Gynaecological causes**
 - 5.1 Recurrent pain related to menstruation can be due to endometriosis, while chronic pain and vaginal discharge are suggestive of chronic pelvic inflammatory disease. For acute onset of abdominal pain in sexually active females, the possibility of ectopic pregnancy or other pregnancy-related complications as well as acute pelvic inflammation should be considered. All these conditions warrant further investigation by US.^{5,6}
 - 5.2 Gastroenteritis and constipation are clinical diagnoses. Radiographs are usually unnecessary.⁵
 - 5.3 For suspected non-accidental injury, please refer to the guideline PD1.
- 6 **Extra-abdominal causes**
 - 6.1 Diabetic ketoacidosis, porphyria, lead poisoning, in which biochemical tests are needed for diagnosis.
 - 6.2 Pneumonia, bronchiolitis, asthma, in which chest X-ray (CXR) will be useful for diagnosis.⁵
- 7 **Acute appendicitis**³
 - 7.1 Meta-analysis showed US is nearly as good as CT in experienced hands, with a pooled sensitivity of 88% and specificity of 94%, as compared with CT, with a pooled sensitivity of 94% and specificity of 95%. Given the lack of ionizing radiation, US is the preferred examination in children, particularly if equivocal results are followed up by CT.
 - 7.2 CT-after-US approach has excellent accuracy, with reported sensitivity and specificity of 94%.
 - 7.3 If CT is performed, use of intravenous (IV) contrast is recommended; however, the use of enteric contrast, such as oral or rectal contrast, has not been shown to significantly increase sensitivity in children and should be left to the discretion of individual department and hospital policy.
 - 7.4 Non-visualization of the appendix on normal CT has been shown to have a high negative predictive value of 98.7%.⁹

8 Hirschsprung Disease²

- 8.1 Barium or water-soluble contrasts are the routine contrast media used for evaluating childhood Hirschsprung disease.
- 8.2 In the neonate or infant, water-soluble media diluted to near-isotonic or iso-osmolar concentration is preferred, as there may be potential for bowel perforation.

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REMARKS

1 Plain radiograph

- 1.1 Plain abdominal X-ray (AXR) is useful to exclude intestinal obstruction in children with constipation or abdominal distension, to locate mass, to detect any calcification, and to look for any skeletal involvement.

2 US

- 2.1 US helps to determine the organ of origin, to define the mass, to look for any metastases and to assess the vascularity of the mass with colour Doppler. A likely diagnosis can usually be made.

3 Nuclear medicine

- 3.1 Technetium 99m - Mercaptoacetyltriglycine (Tc-99m-MAG3) is the preferred radiotracer for renal scan.¹
- 3.2 Tc-99m-MAG3 renography is able to provide information on renal position, perfusion, differential function and transit times. If hydronephrosis is seen, diuretics can be administered to evaluate functional significance of hydronephrosis.¹
- 3.3 Indirect radionuclide cystography can be performed in the same setting as renography, although its sensitivity is lower than direct radionuclide cystography (DRC),² therefore follow up DRC or micturating cystourethrography (MCU) is required for patients with hydronephrosis, whether or not vesicoureteric reflux (VUR) was detected on indirect radionuclide cystography.
- 3.4 Nuclear medicine cystography carries a lower radiation dose than MCU.³
- 3.5 Metaiodobenzylguanidine (MIBG) scan is used in diagnosis, staging and follow up of neuroblastoma.
- 3.6 MIBG has higher sensitivity than bone scan for skeletal metastases. However, bone scan is needed for patient whose tumour is MIBG negative.⁴
- 3.7 Dynamic Tc-99m - iminodiacetic acid (IDA) scan may be used to diagnose choledochal cyst.

4 CT

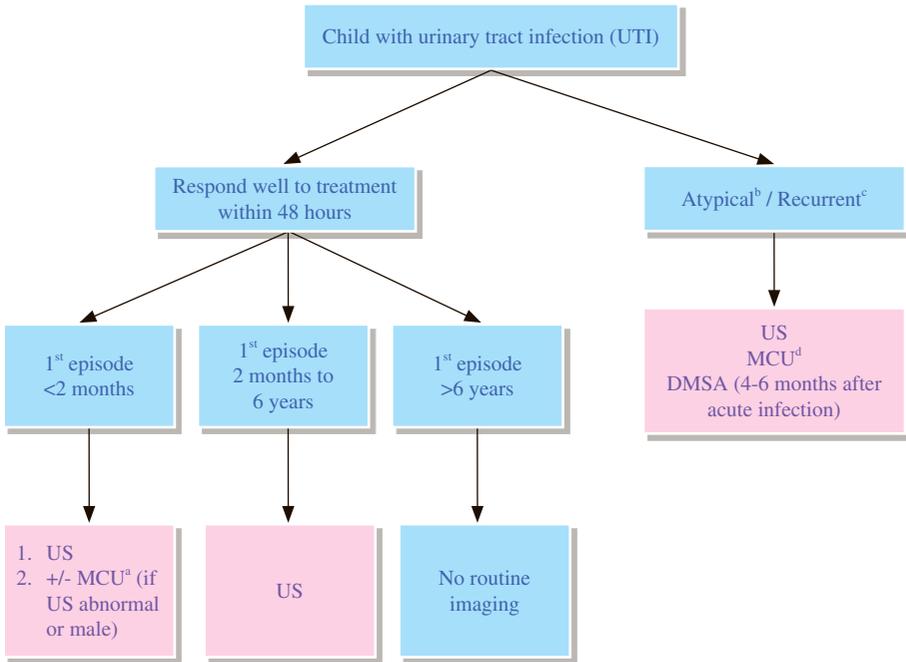
- 4.1 CT is used for anatomical and morphological characterization of mass and in assessing the involvement of adjacent structures and distant metastases.
- 4.2 Sedation is often required to reduce movement artefacts.

5 MRI

- 5.1 MRI provides excellent contrast resolution of soft tissues and is the best study to exclude intradural extension of mass. Status of vasculature can also be evaluated.
- 5.2 MRI is nonionizing but expensive. Sedation of the children is required.
- 5.3 Magnetic resonance cholangiopancreatography (MRCP) is a non-invasive biliary study.

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- a. Radionuclide cystography or contrast-enhanced voiding urosonography may be alternative to MCU in initial assessment of girls or follow up studies (see Remarks)
- b. Definition of atypical UTI: poor response to antibiotics within 48 hours, poor urine stream, sepsis, raised creatinine, non E-coli UTI
- c. Definition of recurrent UTI: two or more acute pyelonephritis / upper urinary tract infection, OR one acute pyelonephritis / upper urinary tract infection plus one or more cystitis / lower urinary tract infection, OR three or more cystitis / lower urinary tract infection
- d. In atypical / recurrent UTI, NICE guideline 2016 reserves MCU in child < 6months or child between 6 months to 3 years with the following:
 - Dilatation on US
 - Poor urine flow
 - Non E-coli infection
 - Family history of VUR

REMARKS

Imaging protocol of febrile urinary tract infection (UTI) in children

UTI is a frequent indication for imaging evaluation of paediatric urinary tract. The goal of all imaging has been to improve outcome and prevent end-stage renal failure due to scarring from late diagnosis and inadequate treatment.¹

Imaging approach of UTI in children younger than 2 months may need to be more aggressive, as there is limited research on this age group and neonates with UTI have a high incidence of renal anomalies and are more likely to be complicated with sepsis.²

US of kidneys and bladder is usually appropriate² and it is recommended in National Institute for Health and Care Excellence (NICE) guideline.³ Micturating cystourethrography (MCU) may be appropriate and can be considered in boys and in presence of sonographic abnormality. Radionuclide cystography may be appropriate and can be considered in girls.² Contrast-enhanced Voiding Urosonography (ceVUS) is a valid and radiation-free alternative examination for MCU and radionuclide cystography.^{1,4}

American Academy of Pediatrics (AAP) 2011 guidelines recommends US for all children between ages of 2 months and 2 years after first episode of UTI.^{3,5} AAP 2011 recommends that MCU is indicated if US reveals hydronephrosis, scarring or other findings that would suggest high grade vesicoureteric reflux (VUR) or obstructive uropathy or in other atypical and complex clinical circumstances. It should also be performed for recurrent UTI.⁵ NICE 2007 recommends that MCU should be considered if several clinical and imaging features are present. Guideline from Italian group recommends MCU for patients with abnormal US findings, risk factors or recurrent UTI.⁶

Risk factors are derived from NICE 2016, American College of Radiology (ACR) Appropriateness Guideline and Italian Guideline^{2,3,6}:

- First degree relative with VUR
- Septicemia
- Urinary retention
- Poor urine stream
- Raised creatinine
- No or poor response to antibiotics treatment within 48 hours
- Bacteria other than E. Coli

NICE 2016 defined Recurrent UTI as follows:³

- 2 or more episodes of UTI with acute pyelonephritis / upper urinary tract infection, or
- 1 episode of UTI with acute pyelonephritis / upper urinary tract infection plus one or more episode of UTI with cystitis / lower urinary tract infection, or
- 3 or more episodes of UTI with cystitis / lower urinary tract infection

Renal cortical scintigraphy (with dimercaptosuccinic acid [DMSA]) in six months is recommended in patient with high risk factors, recurrent UTI, abnormal US or VUR shown to evaluate for renal parenchymal defects and relative renal function.^{3,6}

1 MCU

The main role of MCU is to detect VUR. Patient with high grade VUR (grade 3-5) are more likely to have recurrent UTI and scarring.² It can also detect obstructive anomalies, such as posterior urethral valves or ectopic ureterocele.

2 US

US can detect urinary tract anomalies such as hydronephrosis, duplex renal system, hydroureter and ureterocele. Sensitivity of US for detecting VUR and renal scarring is low.²

3 Nuclear medicine

3.1 Renal cortical scintigraphy

Renal cortical scintigraphy with DMSA has greater sensitivity for detection of acute pyelonephritis and renal scarring than does either US or MCU. The findings on nuclear scans rarely affect acute clinical management. Hence, it is not recommended as part of routine evaluation of infants with their first febrile UTI.⁵ It is recommended 6 months after the febrile UTI to obtain a morphological and functional evaluation of the renal parenchyma.⁶

3.2 Radionuclide cystography (RNC)

Direct RNC is comparable in sensitivity to MCU in detecting VUR. RNC has a lower absorbed radiation dose than MCU but it does not have the spatial resolution needed to identify anatomical abnormalities of urethra, bladder and ureters. Initial evaluation of VUR in girls and follow-up studies may be done by RNC.²

4 Contrast-enhanced voiding urosonography (ceVUS)

ceVUS is an ultrasound-based reflux examination, involving intravesical instillation of ultrasound contrast and continuous alternative sonographic examination of the kidneys, bladder and urethra. It has been applied in Europe for two decades. The procedure is similar to MCU except the replacement with ultrasound contrast and sonographic examination.⁴ ceVUS has been considered as a safe, reliable, radiation-free and valid alternative to MCU or RNC, and has a higher reflux detection rate than MCU due to stability of ultrasound contrast microbubbles, advances in ultrasound technology, and longer examination time.^{1,7} The currently used stabilized ultrasound contrast agent has been approved in paediatric use by the U.S. Food and Drug Administration in 2016, though the intravesical application in ceVUS is still off-label.⁸

ceVUS can be considered as an alternative to MCU in the following conditions:

4.1 First examination for vesicoureteric reflux in girls

4.2 Follow up examination for vesicoureteric reflux in boys and girls after conservative or surgical treatment

4.3 Screening high-risk patients for vesicoureteric reflux

Application of ceVUS in male urethral assessment is feasible and accurate,⁸⁻⁹ and expanded use of ceVUS in first examination in boys will be further validated.

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