13 Liver Analysis

The Liver Analysis application provides segmentation tools to facilitate for assessing the liver, hepatic vasculature of individual vascular segments, and physician-identified lesions. The application has 3 stages, with specific goals and clinical uses:

1. **Segmentation.** Perform segmentation of the liver tissue, vessels, and lesions.
2. **Liver Segments.** Define liver segments as well as the number of segments.
3. **Surgery Planning.** Plan liver resection.

NOTICE

Liver volume can be auto segmented on any series. However the auto segmentation of the vessels is done only for the hepatic and portal veins.

A Portal-Hepatic scan of the liver is recommended for the Liver Analysis application.

NOTICE

Each time a study is loaded, the system performs a new auto segmentation. Auto segmentation data is not automatically saved when the study is closed. You must save the segmentation using Save Results in the Common Tools.

When you load a study, automatic segmentation segments the liver tissue and portal and hepatic vessel trees, and classifies the liver vascular segments. This process may take several minutes.

WARNING

Verify the accuracy of the automatic segmentation. If necessary, manually correct the segmentation using the correction tools provided in this stage.

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

- **Volume or slab images may appear in this application. Measurements you make on such processed images can sometimes be misleading. When saving such images, make sure they are labeled properly.**
- **Objects in thick-slab images may appear distorted. Use caution when making measurements.**

881 * 2021-06-30

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NOTICE

Cross sectional images cannot be rotated. Please note orientation annotations on images.

WARNING

Loading cases with thicknesses greater than 2 mm may result in inaccuracies when the Add/ Remove Smart Brush and Add/Remove Smart ROI editing tools are used.

WARNING

When loading images into the application, all images which contain 16 bit data are converted into 12 bit images. (Therefore, when the rescale intercept equals -1000, Hounsfield Unit values above 3095 are displayed as 3095, and when the rescale intercept equals -1024, Hounsfield Unit values above 3071 are displayed as 3071.)

About Anatomical Landmarks

The method of using anatomical landmarks for liver-segments definition was developed in a close collaboration with Professor Pierre-Jean Valette (Hospices Civils de Lyon, France).

Load Multiple Studies in Application

To load multiple studies in the application:

1. Use the **Ctrl** key when selecting studies from the Directory list.
2. Select the application from the Applications menu.
3. Confirm the studies are from the same patient.

NOTICE

Depending on your Portal configuration, this application may not be available.

Loading Results from the Multimodality Tumor Tracking Applications

The application supports the loading of Tumor Tracking results. Findings that were marked in the Tumor Tracking application appear in the Liver Analysis Findings List and on the image (with the name that was assigned in the Tumor Tracking application). Results from the Liver Analysis application can also be loaded to the Tumor Tracking application.

/881 * 2021-06-30

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Indications for Use

CT Liver Analysis is a post-processing application providing tools to assess the whole liver, hepatic and portal vasculature, liver segments as well as user-defined ROIs. The application supports the user in the analysis and assessment of quantification parameters of the liver, liver segments as well as user-defined ROIs from liver CT imaging.

Liver Analysis Options and Tools

Use the following options and tools (in the upper tool box) during each stage, except where noted, to modify the view and perform analysis.

Incremental Segments Creation (Stage 2)

By default, the **Incremental Segments Creation** feature is active. This enables you to view and edit the segmentation results during landmark placement. If real-time segment creation is excessively slow, uncheck the box to disable the feature.

Show Liver (All Stages)

Check the box to show the liver tissue and segments in the 3D and 2D rendering viewports on and off. This only works after liver segmentation is complete.

Show Vessels (All Stages)

Check the box to show blood vessels.

Show Findings (All Stages)

Check the box to show findings (if any). This option shows the Findings you add on the Findings tab during the Segmentation stage.

Show Crosshair (Stages 1 and 2)

Check the box to show the crosshair in the axial, coronal, and sagittal viewports.

Show Transparent (All Stages)

Use to show or hide the liver segments. Only active after segmentation has been completed **and** the volume image is in Volume Rendering mode.

Show Contour (Stage 1)

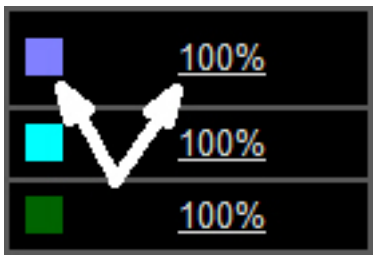
Click to show or hide tissue contour on slab image. When selected, the active tissue contour is highlighted in green.

Show Summary Table (All Stages)

Click to show or hide a summary of the view (the table is shown by default. The table provides stage-specific information and functionality. During Segmentation stage use the table to view the HU, Volume, and Percentage of segmented liver, vessels, and your findings. During the Liver Segment stage, the table includes additional information about the segments you create. For the Surgery Planning stage, the table provides a summary of placed electrodes and resections (the table during this stage is not interactive). Within the table, change the liver or vessel color and opacity.

Click on the color icon in the Edit color and opacity column and select the Color dialogue box.

To change liver or vessel opacity, hover over the Edit color and opacity column and drag the opacity indicator right or left.



NOTE: Editing the color and opacity is only available for the first and second stages.

When viewing the table in the Liver Segments stage, adjust the opacity and color as outlined for the Segmentation stage. Any changes made are specific to the stage and will not change the view settings of the Segmentation stage.

NOTICE

In the Segments stage (second stage), the table gives the results (in cc and %) of the segments based on the total liver or on the functional liver (click on the table header to switch between results): functional liver = Total liver – (total vessels + total findings).

For the Surgery Planning stage, click to view the resection summary table and any findings.

Copy Table to Clipboard (Stages 1 and 2)

In the **Segmentation** and **Liver Segments** stages, use the **Copy Table to Clipboard** button to add the selected table to the clipboard. The button is located in the table header. The first table has an additional option to copy all the tables to the clipboard (as shown in the image).

Once on the clipboard, the contents may be pasted into a different application, such as a reporting system or Microsoft Word document.

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.

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

Segmentation Stage

When the Segmentation stage opens, the liver tissue is segmented automatically, followed by the vessels segmentation. When segmentation completes, all tissues are displayed in the appropriate viewport.

WARNING

Please verify correctness of the segmentation on all the segmented slices and edit if required.

NOTICE

SSD - Surface Shading Display is a rendering mode that provides superior transparency for tissues. This is the ideal rendering mode for displaying tissues which reside inside another tissue. SSD is the default rendering mode for the Liver Analysis application.

Edit Tissues

Review the liver segmentation and volume, and correct the segmentation if required. You can manually activate liver segmentation if needed for another series (different contrast phase). If correction is required, it can be done in a subsequent stage using the editing tools on the Liver/ Vessel Segmentation tab. Review classification into vascular segments, and correct if required.

NOTICE

If initial vessel segmentation is incomplete, the re-segment vessels function might result in an improved segmentation of the vessels. If not, use the manual tools to edit.

WARNING

Please verify correctness of the segmentation on all the segmented slices and edit if required.

WARNING

Verify correctness of vessels segmentation. If required use the editing tissues or the reclassify tools.

1. Go to the **Liver/Vessels Segmentation** tab.

881 * 2021-06-30

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2. In the Select Tissue table, click a tissue segment to highlight it (for example, Liver, Hepatic, Portal, Unclassified).
   - Check the box to show or hide the tissue segment in the viewer.
   - To change the color of a segment, click on the color icon to open the Color dialogue box. See section “Liver Analysis Options and Tools” on page 327.
3. To edit active tissue, modify the view and the segmentation of the selected tissue. Set the opacity. Add tissue using one of the draw tools. See section “Liver Analysis Options and Tools” on page 327.
4. Where necessary, change the classification and segmentation of selected vessels.
5. When done, Go to the **Findings** tab.

Re-classify Vessels

Use to turn a portal vessel into a hepatic vessel, hepatic into portal, or unclassified into hepatic or portal. First activate the tool, then select a vessel from the pop up dialog, you want to assign a seed to.

WARNING

Verify correctness of vessels classification. If required use the editing tissues or the reclassify tools.

1. Activate the reclassify tool. This will open a menu to the active viewport. In addition, activating the tool will show the seed points used for the auto segmentation of the vessels. These seed points can be moved by dragging them.
2. Position seeds by dragging the +H (hepatic) or +P (portal) seeds onto the vessel to be re-classified. Or, use the Edit menu and select:

   Place seeds on Hepatic

   then

   Place seeds on Portal

   if multiple seeds must be placed. This may be done on either the volume or MPR images.
3. When done click the **Accept** seed button.

Re-segment Liver

Use **Re-segment Liver** if the zero-click, automatic liver-segmentation failed.

WARNING

Verify correctness of the segmentation on all segmented slices and edit if required.

1. Active the **Re-segment liver** button.

2. Place a seed point in the center of the liver.

The auto segmentation will start looking for the liver based on the seed point.

Re-segment Vessels

Use to toggle between standard and high resolution rendering when re-segmentation is used. While high quality segmentation increases the process time, using this re-segment option may improve upon the standard segmentation performed during automatic segmentation.

WARNING

Verify correctness of vessels segmentation. If required use the editing tissues or the reclassify tools.

NOTICE

Using Re-segment will remove any re-classification changes you have made.

Findings

Use the Findings tools to segment lesions (and other areas of interest) inside the liver. The tools used to mark and edit findings function similar to those described in the Liver/Vessels Segmentation section.

WARNING

Please verify correctness of the segmentation on all the segmented slices and edit if required.

Mark your findings on the MPR images (not the Volume image).

NOTICE

This is a volumetric tool and its effect extends beyond the current visible slice. After using this tool, review its effects by scrolling through the slices on which the lesion is displayed.

1. Go to **Segmentation** stage > **Findings** tab.
2. Use either the:
   - **Draw Smart ROI (3D)**

     OR
   - **Draw smart brush (3D)**

   tool to mark lesions and other areas of interest.
3. To edit finding, click on a finding in the Findings table and use the **Add**, **Subtract**, and **Edit contour** functions to modify the selected Finding. The editing tools are automatically activated when you draw a finding.
4. Repeats the previous steps for each finding. When done, Go to the **Liver Segments** stage by using the stage navigation pane.

WARNING

Loading cases with thicknesses greater than 2 mm may result in inaccuracies when the Add/ Remove Smart Brush and Add/Remove Smart ROI editing tools are used.

Liver Segments Stage

In the Liver Segments stage, a complete segmentation of the liver vessels and lobes, using seed points you provide, is performed. Using the segmentation tools, place seed points on one of the images.

WARNING

Verify correctness of the division of the segments. If required edit or add the appropriate seed points.

Determine Number of Segments

During the Liver Segments stage, use when defining the liver segments. Once defined, use the drop-down to switch among the different liver segment views. Select from the following options:

1. **Two (2) segments L-R Liver.** Landmarks include: Inferior vena cava; middle hepatic vein.
2. **Two (2) segments L-R Lobe.** Landmarks include: Inferior vena cava; Umbilical fissure; Left portal bifurcation; Superficial ligamentum venosum; Deep ligamentun venosum; Superior deep ligamentum venosum.
3. **Four (4) segments L-R medial and lateral.** Landmarks include: Inferior vena cava; Right hepatic vein; Mid hepatic vein; Umbilical fissure; Left portal bifurcation; Superficial ligamentum venosum; Deep ligamentum venosum; Superior deep ligamentum venosum.
4. **Seven (7) segments.** Landmarks include: Inferior vena cava; Right portal bifurcation; Right hepatic vein; Mid hepatic vein; Umbilical fissure; Left portal bifurcation; Superficial ligamentum venosum; Deep ligamentum venosum; Superior deep ligamentum venosum.
5. **Eight (8) segments Couinaud.** Landmarks include: Inferior vena cava; Right portal bifurcation; Right hepatic vein; Mid hepatic vein; Umbilical fissure; Left portal bifurcation; Tip left liver; Superficial ligamentum venosum; Deep ligamentum venosum; Superior deep ligamentum venosum.
6. **Nine (9) segments Bismuth.** Landmarks include: Inferior vena cava; Right portal bifurcation; Right hepatic vein; Mid hepatic vein; Umbilical fissure; Left portal bifurcation; Tip left liver; Superficial ligamentum venosum; Deep ligamentum venosum; Superior deep ligamentum venosum.

Define Segments

Use the Add Landmark tool to identify the liver segments. The number of landmarks placed depends on the number of liver segments selected using the Segment Liver tool. Landmark placement determines the 3-dimensional segmentation of the liver.

WARNING

Verify correctness of the division of the segments. If required edit or add the appropriate seed points.

To assist in placement, click the **Show segmentation guidance** tool.

881 * 2021-06-30

Philips

Add Landmark

NOTICE

By default, the **Incremental Segments Creation** feature is active. This enables you to view and edit the segmentation results during landmark placement. If real-time segment creation is excessively slow, uncheck the box to disable the feature (you will need to click the **Start Segmentation** button to complete segmentation).

Click the Add landmark button and place landmark seeds on either the slab or volume images for every segment in the list.

Inferior vena cava	Position landmark in center of the Vena Cava. It serves as a central point connecting with other landmarks.
Right portal bifurcation	Position landmark at bifurcation of the Right Portal Vein to horizontally divide the right liver lobe.
Right hepatic vein	Position landmark in the direction of the Right Hepatic Vein to define the borders of right lateral segments .
Mid hepatic vein	Position landmark in the direction of the Middle Hepatic Vein or gall bladder fossa direction to define the borders of the right medial segments .
Umbilical fissure	Position landmark at umbilical fissure to define the separation between left and right liver lobe.
Left portal bifurcation	Position landmark at bifurcation of Left Portal Vein to horizontally divide the left liver lobe.
Tip left liver	Position landmark at tip of the left liver lobe. Optimal location is the most left position of the liver at the same slice where the Left Portal Bifurcation landmark is positioned.
Superficial ligamentum venosum	Position landmark superficial and posterior of the liver where the separation between segment 1 and 2 is clearly visible.
Deep ligamentum venosum	Positioned landmark on the same slice as the Superficial ligamentum venosum.
Superior deep ligamentum venosum	Position landmark in the cranial direction, where segment 1 is ending.

NOTICE

Scroll through the slices while dragging the mouse.

When placing landmarks, use the Show Segmentation Guidance tool (see below) for assistance or perform the following:

1. Click the **Add Landmark** button. When the button is active, the first landmark is highlighted in the table by default. To place a different landmark first, select it from the table.

2. Place the necessary landmarks on either the volume or slab images to identify the tissue segments. If using the default settings, the next landmark is automatically selected and real-time segmentation begins.
3. When all landmarks are placed, the system completes segmentation.

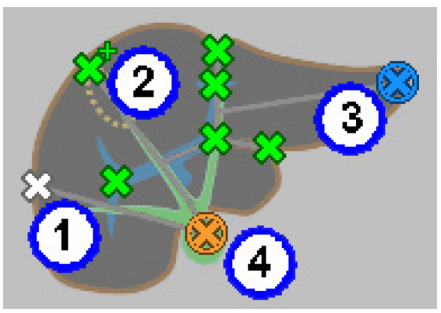
   Use multiple landmarks, except for the left and right portal end, to increase the accuracy of a segment. Highlight the landmark in the table or on the guided image and mark the extra landmark onto one of the images in the available viewports. The system will add an addition landmark in the table and on the image.
4. Verify the segmentation and make changes as necessary.
   - Click a landmark to view the landmark's associated seed point.
   - Drag and drop the landmarks in the new location.
   - Select a landmark from the table and place additional landmarks to improve segmentation.
   - Right-click a landmark to delete it.
   - Click the **Start Segmentation** button to complete segmentation if you disabled the **Incremental Segments Creation** feature.

     
5. If segmentation failed, move or replace the landmarks and perform segmentation again. Use the Show Segmentation Guidance tool (see below) for assistance when placing landmarks.

Show Segmentation Guidance

Use the interactive Segmentation guidance dialogue when seeding landmark points using the Add Landmarks tool.

1. White cross indicates landmark inactive and no seed points have been assigned.
2. Green cross indicates landmark not active but seed points have been assigned. The small green cross represents a secondary seed has been placed for the landmark.



3. Blue cross indicates landmarks is active and has a seed point already assigned.
4. Orange cross indicates landmark is active but no seed points are defined.

The guidance image and the landmark list are related. Once a landmark is assigned with the guidance image, the list is updated to help with assigned landmarks.

To use the guidance image when placing landmarks perform the following:

1. Click the **Show segmentation guidance** button.
2. Click the **Add landmark** button.
3. Place the landmark seed on the volume or slab image in the appropriate location, as indicated by the orange cross in the guidance dialogue box.

   After placing a seed, the system will automatically move to the next landmark. Follow the same process when placing multiple seeds.
4. Perform and verify segmentation. Click a seed on the guidance image to highlight it on the volume and slab images. Click the **Start Segmentation** button to complete segmentation if you disabled the **Incremental Segments Creation** feature.

Surgery Planning Stage

Use this stage for planning resection or transplant surgery procedures. Define what parts of the liver will be removed.

NOTICE

When safety margins are applied they are added to the volume of the findings.

Use for resection/transplant planning. Determine the atypical or anatomical resection.

NOTICE

Icons with “-” sign are used to define a region for resection and icons with “+” sign are used to define a region that should not be resected.

Anatomical Resection

To perform an anatomical resection, click the **Remove segment** button to define the lobe/segment that is planned for resection. Resection can be done by clicking the **Add segment** button. Use the Clipping Tools as outlined in the Common Tools and Common Processes sections.

Atypical Resection

To perform an atypical resection, click the **Remove tissue** button to define the lobe/segment that is planned for resection. Resection can be done by clicking the **Add tissue** button.