Standardised Operating Procedure

Radiology

chILDRANZ 2020

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Proposed Best Practice Checklist

Imaging Protocols for chILD

Indications

CT scanning is performed to confirm the presence of Interstitial Lung Disease (ILD), because often the paediatrician cannot be sure of this from the CXR alone; occasionally the CT is diagnostic, and no further testing is needed. CT is also useful to guide the site of a biopsy if required and, subject to the limitations below, for follow up.

CT PROTOCOL FOR CHILDREN WITH KNOWN OR SUSPECTED DIFFUSE LUNG DISEASE

The principles in these recommendations are applicable to all modern (post 2005) multi detector CT scanners and where possible parameters specific to a given manufacturers CT machine have been avoided.

Patient Preparation

While ventilation-controlled CT provides the highest quality images and enables inspiratory and expiratory reviews, awake CT may provide sufficient information and should be considered against the risk of general anaesthesia or sedation. Special considerations apply to neonates and very young children, but most children over 3 years of age can comply with the demands of an unenhanced CT of their lungs. A short interaction with the child before the CT allows an opportunity to determine whether the child is able to carry out instructions to breath-hold during the scan. Quiet respiration might be acceptable if voluntary breath-holding is not possible though tachypnoea can affect the quality of the image thus potentially increasing the risk of a failed investigation and unnecessary exposure to radiation. Feeding neonates prior to the CT may encourage them to fall asleep during the procedure. Sedation procedures in agreement with in-house anaesthetics may be recommended. General anaesthesia (GA) is rarely necessary and reserved for non-compliant patients and/or those who are unsuitable for sedation.

A suggested protocol for general anaesthesia, which will also allow expiratory films to be obtained, is given as an appendix to this SOP. If either sedation or general anaesthesia is used, then possible effects on image quality (e.g. atelectasis) should be considered. The other advantage of general anaesthesia is a combined approach with bronchoscopy and lavage to be performed AFTER acquisition of scan in some centres. Consideration should be given to spirometry gated CT scans if available.

Patient Positioning

The CT imaging couch is primarily designed for adult use. Younger children must be raised up on extra blankets/sponges to ensure they are optimally positioned in the gantry's isocentre -if too far off the isocentre, the tube current and spatial resolution is affected. The supine child should be placed feet first into the scanner with their arms extended above their head, in this way parents are able to maintain physical contact with their child and reassure them during the procedure. Keeping the arms up and away from the chest reduces image artefacts, particularly at the lung apices. It also improves the performance of the machine's automatic tube current modulation (ATCM). Patients under GA should also ideally be imaged in this position with ventilation tubing positioned away from the chest area. Under GA, respiration can be suspended at near total lung capacity (TLC) to optimize imaging of the lung parenchyma. Please see Diagram 1 for Patient positioning and management.

Basic Imaging Protocol

The preferred initial diagnostic CT imaging protocol is a low-dose thin-slice volumetric acquisition of the entire lung volume with the patient performing an inspiratory breath-holding at Total Lung Capacity (TLC), without the administration of intravenous contrast medium. Specifically, administration of contrast medium will make the assessment of ground glass shadowing almost impossible. Details of recommended acquisition and reconstruction parameters for the topogram/scout-view and subsequent CT of the lungs are given in Tables 1 and 2 respectively.

Although the radiation burden involved in this volume technique is higher than the traditional non-contiguous, interspaced axial technique 'high resolution' CT (HRCT) the obvious advantage of a volumetric acquisition is that it allows examination of all of the lungs, thus minimising underestimation of subtle or localised abnormalities.

Acquisition times for volumetric scanning are short, and no longer than a single breath hold (again, shallow breathing might acceptable if the child is uncooperative or young) and hence easier to perform than repeated non-contiguous, sequential HRCT acquisitions, which requires more skill and patience on the part of technologists/radiographers.

Image data are reconstructed on a high spatial resolution (lung or bony) algorithm for optimal lung parenchyma and on a medium-soft algorithm to demonstrate mediastinal structures.

If a mixed airways and interstitial process is suspected (for example subacute hypersensitivity pneumonitis) a limited interspaced 3-slice end-expiratory CT acquisition may be undertaken to demonstrate the presence of lobular air-trapping, although this should not be regarded as a routine of obligatory addition in patients with diffuse lung disease. An alternative technique for patients unable to breath-hold at end-expiration is to place the individual in the decubitus position, with two axial slices taken in both right and left decubitus positions - see Table 3. The dependent lung behaves as if in a state of expiration, whilst the non-dependent lung is in inspiration.

The near isotropic resolution of modern CT scanners means that high quality image reformats in any viewing plane are possible; in addition, various post-processing techniques such as minimum intensity (MinIP) and maximum intensity projections (MaxIP) may aid diagnostic interpretation.

In cases in which follow-up CT is felt justifiable, for example to monitor disease progression, a non-contiguous sequential HRCT acquisition should be followed, essentially sampling the lungs (apices to lung base) at end-inspiration using 1mm slice width with a 10mm (in larger children 15 or 20 mm) inter-slice gap - see Table 4.

Optimising Exposure Parameters

Because CT can carry a relatively high radiation burden to the patient, every effort must be made to limit the radiation dose and thus minimise risks of harm to children who are particularly susceptible to the deleterious effects of radiation. Optimisation of the imaging parameters is mandatory, with protocols tailored to take into account the patient's age and weight. This can be done by having weight-specific protocols as given in Tables 2-4. Particular care should be taken to limit the CT examination only to the area of interest, so that radiosensitive organs are not inadvertently included.

It is now standard practice to use a relatively low kVp (80 -100kVp) when imaging children, without detriment to image quality. The mAs can be set manually or the ATCM image quality indicator can be set instead.

Weight-specific scan protocols with manual mAs can be configured by adjusting the mAs to obtain the target CTDIvol values in Tables 2-4. Configuring ATCM protocols is more complex but can be approached as follows:

1) Initially configure the weight-specific scan protocols using the manufacturer's suggested values for the image quality indicator (quality reference mAs, noise index etc.)
2) When scanning patients using these protocols, note the predicted CTDIvol after the topogram/scout view and adjust the image quality indicator until the target CTDIvol is achieved. Make a note of the new value. Proceed with the scan.
3) Use the scan technique described in (2) for a few patients (about 5) in each weight range. Taking an average of the post-adjustment image quality indicators will provide best-estimates of what the image quality indicator values should be in the various scan protocols.
4) Re-configure the scan protocols by setting the image noise indicators to the average values obtained from the exercise above.
5) Build a separate protocol for use during cases requiring General Anaesthetic to build in suitable pre-scan delays – see Appendix. Protocol for general anaesthetic HRCT scans. However, institution specific protocols can be used.
6) Scan patients as normal.

Scan pitch is also important in spiral acquisition: a pitch greater than 1 decreases examination time, which is beneficial when imaging younger children, particularly as a means of reducing motion and respiratory artefact. However, with increasing pitch (in an attempt to scan more rapidly), the over scan at the beginning and end of the scan increases, thus use the pitch suggested by the scanner vendor to optimise this protocol.

Diagram 1 for Patient positioning and management (with Spirometry gating if using)

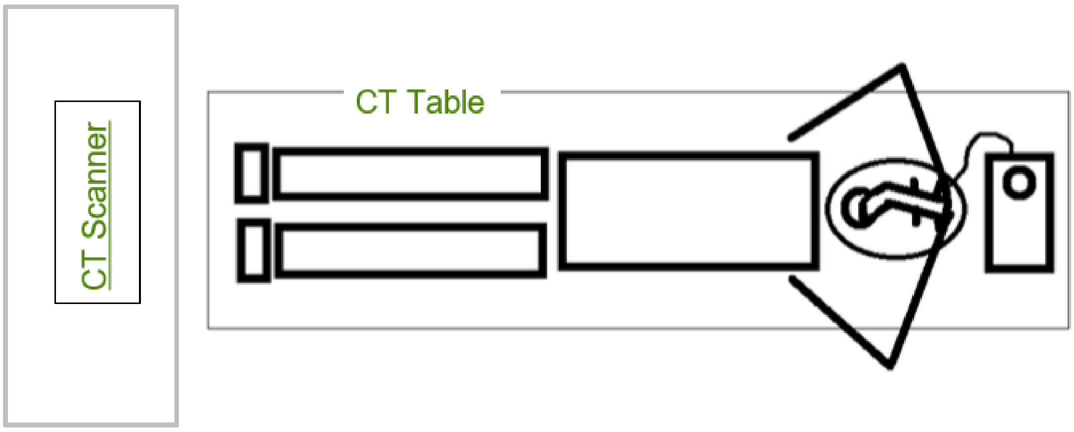

Table 1. Topogram / scout view imaging parameter

Scan Parameter	80kV, 20mA
Scan Direction	Cranial-Caudal
Tube Position	Under Table

Table 2. Inspiratory Volumetric Chest CT Imaging Protocol

Scan Mode	Helical
Scan Parameter: Under 9kg 10 -15kg 16 -25kg 26 -35kg 36 -45kg Over 46kg	kV Target CTDIvolmGy (IEC Body dosimetry phantom) 80 0.9 100 1.0 100 1.3 100 1.4 100 1.6 100 1.8
Dose Modulation	On
Tube Rotation	0.5sec
X-ray Collimation	20 mm or more at 0.5 or 0.6mm slice collimation
Coverage	Apices to lung bases
Scan Pitch	1 or less for x-ray collimations greater than 20 mm – or *as per manufacturer's suggestions*
Recon Slice Width	1mm
Recon Slice Interval	0.7mm
Recon Kernel	1st recon – sharp (e.g. B60 / I70 for Siemens; YA for Philips; Lung for GE; FC55 for Canon) 2nd recon – medium-soft (e.g. B30 / I41 for Siemens; A for Philips; Standard for GE; FC18 for Canon)
Window Width/Centre	1st recon – high-resolution lung parenchymal setting 2nd recon – mediastinal setting
Post Processing	1mm coronal MPR, sharp kernel (e.g. B60 / I70 for Siemens; YA for Philips; Lung for GE; FC55 for Canon), lung setting 3mm coronal MPR, medium-soft (e.g. B30 / I41 for Siemens; A for Philips; Standard for GE; FC18 for Canon) mediastinal setting Optional: use the thin, medium-soft axial image data set for coronal MinIPs, 4mm thick/2mm interval, lung setting.

*Table 3. Expiratory Axial HRCT Imaging Protocol (NB ONLY USED IF SMALL AIRWAYS DISEASE ALSO SUSPECTED)

Scan Mode	Sequence
Scan Parameter: 1 - 25kg 26 - 35kg 36 - 45kg Over 46k	kV Target CTDIvolmGy (IEC Body dosimetry phantom) 100 0.06 100 0.08 100 0.09 100 0.10
Dose Modulation	On
Tube Rotation	0.5sec
X-ray Collimation	~1mm (e.g. 2 x 1mm for Siemens)
Coverage	Ability to breath-hold-3 evenly spaced slices at the apices, carina and lung bases Inability to breath-hold -2 slices each side with patient in R & L decubitus position
Table Feed	25mm-35mm dependent on size of child
Recon Slice Width	1mm
Recon Kernel	1st recon - sharp (e.g. B60/ I70 for Siemens; YA for Philips; Lung for GE; FC55 for Canon) on lung setting 2nd recon – medium-soft (e.g. B30 / I41 for Siemens; A for Philips; Standard for GE; FC18 for Canon) on mediastinal setting
Window Width/Centre	1st recon – high-resolution lung parenchymal setting 2nd recon – mediastinal setting

* Table 4. Inspiratory interspaced Axial 'HRCT' Imaging Protocol (for follow-up studies)

Scan Mode	Sequence
Scan Parameter: 1 - 25kg 26 - 35kg 36 - 45kg Over 46k	kV Target CTDIvolmGy(IEC Body dosimetry phantom) 100 0.17 100 0.20 100 0.25 100 0.35
Dose Modulation	On
Tube Rotation	0.5sec
X-ray Collimation	~1mm (e.g. 2 x 1mm for Siemens)
Coverage	Apices to lung bases
Table Feed	10mm (15 or 20mm in older taller patients)
Recon Slice Width	1mm
Recon Kernel	1st recon - sharp (e.g. B60 / I70 for Siemens; YA for Philips; Lung for GE; FC55 for Canon) on lung setting 2nd recon – medium-soft (e.g. B30 / I41 for Siemens; A for Philips; Standard for GE; FC18 for Canon) on mediastinal setting
Window Width/Length	1st recon – high-resolution lung parenchymal setting 2nd recon – mediastinal setting

RECOMMENDATIONS:

We should report and audit for all centres:

1) Radiation dose used; the figures here may need to be exceeded for various reasons, but this should be the exception.
2) Diagnostic quality of the scans. Clearly, we all need to balance radiation and diagnostic quality, but we also need to audit our performance

Acknowledgement:

European Management Platform for Childhood Interstitial Lung Diseases

Australian Genomics Health Alliance

Further Support:

Please contact your local radiologist/s +/- anaesthetist/s for further advice pertaining to your site.

References:

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Mahmoud, M., Towe, C., & Fleck, R. J. (2015). CT chest under general anesthesia: pulmonary, anesthetic and radiologic dilemmas. *Pediatr Radiol, 45*;7 pp 977–981.

Newman, B., Krane, E. J., Gawande, R., Holmes, T. H., & Robinson, T. E. (2014). Chest CT in children: anesthesia and atelectasis. *Pediatr Radiol, 44*;2 pp 164-172.

Appendix. Protocol for general anaesthetic HRCT scans.

This has been used successfully in the London Cystic Fibrosis Collaborative multicentre study. Institution specific protocols may be appropriate.

ANAESTHETIST'S and RADIOGRAPHER'S GUIDELINES

The DAY before CT scan

- Senior clinician at each centre to ensure that anaesthetist and assistants, and radiographer responsible for the procedure realise that this is a CT with a special protocol that must be adhered to from the point of anaesthetics, ventilatory pattern and scanning parameters.
- To read the respective research protocols (anaesthetics and scanning protocols) prior to the day of the procedure.
- Anaesthetist, radiographer, any assistants and senior clinician meet to discuss execution of the protocol and to clarify instructions/ communication about acquiring topogram, inspiratory spiral and expiratory scans.
- Ensure that handheld manometer gauge and anaesthetic circuit set up as per protocol and working (fresh circuit per subject).
- Ensure that intercom between CT scan and control room is working and at adequate volume. It is VITAL that anaesthetist and radiographer can hear each other clearly, as communication MUST be verbally expressed and not through automated CT machine.
    - Timing anaesthetic breath holds to the voice form the CT machine, giving the patient breath hold instructions may be an alternative.

THE DAY OF THE SCAN

- Unless contra-indicated, induction of anaesthesia will generally be gaseous using oxygen and nitrous oxide and sevoflurane.
- Atracurium(0.5mg/kg) administered IV as a muscle relaxant, paralysis being maintained throughout the CT and BAL.
- The child will be intubated with an appropriately sized endotracheal tube to ensure minimal leak at 35 cmH2O and sufficient calibre to pass a 2.8mm bronchoscope.
- Anaesthesia will be maintained for the CT scan with sevoflurane oxygen and air (FiO20.3) and patient ventilated to maintain appropriate end tidal CO2 (4.5-5kPa) with 5 cmH20 PEEP, using handheld pressure gauge/manometer (essential equipment to take to CT–you cannot rely on ventilator settings)
- During initial mask bagging, there is a tendency for air to enter stomach which may distort images. Pass NG tube and apply suction to reduce any gastric distension PRIOR to initial topogram. Depending on how the induction is managed as to the likelihood of air in the stomach
- Baseline ventilatory pattern via anaesthetic machine: pressure controlled IPPV,
    - Respiratory rate 20 bpm
    - I:E ratio 1:2
    - VT 8-10ml/kg
    - PEEP: 5 cmH20

    Suitable for most patients, otherwise choose a rate suitable for a given patient weight/ age

KEY MESSAGES

- Undertake a thorough airway and respiratory assessment of the patient.
- Tailor the anaesthetic management for each patient.
- Use an endotracheal tube.
- Ideally use an air/oxygen mix during scanning.
- Perform a robust recruitment manoeuvre. For example, inflate the lungs to 35 cm h20 for 15 seconds; repeat >3 times. Use lower pressures if the patient has risk factors for barotrauma.
- Perform the inspiratory scan with 35cm H20 breath hold as used for the recruitment manoeuvre.

PROCEDURE

- Radiographer will adjust scan parameters and once ready for topogram will say **'READY FOR TOPOGRAM'.**

- The anaesthetist will then ensure patient breath-hold on full inspiration at 25 cmH2O and say **'GO FOR TOPOGRAM'** until instructed to release by radiographer who will say **'FINISHED'.**

- Radiographer will adjust scan parameters for inspiratory and expiratory acquisitions. Once ready, radiographer will say **'START INFLATIONS for INSPIRATORY SCAN'.**

- Anaesthetist will then perform
  - **6 deep slow inflations** to **35-40cmH2O** with a PEEP of 6 cmH2O to reverse any anaesthetic related atelectasis (anaesthetist will count from **1 to 6**), followed by
  - **4 deep slow inflations** to **25cmH2O** with a PEEP of 5 cmH2O to provide standard lung volume history (anaesthetist will count down from **4 to 1** and then say **'GO'** at the final inflation (on the count of 1) to 25cmH2O.
  - During the inspiratory scan, the child's lungs will be held in inspiration for ~6s at 25 cmH2O, or default 35CM H2O for 15 seconds, until radiographer instructs **'FINISHED INSPIRATORY SCAN'.**

- Anaesthetist will then release BAG completely to **allow passive expiration to relaxed end expiratory volume (ZERO PEEP).**

- Once lung deflation complete; Anaesthetist instructs radiographer by saying **'GO FOR EXPIRATION'** (In-built 6s delay before scan commences ensures stable end expiratory level).

- Radiographer will inform anaesthetist when complete and **normal ventilator support can resume.**