

Chapter 80. Chest Computed (CT) Tomography

80.1 General Overview and Logistics

Purpose

1. To obtain thin slice high resolution chest computed tomography (CT) scans of the chest in participants with pulmonary vascular disease.
2. To provide standardized reading/data interpretation.

Rationale

Refinements in CT image acquisition and post processing have enabled the identification and quantification of clinically relevant features of acute and chronic conditions such as pulmonary vascular disease. These include vascular enlargement, tortuosity and pruning that selectively affect the arterial and venous circulatory beds in the lung. Associated changes in lung density and overall lung morphology may aid in disease characterization as well. Diffuse lung diseases such as obstructive physiology from emphysema or chronic bronchitis, or restrictive physiology from chronic fibrotic interstitial lung disease may contribute to the etiology in pulmonary hypertension and will likely be evident on CT imaging. As core imaging investigators, we hypothesize that these features may be used to discriminate the etiology and pathophysiology of disease. Objective assessments of these features may also be used in therapeutic trials as an intermediate study endpoint (i.e. change in tortuosity or distribution of blood vessel volume) and potentially even as a metric of disease that may predict response to therapy (i.e. severity of arterial pruning may predict vasodilator response).

Introduction

Detailed CT parameters and procedures can be found in Sections 80.5 and 80.6. Briefly, there are some scanner to scanner variations in image acquisition and reconstruction. These differences may influence qualitative and quantitative analysis of vascular and lung morphology. To account for and try to adjust for these differences, imaging investigators will be using predefined CT parameters that may provide comparable images for analysis. The most important aspect of image standardization is that each participant undergoes the same imaging protocol. Inter-subject consistency is critical for the most accurate measures of change in vascular and lung morphology.

CT scans will be collected at all participating centers, stored locally and digitally transferred to the Lung Imaging Core (LIC) at the Cleveland Clinic for further analysis. The Lung Imaging Core Lab, under the direction of Jason Lempel, MD, will serve as the radiology core to provide standardization, secondary interpretation and data analysis of all chest CT imaging obtained and performed for the PVDOMICS Study.

The Lung Imaging Core's contact information is located in the PVDOMICS Address Directory located at http://qhsapps.ccf.org/pvdomics/General_info.htm. Click on 'Address Directory.'

Additionally, the LIC will provide qualitative and quantitative CT analysis following these predefined CT parameters and provide these data to the PVDOMICS DCC.

Use of historical Chest CT scans will be permitted for the study provided the following criteria are met:

- o CT scan slices must be thin (1 mm) or less
- o Images obtained can be uploaded to LIC using iUploader software
- o Local radiologist analysis and interpretation is available
- o Scan is within 1 year prior to Form 100-General Enrollment date
- o Historical CT scans obtained from outside institutions may be uploaded if all other criteria are met

80.2 System and Personnel Requirements

80.2.1 Local Center provides:

- o Dedicated room
- o Scanner(s) (current manufacturer information as provided on Form 20, *changes to type of scanner and/or software must be kept current, see appendix X*)
- o Computer with windows operating system, version 7-10 (*contact LIC if other operating system on computer is used for PVDOMICS Study as there may be compatibility issues with iUploader software.*)
- o Names and contact information of PVDOMICS CT imaging personnel (*via Form 10 and kept current as personnel may change over the course of the study*)
- o Sheets/blankets/pillows for participant comfort
- o PVDOMICS data collection form(s), pens
- o PVDOMICS Study ID and Alphacode (provided by the Study Coordinator)

80.2.2 CT Imaging Core Provides:

- o Scanning parameters
- o TeraRecon iUploader software
- o Instructions for standardized participant breathing
- o CT Technologists training for:
 - PVDOMICS Study Participant Scanning Procedures
 - Instructions for image transfer to LIC

80.2.3 Local Center Personnel Requirements

All centers have a radiologist certified by the American Board of Radiology (ABR) with dedicated subspecialty training in thoracic imaging. ABR certified radiologists participating as part of the PVDOMICS Study should be familiar with study related procedures.

Technologists must be American College of Radiology (ACR) certified. Technologists must review PVDOMICS Chest CT Manual of Operations Chapter 80 and all appendices. The PVDOMICS Study Coordinator should have all signed attestation statements on file and record each technologist's date of review on Form 10. This documentation must be current and properly recorded before scanning study enrolled participants.

Centers should have an IT administrator/director with authority to manipulate firewalls and assist with TeraRecon iUploader software installation and trouble-shooting.

The LIC Core will provide training for techs and coordinators as follows:

- o Initial PVDOMICS Study central training
- o Webinar for software installation and use
- o Review and provide feedback to local center on transfer of test case
- o Individual guidance by LIC Radiologist(s)

80.3 Participant Exclusion from Chest CT Scan

In the instance where a participant may be obese, the study team should determine the participant's ability to safely fit into the CT scanner. If the participant exceeds the scanners weight limit, do not attempt the CT scan, regardless of whether or not a historical scan is available.

80.4 Chest CT Scanning Parameters and Procedures Overview

For the purposes of PVDOMICS study, CT scans obtained as part of routine clinical care may be performed with or without intravenous contrast as deemed appropriate by the ordering clinician at the local center. In this setting, the CT protocol utilized will be one prescribed by the local imaging department for evaluation of the clinically suspected disease, as long as the raw data is reconstructed into 1mm or thinner sections.

CT scans performed on comparator subjects or on participants with pulmonary hypertension but for research purposes only (not part of clinical evaluation), will be performed without intravenous contrast.

Furthermore, participants who have had previous CT scans performed within 1 year prior to study enrollment and for whom the study center has reconstructed and saved the images on their PACS server at 1mm thickness or less, may use these previously obtained images as part of the participants full PVDOMICS imaging evaluation. These previously obtained CT scans, whether performed with or without IV contrast, will be uploaded with their full DICOM set and sent to the Lung Imaging Core in place of new CT images. These images will be used for review by the Imaging Core Director.

Each center has specific parameters that must be implemented for the PVDOMICS chest CT scans. Scout films use default parameters. Centers have the discretion on type and number of scouts, however, must maintain ALARA principle. (*ALARA is an acronym for As Low As Reasonably Achievable. This is a radiation safety principle for minimizing radiation doses and releases of radioactive materials by employing all reasonable methods.*)

These items are provided for each center: Parameter, Scanner, Scan Type, Rotation Time (s), Detector Configuration, kV, Pitch, , Reconstruction Algorithm 1, Reconstructure Algorithm 2, Thickness (mm), Interval (mm),

80.5 Radiation Dose Selection

The Study Coordinator should assist the CT Technologist with providing the Body Mass Index (BMI) to set the effective mAs. A measured BMI is recorded on PVDOMICS Form 132-BIA or the Coordinator can provide a measured height and weight as recorded on this same

- Extra small, small, medium or large effective mAs settings for the PVDOMICS scans are based upon the participant's BMI.

Identify the correct effective mAs setting based on the patient's BMI using Table 1 below.

Table 1 Effective mAs as a function of BMI

Body Size	BMI Range	Effective Milliaperages (mAs) setting to be used
Large	>30	165
Medium	20 - 30	110
Small	15 - 19	90
Extra Small	<15	60

If the CT scan is being done for research only, the participant does not need to wait for an assessment of the image quality as the participant is scanned once and is done.

80.6 Chest CT Scanning Procedure

For the purposes of PVDOMICS study, CT scans obtained as part of routine clinical care may be performed with or without intravenous contrast as deemed appropriate by the ordering clinician at the local center. In this setting, the CT protocol utilized will be one prescribed by the local imaging department for evaluation of the clinically suspected disease, as long as the raw data is reconstructed into 1mm or thinner sections.

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Scanners of different makes and models deliver different number of photons to the subjects for a given milliamperage (mA) setting because of differences in beam infiltration, variances in tube potential, etc. Therefore, using fixed mA across scanners will result in dissimilar exposures, leading to noise differences and possible inconsistencies in the reported CT number, Hounsfield units (HU) and radiation exposures. Dose modulation is not allowed for quantitative CT study since each manufacturer modulates differently, causing increased likelihood of system differences across scanners. BMI and scan type will determine the effective mAs or mA setting. These are recommended as a function of large, medium, small or extra small BMI as detailed in Table 1. This mechanism allows for optimal doses to the various size subjects. The CT technologist will use these guidelines to choose the effect of milliamp seconds (mAs) (Siemens) or mA (GE) setting for a given BMI. Table 1 demonstrates examples of the radiation doses for a given BMI size.

Scout scans will be obtained to minimize the subject's exposure to radiation and must be performed at the lung volume for which anatomical boundaries are being evaluated. Each study site should perform scouts as deemed locally appropriate such that when spirally scanned, the full extent of the lung is acquired at the respective lung volumes and over scanning is kept to a minimum. Inadequate scout scans maybe repeated as per site-specific determination. Spiral scans however may not be repeated, unless clinically warranted as determined by an on-site thoracic radiologist.

Exposure factors (kV and mA) for the topogram should be set to the lowest available on the CT scanner that provides an acceptable image. The scanner settings utilized in PVDOMICS should

be maintained consistent throughout the duration of the study. The data shall be displayed using a display field of view (DFOV) that includes the lungs and entire chest wall in the right/left dimension so that resolution of the lung is maximum. The standard reconstruction algorithm data is all that will be used for further computer analysis. The soft tissue and lung reconstruction algorithm (B30 and B60, respectively, or standard and detail, depending on vendor) data is necessary for the supervising radiologist to interpret the image data set in standard fashion.

The specific CT scanning parameters will vary slightly from center to center based upon the differing types of CT scanners used. Manufacturer and type CT scan parameter data specific for each of the centers starts in this chapter.

Each center will be using multi-detector CT scanners (64 detectors or greater). CT scans will be obtained at maximum inspiration using the center-specific parameters in this chapter. The DFOV will be selected to include the chest wall. ***Note that dose modulation based upon body habitus is not used.***

After acquiring the CT data, images will be reconstructed using standard algorithms as detailed in using center-specific parameters in this chapter.

If the CT scan is being done for research only, the participant does not need to wait as the participant is scanned once and is done.

Scan Coverage

CT scan must include the lungs and minimize additional exposure. Start the scan slightly above the apex of the lungs and stop it once the scan is through the base of the lungs as shown in Figure 1. The DFOV should fit the lung and include some of the chest wall as shown in Figure 2.



Figure 1.

The DFOV should fit the lung and include some of the chest wall as shown in Figure 2.

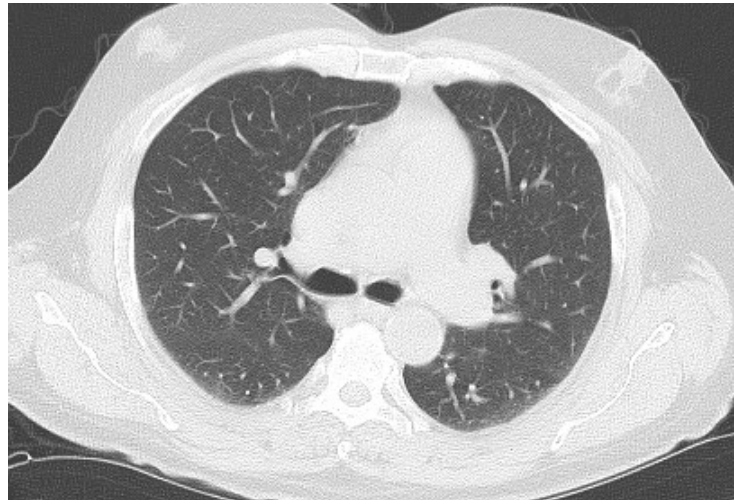


Figure 2.

80.7 Participant Preparation and Positioning on Scanner Table

Follow individual center's guidelines for participant identification and preparation for the CT scan.

It is important that the patient fully understands the breath hold and scanning procedure and that all concerns are addressed prior to performing the CT scan. It is recommended that the Study Coordinator will assist the CT technologist in the effective mAs and DFOV settings.

Patient Positioning

- Place patient in a supine position, arms positioned comfortably above the head in a head-arm rest, lower legs supported.
- Using the laser positioning lights, line up the patient so the chest is iso-center (in the middle: left-right; up-down) of the CT gantry.
- Move the table so the patient is in the correct position for a chest CT scan.



80.8 Local Center CT Scan Results Reporting

All CT images obtained as part of PVDOMICS will be reviewed and reported by a member of the local center's thoracic radiology group. All CT scans obtained will be accompanied by full clinical radiology reports. The reporting local radiologist will follow normal clinical workflow guidelines regarding notification and communication of both urgent and actionable findings to the referring physician and/or PVDOMICS center's Principal Investigator (PI).

80.9 Data De-Identification and Data Transfer Overview

All imaging (DICOM) data obtained or submitted to PVDOMICS Lung Imaging Core review will be de-identified and uploaded from the local center to LIC iNtuition Research server. This data de-identification and data transfer procedure is detailed in Chapter 80 Appendix A.

(Note: it is anticipated that a center's PVDOMICS Study-trained CT Technologist will complete these steps but a study coordinator may work with the CT tech to complete the process.)

80.10 Chest CT Data Collection Forms

The Study Coordinator or CT technologist should fill out Form 252-Center the appropriate form for each CT scan in the study as they are obtained. This process will help ensure quality data and minimize deviations from the desired CT protocol.

Form #252 should then be given to the study coordinator. The coordinator needs to obtain a final radiologist's report and de-identify it by marking through identifying information and placing PVDOMICS Study ID and alphacode. This anonymized copy should be scanned into pdf format and submitted to secure PVDOMICS location (to be determined), Form #252 should be completed and entered into PVDOMICS database and transmitted to the Lung Imaging Core.

If a historical CT scan was used, Form #253 should be completed by the coordinator and entered into PVDOMICS database along with an accompanying anonymized center CT scan final report.

80.11 Image and Data Storage at Local Centers

Images used for the purposes of the PVDOMICS Study should be maintained locally in DICOM format until the study has been completed. It is recommended that a document be maintained to identify both the local center's identifying information and the PVDOMICS Participant's identifying information (Study ID, alphacode, date of CT). This document is for local use only and not provided to the Lung Imaging Core.

A de-identified copy of the report from the local center should be stored with participant's study ID and alphacode.

Appendix A. Data De-Identification and Data Transfer Procedure

1. Obtain a copy of DICOM Images and make available either on CT console, local drive, cd or other destination folder.
2. Make sure the patient identification on the DICOM images match the PVDOMICS Study participant number and alphacode.
3. De-identify the DICOM images by dragging and dropping the DICOM data into the iNtuition uploader to be manually anonymized (with removal of pre-configured DICOM tags). PVDOMICS ID # is added during this same step.
4. Transmit through secure digital network to the LIC iNtuition server. This complete step-by-step process is detailed in *Appendix D*.

These next steps are generally completed by the Study Coordinator:

5. Obtain a copy of the radiologist's finalized clinical report. This report will be used by the Core for review and to assure correct interpretation of the radiology images.
6. Review report thoroughly to catch any participant identifiers. There may be redacting capabilities via your site's adobe software or you may have to print the report and blacken out any patient information. Date of image on the report must match the DICOM images.
7. Write the PVDOMICS participant number and alphacode on the top of each page of the report.
8. Submit this report electronically in a .pdf format. ***This section will be updated.***
9. Complete and enter Form 252 into the PVDOMICS database to alert the Core that an image is sitting in a queue on the research server. (Once a form is saved in the database, an email notification will be sent automatically to local site, Core, and DCC.)

The email message to the local center will be the only notification sent that a participant's images, radiology report and transmitted data have been received. The center will be notified only if there were any discrepancies identified such as PVDOMICS ID/alphacode mismatches.

Routine, weekly reports will be generated by the database identifying any problems with missing reports or Form 252's. Each enrolled participant will have either a Form 252 or 253 entered into the database even if the CT scan was not done.

(Center Specific Scanning parameters to follow after data transfer section) Each will be linked for center to print out its own center information.