Clinical uses for CT Liver Analysis application

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Introduction

Application overview

The Liver Analysis application is intended for visualization, assessment and quantification of the liver that is extracted from abdominal CT images: specifically providing quantitative measurements of the liver volume, including blood supply and abnormalities within the liver. The application supports both native and contrast-enhanced images acquired on any CT-scanner. It provides automatic segmentation of the liver. In those cases where the hepatic and portal vessels are able to be visualized due to the use of an IV contrast agent, it provides an automatic segmentation of the vessels including classification of the hepatic and portal vessel systems. In addition the application offers manual tools for the user to make adjustments to the automatic segmentation results if needed. The user is also able to subdivide the liver into several segments allowing detailed quantitative measurements as an input for an interventional procedure such as an RF-Ablation, or for pre-surgical guidance. The clinician retains the ultimate responsibility for making the pertinent assessment based on the standard practices and visual assessment of the liver CT images.

Clinical background and purpose

There is clinical evidence that complete tumor removal is still the only treatment of liver primary cancers or metastases that can ensure acceptable long-term survival and cure in some patients.[1] However, due to the continuous development of various tools, liver tumor surgery is no longer the sole treatment. This has led to a consideration in most cases of a multidisciplinary management of these patients.[2]

Effective chemotherapy allows more patients to benefit from surgery after reducing the size of metastases. It also improves at least the medium-term outcome in those who are operable at the outset, and is now used to select responding patients before extensive surgery.[3] However, such a good response may also raise the problem of “disappearing” metastases when local resection or ablation should be performed. Interventional Radiology may then play a role: tumors that will not be removed at the time of the planned partial hepatectomy can be tagged with a metallic clip prior to chemotherapy and ablated later with a percutaneous image guided intervention. The RF or micro-wave tumor ablation may also be performed at the time of the surgery, or after, as a complementary treatment. In case of hepatocellular carcinoma or hypervascular metastases (kidney, endocrine) the preoperative chemoembolization may help to reduce tumor size. Lastly, portal vein embolization causing hypertrophy of the future remnant liver allows acceptable long-term survival and cure in some patients who previously could not have survived resection.[4]

The Philips IntelliSpace Portal Liver Analysis application is aimed to assist the radiologist or liver surgeon in the assessment of the liver for both the planning of treatment, as well as for its follow up. A concise reporting of the results to the referring physicians and surgeons can be generated in the application. Literature indicates that in the near future there will be a major increase in number of oncology-related treatments (partial resection, tumor ablation).[5] One aspect of this growth is the increasing number of patients due to the aging population. Another clinical need arises from the monitoring of new treatments preserving and/or regenerating healthy tissue, which requires precise volume measurements and lesion delineation. CT-based liver analysis aims at calculating the complete liver volume, the liver territories and lesion volumes. The visualization of the vessels locations in relation to the lesions is also of particular interest in defining a treatment strategy. Liver assessment is an emerging area for the radiologist and allows providing dedicated consultation to other medical disciplines.

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Total liver segmentation

The first step of the Liver Analysis application is an automatic total liver segmentation. This fast and zero-click segmentation is already a major advantage compared to mostly manual or semi-automatic techniques currently available. If corrections are necessary, the fully interactive and real-time 3D segmentation tools are easy to use and efficient to achieve a final result with little extra time required.

The total liver is used to calculate the functional liver. This is an important parameter to evaluate the possible treatment options as the remnant functional liver (after surgery or treatment) should always exceed 30% of the initial total functional liver to maintain patient safety.[6,7]

Vessels segmentation and classification

The second step of the Liver Analysis application is an automatic segmentation and classification of the portal and hepatic vessel trees in the liver.

The vessel segmentation uses a state-of-the-art segmentation technique and knowledge model of the liver surface. Once the vasculature has been segmented, the hepatic and portal venous trees are separated, and color coded, using further anatomical knowledge of the organ and the relationships between the trees.

The quality of the vessel segmentation is related to the vessel enhancement from the iodine contrast-medium injection. Semi-automatic segmentations tools can be used to manually correct the segmentation of the portal and hepatic trees.

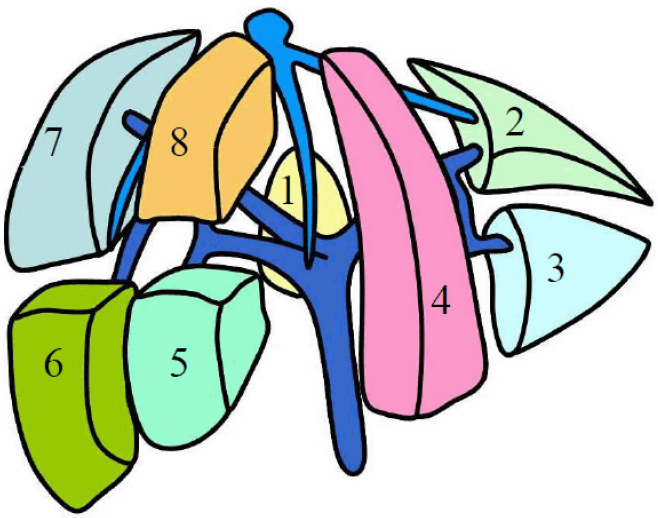
In case of a mislabeled vessel branch, a manual classification tool allows to re-classify it in the correct tree.

The advantage of a good vessel tree segmentation and classification for both radiologist and corresponding physicians and surgeons is a comprehensive analysis of the blood flow pathways to the different regions of the liver, including tumors. Semi-automatic segmentation tools can also be used to manually segment the part of the Inferior Vena Cava (IVC) that is part of the liver volume, in order to accurately calculate the functional liver volume by removing the volume of all the segmented vessels and lesions in the liver from the total liver volume.

Lesions segmentation

Similar 3D semi-automatic and interactive segmentation tools that can be used to edit the liver segmentation or to segment the IVC also allow segmenting the lesions in the liver. The main advantage of these tools is that they allow quick segmentation of all different kinds of lesion regardless of size, shape, density, or heterogeneity.

Couinaud segmentation



The anatomical segmentation of the liver proposed by Couinaud in the 1950s[8,9] is dividing the liver in 8 segments, and is still being used as a gold standard by many liver surgeons. Each of them represents a functional sub-unit of the total liver volume, according to the portal and hepatic blood supply of the liver. Each segment has its own vascular and biliary system.

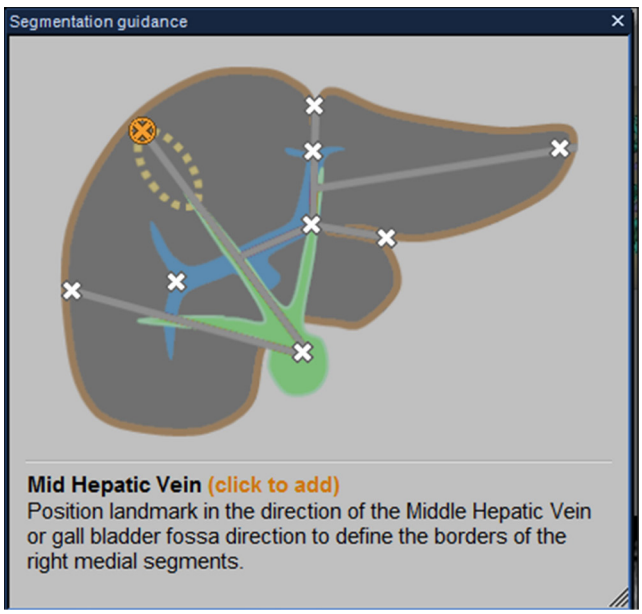
This segmentation is used to give the localization of liver lesions. It is also used to plan the surgical resection of lesions, if the clinicians decide for this approach. The knowledge of the segments´ limits allows for removal of those segments that include the lesions, without damaging the neighboring segments.

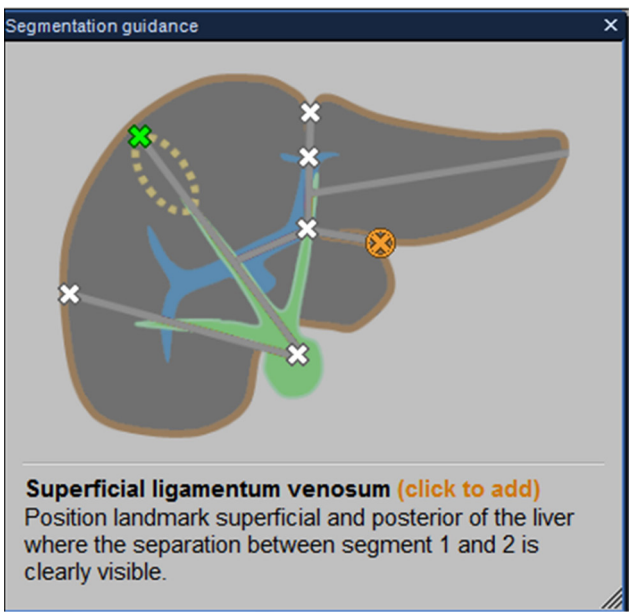
The Couinaud segmentation implemented in the IntelliSpace Portal Liver Analysis application is based in part on an concept proposed by Prof. P.J. Valette from Hospices Civils de Lyon, France.[10,11] The method used sets the limits of the hepatic segments not only using the division of the intra-hepatic branches of the portal vein, but also utilizing certain ligament landmarks at the surface of the liver and the hepatic veins. Philips in collaboration with Prof. Valette developed this technique that has the following major advantages:

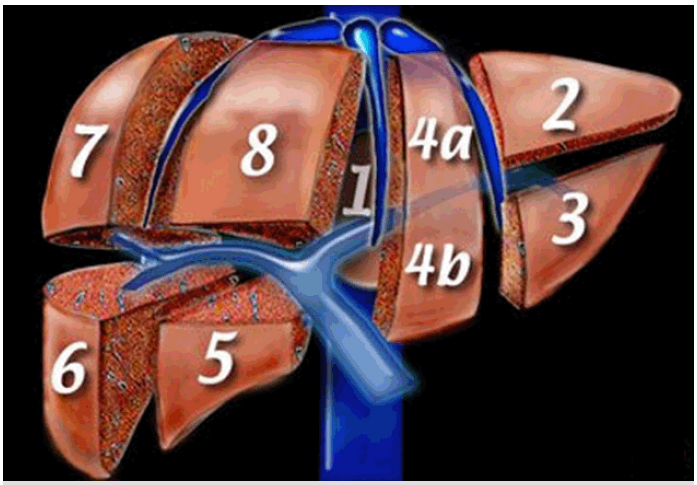
- Similarity with the anatomical landmarks used by the surgeons for partial hepatectomies
- Fast manual positioning of the anatomical landmarks
- Robustness of segmentation, when enhancement of the portal vein is limited by a poor concentration of the iodinated contrast media, or in case of anatomical variation

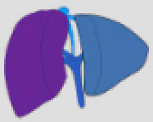
In concrete terms, this technique rests on the manual marking of references points on anatomical landmarks. These are located at the liver surface or on some portal and hepatic veins. These are then used by the software to generate the surface of the hepatic segments.

The user can use a guided mode with schematics and a text description for each required landmark.








2 segments L-R Liver

2 segments L-R Lobe

4 segments L-R medial and lateral

7 segments

8 segments Couinaud

9 segments Bismuth

The user can also choose between different segmentation levels according to their need. The number of required anatomical landmarks is set to the minimum required for the selected segmentation (minimum of 2). In some anatomical variations, adjusting the segment limits is straightforward and intuitive simply by moving the landmarks or by adding reference points for some of the landmarks. Thereby the user has the freedom to achieve a suitable segmentation even in these rare cases, and is not confined to any solutions the application proposes. Thus the technique is flexible and complex cases can be processed easily.

Once the segmentation is done, the volume of each segment is available in table format as well as the volume of each lesion that was previously segmented. These can be displayed in absolute volumes or relative to the different segments, expressed in percentages.

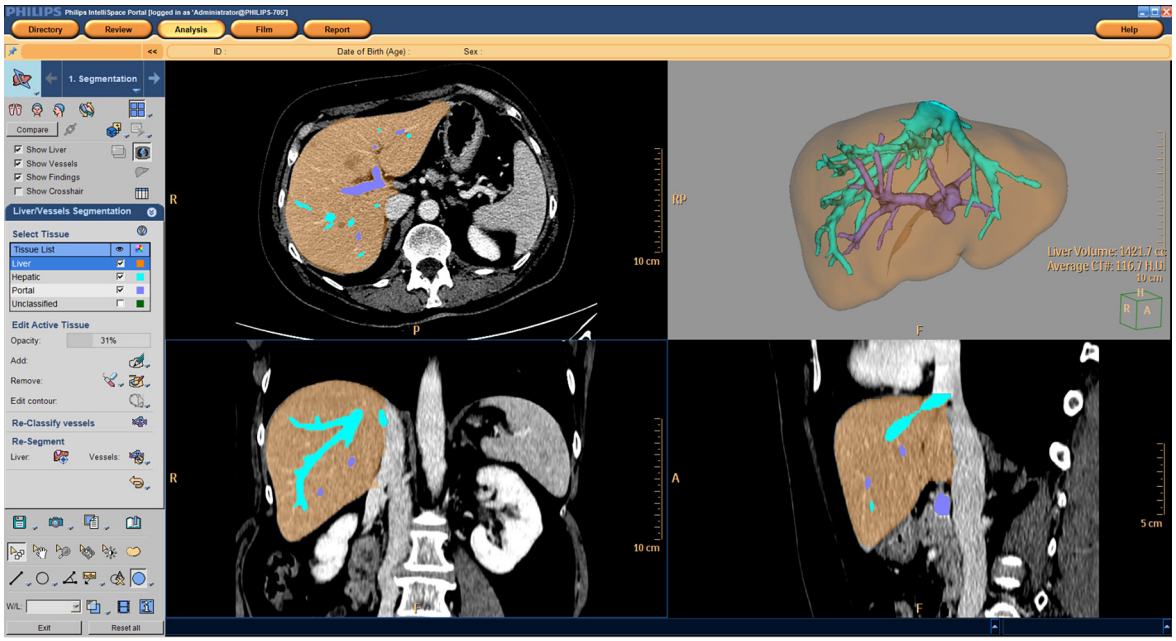
Lesion ablation planning

This stage allows a simple preplanning of the RF ablation of individual lesions. It allows clinicians to determine what kind of needles' shape, size and length are expected to be used. In addition it offers to preview the needle trajectory, allowing pre-planning the preferred approach of the needle entrance. The goal of using such pre-planning tools is to better prepare the intervention in order to reduce the stress during the intervention and possibly reduce the procedure time.[12]

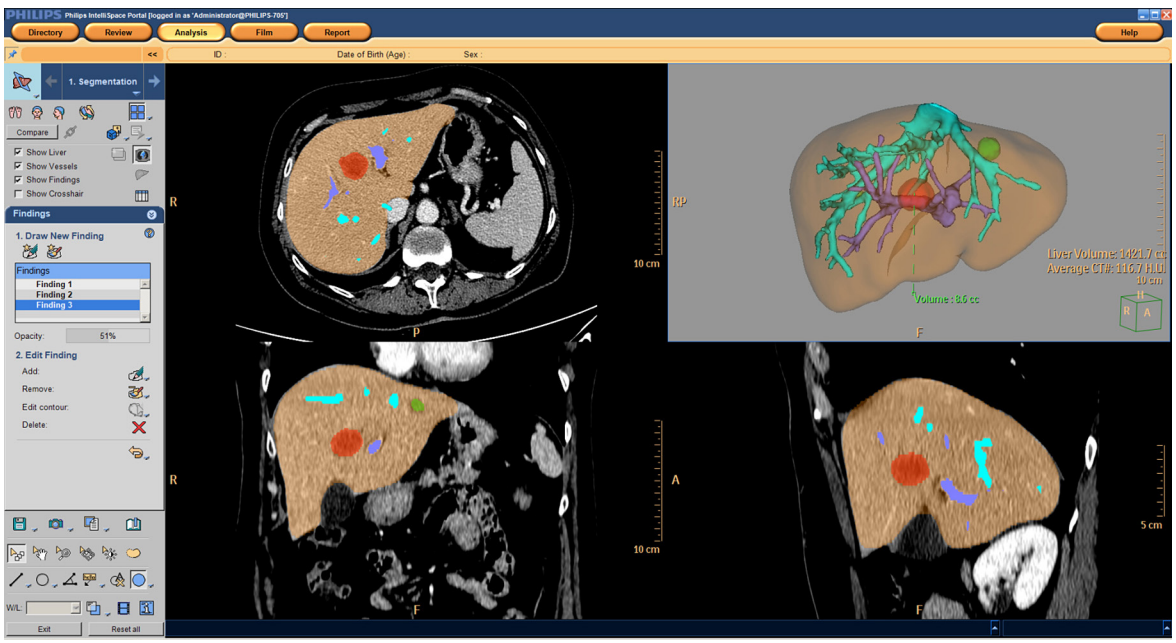
Pre-surgery planning

This stage allows planning the partial liver resection by virtually removing the segments including the lesions from the volumetric CT dataset or by manually setting a freehand atypical cutting surface. It provides an automatic calculation of the remaining liver volume in absolute values, or relative to the initial functional liver. Thereby the clinician immediately knows if the planned hepatectomy is within safe limits for the patient. This is of critical importance since an extended resection over 70 percent of the total liver volume may result in post-operative liver failure.[6,7]

Clinical examples

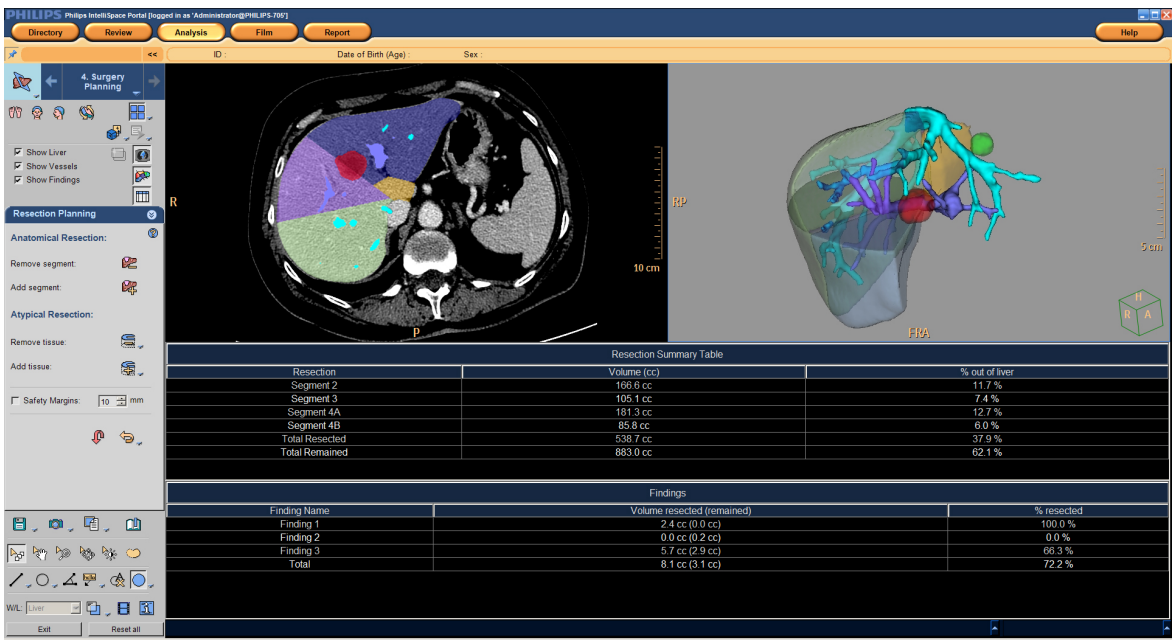


Result of the automatic liver and vessel segmentation.

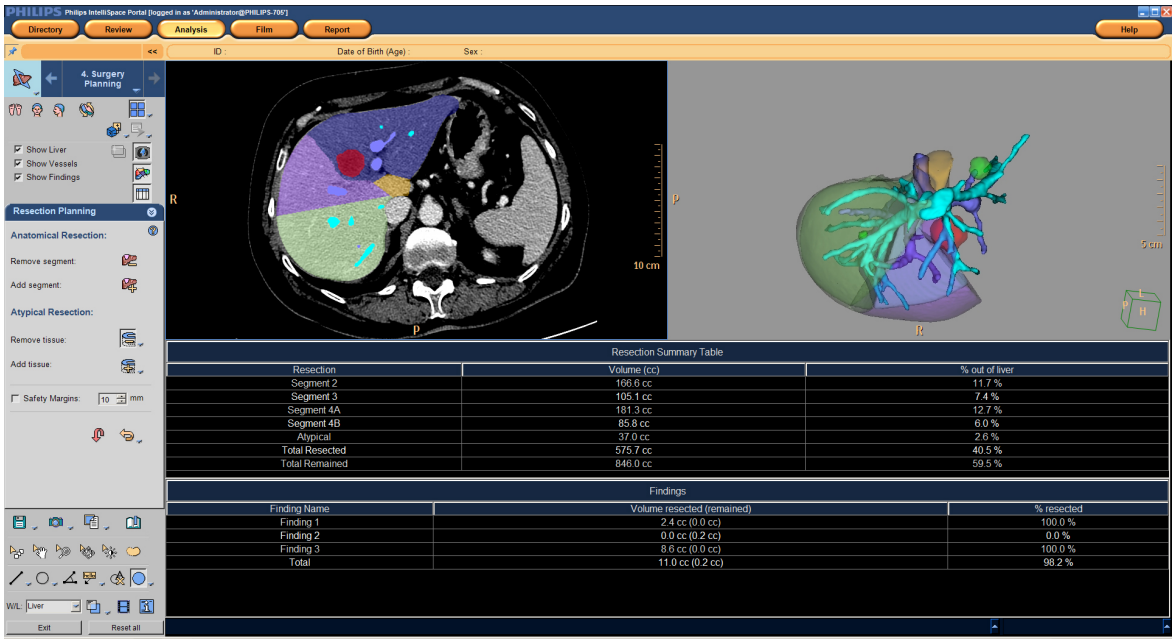


Result of the semi-automatic lesion segmentation:
tumor volume and localization.

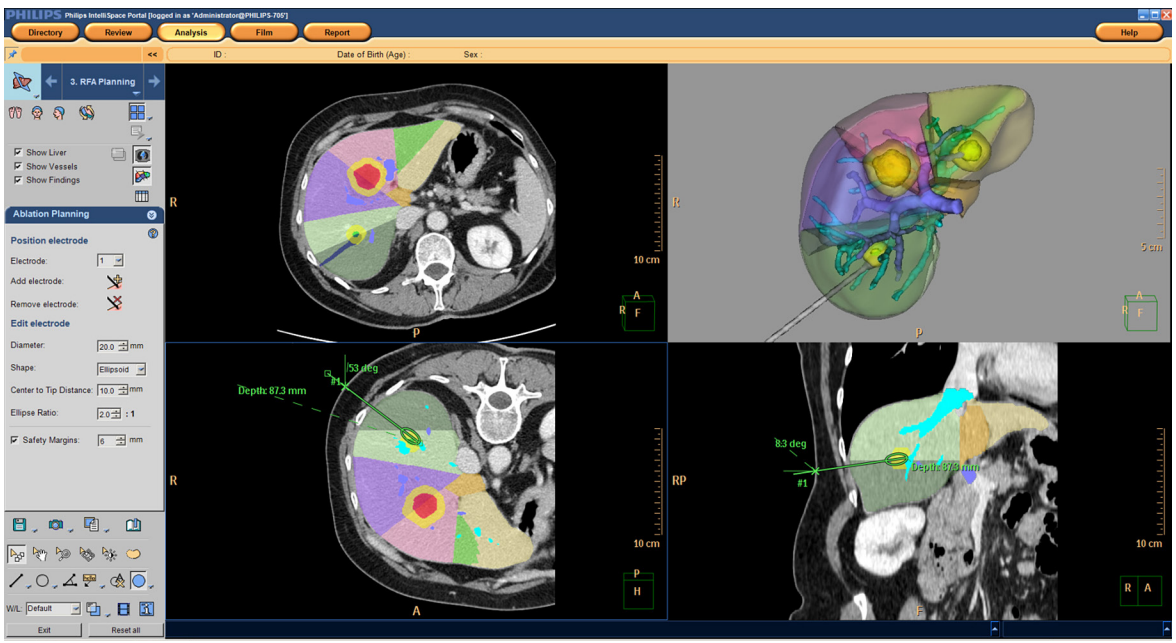
Result of the semi-automatic Couinaud segmentation.



Surgery planning with selection of segments to be cut:
anatomical resection.



Surgery planning with manual virtual cut: atypical resection.



Tumor ablation planning showing ablation margin around the segmented findings and virtual ablation probe (path and ablation area).

Liver Analysis application key benefits

- Full Liver assessment in a short amount of time (10 minutes in average)
  - Total liver segmentation
  - Portal and hepatic veins segmentation and classification
  - Fully real-time interactive 3D segmentation tools for fast and easy segmentation of lesions including complex heterogeneous ones, manual correction of liver segmentation in cases when the automated one is not suitable
  - Semi-automatic liver segments with guided workflow from Right-Left lobe or liver up to Couinaud (8) or Bismuth (9) segmentation
- Volume measurements
  - Functional liver before and after planned treatment
  - Lesions
- Treatment planning
  - Virtual hepatectomy
  - RFA planning
- Lesion location
  - Couinaud segments
  - Vessels (location + feeding)
- Management of complex cases and anatomy variations
  - Fully interactive and real-time 3D segmentation tools
  - Semi-automatic Couinaud segmentation
- Interactive communication tool
  - Sharing of the results with IntelliSpace Portal
  - Treatment planning can be modified on the fly by the surgeon

Conclusion

CT is of major importance in the management of liver primary cancer and liver metastasis for treatment planning, monitoring and follow up. The assessment of total and functional liver volume, lesion volume and location relative to functional liver segments and vessels can be time consuming with conventional image post processing tools.

The Liver Analysis application provides a comprehensive analysis of the liver, allowing efficient patient management and treatment planning. Taking advantage of the application server capabilities of IntelliSpace Portal, Liver Analysis is an outstanding tool for extracting information from a liver CT, communicating this information to physicians and surgeons, planning the strategy for patient management, and guiding surgery.

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