4 Chronic Obstructive Pulmonary Disease Analysis

The **Chronic Obstructive Pulmonary Disease (COPD) Analysis** application provides semiautomatic and manual tools to help visualize and measure COPD disease in adults.

COPD supports loading up to 4 **Studies** of the same patient for comparison, as well as loading **Results** saved from the **Lung Nodule Assessment (LNA)** and **Multimodality Tumor Tracking (MMTT)** applications.

The COPD application enables the calculation of total lung volume, right lung volume, left lung volume, individual lobes in the lungs, volume of low attenuation area in lung in each lobe (LA Volume), each lung and total Low attenuation volume. The application can also be used to calculate the measurement of the airway and lumen along the centerline of the segmented airway tree.

COPD Analysis consists of 4 workflow stages:

- **Segmentation**. Review, edit and verify the results of semiautomatic airway segmentation, lung segmentation and lung lobe segmentation.
- **Lung Density**. Calculate the low attenuation volume for each lung and lung lobe on the **Emphysema Analysis** tab. On the Air Trapping Analysis tab, measure the air trapped in each lung based on the identified end inspiration and end expiration scans (requires at least 2 **Series**).
- **Airway Extraction**. Review and edit the airway tree and centerline during this stage. If only non-contiguous contrast or non-contrast axial datasets are loaded into the application, this stage is unavailable.
- **Airway Measurement**. Measure the airway lumen and wall cross sectional for different locations on the airway tree.

Supported Scan Types

The application supports contrast-enhanced and non-contrast prospectively ECG-gated axial or retrospectively-gated helical CT images, as well as contrast and non-contrast volumetric helical scans of the lungs, 1-mm thin images every 10 to 15 mm in either standard or high resolution. Data reconstructed with 512, 768, and 1024 matrix is also supported.

COPD only supports Supine scans.

Exclusion Criteria for COPD Analysis

The COPD application might have sub-optimal segmentation and measurement results for studies in which the patient has one of the following:

- Partial lung (for example, post lobectomy or congenital disorder)
- Severe lung disease (for example, pleural effusion or pulmonary edema)
- Post treatment hardware (for example, metal grafts, endo bronchial tubes, pacemakers)

Recommended Protocol for COPD Analysis

For optimal results, the use of thin slices (up to 3 mm, with overlap) and a sharp reconstruction filter (C, L or YA, YB, YC on Philips scanners) is recommended. However, excessive noise may result in sub-optimal airway, lung and lobes segmentation and measurements. To mitigate high noise studies, apply the soft tissue reconstruction filter and/or make use of the appropriate iterative reconstruction (IR) techniques such as Philips iDose4 or IMR.

Pre-processing

When pre-processing is configured in the **Preferences**, segmentation is performed on the **Study** prior to loading it into the application (reducing loading time). For example, pre-processing may be configured for the following CT helical **Exams**: **Chest**, **Large Chest**, and **HRCT Spiral** scan types in the **Chest** protocol group on Philips scanners (pre-processing is also supported for non-Philips scanners). The following algorithms should be selected:

- Automatic Airway Segmentation
- Automatic Lung Segmentation
- Automatic Lung Lobe Segmentation
- Automatic Airway Centerline Calculation

Threshold Settings for Calculating Low Attenuation Area/Volume (LAA/LAV)

It is possible to set the default threshold values for the emphysema calculation (available in the Lung Density stage). This is set within **Preferences** (**Viewing Applications** page). The two threshold values that can be set are:

- **Threshold for Threshold method**
- **Threshold for Percentile method**

Additionally, for clinical administrators only, there is an option available to share these settings with all users. Placing a check mark in the **Share with all users** check box will share the default threshold values with all users.

WARNING

When loading images into the application, all images which contain 16 bit data are converted into 12 bit images. This means that for rescale intercept equal to -1000, HU values above 3095 are displayed as 3095. For rescale intercept equal to -1024, HU values above 3071 are displayed as 3071.

Indications for Use

The CT Chronic Obstructive Pulmonary Disease (COPD) application supports users with the viewing and analysis of Chest CT scans. The application enables localization of affected areas and calculates diseased lung volume and percentage of affected lungs based on low attenuation areas/volumes via a guided workflow for airway analysis, reviewing and measuring airway lumen, and assessing air trapped.

Launch COPD Analysis

Select the desired **Study** in the **Directory** and select **COPD** from **Analysis** applications menu.

NOTICE

When launching the COPD application, Portal also loads the **Study** into the **CT Viewer**. See the **CT Review** section for more information on using the viewer.

1. From the **Patient Directory** find and select the desired **Study** and **Series.**
2. Select the **COPD** icon from the application icon chart.

3. The application opens in the **Verify Segmentation** stage.

NOTICE

If non-contiguous, 2D datasets are loaded, the application opens in the **Lung Density** stage. Automatic segmentation is not performed with non-contiguous axial (contrast or non-contrast) datasets.

Loading Multiple Series

If multiple **Series** of an acquisition are loaded, automatic segmentation is performed on all **Series**. When segmentation is complete, select the desired **Series**. For example, the end-inspiration or end-expiration **Series** may be viewed using the **Series** tab or **Next Series** button.

NOTICE

Once all **Series** are loaded, review, verify, and edit every **Series** before continuing.

Loading Follow-up Data Sets

When loading data sets from different time points of an acquisition, segmentation is performed on the most recent set. In cases where previously saved **COPD** results are loaded, segmentation begins on the most recent data set without results. Once loaded, the **Compare** feature can be used.

NOTICE

Saved results from the **COPD Analysis** application are available on the **Findings** tab.

Loading Results from Other CT Applications

Saved results from the **LNA** and **MMTT** applications may be loaded to the application. Once loaded, the results are available on the **Findings** tab.

COPD Options, Tools and Functions

Use the common tools and processes to perform many basic tasks, including: saving, filming, reporting, scrolling, measurements/annotations, panning, zooming, rotating, and windowing during all stages of **COPD Analysis**.

See **Report**, **Film**, **CT Common Processes** and **CT Common Tools** for information on using common options, tools, functions, and processes.

Viewing Tools and Options	
Orientation	Use these buttons to select the viewing orientation of the main viewport: axial, coronal, or sagittal.
Flip	Use this button to flip the image in the main viewport right to left.
Layout	Click the down arrow to select an alternate layout. The currently active layout is displayed as the icon. Use the tool to launch the **Layout Manager** to create a custom layout (see the **CT Common Processes** section for more).
Compare	Select the **Compare** button to compare up to 4 **Studies** from different time points for the same patient. When using the **Compare** function, the **Link** icon, which is active by default, allows you to lock **Series** together. Enabling you to perform the same tasks on all linked images: for example, filming or saving. It is not possible to compare a 2D axial data set with a volumetric dataset. When the **Compare** mode is active, you can click the **Spread** icon to spread the images you are comparing across both of the system's monitors (only available with Dual Monitor option).

Viewing Tools and Options	
Relate	**Relate** allows you to relate a location on one image of the patient to that location as viewed on other image(s) of the patient. Use the drop-down to access scene and view port options.
Next Series	Use this button to move to the next series. The button is only enabled when more than one series has been loaded to the current application.

Saving and Reporting Results

All saved segmentation and table measurements can be reloaded into the **COPD Analysis** application. The saved segmentation tissues can be loaded into the **CT Viewer**. The results table may also be saved in .csv or .txt format. You may also use the standard CT saving options.

Use the **Send Findings to Report** option to automatically send the volume rendered image/SSD image and the result table to the **Report** application. Or, use the standard CT reporting options.

Common Functions

To access additional functions, click the down arrow in the tab window, or hover the mouse over the tab window. The list of available functions displays.

- **Bookmarks**. This function allows you to access any saved **Bookmarks**.
- The **Batch** function allows you to create a series of sequential images for viewing, saving, reporting and filming purposes.
- The **Series** function displays a list of the studies and series that are loaded into the application, and also any other elements (like batches) that have been created.
- **Findings**. Review all the previously saved results on all viewports when selecting a finding from the list.

Key Images

Save groups of images that can be reviewed in any system supporting the defined standard. See **Instructions for Use** > **Directory** > **Key Image Notes** for more information.

Verify Segmentation Stage

Review, edit and verify the lung anatomy structures resulting from automatic airway segmentation, lung segmentation and lung lobe segmentation.

The three segmentation processes run serially (**Airways** followed by **Lungs** and **Lung Lobes**) upon launching the application and cannot not be interrupted. Each segmentation process depends on the previous process.

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Once the segmentation processes are done, editing is available for each segmented lung structure (via the **Edit Lung Structures** section). If a step in the segmentation process is missing, use the Re-segment options in the **Edit Lung Structures** options, to initiate the required segmentation process.

Studies that contain multiple **Series** require review and verification of each **Series** before completing the stage.

NOTICE

If non-contiguous, 2D data sets are loaded or slices are too thick (above 3 mm), the application opens in the **Lung Density** stage. Automatic segmentation is not performed with non-contiguous axial (contrast or non-contrast) data sets. The 2D low attenuation area calculation and 3D ROI tools are available.

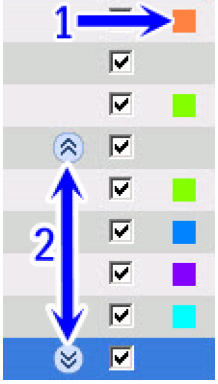
⚠ **WARNING**

In cases where the orientation annotations are not displayed on the image, do not assume any specific orientation. For correct orientation information, use only the images that display such information.

COPD Segmentation Options, Tools and Functions

In addition to the basic **COPD Analysis** tasks (see section “COPD Options, Tools and Functions” on page 104), the **Segmentation** stage has additional selections to control views and perform analysis.

See **Report**, **Film**, **CT Common Processes** and **CT Common Tools** for information on using common options, tools, functions, and processes.

Tools and Options	
Show Table	Click **Show Table** to view or hide the results table. This option displays the **Volume** and **Mean Density** of the **Lung Structures**. Use the **Copy Table to Clipboard** button, located in the table header, to add the selected table measurements to the clipboard. The measurements may then be pasted into common document types, including plain text, Microsoft Word, and Microsoft Excel documents.
Lung Structures List  	Lung tissues resulting from automatic segmentation are displayed on the **Lung Structure** tissue list. Check the box next to the tissue name to show or hide the tissue in linked viewports. The **Right Lobes** and **Left Lobes** checkbox toggles the view for all the left and right lobes. To change the color of a tissue, click on the color button in the list (item 1 in the image). The left/right lung lobes groups are not assigned a color; however, the individual lobes are colored. Once a color is changed, it is saved for the next loading of this segmentation. Use the expand/collapse button to display the contents of the tissue groups (item 2). Display of tissues may also be controlled using the **Show this Structure** and **Show All** right-click options. The default structures are: • Airways • Both Lungs • Right Lobes – RUL – RML – RLL • Left Lung • Left Lobes – LUL – LLL
Adjust Opacity of Active Tissue	To adjust the opacity of the active tissue (highlighted in blue), grab the slider bar and move it left to reduce opacity or right to increase opacity.

Review and Edit Airways

Click the **Edit Airways** button to review and edit airways as necessary. When active, only the segmented airways are shown and editable.

NOTICE

During editing, all the **CT Common Tools** are available. The editing tools are also available using the right-click menu.

Add Airway Segment

Select the **Click to Extend** button to add a new airway segment. When active, the **Place Seed** tool becomes available on all MPR images.

Once this button is selected, there are two options available to extend airways:

Fine extend - Allows multiple clicks. The result will be a very fine extension of the airway tree, up to the point where the user clicked.

Coarse extend - Allows a single click. The result is a rough segmentation of the area that was clicked.

NOTICE

For optimal functionality of the **Add Airway Segment** tool, always use this tool before proceeding to the **Verify Airway Extraction Stage** (section “Verify Airway Extraction Stage” on page 120).

1. Scroll through the MPR images (Ctrl + left mouse button) to find the airway to add to the segmentation.
2. Place the seed in the desired location. If necessary, grab the point (it turns yellow) to adjust its location.
3. Once the seed is placed, use the **Accept/Reject** pop-up to add the airway or to reject it.

   ✓ ✗

   You can move the pop-up if it obstructs the airway of interest. When the pop-up is active and you click anywhere else on the image, the dialog will disappear along with the seed you placed.

   Upon acceptance, the segmentation is extended into the airway, connected to the nearest airway tree, and the centerline calculated. All images are automatically updated.
4. If necessary, use the **Swivel** tool to review the volume image. The new airway is shown with a colored overlay.
5. Use the **Undo/Redo** button ↶ to remove the new segment as necessary.

6. Click **Update and Close** to complete editing and update the airway segmentation. Or, click **Cancel** to exit the editing tools without applying changes.

Remove Airway Segment

Select the **Click to Remove** button to remove an airway that was included as part of the automatic segmentation. When active, the **Place Seed** tool becomes available on all MPR images.

1. Scroll through the MPR images (Ctrl + left mouse button) to find the segmentation to be removed.
2. Place the seed in the desired location. If necessary, grab the point (it turns yellow) to adjust its location. Segment to be removed has a red overlay.
3. Once the seed is placed, use the **Accept/Reject** pop-up to remove the airway.

   ✓ ✗

   You can move the pop-up if it obstructs the airway of interest. When the pop-up is active and you click anywhere else on the image, the dialog will disappear along with the seed you placed.

   Upon acceptance, the segmentation is removed, along with any leakage into the associated parenchyma, and the airway centerline is deleted. All images are automatically updated.
4. If necessary, use the **Swivel** tool to review the volume image.
5. Use the **Undo/Redo** button ↶ to revert changes as necessary.
6. Click **Update and Close** to complete editing and update the airway segmentation. Or, click **Discard changes and close** to exit the editing tools without applying changes.

Review and Edit Lungs and Update Lobes

Click the **Edit Lungs** button to review and edit the left and right lungs as necessary. When active, only the segmented lung tissues are editable.

NOTICE

During editing, all the **CT Common Tools** are available. The editing tools are also available using the right-click menu.

Edit Lung Segmentation with Smart Segmentation Tools (3D)

Select the **Smart Segmentation Tools (3D)** button to edit the lung segments if segmentation missed a portion of the lung or if another organ was identified as part of the lung. Select the eraser tool if another organ was identified as part of the lung.

1. Scroll through the MPR images (Ctrl + left mouse button) to find the segmentation to be added or removed.
2. Use the **Smart Segmentation Tools (3D)**. For information on using the **Smart Segmentation Tools (3D)**, see **CT Common Processes** in the **CT Review** section.
3. If necessary, use the **Swivel** tool to review the volume image.
4. Use the **Undo/Redo** button to remove the new segment as necessary.
5. Click **Update lobes and close** to complete editing and update segmentation. Or, click **Discard changes and close** to exit the editing tools without applying changes.

Use the Eraser tool to remove organs that are not part of the lungs. To change the size of the eraser tool, click on the arrow to choose between a small, medium, or large spherical eraser.

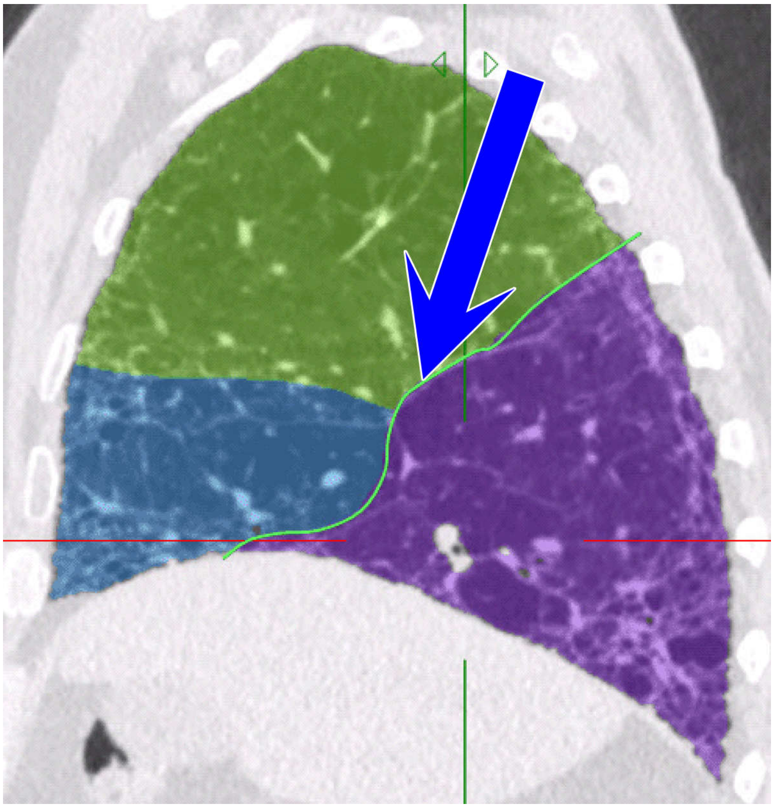
Review and Edit Lung Lobes

Click the **Edit Lobes** tools button to review and edit the lung lobes as necessary. The result effects the segmentation of the lobes.

Edit Fissures

If minor edits are required for the lung fissures, use the **Edit Fissures** tools.

1. Select the appropriate fissure under **Edit Fissures** to edit the Left oblique , Right oblique or Right horizontal . The selected fissure is highlighted in green.



2. Use the left mouse button to edit the line. When finished editing, click the Accept/Reject ✓ ✗ button. A preview of the updated lobes is displayed.
3. Repeat the previous steps until all fissures are segmented correctly.
4. Use the **Undo/Redo** button ↶ to revert changes as necessary.
5. After editing all the required fissures, click **Update lobes and Close**. Or, click **Discard changes and close** to exit the editing tools without applying changes..

Re-draw Fissures

In cases where automatic segmentation fails or requires extensive manual editing, click one of the **Re-draw Fissure** tools to draw a left oblique , Right oblique , or Right horizontal fissure .

1. Select one of the **Re-draw Fissure** tools.
2. Scroll through the MPR images (Ctrl + left mouse button) to find an appropriate image on which to redraw the selected fissure.
3. Draw a new fissure using the active editing tool.
4. Verify that the interpolation is correct and edit as necessary.

5. Repeat the previous steps until all fissures are segmented correctly.
6. Use the **Undo/Redo** button to revert changes as necessary.
7. Click **Update lobes and Close** to complete editing and update the fissures. Or, click **Discard changes and close** to exit the editing tools without applying changes.

Re-segment Lung Structures

In cases where automatic airway segmentation fails or requires extensive manual editing, use the **Mark Trachea** tool to initiate a complete re-segmentation of lung structures.

Review, edit and verify the lung anatomy structures resulting from automatic airway segmentation, lung segmentation and lung lobe segmentation. Once the segmentation processes are done, editing is available for every segmented lung structure (via the Edit Lung Structures section). If a step of the segmentation process is missing, use Re-segment options (either Re-segment Structures or Re-segment Lungs and Lobes) in the Edit Lung Structures options, to initiate the required segmentation process.

1. Click the **Edit Airways** button and select the **Mark Trachea** tool .

   Scroll through the MPR images (Ctrl + left mouse button) to find the trachea.
2. Place the seed in the desired location. Once the seed is placed, the system automatically resegments airways and proceeds to Lung and Lobe segmentation.
3. Review and, if necessary, edit the re-segmentation.

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Lung Density Stage

NOTICE

If non-contiguous, 2D datasets are loaded, the application opens in the **Lung Density** stage. Automatic segmentation is not performed with non-contiguous axial (contrast or non-contrast) datasets. Only the 2D emphysema calculation tools are available.

During the Lung Density stage, calculate the Low attenuation Area/Volume for each lung and lung lobe on the Lung Density Analysis tab using the default **Emphysema** Preset option. The **Custom** preset allows selecting a Custom HU Threshold range for defining lung structures. On the Air Trapping Analysis tab, measure the air trapped in each lung based on the identified end inspiration and end expiration scans (both Series must be loaded to perform Air Trapping Analysis).

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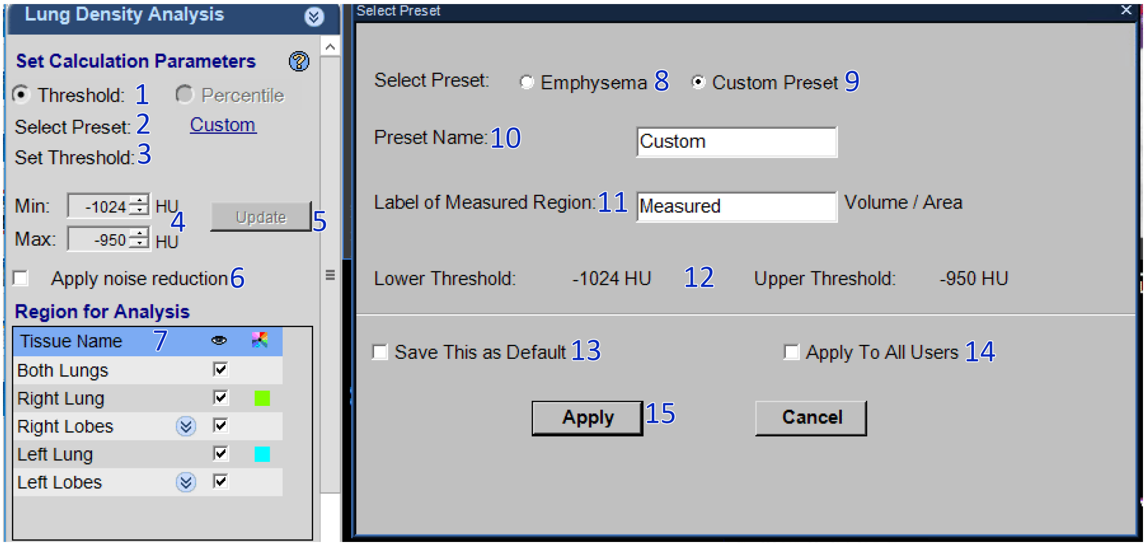
The Lung Density Analysis stage enables setting the Calculation Parameters and Region for Analysis. The Region for Analysis (#7) settings are described in section “COPD Lung Density Options, Tools and Functions” on page 115.

Setting Calculation Parameters

There are two Preset measurement options available in the Lung Density stage: **Emphysema Preset** and **Custom Preset**.

Note: Refer to the below image for the labeling in this section.



Threshold/Percentile values (#1)	Sets Threshold value type for emphysema calculation.
Select Preset: for Measurements #2)	Use this option to select one of the presets for measurement: • **Emphysema** Preset (#8): Used to calculate the Low attenuation Area/ Volume for each lung and lung lobe. This is the default option for measuring Low attenuation volumes. • **Custom Preset** (#9): Allows the selection of a Custom HU Threshold range for defining lung structures. This method allows editing values for the lower and upper HU Thresholds (Min and Max HU thresholds).
Set Threshold: (#3)	When the Custom Preset is selected, Min and Max (#4) values can be edited. After editing the desired threshold values, click **Update** (#5) to apply the changes.
Apply noise reduction (#6)	The noise reduction filter removes noise from sharp filters, low dose acquisitions, or other sources when 3D volumetric images are loaded. Apply noise reduction by enabling the **Apply noise reduction** check box.

Setting Custom Preset Parameters

1. Select the **Custom** (#9) option.

   Preset Dialog includes an option to input a Custom **Preset Name** (#10) and also Custom **Label of Measured Region** (#11).

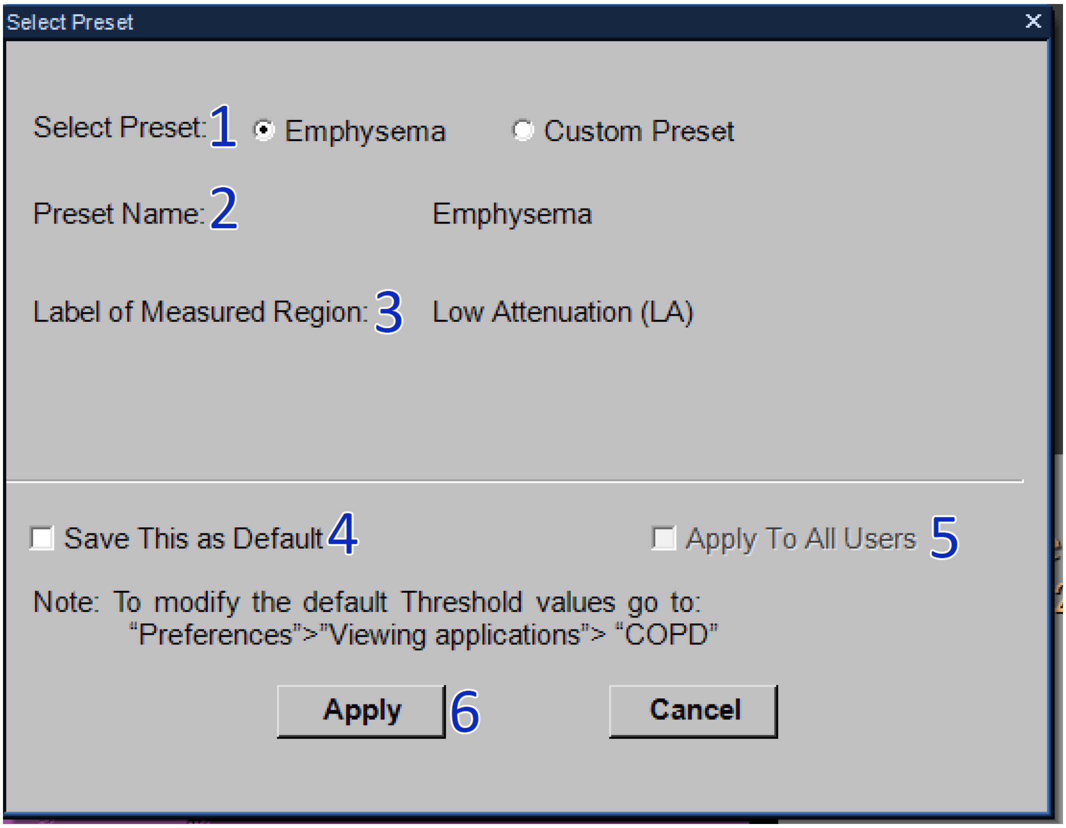
2. Enter a **Custom Preset Name** and select **Apply** (#15) to automatically display the labels in the measurement tables headers and exported results.

   The Custom presets use the Threshold (#1) method. The Percentile method is disabled for Custom presets.
3. Edit the **Min:** and **Max:** values (#4).
4. Review the lung structures segmented with the updated custom threshold range. The measurement tables and histogram are also updated accordingly.
5. To make this the default setting, enable **Save this as Default** (#13) and select **Apply** (#15).

Administrative users can apply this setting to all users by enabling **Apply To All Users** (#14).

Setting Emphysema Preset Parameters

Note: Refer to the below image for the labeling in this section.



Select Preset

Select Preset: 1 ● Emphysema ○ Custom Preset

Preset Name: 2 Emphysema

Label of Measured Region: 3 Low Attenuation (LA)

☐ Save This as Default 4

☐ Apply To All Users 5

Note: To modify the default Threshold values go to: “Preferences”>”Viewing applications”> “COPD”

Emphysema is the default option for measuring Low attenuation volumes.

In the **Emphysema** preset for Threshold based Low attenuation volume calculations, the table displays the LA Volume, the Total Volume and the LA Volume Ratio (LA Volume/Total Volume) lung structures.

For Percentile based calculation, the table displays the LA Volume, the Total Volume and the LA Volume Threshold.

Users can select a desired setting for the Upper threshold value in the control panel and use the **Save This as Default** (#4) save option shown below to make it as default.

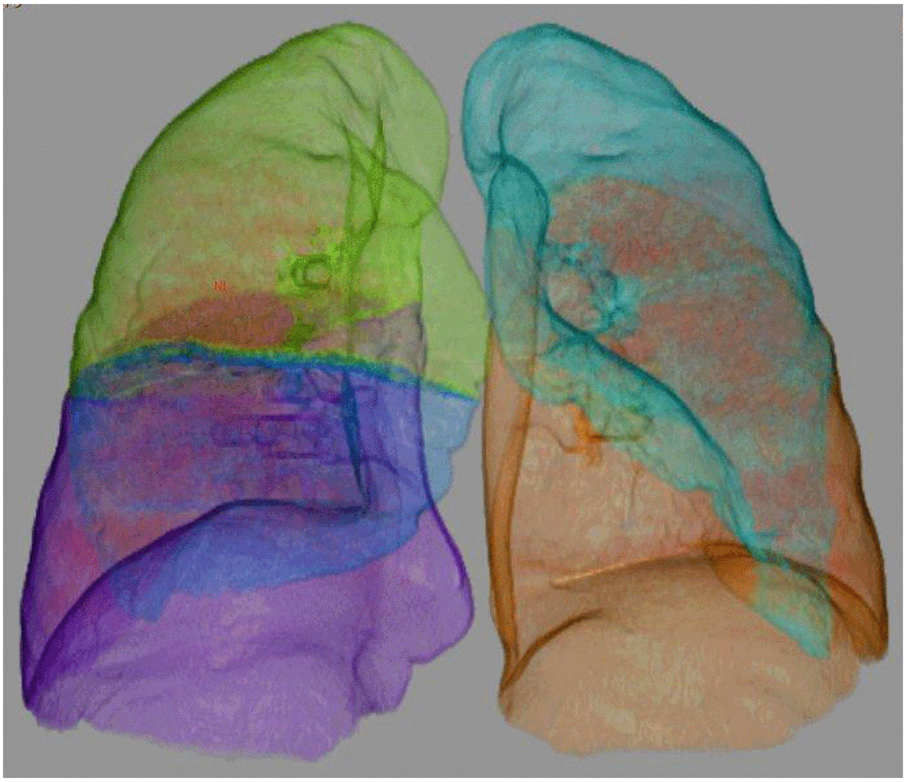
Administrative users can apply this setting to all users by enabling **Apply To All Users** (#5).

Select **Apply** (#6) to save all changes.

COPD Lung Density Options, Tools and Functions

In addition to the basic **COPD Analysis** tasks (see section “COPD Options, Tools and Functions” on page 104), the **Lung Density** stage has additional selections to control views and perform analysis.

See **Report**, **Film**, **CT Common Processes** and **CT Common Tools** for information on using common options, tools, functions, and processes.

Tools and Options	
Show low attenuation Volume	Check the box to show or hide the segmented Low attenuation volume on the viewports during **LA Volume Analysis**. Detected low attenuation area is represented by a red overlay. 
Show Airway	Check the box to show or hide the segmented airways in all the view ports.
Show Color Overlay	Check the box to show the color overlay.
Show Air Trapping	Check the box to show or hide the trapped air during **Air Trapping Analysis**. The display is automatically updated when the threshold values are changed using the **Recalculate Air Trapping** tool.

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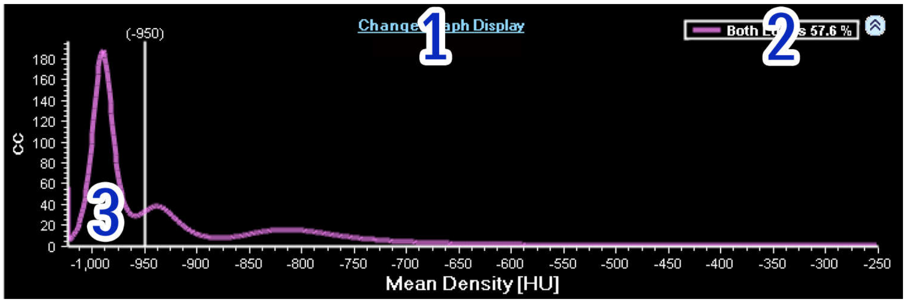
Tools and Options	
Show Table	Click **Show Table** to view or hide the results table as well as the graph.
Low attenuation Volume Histogram Display	The table viewport includes a histogram during **Lung Density Analysis**. The histogram displays the threshold or percentile, depending on which method is being used. To change the histogram, click on **Change Graph Display** (item #1 in the image) and select the segments you want displayed. Select the curves to display from the pop-up menu. The legend (item #2) corresponds to the selected curves that are displayed, with each curve a different color. Any overlapping curves are represented by a dashed line. By default, the curve of both lungs is displayed (item #3). 

Tools and Options	
Region for Analysis  	Check the box next to the tissue name to show or hide the tissue in linked viewports and the corresponding measurements in the table. The **Right Lobes** and **Left Lobes** checkbox toggles the view for all the left and right lobes. To change the color of a tissue, click on the color button in the list (item 1 in the image). The left/right lung lobes groups are not assigned a color; however, the individual lobes are colored. Use the expand/collapse button to display the contents of the tissue groups (item 2). Display of tissues may also be controlled using the **Show this Structure** and **Show All** right-click options. The default structures for emphysema analysis are: • Both Lungs • Right Lung • Right Lobes – RUL – RML – RLL • Left Lung • Left Lobes – LUL – LLL
Adjust Opacity of Active Tissue	To adjust the opacity of the active tissue (highlighted in blue), grab the slider bar and move it left to reduce opacity or right to increase opacity.

Perform Lung Density Analysis

In the Emphysema option, review emphysema calculations , modify the parameters, draw regions of interest, and recalculate emphysema as necessary.

NOTICE

When non-contiguous non-contrast- or contrast-enhanced axial images are loaded into the application, only the 2D emphysema calculation tools are available.

Set Emphysema Calculation Parameters

By default in the Emphysema Preset, the **Threshold** (-950 HU) parameter is used to calculate Emphysema. Use the up and down arrows or type a new value in the box to change the threshold as required. Click the **Update** button.

Select the **Percentile** radio button and use the up and down arrows or type a new value in the box to view the calculations based on percentage. Click the **Update** button.

Apply Noise Reduction

The noise reduction filter removes noise from sharp filters, low dose acquisitions, or other sources when 3D volumetric images are loaded. Apply noise reduction by enabling the **Apply noise reduction** check box.

Measure Emphysema Based on Selected Region(s)

Use the **Draw ROI** or **Draw VOI** tools to calculate emphysema within the ROI or VOI based on threshold or percentile methods.

NOTICE

For more information on using the ROI and VOI tools, see **Smart Segmentation Tools (3D)** and **Spline ROI** in the **CT Review** section.

Measurements Table

For Threshold based Emphysema calculation, the table displays the Emphysema Volume, the Total Volume and the Emphysema Ratio (Emphysema Volume/Total Volume) of structures checked in the **Tissue Name** list. For Percentile based calculation, the table displays the Emphysema Volume, the Total Volume and the Emphysema Threshold.

Perform Air-trapping Analysis

Measure the amount of air trapped in the lungs: manually select the end inspiration and end expiration scans, set parameters, and identify areas of interest.

NOTICE

Air-trapping requires at least 2 **Series**: inspiration and expiration scans.

The air trapping measurements are calculated by subtracting relative lung volume of end inspiration from end expiration.

Air Trapping	
$RLV_{exp} – RLV_{ins}$	RLV_{exp} : Relative Lung Volume from end expiration
	RLV_{ins} : Relative Lung Volume from end inspiration

The relative lung volume is calculated for each **Series** by measuring the volume of voxels between upper and lower thresholds (by default, -860 HU to –950 HU) and dividing it by volume of voxels with attenuation greater than -950 HU.

$$\frac{Vol_{-950x<-860}}{Vol_{x>-950}}$$

Change End Expiration/Inspiration

By default, the application selects the end expiration and end inspiration **Series**. After review, either accept the automatic detected **Series** or select a different **Series** from the drop-down.

Click the button to review and, if necessary, edit the selected **Series**. Once selected, ensure that the correct series is marked as either **End Inspiration** (often the largest volume) and **End Expiration** (often the smallest volume) on the view ports.

Change Upper and Lower Thresholds

Use the up and down arrows or type in new HU values to change the parameters as desired. When done, click the **Recalculate Air Trapping** button.

Region of Analysis

Select the appropriate tissues from the list. By default, both lungs are selected. Use the Opacity slider to control the segmentation overlay.

Measure Air Trapping Based on Selected Region(s)

Use the **Draw ROI** tool to calculate air trapping for the region. At least one ROI must be drawn on both the inspiration and expiration **Series**. Once drawn, the table updates with the new calculations. Click on the ROI in the table to show the corresponding image.

NOTICE

For more information on using the ROI tool, see **Spline ROI** in the **CT Review** section.

Measurements Table

The table displays the Total Volume End-Inspiration, Total Volume End-Expiration, Relative Volume Ration End-Inspiration, Relative Volume Ratio End-Expiration, Relative Volume Change, and Mean Lung Density E/I Ratio of structures checked in the **Tissue Name** list.

Verify Airway Extraction Stage

Review, identify, and edit the segmented airway tree and centerline during this stage. Ensure that:

- the centerlines are complete, properly located and positioned in the airway centers; and
- the airways are correctly named.

At least one airway must be identified before continuing to the next stage.

WARNING

Verify the accuracy of the airways and their labels. If needed, use the manual tools provided in this stage to correct airway extractions and labels.

NOTICE

If only non-contiguous contrast or non-contrast axial datasets are loaded into the application, this stage is unavailable.

COPD Airway Extraction Options, Tools and Functions

In addition to the basic **COPD Analysis** tasks (see section “COPD Options, Tools and Functions” on page 104), the **Airway Extraction** stage has additional selections to control views and perform analysis.

See **Report**, **Film**, **CT Common Processes** and **CT Common Tools** for information on using common options, tools, functions, and processes.

Tools and Options	
Show Centerline	Check the box to view/hide the centerline.
Show Cursor	Check the box to view/hide the cursor.
Highlight Airway Tree	Check the box to view/hide the airway tree.
Show Color Coded Mesh	Check the box to display the tubular representation of the automatically detected airway segments.

Verify and Edit Centerlines

On the volume image, right-click on the segment of interest to rename it. Select one of items from the menu or type the airway name in the space provided. The **Label Airways Path to Carina** dialog automatically detects the right and left lung. Verify the side of the lung. Once done, the airway is added to the airways list. Review and edit the centerlines as needed.

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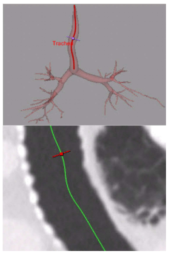
NOTICE

To rename or remove an airway, right-click on it in the tissue list and select **Remove from list** or **Rename.**

On the volume image, hover over the airways to select the segment of interest. Right-click on the segment of interest and label it. Once selected, a path to the carina is created

Adjust Centerlines



The automatically defined centerline will, in most cases, pass though the center of the airway. If this is not the case, use the **Edit Centerline** tool.

1. Select an Airway from the **Select Airway** list.
2. Select the **Edit Centerline** button under **Edit Select Airway** to edit the selected airway.
3. Edit the centerline as needed from the volume, cMPR or cross-sectional views.

Airway Measurement Stage

Measure the airway lumen and wall cross section for different locations on the airway tree. There are two modes for contour inspection:

- **Along Centerline**. Review the inner and outer contours for the airways identified in the previous stage. If 2D axial data sets are loaded, this mode is not available.
- **Local 2D inspection**. Manually mark airways of interest and review measurements for axial datasets.

Once the airways are identified, it is possible to review the airways using the **Endo Luminal View**.

NOTICE

Airway measurements can be impacted by the phase of respiration. For optimal results, please use inspiration datasets.

NOTICE

Contour measurements might be incorrect in the area of branching.

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COPD Airway Measurement Common Tools and Functions

In addition to the basic **COPD Analysis** tasks (see section "COPD Options, Tools and Functions" on page 104), the **Air Extraction** stage has additional selections to control views and perform analysis.

See **Report**, **Film**, **CT Common Processes** and **CT Common Tools** for information on using common options, tools, functions, and processes.

Tools and Options	
Show Centerline	Check the box to view/hide the centerline.
Show Cursor	Check the box to view/hide the cursor.
Show Airway Tree	Check the box to view/hide the airway tree.
Show Graph	Use the checkbox to show or hide the **Lumen Maximum Diameter** graph. The vertical line is linked to the images. Drag the line to navigate through the images.
	Display Lumen Contours
	Display Airway Contours
▦	Show Summary Table

Measurement Display

By default the lumen maximum diameter and wall thickness are displayed on the cross-section image. To modify the displayed measurements:

1. On the axial image, hover over the measurements until it turns yellow.
2. Right click and select **Properties** from the menu.
3. Click on the desired measurement to either show or hide it.

Table

When using the centerline mode, the table displays the measurements from the cross-sectional image for centerline mode and displays the measurements from the active axial image for 2D mode.

There are two tables that are displayed when using centerline mode, local measurements and average measurements. Average measurements take into account the values between the two yellow lines (the start and end positions).

Table columns can be configured by clicking on **Edit Column**.

Integral Airway Measurements

Airway measurement is performed using the Integral (Weinheimer) method.

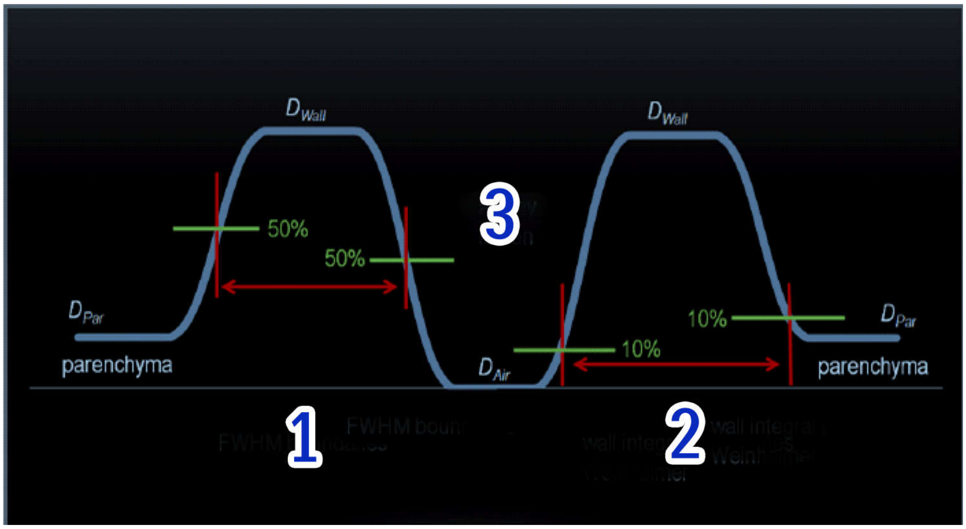
The principal underlying idea of the estimation method presented by Weinheimer et al [P. A. de Jong, N. L. Müller, P. D. Paré, and H. O. Coxson, “Computed tomographic imaging of the airways: relationship to structure and function,” European Respiratory Journal, vol. 26, no. 1, pp. 140–152, Jul. 2005] is that the airway wall has a certain characteristic density independent of its thickness and that the blur, as well as the rebinning, is essentially only spreading out the mass of the wall while conserving its total amount. Consequently, an integration over the spread-out wall can recover the total mass completely and division by the true density will then yield the true thickness. Although the assumption of a constant characteristic true wall density (DW) may be oversimplifying, the approach is straightforward, computationally efficient, numerically robust, and has been confirmed with physical tube phantoms.

The image below displays the difference between the Integral method and the conventional FWHM (Full Width Half Maximum) measurement method used in CT. FWHM was found inaccurate on small airways due to the blurring effect.

#1 - FWHM boundaries

#2 - Wall integral boundaries Weinheimer

#3 - Airway lumen

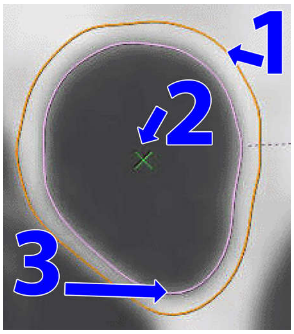


NOTICE

The contour measurements close to the bifurcation area may be incorrect. Before capturing a measurement, please verify the correctness of the contours as displayed on the cross-sectional image. When placing the start and end regions to obtain the average measurements, do *not* include bifurcation area.

Review Along Centerline

In the image below, the airway contour is orange (item 1) and the lumen contour is colored pink (item 3). The centerline is a green crosshair (item 2) on cross-sectional images.



NOTICE

If only 2D axial datasets are available, you must use the **Local 2D Inspection** mode.

To view additional contours along the vessel:

- scroll the image in the viewport (above); or
- drag the reference marker along the centerline in a cMPR viewport.

NOTICE

It is possible to compare the centerlines of up to four studies for one patient. However, one-click compare only shows the centerlines that are repeated in all studies.

Perform Local 2D Inspection

In cases where only 2D datasets are available, manually mark the airways of interest.

1. Ensure the **Local 2D Inspection** and **Mark Airway for Inspection** buttons are selected.
2. Scroll through the axial image and click on the airway of interest.
3. The other viewport displays the airway lumen and wall contours.

   Continue scrolling through the images until all airways of interest are marked.
4. To review airways, select the airway from the table. The reference images will snap to the location.
5. To review the captured measurements, select the relevant row from the table. The reference images will snap to the location.

Endo View

Navigate through the active centerline navigation in the endo view.

1. Select the **Endo Luminal View** function tab from the drop-down menu.
2. From the tissue list, click on the airway of interest.
3. Use the **Forward** and **Back** buttons to move forward and backward through the airway. If necessary, change the speed.
4. To manually move through the view, hover over the Endo view and use the paddle wheel to scroll forward and back.

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