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(54) **SYSTEMS AND METHODS FOR DETERMINING HEPATIC FUNCTION FROM LIVER SCANS**

SYSTEME UND VERFAHREN ZUR BESTIMMUNG DER LEBERFUNKTION AUFGRUND VON LEBER-SCANVORGÄNGEN

SYSTÈMES ET PROCÉDÉS PERMETTANT DE DÉTERMINER LA FONCTION HÉPATIQUE À PARTIR DE SCINTIGRAMMES DU FOIE

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Description

BACKGROUND

[0001] Chronic liver disease is characterized by the gradual buildup of scar tissue (fibrosis) in response to many forms of chronic hepatic inflammation. This can lead to cirrhosis with a decrease in hepatic function. Liver biopsy is one of the most common methods of detecting a liver's health. The biopsy is, however, invasive as it requires removing a portion of the liver for analysis. Furthermore, liver biopsy analysis is subjectively scored and may also vary depending on the location of biopsy. Document "Perfused Kupffer cell mass", J. Hoefs et al., Digestive Diseases and Sciences 1995; 40(3):552-560, discloses a method defining regions of interest corresponding to the liver and spleen in SPECT images and using said regions of interest to determine a liver-spleen index.

SUMMARY

[0002] The systems and methods described herein can be implemented by a computer system comprising computer hardware. The computer system may include one or more physical computing devices, which may be geographically dispersed or co-located.

[0003] Certain aspects, advantages and novel features of the inventions are described herein. It is to be understood that not necessarily all such advantages may be achieved in accordance with any particular embodiment of the inventions disclosed herein. Thus, the inventions disclosed herein may be embodied or carried out in a manner that achieves or selects one advantage or group of advantages as taught herein without necessarily achieving other advantages as may be taught or suggested herein. The invention is defined by the independent claims. Further embodiments of the invention are defined by the dependent claims.

[0004] In certain embodiments, a system for detecting a liver health parameter of a patient can include a single photon emission computed tomography (SPECT) scanner that can obtain image data of organs of a living patient, including a liver and a spleen of the patient. The SPECT scanner can obtain the image data by at least detecting radiation counts responsive to administration of a radioactive compound to the patient. The system can further include a memory device including an image detection module and a parameter calculator stored thereon as computer-executable instructions. The system can further include a hardware processor that can implement the image detection module by executing the computer-executable instructions to at least access the image data output by the scanner. The instructions may further include programmatically identify a first region of interest corresponding to the liver of the patient from the image data, the first region of interest comprising a bounded region around the liver of the patient and being indicative of a size of the liver, wherein the size of the liver is correlated with a health condition of the liver, such that a size of the first region of interest is indicative at least in part of the health condition of the liver. In some embodiments, the instruction can further include programmatically identify a second region of interest corresponding to a spleen of the patient from the image data. Additionally, the hardware processor may also implement the parameter calculator by executing computer-executable instructions to at least programmatically determine a first attribute associated with the first region of interest. The instructions can further include programmatically determine a second attribute associated with the second region of interest. In addition, the instructions can include calculate a first parameter indicative of the health condition of the liver of the patient based at least in part on the first attribute associated with the first region of interest and the second attribute associated with the second region of interest. In some embodiments, the instructions can include output, in a computer-generated graphical user interface, an indication of the first parameter for presentation to a clinician, enabling the clinician to make a clinical care decision for the patient.

[0005] The system of the preceding paragraph can have any subcombination of the following features: wherein the first parameter includes perfused hepatic mass; wherein the first attribute includes a representation of radiation counts in the first region of interest; wherein the image detection module can compare a geometric property of the first region of interest relative to the second region of interest; wherein the memory further includes a user interface module that can include additional instructions configured to generate and output a second user interface, the second user interface can provide functionality for the clinician to input a command to modify the first region of interest; wherein the image detection module can combine a plurality of frames from the image data, said frames corresponding to planes transverse to the patient's body; wherein the image data includes a plurality of frames; wherein the image detector module can programmatically detect the first region of interest from a first frame and programmatically detect the second region of interest from a second frame, wherein said first frame corresponds to a different plane with respect to the patient's body than the second frame; wherein the graphical user interface includes a display of the first region of interest.

[0006] Additionally, in certain embodiments, a method for detecting a liver health parameter of a patient can include receiving image data comprising a representation of detected radiation counts corresponding to one or more organs of a patient. The method can also include programmatically identifying a first region of interest corresponding to a liver of the patient from the image data. In addition, the method can include programmatically identifying one or more additional regions of interest corresponding to one or both of a spleen of the patient and marrow of the patient from the image data. Further the method can include determining a first parameter indicative of health of a patient based at least in part on a first attribute associated with the first region of interest and optionally also based on a second attribute associated with the second region of interest. In some embodiments, the method can include programmatically generating an output responsive to the first parameter for presentation to a clinician, wherein the output comprises one or more of a value of the first parameter and a health report associated with the first parameter. In some embodiments, at least said programmatically identifying a first region of interest corresponding to a liver of the patient from the image data is performed under control of processing electronics.

[0007] The method of the preceding paragraph can have any subcombination of the following features: wherein the first parameter includes perfused hepatic mass; wherein the first attribute includes a representation of radiation counts in the first region of interest; further including detecting a first centroid associated with the first region of interest and detecting a second centroid associated with the second region of interest; further including programmatically identifying a third region of interest based at least in part on the detected first and second centroids.

[0008] In certain embodiments, a system for detecting a liver health parameter of a patient can include a hardware processor. The system can receive scanner output data responsive to detected radiation from a radiation detecting scanner, said scanner output data responsive to a radioactive compound administered to a patient. The system can further apply image processing techniques to detect two or more separate tissue masses in the scanner output data, at least one of the two or more separate tissue masses corresponding to an organ selected from a group consisting of a liver and a spleen. The system can also determine a parameter corresponding to function of one or more of the two or more separate tissue masses of the patient. In some embodiments, the system can output a graphical indication of the parameter for presentation on a display.

[0009] The system of the preceding paragraph can have any subcombination of the following features: wherein the system can further detect a bone marrow region based at least in part on the detected one or more organs; wherein the parameter includes one of a liver volume, a spleen volume, a perfused hepatic mass, a total count ratio, a staging indicator, an estimated peritoneoscopic score, a normalized liver volume, a normalized spleen volume, a highest average concentration, liver counts, a liver spleen index, a liver bone marrow index, a liver length, a spleen length, spleen counts, bone marrow counts, and a hepatic activity index; wherein the scanner output data includes at least one of or more frames corresponding to images of the patient in a plane transverse to a long axis of the body of the patient; wherein the system can further combine a plurality of frames from the image data, said frames corresponding to planes transverse to a long axis of the body of the patient.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Embodiments disclosed herein are described below with reference to the drawings. Throughout the drawings, reference numbers are re-used to indicate correspondence between referenced elements. The drawings are provided to illustrate embodiments of the disclosure described herein.

FIGURE 1 illustrates an embodiment of a computing environment including a quantitative liver spleen scan diagnostics (QLSSD) system that can enable clinicians to quantitatively analyze health of a patient's liver.
FIGURE 2 illustrates an embodiment of an organ health detection process.
FIGURE 3 illustrates an embodiment of a liver health detection process.
FIGURE 4 illustrates an embodiment of a process for identifying liver, spleen, and bone marrow ROI.
FIGURE 5 illustrates an example graphical representation of the embodiment of processes described with respect to FIGURES 3 and 4.
FIGURE 6 illustrates liver, spleen, and bone marrow ROI detected from the SPECT scan.
FIGURE 7 illustrates an embodiment of a process to detect three dimensional ROIs.
FIGURE 8 illustrates an embodiment of a process for predicting post-surgery liver health.
FIGURE 9 illustrates an embodiment of a user interface that can enable clinicians to generate health parameters corresponding to liver's healthiness.
FIGURE 10 illustrates an embodiment of a PACS import user interface.
FIGURE 11 illustrates an embodiment of a user interface that allows clinician to review and modify automatically generated ROIs.
FIGURE 12 illustrates an embodiment of a user interface showing length of a patient's spleen.
FIGURE 13 illustrates an embodiment of a user interface that can enable clinicians to adjust frame range.
FIGURE 14 illustrates an embodiment of a user interface including a report with the PHM parameter.
FIGURE 15 illustrates an embodiment of a user interface that includes a suggested impression and enables clinicians to enter their own impressions.
FIGURE 16 illustrates an embodiment of a user interface that enables sending a report to PACS.

FIGURE 17 illustrates an embodiment of a user interface including a report showing a trend in PHM parameter over time.

FIGURE 18 illustrates an embodiment of a user interface including an example report showing liver health parameters.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

I. Introduction

[0011] The liver is a vital organ with a wide range of functions, including filtering blood coming from the digestive track before passing it to the rest of the body. The liver also detoxifies chemicals and metabolizes drugs. Diseases can reduce the functionality of the liver. Long-term damage to the liver from any cause can lead to permanent scarring, called cirrhosis. Assessing health of a liver is critical in order to predict prognosis and for treatment of patients. A liver biopsy is most commonly used test to determine hepatic functionality. But, the test is invasive and subjective, depending on the analyzing clinician. The results may also depend on the location of the biopsy. Furthermore, the decrease in hepatic function relates more to a patient's health than information gathered from routine blood tests or even fibrosis. Accordingly, in some embodiments, the system described herein can generate quantitative measurement of hepatic function. In addition to its ordinary meaning, hepatic can mean of or pertaining to function of the liver. The hepatic function can correspond to healthiness or functionality of liver.

[0012] Non-invasive method of detecting health of a patient's liver can include analyzing images generated by a Single Photon Emission Computed Tomography (SPECT) scanner. The SPECT scanners can generate images responsive to administrating radioactive compound to patients. Because one of the functions of the liver is to filter blood, the radioactive compound is filtered by the liver and the SPECT scanner can pick the radiation counts to detect absorption of the radioactive compound. The absorption depends on the health of the liver. A healthy liver absorbs the majority of the compound, and the radiation detected by the scanner may mostly be concentrated in the liver. However, when the liver is diseased, more of the radioactive compound can leak out of the liver and flow into, for example, the spleen and/or bone marrow. Accordingly, the radioactive counts from the SPECT scan responsive to absorption of the compound can indicate hepatic function.

[0013] Abstracting information from the image scans can be difficult. The analysis may change for different SPECT scanners. Further, significant training might be required for clinicians to determine parameters from the images. In addition, the analysis may suffer from subjective determinations of clinicians (who may, for example, hand-draw regions of interest as described more in detail below). The regions of interests (ROIs) calculated using a QLSSD system (discussed below) can be robust compared to hand drawn ROIs. For instance, there may be variations in hand drawn ROIs between different clinician. Moreover, it may be cumbersome and time-intensive to hand draw ROIs. Also, the clinicians may not be able to detect counts appropriately from the image as it may depend on the contrast levels of images and may vary between scanners. In some instances, splenectomy, liver-spleen overlap, and anatomical variability may also increase the difficulty in analyzing SPECT images for the clinicians. Accordingly, the QLSSD system can diagnose and identify stages of chronic liver diseases based on the image scans.

[0014] This disclosure describes embodiments of a quantitative liver spleen scan diagnostics (QLSSD) system that can provide clinicians a tool to determine a patient's health based on characterization of the patient's liver through one of the scanning techniques, e.g. from a SPECT scanner. In some embodiments, the QLSSD system can calculate one or more numerical parameters that may be correlated with the patient's liver health. The QLSSD system can also generate text or graphical impressions based on the calculated numerical parameters to report results based on the scans.

II. Example QLSSD System

[0015] **FIGURE 1** illustrates an embodiment of a computing environment 100 for providing clinicians with access to QLSSD system 120 to determine a patient's health based on analyzing scans of the patient's organ. In an embodiment, the QLSSD system 120 determines the patient's health based on analyzing images of liver from a SPECT scanner. The computing environment 100 can include clinician systems 108 that can access the QLSSD system 120, which may include one or modules to determine the patient's hepatic function.

[0016] For instance, the QLSSD system 120 can include an image retriever module 122 that can retrieve images corresponding to scans of a body part, e.g. liver. In an embodiment, the image retriever 122 can receive raw images directly from the SPECT scanner 106. In other embodiments, the image retriever 122 can receive images from a PACS (Picture Archiving and Communication System) repository 102. The image retriever 122 can also receive images from a storage medium such as a compact disc (CD), a portable hard drive, etc. The PACS system 102 may store images in a DICOM (Digital Imaging and communication in Medicine) format. The PACS system 102 may also include other non-image data regarding patients. The image retriever 122 can also receive images of different formats (e.g. jpeg, png, pdf, bmp, CT scanner raw files, MRI raw files, PET raw files, x-ray raw files, etc.). In an embodiment, the image retriever

122 retrieves images from the PACS or SPECT scanner over a network 104. The image retriever 122 may get the images from PACS 102 in response to an input from clinician system 108. In some embodiments, the image retriever may automatically receive the images from the SPECT scanner 106 after a predetermined time interval.

[0017] The QLSSD system 120 can include an image detection module 124 to analyze the images retrieved by the image retriever 122. The image detection module 124 can process the images and identify one or more regions of interests (ROI) from the images as described more in detail below. The regions of interests can include organs, tissues, tissue masses, bones, etc. In an embodiment, the ROI can include a region corresponding to a patient's liver. The image detection module 124 can process images generated by SPECT scanner. In some embodiments, the image detection module 124 can also process images produced from a CT scanner or a MRI machine or from another type of scanner. The image detection module 124 can use information obtained from one type of image to process another type of image for the same patient. For instance, the image detection module 124 can use information detected from CT scan of the patient to detect regions of interest in the SPECT scans. The image detection module 124 may store analyzed images in patient data repository 140 or transmit it back to PACS 102. In some embodiments, the image detection module 124 may include internal checks to ensure that the ROI corresponds to the particular organ. If the detection module 124 determines that the detected ROI does not accurate reflect a particular organ, then it can give clinicians an option to override the automatic ROI detection as described more in detail below.

[0018] The parameter calculator 126 of the QLSSD system 120 can determine one or more attributes from the region of interests identified by the image detection module 124. For instance, the parameter calculator 126 can determine a length of a region of interest corresponding to the spleen. The parameter calculator 126 can also determine a volume or concentration corresponding to a region of interest in terms of total counts or voxels. In an embodiment, a voxel represents a value (e.g. radiation count) in a three dimensional space. In some embodiments, the parameter calculator 126 can calculate parameters corresponding to health of a liver. Some of the example parameters include Perfused Hepatic Mass (PHM), Hepatic Activity Index (HAI), Total Counts Ratio (TCR), Normalized Liver Volume (NLV), and Normalized Spleen Volume (NSV). These parameters may quantitatively indicate hepatic function. The calculated parameters can be stored in the patient data repository 140. In some instances, the calculated parameters can be transmitted and stored in PACS along with other data for that patient. The parameters can also be transmitted over a network to a clinician system. The parameter calculator 126 can also generate a trend based on stored parameters to allow clinicians to monitor health of patients over time.

[0019] The user interface module 128 can interact with one or more other modules of the QLSSD system 120 to generate one or more graphical user interfaces. In some embodiments, the user interfaces can be one or more web pages or electronic documents. The user interface module 128 can also receive data such as patient information from the clinician systems 108. In some instances, the user interface module 128 may receive commands from the clinician systems 108 to initiate one or more functionalities of the QLSSD system. The data can be stored by patient data repository 140. Embodiments of user interfaces are described in detail below.

[0020] The QLSSD system 120 can be implemented in computer hardware and/or software. The QLSSD system 110 can execute on one or more computing devices, such as one or more physical server computers. In implementations where the QLSSD system 110 is implemented on multiple servers, these servers can be co-located or can be geographically separate (such as in separate data centers). In addition, the QLSSD system 110 can be implemented in one or more virtual machines that execute on a physical server or group of servers. Further, the QLSSD system 110 can be hosted in a cloud computing environment, such as in the Amazon Web Services (AWS) Elastic Compute Cloud (EC2) or the Microsoft® Windows® Azure Platform. The QLSSD system 110 can also be integrated with scanners 106 and 110 through software or hardware plug-in or an API (application programming interface). In some embodiments, the clinician systems 108 may implement some or all of the modules of the QLSSD system 120. For instance, the clinician systems 108 may implement the user interface generator module 128, while the rest of the modules are implemented remotely on a server. In other embodiments, a plugin to the QLSSD system 110 may be installed on to a third party tool.

[0021] The clinician systems 108 can remotely access the QLSSD system 110 on these servers through the network 104. The clinician systems 108 can include thick or thin client software that can access the QLSSD system 110 on the one or more servers through the network 104. The network may be a local area network (LAN), a wide area network (WAN), such as the Internet, combinations of the same, or the like. For example, the network 104 can include a hospital's private intranet, the public Internet, or a combination of the same. In some embodiments, the user software on the clinician system 108 can be a browser software or other application software. The clinician system 108 can access the QLSSD system 110 through the browser or application software.

[0022] In general, the clinician systems 108 can include any type of computing device capable of executing one or more applications and/or accessing network resources. For example, the clinician systems 108 can be desktops, laptops, netbooks, tablet computers, smartphones, smartwatches, augmented reality wear, PDAs (personal digital assistants), servers, e-book readers, video game platforms, television set-top boxes (or simply a television with computing capability), a kiosk, combinations of the same, or the like. The user systems 108 include software and/or hardware for accessing the QLSSD system 110, such as a browser or other client software.

III. Organ Health Detection Process

[0023] FIGURE 2 illustrates an embodiment of an organ health detection process 200 for calculating a parameter corresponding to the health of the organ (or more generally a mass of tissue). The parameter can be a numerical, graphical, or textual indicator. The organ health detection process can be implemented by the system described above. For illustrative purposes, the process 200 will be described as being implemented by components of the computing environment 100 of FIGURE 1. The process 200 depicts an example overview of calculating a parameter based on scanned images of a patient.

[0024] The process 200 can begin at block 202 with receiving image data responsive to imaging a patient. The image retriever module 122 can receive image data corresponding to SPECT, CT, or MRI scans of the patient's organ. The received images may include one or more anatomical features (e.g. liver, spleen, bone marrow, etc.). The image detection module 124 can automatically detect these anatomical features using one or more object detection techniques (e.g. morphology, edge detection, centroid search, histogram, etc.) at block 204.

[0025] The detected anatomical features can be used to extract quantitative information from the image scan. For example, at block 206, the parameter calculator 126 can calculate an attribute associated with the detected anatomical feature. In an embodiment, the detected anatomical feature can include a spleen, and the corresponding attribute can be the length of the spleen. A more detailed example with respect to liver and spleen will be discussed below with respect to FIGURES 3 and 4. The parameter calculator 126 can further determine an indicator or a parameter associated with the health of the detected anatomical features or the health of the patient at block 208. In one embodiment, the indicator includes Perfused Hepatic Mass (PHM), which may directly correlate with hepatic function or healthiness of the liver. The PHM can be a numerical indicator or graphical output based on a numerical indicator and may provide an objective standard to determine a patient's liver health.

[0026] The process 200 can be used to determine a parameter corresponding to health of different anatomical features of a patient. As discussed above, the process 200 can be used to determine a parameter corresponding to hepatic function. In another example, the process 200 can be used to determine a parameter corresponding to a patient's heart or cardiac output, pulmonary nodule classification, or kidney function, or function of any other organ or tissue mass of a patient.

IV. Liver Health Detection Process

[0027] FIGURE 3 illustrates a more specific example process 300 of the organ health detection process 200 described above. The process 300 can enable clinicians to obtain a parameter corresponding to healthiness of the patient's liver. The liver health detection process 300 can be implemented by the system described above. For illustrative purposes, the process 300 will be described as being implemented by components of the computing environment 100 of FIGURE 1. The process 300 depicts an example overview of calculating a parameter associated with hepatic function using scanned SPECT images of a patient.

[0028] The process 300 may begin with acquiring scanned images from a SPECT scanner at block 302. The SPECT scanner generates images by measuring radiation counts responsive to administrating radioactive compound to a patient. In an embodiment, the images are generated 30 minutes after administration of the compound. The time may vary between patients, but typically it takes about half an hour for the radioactive compound (e.g. Technetium-99 metastable) to be filtered from the blood by the liver. For a patient with a healthy liver, most of the radioactive compound will be found in the liver. However, in a diseased liver, the compound can leak into the spleen and bone marrow. Since most of the compound may be found in the liver, spleen, bone marrow (near vertebrae) region, the SPECT scanner output can provide mechanism for separating liver, spleen, and bone marrow from rest of the organs. An example summarized transaxial SPECT scan of liver, spleen, and bone marrow is shown in FIGURE 6.

[0029] As discussed above, the scanned images can be received directly from the scanner or via PACS. The image retriever module 122 can automatically process the received images depending on the source at block 304. The received images can include multiple orientations. In one embodiment, the image retriever module 122 can retrieve planar posterior and transverse SPECT images from SPECT scanner or PACS. The transverse SPECT images may include one or more frames corresponding to planes perpendicular to the long axis of the patient's body. The planar posterior images may include one or more frames taken from the perspective of the patient's backside and may correspond to planes parallel to the long axis of the patient's body. Other image views include anterior, oblique, sagittal, coronal, reformatted, secondary captures, or derived images. In some embodiments, the image retriever module 122 can directly process raw scanner data instead of image data. The received images may be divided into multiple frames spanning an area of the patient's body. Accordingly, the received images can include a three dimensional perspective of the SPECT scan.

[0030] The image detection module 124 can process the received images at block 124. In an embodiment, the image detection module 124 can generate a combined transaxial image (CTI) from the transverse liver-spleen images obtained from the SPECT scanner at block 306. In an embodiment, the CTI is a summarized transaxial image (STI), which can be a combination or a sum of each of the transaxial images covering the liver-spleen area. In other embodiments, the CTI is generated using through voxel-by-voxel averaging of the transverse images. Other methods for generating CTI that can be used include using median, mode, maximum intensity, auto-correlation, and similar statistical techniques. In an embodiment, maximum intensity transaxial image (MITI) is detected by selecting the highest intensity pixel at (x,y) from some or all the transaxial images covering the liver-spleen area. Accordingly, the final MITI may have highest intensities from some or all the transaxial images for each pixel. In some embodiments, MITI can provide a better contrast than STI. The image detection module 124 can combine the transaxial images before detection of region of interests. In some embodiments, the regions of interests may be detected prior to combination of frames.

[0031] The image detection module 124 can use the CTI to detect regions of interests. The regions of interest can correspond to anatomical features of the patient. In an embodiment, the image detection module 124 detects liver, spleen and bone marrow. The image detection module 124 can locate the liver based on a comparison of intensities in the CTI. FIGURE 5 illustrates a simplified diagram to show the steps for detecting and separating liver, spleen and bone marrow ROIs.

[0032] The image detection module 124 can select frame boundaries and conduct directional searching to locate the liver. At block 308, the image detection module 124 can identify a body contour 520 as shown in step 502 in FIGURE 5 by comparing intensities. In general, counts will be near zero outside of the body. A healthy liver will include much higher intensity counts than surrounding tissue. Even a diseased liver may include at least some portions with high intensity counts.

[0033] At block 310, the image detection module 310 can determine liver boundary threshold. Step 504 of FIGURE 5 illustrates an example for determining liver boundary threshold. The image detection module 124 can identify a border region 522 around the body contour 520 to determine the threshold. In an embodiment, the threshold is the average pixel intensity in the border region or some other value. The threshold can also be the maximum or minimum pixel intensity in the border region. In some embodiments, the threshold can be determined using a logarithmic formula.

[0034] Using the threshold value, the image detector 310 can use directional searching to locate a region of interest corresponding to the liver at block 312. As an example, the image detector 124 can select the north-west corner of the body contour (although any other starting region may be selected) and move across the rows and columns of pixels to determine when the intensity count exceeds the threshold. Accordingly, the image detector 310 can find a pixel location that exceeds the threshold value indicating that the pixel is most likely inside the liver. In one embodiment, a value of 20% above the tissue threshold is used. After finding the pixel location, the image detection module 124 can implement a directional searching to identify the boundary points of the liver. As shown in step 506 of FIGURE 5, the image detector 124 can search along eight directions in a star pattern from the pixel location (526). In other embodiments, the image detector 124 can also implement other methods of searching, e.g. 16-point star, etc. The boundary points can be identified by comparing intensities of pixels with the threshold value as discussed above. In some embodiments, the image detection module 124 can also use sampling to identify boundary points of the liver.

[0035] Accordingly, the image detector 124 can identify (for example) 8 boundary points of the liver. At block 314, using these boundary points, the image detector 124 can calculate a first centroid location. In some embodiments, the image detector 124 can quickly locate the centroid of the organ without using trigonometric calculations by using straight combinations of matrix indices. For example, the matrix indices may be combined using summations. After finding the first centroid, the image detector 124 can repeat the process to locate the second centroid using directional searching from the first centroid location. In some embodiments, the image detector can rotate the star search direction. For example, the rotation angle can be offset by 10 degrees in between centroid search. The eight point star search may be repeated multiple times until the location of the centroid appears to converge. In some embodiments, the number of iterations can be fixed. Step 508 of FIGURE 5 illustrates the final centroid location 528. Accordingly, the image detector 124 can identify boundary points of the liver and the centroid of the liver.

[0036] In blocks 316 to 318 of the process 300, the boundary points and the centroid of spleen can be identified in a similar manner as discussed above with respect to the liver. In most patients, the spleen is located in a south-east direction relative to the liver. Thus, the image detector module 124 can conduct a similar search from the south-east corner of the body contour 520 to identify the spleen boundary points and centroid. Step 510 of FIGURE 5 illustrates both the liver 524 and the spleen 530.

[0037] The image detector 124 can automatically validate the detected liver and spleen. At block 324, the image detector 124 can calculate the distance between the liver and spleen centroids and compare with an acceptable range to validate the detected liver and spleen. If the distance is not within a range, e.g., it is less than the minimum or more than the maximum value, the image detector can notify one or more modules of the QLSSD system 120. The QLSSD system 120 can notify the clinician systems that organ detection might have failed and may give an option to the clinician to manually draw the ROIs. The user interface generator module 128 can generate user interfaces for the clinician to draw the ROIs.

[0038] The image detector 124 can also validate for overlaps. For instance, if the liver and spleen regions overlap, the QLSSD system 120 may send a message to the clinician system that enables a clinician to select a brightest area of the liver or indicate that liver is not visible. The clinician may also be able to select the brightest spleen area. Based on the selection, the image detector 124 can use directional searching and centroid analysis to re-identify the liver and spleen. In some embodiments, clinicians may be given an option to select the liver and spleen pixels before any of the search process. Thus, the QLSSD system 120 can validate organ detection.

[0039] If the liver and spleen regions are validated, then at block 330, the image detector 124 can automatically draw ROIs around liver, spleen, and bone marrow as described more in detail with respect to FIGURE 4. Once the ROIs are determined, the parameter calculator 126 can calculate parameters corresponding to hepatic function as discussed below. In some embodiments, the process 300 includes the step of preparing and generating a report including impressions at blocks 332-334. The user interface generator 128 can prepare reports based on the calculated parameters and a lookup table. The lookup table may be stored in the data repository 140. The lookup table can store appropriate impressions for different ranges of parameters. An example impression is shown in FIGURE 15.

V. Regions of Interest Analysis

[0040] FIGURE 4 illustrates an example ROI detection process 400 for determining ROIs based on the detected liver and spleen centroids using the process illustrated in FIGURE 3. The ROI detection process 400 can be implemented by the system described above. For illustrative purposes, the process 400 will be described as being implemented by components of the computing environment 100 of FIGURE 1.

[0041] In an embodiment, once the liver and spleen centroids are identified along with boundary points, the image detector 124 can proceed with identifying region of interests to segment liver, spleen and bone marrow. At block 402, the image detector 124 can fit in a geometric shape such an elliptical shape over the liver and spleen based on the respective boundary points and centroid detected by the process 300 discussed above. As an example, the image detector can fit an ellipse based on a least squared error reduction method. In some embodiments, the major axis of the fitted ellipse passes through the centroid of the detected organs.

[0042] The image detector 124 can determine a centroid-centroid line connecting the centroid of the liver to the centroid of the spleen at block 404. The image detector 124 can then identify a boundary point along the centroid-centroid line that corresponds to a valley (lowest) in count distribution. The image detector 124 can find additional boundary points north (or above) of the centroid-centroid line using the liver and spleen major axis as the starting points and finding the minimum concentration in between. The image detector 124 can use these boundary points to obtain a demarcation line between the liver and the spleen. An example demarcation line (or liver-spleen boundary line) 610 is illustrated in FIGURE 6. One side of the demarcation line can be the liver ROI 602 and the other side of demarcation line can be part of the spleen ROI 606.

[0043] At block 406, the image detector 124 can detect a boundary line 612 (see FIGURE 6) between the liver and the bone marrow. In an embodiment, the image detector 124 can attempt to calculate centroid of the bone marrow and the liver-marrow boundary line can be calculated as discussed above. But, in some embodiments, the image detector 124 may not be able to identify a bone marrow centroid. In these instances, the image detector 124 can start from a point (below the centroid) on the major axis of the liver ellipse and look for pixels in the direction of bone marrow where the value of count is at a certain liver-marrow number. In one embodiment, the liver-marrow number = threshold (as calculated above) + 20% (maximum intensity in liver - threshold). Other variations and percentages can be also be used. Accordingly, the image detector 124 can identify boundary line 612 between liver and bone marrow.

[0044] At block 408, the image detector 124 can connect the liver-spleen boundary 610 with the liver marrow boundary 612 as seen in FIGURE 6. As discussed above with respect to liver, at block 410, the image detector 124 can identify a spleen-bone marrow boundary line 614 using a spleen-marrow number. In one embodiment, the spleen-marrow number = threshold + 20% (maximum intensity in spleen - threshold). At block 412, the image detector 124 can connect the liver-spleen boundary 610 to the spleen-marrow boundary 614 as illustrated in FIGURE 6.

[0045] At block 414, the image detector 124 can detect outer boundary 616 (see FIGURE 6) of the marrow. In an embodiment, the image detector 124 can connect the end point of the liver-marrow boundary to the end point of the spleen-marrow boundary. The image detector 124 can use the tissue threshold to connect the end points. At block 416, the image detector 124 can find the outer boundary 618 of the liver using the tissue threshold and body contour as discussed above. The image detector 124 can connect the outer boundary 618 to the end point of the liver-marrow boundary on the bottom and the end point of the spleen-marrow boundary on the top.

[0046] Similarly, at block 420, the image detector 124 can find the outer spleen boundary 620. The image detector 124 can connect the outer spleen boundary 620 to the end point of the liver-spleen boundary on the top and the end point of the spleen-marrow boundary on the bottom at block 422. Accordingly, the image detector can generate liver ROI 602 and the spleen ROI 606 from the calculated boundaries. The image detector can generate the marrow ROI 604 from the liver-marrow, spleen-marrow, and the outer marrow boundaries.

[0047] In some embodiments, the image detector 124 can validate the calculated ROIs. For example, the image detector 124 can check whether there is a large gap in liver-spleen boundary or if there are too many voxels above tissue threshold in liver ROI connection with liver/spleen boundary. Based on the validation, the user interface generator 128 can generate a user interface that can enable a clinician to modify the generated ROIs.

[0048] The ROIs calculated using the QLSSD system 120 can be robust compared to hand drawn ROIs. For instance, there may be variations in hand drawn ROIs between different clinician. Moreover, it may be cumbersome and time-intensive to hand draw ROIs. Also, the clinicians may not be able to detect counts appropriately from the image as it may depend on the contrast levels of images and may vary between scanners.

VI. Parameters

[0049] As discussed above, most of the existing health detection techniques suffer from subjective analysis. There is a lack of an objective analysis that is repeatable (within a small error range) between clinicians and patients. The QLSSD system 120 can abstract parameters from the scanned images to generate objective parameters for evaluating hepatic function. The parameter calculator 126 can use the processed images with detected ROIs to calculate one or more of the following parameters. Other variations in calculation of these parameters are possible as can be understood by a person skilled in the art.

Liver, Spleen, and Bone Marrow Counts

[0050] In SPECT images, the counts correspond to detected radiation from the compound. Accordingly, higher counts may indicate higher concentration of the compound in a particular organ. The parameter calculator 124 can use the detected ROIs for liver, spleen, and bone marrow to calculate total counts in each of the respective ROIs from one of the combined transaxial image. For combined frames, the counts can represent volume as the stack of frames may include multiple slices of the patient's body. In some embodiments, a single mid-organ frame is used to compute liver and spleen concentration. Concentration may also be computed by averaging counts in a particular sub-region of the organ from a frame with the highest counts. The image detector can find 3 x 3 voxel areas in the highest count frame and average the counts to determine a concentration (e.g. counts/minute/voxel). For three dimensional ROIs, the counts may be summed across all frames for respective organ ROIs. The counts can indicate to clinicians how much of the compound is in the liver versus the other organs. As discussed above, for a healthy liver, most of the counts might be found in the liver ROI as compared to other organ ROIs. In some embodiments, bone marrow counts are expressed as a ratio to the number of frames to normalize for number of vertebral bodies covered by the scan. In another embodiment, the number of vertebral bodies is counted and that is used to normalize the bone marrow counts.

Liver and Spleen Length

[0051] In an embodiment, the parameter calculator 128 can calculate lengths of detected organs. For example, the parameter calculator 128 can detect length of the liver from an anterior planar image for right lobe from mid-liver dome to the right inferior margin and left love from right dome to inferior left lobe margin.

[0052] The parameter calculator 128 can measure the spleen length as the greatest pole to pole length in posterior planar view. In some embodiments, the spleen length is determined from the transverse images. If there is a difference in spleen length by 10% or more between different frames, the clinician may be warned and manual intervention may be required via one of the user interfaces described below.

Liver Spleen Index, Liver Bone Marrow Index (LBI), and Perfused Hepatic Mass (PHM)

[0053] In some embodiments, the hepatic function may be understood from distribution ratios using counts obtained from the one or more scanned images. For instance, the liver-spleen index (LSI) can be determined from comparing counts in the liver to the counts in spleen. In an embodiment, the liver-spleen index (LSI) is a function of liver to spleen ratio of total counts corrected for spleen length. The parameter calculator 128 can calculate total count ratio between liver and spleen as a total liver counts divided by total liver plus spleen counts, or $L/(L+S)_t$. In some embodiments, the ratio is reproducible within 1%. The ratio might be affected by spleen size independent of chronic liver disease. A correction might be required for variation in spleen length between patients. In one embodiment, the parameter calculator 128 can correct for the spleen length. The parameter calculator 128 can estimate the $L/(L+S)_t$ ratio expected from the impact of spleen length in patients with normal livers (empirically derived formula from patients with normal livers and varying size spleens). The parameter calculator can then divide the measured $L/(L+S)_t$ ratio by the estimated normal $L/(L+S)_t$ ratio and multiply it by 100 to derive the liver spleen index (LSI).

[0054] The distribution of counts between liver and bone marrow may be expressed as the liver-bone marrow index (LBI). In an embodiment, the parameter calculator 128 can calculate LBI as the log of liver count divided by bone marrow count per frame and multiplied by 50 to produce a similar range to LSI.

[0055] In some embodiments, the parameter calculator 128 can generate a parameter that is a function of both LSI and LBI. For example, the parameter calculator 128 can calculate the perfused hepatic mass (PHM) parameter by averaging of LBI and LSI, that is: PHM = (LBI + LSI)/2.

Spleen and Liver Volume

[0056] The parameter calculator 128 can also calculate liver and spleen volumes. Spleen and liver volumes may be calculated using the total counts in an organ divided by a representative concentration on the cross-sectional frame times the voxel volume. In one embodiment, the parameter calculator 128 can use a single mid-organ frame that is representative for the concentration. The volumes in cc may be expressed as a ratio to the ideal body weight (IBW) in pounds. One skilled in the art can recognize alternate methods of obtaining representative concentrations of the organ of interest, such as, sampling, histogram analysis, whole organ averaging, or single organ slice. Additional example calculations are discussed in "A Novel, Simple Method of Functional Spleen Volume Calculation by Liver-Spleen Scan," by Hoefs et al, The Journal of Nuclear Medicine, Vol. 40, No. 10 (Oct. 1999). In some embodiments, volumes do not rely on precise edge detection and are insensitive to voxel size.

[0057] In some embodiments, the liver volume is automatically calculated by performing a search through the scanned images to identify a frame that contains the highest concentration areas of the liver. The image detector can find 3 x 3 voxel areas in the identified frame and average the counts to determine a concentration (e.g. counts/minute/voxel). The parameter calculator 128 can use the highest average concentration value to calculate the volume of the liver using the following formula:

$$\text{Liver Volume} = ((\text{Total Liver Counts}/\text{Highest Average Liver Concentration}) * \text{Voxel Size} * 0.9562) - 66.5.$$

[0058] The constants in the liver volume formula can be modified based on calibration samples. For example, the calculated volume can be compared to phantom volumes by linear regression analysis. The spleen volume can be calculated using the method discussed above with respect to liver. In an embodiment, each voxel represents a 4 x 4 x 4 cubic millimeters. Accordingly, the liver volume can be determined in cubic millimeters.

Normalized Liver and Spleen Volumes

[0059] Liver and spleen volumes may depend on the patient's overall size. Thus, in some embodiments, ideal body weight is used to normalize the organ volumes to provide clinically useful parameters. The patient's actual body (e.g. obtained from PACS) may also be used. The parameters can be calculated as follows:

$$\text{Normalized Liver Volume} = \text{Liver Volume}/\text{Ideal Body Weight}$$

$$\text{Normalized Spleen Volume} = \text{Spleen Volume}/\text{Ideal Body Weight}$$

The formula to calculate IBW may be different for males and females.

$$\text{Female IBW} = 100 + \{\text{height (in inches)} - 60\} \times 5$$

$$\text{Male IBW} = 106 + \{\text{height (in inches)} - 60\} \times 6$$

Example: if the liver volume is 952 as calculated in the example above, then A Female, 62 inches tall would have an IBW = 110 lbs and the

Normalized Hepatic volume (corrected for body size) = 8.7 cc/lb IBW

Estimated Peritoneoscopic Score (estPS)

[0060] Peritoneoscopy can provide an indication of the degree of "smoothness" or "granularity" or "nodularity" of the liver. The QLSSD can calculate an Estimated Peritoneoscopic Score (estPS) by combining several parameters. In one embodiment, the estPS is calculated as follows:

$$estPS1 = 4.342 - 2.008\ RR - .0206\ PHM + 18.15/RL$$

where RL is the right lobe length in cm, and RR is the redistribution ratio calculated as:

$$(RR) = [(Lp/Sp/2.5) + (Lp/BMp/17.5)]/2$$

Here Lp, Sp and BMp are pixel counts from the posterior planar view for the liver, spleen and bone marrow respectively.

[0061] The Peritoneoscopic assessment of the liver can be a better indicator than histologic fibrosis measurements since sampling errors may be avoided. Thus, the estPS from QLSSD can provide a good estimate of hepatic fibrosic stage as measured by histology with almost no sampling error

Staging

[0062] The parameter calculator 126 can classify severity of liver disease by comparing one of the calculated parameters with expected ranges. In one embodiment, patients are staged using the PHM parameter as follows:

PHM ≥ 100;	normal hepatic function (low risk)
95 ≤ PHM < 100:	mildly reduced hepatic function (intermediate risk)
PHM < 95:	reduced hepatic function (high risk)

[0063] In another embodiment, high risk patients are further classified as moderately reduced hepatic function if the PHM > 70 or severely reduced hepatic function if PHM <70. Other indicators including colors may also be used for staging. these ranges may vary in other embodiments, or may have more or fewer ranges (e.g. a threshold may be used to determine if the patient's liver is healthy or not).

Hepatic Activity Index

[0064] There may be a close correlation between LSI and LBI. A linear regression equation drawn in a large group of patients can define this relationship. In an embodiment, the LSI can be used in this equation to determine an estimated LBI. The estimated LBI may be subtracted from the Measured LBI and this difference can be divided by the LSI to get the HAI. The HAI of less than a -.10 can indicate a significant departure from the usual relationship and indicates a more rapidly progressive liver disease such as alcoholic hepatitis.

[0065] In some embodiments, the formula for calculating HAI is:

If LSI > 0.0

$$HAI = (LBIt - ((LSI * 0.665) + 43.0))/LSI$$

Otherwise

$$HAI = 0$$

VII. 3D Processing

[0066] In some of the embodiments discussed above, the frames corresponding to slices across the patient's body can be analyzed as combined frame (e.g. STI, MITI, etc.). In the alternative, the frames can be processed individually to detect three dimensional profile of organs. FIGURE 7 illustrates a process for detecting ROIs in three dimensions. The 3D ROI detection process 700 can be implemented by the system described above. For illustrative purposes, the process 700 will be described as being implemented by components of the computing environment 100 of FIGURE 1.

[0067] At block 702, the image detector 124 can detect 2D ROIs of liver, spleen, and bone marrow as discussed above with respect to FIGURES 3 and 4. The image detector 124 can continue detecting ROIs for each frame. Some frames may have low signal content as the organs begin to taper off. The image detector 124 can store the ROIs from each of the frames for liver, spleen, and bone marrow. At block 706, the image detector 124 can combine the stored liver ROIs using morphological features to form a 3D liver volume. Similarly, the image detector 124 can generate 3D spleen volume at block 708 and a 3D bone marrow volume at block 710. In some embodiment, the image detector 124 can use edge following to connect ROIs between frames. The parameter calculator 126 can calculate liver function parameters and liver disease stages from the 3D ROIs using the formulas as discussed above with respect to 2D frame.

[0068] In some embodiments, the image detector 124 can generate 3D ROIs using directional searching and centroid in three dimension instead of combining the results of 2D analysis for individual frames. In three dimensions, the image detector 124 can rotate direction vector of search before conducting iterative directional searching and centroid analysis. In another embodiment, the image detector 124 can use transform processes to map 3D volumes (such as ellipsoids) into points in the transform space. For instance, the liver, spleen, and marrow may be modeled as ellipsoids (or union of ellipsoids) to use the transform techniques.

[0069] The 3D capability may also allow calculation of fibrosis directly. In some embodiments, the functional ratios can overlap because there might be overlap between liver, bone marrow and spleen. Separating the frames before analyzing can reduce effects of overlap.

[0070] The image detector 124 may also use data from CT or MRI scan. The CT and MRI scan include information relating to outline of organs. The image detector 124 can use the outline to map data from SPECT scan on to a CT or MRI scan. Based on the mapping, the image detector 124 can detect ROIs from the SPECT scan.

VIII. Total Count Ratio (TCR)

[0071] The SPECT reconstruction may have a limited range of slices that includes the entire organ being evaluated. Each slice may be the width of the voxel (or pixel). A threshold can be designated as to the surface voxel for inclusion of a surface voxel as a percent of the maximal voxel concentration in the liver. As the liver becomes more diseased, fewer of the surface voxels might have greater than 50 % of the maximal voxel concentration due to the presence of fibrosis. Thus, the volume of the included voxels may be smaller as the liver becomes more diseased (and total counts in this 3-D ROI decreases). The included volume in patients with chronic liver disease has fewer counts compared to the total counts (TCR) compared to a similar procedure on a normal liver. The total counts ratio can be calculated from summarized transaxial image.

[0072] The image detector 124 can determine ROI around the organs as discussed above. Based on the ROIs, the total counts (TC) for each of the organs may be calculated by the parameter calculator 126. The parameter calculator 128 can select a threshold. In an embodiment, the threshold is 50% of the maximal voxel concentration). The parameter calculator 126 can apply the threshold to each slice within the above ROI, therefore picking the surface voxel to be used on each slice. The image detector 124 can take the surface voxels selected from each slice to draw a 3-D image for the whole organ. The parameter calculator 126 can calculate the counts within the generated 3-D image. These counts can represent the threshold counts. The parameter calculator 126 can calculate the total count ratio (TCR), where TCR = threshold count/total count (TC) for each organ. Accordingly, TCR can be calculate for the organs and included in reports.

IX. Predicting Post-Op Surgery

[0073] 3D imaging can enable pre-surgery estimates of the loss of hepatic function after surgery for hepatocellular carcinoma (HCC) and other hepatic masses. The expected anatomic loss from surgery can be overlaid with the 3D ROIs and the loss of function calculated. These factors may be used in the output impressions to stage the liver disease, estimate the risk of complications and for prognosis. In patients with hepatic cancer and limited hepatic reserve, the liver health parameters may be used to estimate the loss of function at surgery to determine surgical risk.

[0074] FIGURE 8 illustrates an embodiment of a process 800 for estimating post-resection parameters. The post-resection parameter calculation process 800 can be implemented by any of the systems described above. For illustrative purposes, the process 800 will be described as being implemented by components of the computing environment 100 of FIGURE 1. At block 802, the image detector 124 can determine 3D ROIs of the liver, spleen, and bone marrow as discussed above. At block 804, the image retriever module 122 can access CT or MRI images including the liver. The image detector 124 can superimpose the CT or MRI image on the 3D ROIs using, for example, image registration techniques.

[0075] In some embodiments, superimposition may be performed using built-in capabilities of hybrid SPECT/CT scanners. At block 806, the user interface module 128 can generate a user interface that can allow clinicians to select or draw resection volume on the superimposed image. In an embodiment, the resection volume is automatically drawn based on importing parameters from surgical planning system. In some embodiments, the QLSSD system 120 can display a suggested resection volume. The suggested resection volume may be based on the differences between the SPECT liver volume and the CT or MRI liver volume. As an example, portions of the liver that contain hepatocellular carcinoma (HCC) will show up in the CT or MRI images but not in the SPECT images. At block 808, the parameter calculator can ignore the area that is part of the planned resection volume to calculate post-resection parameters. Accordingly, the process 800 can enable clinicians to determine liver health post operation and determine whether more or less of the liver should be removed. Also, the clinicians can assess risk of surgery by reviewing the post-resection parameters.

X. User Interfaces

[0076] The example graphical user interfaces shown in FIGURES 9 to 18 may be generated by the QLSSD system 120, the QLSSD system plugins, or a combination of both. For illustration purposes, these user interfaces are shown primarily in application interfaces, although it should be understood that these user interfaces can be generated with web browsers (including mobile apps) other than application interfaces. Further, example user interface controls (active links) are shown, including buttons, status bars, hyperlinks or links, and the like. Any of the user interface controls shown can be replaced with other user interface controls, including but not limited to radio buttons, check boxes, text boxes, select boxes or drop-down boxes, combinations of the same, and the like.

[0077] FIGURE 9 illustrates an embodiment of a user interface 900 generated by the user interface module 128 that can enable clinicians to access functionality of the QLSSD system 120. For example, clinicians can import scanned images for a patient from PACS and view the scanned images in the user interface. The user interface also include active links to change contrast and brightness of the scanned image. Clinicians can further run automated analysis on the scanned images by selecting an active link. The user interface 900 can enable clinicians to navigate a DICOM hierarchy for the selected image (patient, study, series, and image). The navigation button and list can facilitate moving from one image to another, to refresh patient list, etc. Moreover, images can be imported from PACS such as SPECT transverse images and/or static posterior planar images. In some embodiments, image are imported automatically from PACS. The clinician can select an image or a set of images for analysis by the QLSSD system as discussed above.

[0078] FIGURE 10 illustrates an embodiment of a user interface 1000 generated by the user interface module 128 that can enable communications with the PACS system 102. For example, the clinician can run queries to access data corresponding to a particular patient. Based on the selected query, the QLSSD system 120 can communicate with PACS and retrieve the requested data.

[0079] FIGURE 11 illustrates an embodiment of a user interface 1100 that can be generated by the user interface module 128 in response to the detected regions of interest corresponding to organs. The illustrated embodiment of the user interface 1100 shows liver, spleen, and bone marrow ROIs. The user interface 1100 can include an active link 1102 for selecting whether the patient has his or her spleen removed. For patients with no spleen, the ROI detection may need to be repeated by selecting active link 1110 or manually determined from clinicians using active links 1104, 1006, and 1108. The user interface 1100 also includes link 1112 to select spleen length view as shown in FIGURE 12 and link 1114 to select frame range view as shown in FIGURE 13. The spleen length user interface 1200 can enable clinicians to visually confirm the length of the spleen as calculated by the QLSSD system 120. The spleen length user interface 1200 can also enables functionality for the clinician to override calculated spleen length. In the illustrated embodiment, the spleen length is 9.2 cm and scanned image is showing a posterior view of the liver and the spleen. FIGURE 13 illustrates an embodiment of a user interface 1300 that can enable clinicians to select the frame range. In some instances, the image detection module 124 can identify a larger portion of the bone marrow and may include pelvis region. The clinicians 1300 can select the frame range to guide the image detector module 124 to more accurately calculate the ROIs. The user interface 1300 can enable clinicians to visually confirm that the range of frames detected by QLSSD system 120 encompasses the entire liver and spleen.

[0080] FIGURE 14 illustrates an embodiment of a user interface 1400 that includes a report generated by the QLSSD system 120. The user interface module 128 can generate a report in response to receiving a command from a clinician. The illustrated report includes calculation of a PHM parameter for the patient. The report can also include additional details from the patient, such as sex, height, weight, date of the study. In some embodiments, the report can include a trend graph 1402 plotting a parameter over time. In the illustrated embodiment, the trend graph includes PHM over time.

[0081] FIGURE 15 illustrates an embodiment of a user interface 1500 that enables clinicians to write their impressions for a patient based on the calculated parameter. In some embodiments, the user interface 1500 includes automatically generated impressions that can be used by clinicians. As discussed above, the impressions may be generated by the QLSSD system from lookup tables based on the calculated parameters. The clinician has the option of using the suggested impression from the QLSSD system 120.

[0082] FIGURE 16 illustrates an embodiment of a user interface 1600 that enables clinicians to communicate with PACS. In the illustrated embodiment, the clinicians can use the interface 1600 to send reports for storage in PACS. The reports can be automatically associated with the patient and the doctor.

[0083] FIGURE 17 illustrates an embodiment of a reporting user interface 1700 that includes a generated report for a patient. The report includes calculated parameters, for example, PHM and a trend in patient’s PHM over the years. A clinician can review the trend and identify whether the patient is improving or getting worse. In addition, the clinicians can identify effects of a particular treatment. In some embodiments, the trend can include future prediction based on resection parameters as discussed above. The report can also include impression selected by the clinician or automatically generated by the QLSSD system 120. In some embodiments, the report can illustrate SPECT scans overlaid with detected ROIs.

[0084] In one embodiment, the report includes on the left side images from which the raw data were derived: a base image (anterior/posterior), summarized transaxial images, single transaxial slice and distributions of total and planar counts. The sections on the right side have panels for demographics, LSI, LBI and PHM; a panel for volumes by 4 methods (the circled is the one we use); a panel for total counts; 2 panels for posterior planar counts; 2 panels for representative concentrations from the single slice - one for liver and one for spleen; and liver and spleen lengths.

[0085] FIGURE 18 illustrates another embodiment of a reporting user interface 1800 that includes a generated report for a patient. Compared to the report illustrated in FIGURE 17, the user interface 1800 includes additional parameters for clinicians.

XI. Terminology

[0086] A number of computing systems have been described throughout this disclosure. The descriptions of these systems are not intended to limit the teachings or applicability of this disclosure. For example, the clinician systems and described herein can generally include any computing device(s), such as desktops, laptops, video game platforms, television set-top boxes, televisions (e.g., internet TVs), computerized appliances, and wireless mobile devices (e.g. smart phones, PDAs, tablets, or the like), to name a few. Further, it is possible for the clinician systems described herein to be different types of devices, to include different applications, or to otherwise be configured differently. In addition, the user systems described herein can include any type of operating system ("OS"). For example, the mobile computing systems described herein can implement an Android™ OS, a Windows® OS, a Mac® OS, a Linux or Unix-based OS, or the like.

[0087] Further, the processing of the various components of the illustrated systems can be distributed across multiple machines, networks, and other computing resources. In addition, two or more components of a system can be combined into fewer components. For example, the various systems illustrated can be distributed across multiple computing systems, or combined into a single computing system. Further, various components of the illustrated systems can be implemented in one or more virtual machines, rather than in dedicated computer hardware systems. Likewise, the data repositories shown can represent physical and/or logical data storage, including, for example, storage area networks or other distributed storage systems. Moreover, in some embodiments the connections between the components shown represent possible paths of data flow, rather than actual connections between hardware. While some examples of possible connections are shown, any of the subset of the components shown can communicate with any other subset of components in various implementations.

[0088] Depending on the embodiment, certain acts, events, or functions of any of the algorithms, methods, or processes described herein can be performed in a different sequence, can be added, merged, or left out altogether (e.g., not all described acts or events are necessary for the practice of the algorithms). Moreover, in certain embodiments, acts or events can be performed concurrently, e.g., through multi-threaded processing, interrupt processing, or multiple processors or processor cores or on other parallel architectures, rather than sequentially.

[0089] Each of the various illustrated systems may be implemented as a computing system that is programmed or configured to perform the various functions described herein. The computing system may include multiple distinct computers or computing devices (e.g., physical servers, workstations, storage arrays, etc.) that communicate and interoperate over a network to perform the described functions. Each such computing device typically includes a processor (or multiple processors) that executes program instructions or modules stored in a memory or other non-transitory computer-readable storage medium. The various functions disclosed herein may be embodied in such program instructions, although some or all of the disclosed functions may alternatively be implemented in application-specific circuitry (e.g., ASICs or FPGAs) of the computer system. Where the computing system includes multiple computing devices, these devices may, but need not, be co-located. The results of the disclosed methods and tasks may be persistently stored by transforming physical storage devices, such as solid state memory chips and/or magnetic disks, into a different state. Each process described may be implemented by one or more computing devices, such as one or more physical servers programmed with associated server code.

[0090] Conditional language used herein, such as, among others, "can," "might," "may," "e.g.," and the like, unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain embodiments include, while other embodiments do not include, certain features, elements and/or states. Thus, such conditional language is not generally intended to imply that features, elements and/or states are in any way required for one or more embodiments or that one or more embodiments necessarily include logic for deciding, with or without author input or prompting, whether these features, elements and/or states are included or are to be performed in any particular embodiment. The terms "comprising," "including," "having," and the like are synonymous and are used inclusively, in an open-ended fashion, and do not exclude additional elements, features, acts, operations, and so forth. Also, the term "or" is used in its inclusive sense (and not in its exclusive sense) so that when used, for example, to connect a list of elements, the term "or" means one, some, or all of the elements in the list. In addition, the articles "a" and "an" are to be construed to mean "one or more" or "at least one" unless specified otherwise.

[0091] Conjunctive language such as the phrase "at least one of X, Y and Z," unless specifically stated otherwise, is otherwise understood with the context as used in general to convey that an item, term, etc. may be either X, Y or Z. Thus, such conjunctive language is not generally intended to imply that certain embodiments require at least one of X, at least one of Y and at least one of Z to each be present.

Claims

1. A method for detecting a liver health parameter of a patient, the method comprising:
under control of processing electronics,

receiving image data comprising a representation of detected radiation counts corresponding to one or more organs of a patient;
determining a plurality of first boundary points of a liver of the patient in the image data, said determining comprising:

identifying a body contour in the image data based on radiation count intensity comparisons,
determining a liver boundary threshold from radiation count intensities in a border region around the body contour, and
directionally searching the image data to compare intensities of radiation counts with the liver boundary threshold to identify the plurality of first boundary points;

calculating a centroid of the liver from the first boundary points;
determining a plurality of second boundary points of a spleen of the patient in the image data and calculating a centroid of the spleen from the second boundary points in a similar manner as defined above for the liver;
identifying a first region of interest corresponding to the liver of the patient from the determined plurality of first boundary points and the centroid of the liver;
identifying a second region of interest corresponding to the spleen of the patient from the determined plurality of second boundary points and the centroid of the spleen;
determining a first parameter indicative of health of a patient based at least in part on a first attribute associated with the first region of interest and optionally also based on a second attribute associated with the second region of interest; and
generating an output responsive to the first parameter for presentation to a clinician, wherein the output comprises one or more of a value of the first parameter and a health report associated with the first parameter.

2. The method of Claim 1, wherein the first parameter comprises perfused hepatic mass.

3. The method of Claim 2, wherein the first attribute comprises a representation of radiation counts in the first region of interest.

4. The method of Claim 3, further comprising comparing a geometric property of the first region of interest relative to the second region of interest.

5. The method of any of claims 1-3, further comprising programmatically identifying a third region of interest based at least in part on the calculated centroids of the liver and of the spleen.

6. A system for detecting a liver health parameter of a patient, the system comprising:
a hardware processor configured to:

receive scanner output data responsive to detected radiation counts from a radiation detecting scanner, said scanner output data responsive to a radioactive compound administered to a patient;
apply image processing techniques to detect two or more separate tissue masses in the scanner output data, at least two of the separate tissue masses corresponding to a liver and a spleen; wherein the hardware processor is configured to

determine a plurality of first boundary points of the liver in the scanner output data by being configured to:

identify a body contour in the scanner output data based on radiation count intensity comparisons,
determine a liver boundary threshold from radiation count intensities in a border region around the body contour, and
directionally search the scanner output data to compare intensities of radiation counts with the liver boundary threshold to identify the plurality of first boundary points;

calculate a centroid of the liver from the first boundary points;
determine a plurality of second boundary points of the spleen in the scanner output data and calculating a centroid of the spleen from the second boundary points in a similar manner as defined above for the liver;
determine a first region of interest corresponding to the liver from the determined plurality of first boundary points and the centroid of the liver;
determine a second region of interest corresponding to the spleen from the determined plurality of second boundary points and the centroid of the spleen;
determine a first parameter corresponding to function of one or more of the two or more separate tissue masses of the patient; wherein the first parameter is based at least in part on a first attribute associated with the first region of interest and optionally also based on a second attribute associated with the second region of interest; and
output one or more of a graphical indication of a value of the first parameter and a health report associated with the first parameter for presentation on a display.

7. The system of claim 6, wherein the hardware processor is further configured to detect a bone marrow region based at least in part on the detected one or more tissue masses.

8. The system of claim 6, wherein the parameter comprises one of a liver volume, a spleen volume, a perfused hepatic mass, a total count ratio, a staging indicator, an estimated peritoneoscopic score, a normalized liver volume, a normalized spleen volume, a highest average concentration, liver counts, a liver spleen index, a liver bone marrow index, a liver length, a spleen length, spleen counts, bone marrow counts, and a hepatic activity index.

9. The system of claim 8, wherein the scanner output data comprises at least one of or more frames corresponding to images of the patient in a plane transverse to a long axis of the body of the patient.

10. The system of any of claims 6-9, wherein the hardware processor is further configured to combine a plurality of frames from the image data, said frames corresponding to planes transverse to a long axis of the body of the patient.

11. The system of claim 6, wherein the parameter comprises perfused hepatic mass.

12. The system of claim 6, wherein the parameter comprises a representation of radiation counts in the first region of interest.

13. The system of claim 6, wherein the hardware processor is further configured to compare a geometric property of the first region of interest relative to the second region of interest.

14. The system of claim 6, wherein the hardware processor is further configured to generate and output a second user interface, the second user interface configured to provide functionality for the clinician to input a command to modify the first region of interest.

Patentansprüche

1. Verfahren zum Erfassen eines Parameters für Lebergesundheit eines Patienten, wobei das Verfahren umfasst: unter Kontrolle von Verarbeitungselektronik,
Empfangen von Bilddaten, umfassend eine Darstellung von erfassten Strahlungszählungen, die einem oder mehreren Organen eines Patienten entsprechen;
Bestimmen einer Vielzahl von ersten Grenzpunkten einer Leber des Patienten in den Bilddaten, wobei das Bestimmen umfasst:

Identifizieren einer Körperkontur in den Bilddaten basierend auf Strahlungszählungsintensitätsvergleichen,
Bestimmen einer Lebergrenzschwelle aus Strahlungszählungsintensitäten in einem Grenzbereich um die Körperkontur, und
gerichtetes Durchsuchen der Bilddaten, um Intensitäten von Strahlungszählungen mit der Lebergrenzschwelle zu vergleichen, um die Vielzahl von ersten Grenzpunkten zu identifizieren;
Berechnen eines Schwerpunkts der Leber aus den ersten Grenzpunkten;
Bestimmen einer Vielzahl von zweiten Grenzpunkten einer Milz des Patienten in den Bilddaten und Berechnen eines Schwerpunkts der Milz aus den zweiten Grenzpunkten in einer ähnlichen Weise wie oben für die Leber definiert;
Identifizieren eines ersten interessierenden Bereichs, der der Leber des Patienten entspricht, aus der bestimmten Vielzahl von ersten Grenzpunkten und dem Schwerpunkt der Leber;
Identifizieren eines zweiten interessierenden Bereichs, der der Milz des Patienten entspricht, aus der bestimmten Vielzahl von zweiten Grenzpunkten und dem Schwerpunkt der Milz;
Bestimmen eines ersten Parameters, der Gesundheit eines Patienten angibt, basierend mindestens teilweise auf einem ersten Attribut, das mit dem ersten interessierenden Bereich verknüpft ist, und wahlweise auch basierend auf einem zweiten Attribut, das mit dem zweiten interessierenden Bereich verknüpft ist; und
Erzeugen einer Ausgabe, die auf den ersten Parameter anspricht, zur Darlegung an einen Klinikarzt, wobei die Ausgabe einen oder mehrere von einem Wert des ersten Parameters und einen mit dem ersten Parameter verknüpften Gesundheitsbericht umfasst.

2. Verfahren nach Anspruch 1, wobei der erste Parameter perfundierte hepatische Masse umfasst.

3. Verfahren nach Anspruch 2, wobei das erste Attribut eine Darstellung von Strahlungszählungen im ersten interessierenden Bereich umfasst.

4. Verfahren nach Anspruch 3, weiter umfassend Vergleichen einer geometrischen Eigenschaft des ersten interessierenden Bereichs bezüglich des zweiten interessierenden Bereichs.

5. Verfahren nach einem der Ansprüche 1-3,
weiter umfassend programmatisches Identifizieren eines dritten interessierenden Bereichs basierend mindestens teilweise auf den berechneten Schwerpunkten der Leber und der Milz.

6. System zum Erfassen eines Parameters für Lebergesundheit eines Patienten, wobei das System umfasst:
einen Hardware-Prozessor, der konfiguriert ist zum:

Empfangen von Scanner-Ausgabedaten, die auf erfasste Strahlungszählungen von einem Erfassungsscanner ansprechen, wobei die Scanner-Ausgabedaten auf eine einem Patienten verabreichte radioaktive Verbindung ansprechen;
Anwenden von Bildverarbeitungstechniken, um zwei oder mehrere separate Gewebemassen in den Scanner-Ausgabedaten zu erfassen, wobei mindestens zwei der separaten Gewebemassen einer Leber und einer Milz entsprechen; wobei
der Hardware-Prozessor konfiguriert ist zum
Bestimmen einer Vielzahl von ersten Grenzpunkten der Leber in den Scanner-Ausgabedaten, indem er konfiguriert ist zum:

Identifizieren einer Körperkontur in den Scanner-Ausgabedaten basierend auf Strahlungszählungsintensitätsvergleichen,
Bestimmen einer Lebergrenzschwelle aus Strahlungszählungsintensitäten in einem Grenzbereich um die Körperkontur, und
gerichteten Durchsuchen der Scanner-Ausgabedaten, um Intensitäten von Strahlungszählungen mit der Lebergrenzschwelle zu vergleichen, um die Vielzahl von ersten Grenzpunkten zu identifizieren;
Berechnen eines Schwerpunkts der Leber aus den ersten Grenzpunkten;
Bestimmen einer Vielzahl von zweiten Grenzpunkten der Milz in den Scanner-Ausgabedaten und Berechnen eines Schwerpunkts der Milz aus den zweiten Grenzpunkten in einer ähnlichen Weise wie oben für die Leber definiert;
Bestimmen eines ersten interessierenden Bereichs, der der Leber entspricht, aus der bestimmten Vielzahl von ersten Grenzpunkten und dem Schwerpunkt der Leber;
Bestimmen eines zweiten interessierenden Bereichs, der der Milz entspricht, aus der bestimmten Vielzahl

von zweiten Grenzpunkten und dem Schwerpunkt der Milz;
Bestimmen eines ersten Parameters, der Funktion einer oder mehrerer der zwei oder mehreren separaten Gewebemassen des Patienten entspricht; wobei der erste Parameter mindestens teilweise auf einem ersten Attribut basiert, das mit dem ersten interessierenden Bereich verknüpft ist, und wahlweise auch auf einem zweiten Attribut basiert, das mit dem zweiten interessierenden Bereich verknüpft ist; und
Ausgabe eines oder mehrerer von einer grafischen Angabe eines Werts des ersten Parameters und eines mit dem ersten Parameter verknüpften Gesundheitsberichts zur Darlegung auf einer Anzeige,

7. System nach Anspruch 6,
wobei der Hardware-Prozessor weiter konfiguriert ist, um einen Knochenmarkbereich basierend mindestens teilweise auf den erfassten einen oder mehreren Gewebemassen zu erfassen.

8. System nach Anspruch 6,
wobei der Parameter eines von einem Lebervolumen, einem Milzvolumen, einer perfundierten hepatischen Masse, einem Gesamtzählungsverhältnis, einem Stufenindikator, einer geschätzten peritoneoskopischen Punktzahl, einem normalisierten Lebervolumen, einem normalisierten Milzvolumen, einer höchsten Durchschnittskonzentration, Leberzählungen, einem Leber-Milz-Index, einem Leber-Knochenmark-Index, einer Leberlänge, einer Milzlänge, Milzzählungen, Knochenmarkzählungen, und einem Index hepatischer Aktivität umfasst.

9. System nach Anspruch 8,
wobei die Scanner-Ausgabedaten mindestens ein von oder mehrere Frames umfassen, die Bildern des Patienten in einer Ebene quer zur einer Längsachse des Körpers des Patienten entsprechen.

10. System nach einem der Ansprüche 6-9,
wobei der Hardware-Prozessor weiter konfiguriert ist, um eine Vielzahl von Frames aus den Bilddaten zu kombinieren, wobei die Frames Ebenen quer zur einer Längsachse des Körpers des Patienten entsprechen.

11. System nach Anspruch 6,
wobei der Parameter perfundierte hepatische Masse umfasst.

12. System nach Anspruch 6,
wobei der Parameter eine Darstellung von Strahlungszählungen im ersten interessierenden Bereich umfasst.

13. System nach Anspruch 6,
wobei der Hardware-Prozessor weiter konfiguriert ist, um eine geometrische Eigenschaft des ersten interessierenden Bereichs bezüglich des zweiten interessierenden Bereichs zu vergleichen.

14. System nach Anspruch 6,
wobei der Hardware-Prozessor weiter konfiguriert ist, um eine zweite Benutzerschnittstelle zu erzeugen und auszugeben, die zweite Benutzerschnittstelle konfiguriert, um Funktionalität für den Klinikarzt bereitzustellen, um einen Befehl einzugeben, um den ersten interessierenden Bereich zu modifizieren.

Revendications

1. Procédé de détection d'un paramètre de santé d'un foie d'un patient, le procédé comprenant :

sous contrôle d'électronique de traitement,
la réception de données d'image comprenant une représentation de comptages de rayonnement détectés correspondants à un ou plusieurs organes d'un patient ;
la détermination d'une pluralité de premiers points de limite d'un foie du patient dans les données d'image, ladite détermination comprenant :

l'identification d'un contour de corps dans les données d'image sur la base de comparaisons d'intensité de comptage de rayonnement,
la détermination d'un seuil limite de foie à partir d'intensités de comptage de rayonnement dans une région frontalière autour du contour de corps, et
la recherche directionnelle des données d'image pour comparer des intensités de comptages de rayonne-

ment avec le seuil limite de foie pour identifier la pluralité de premiers points de limite ;

le calcul d'un centroïde du foie à partir des premiers points de limite ;
la détermination d'une pluralité de seconds points de limite d'une rate du patient dans les données d'image et le calcul d'un centroïde de la rate à partir des seconds points de limite d'une manière similaire à celle définie ci-dessus pour le foie ;
l'identification d'une première région d'intérêt correspondant au foie du patient depuis la pluralité déterminée de premiers points de limite et du centroïde du foie ;
l'identification d'une deuxième région d'intérêt correspondant à la rate du patient depuis la pluralité déterminée de seconds points de limite et du centroïde de la rate ;
la détermination d'un premier paramètre indicatif de la santé d'un patient sur la base au moins en partie d'un premier attribut associé à la première région d'intérêt et facultativement également sur la base d'un second attribut associé à la deuxième région d'intérêt ; et
la génération d'une sortie sensible au premier paramètre pour la présentation à un clinicien, dans laquelle la sortie comprend un ou plusieurs parmi une valeur du premier paramètre et un rapport de santé associé au premier paramètre.

2. Procédé selon la revendication 1, dans lequel le premier paramètre comprend une masse hépatique perfusée.

3. Procédé selon la revendication 2, dans lequel le premier attribut comprend une représentation de comptages de rayonnement dans la première région d'intérêt.

4. Procédé selon la revendication 3, comprenant en outre la comparaison d'une propriété géométrique de la première région d'intérêt par rapport à la deuxième région d'intérêt.

5. Procédé selon l'une quelconque des revendications 1 à 3, comprenant en outre l'identification sur le plan programmatique d'une troisième région d'intérêt sur la base au moins en partie des centroïdes calculés du foie et de la rate.

6. Système de détection d'un paramètre de santé d'un foie d'un patient, le système comprenant :
un processeur matériel configuré pour :

recevoir des données de sortie de scanner sensibles aux comptages de rayonnement détectés depuis un scanner de détection de rayonnement, lesdites données de sortie de scanner sensibles à un composé radioactif administré à un patient ;
appliquer des techniques de traitement d'image pour détecter deux ou plus masses tissulaires séparées dans les données de sortie de scanner, au moins deux des masses tissulaires séparées correspondant à un foie ou une rate ; dans lequel
le processeur matériel est configuré pour
déterminer une pluralité de premiers points de limite du foie dans les données de sortie de scanner en étant configuré pour :

identifier un contour de corps dans les données de sortie de scanner sur la base de comparaisons d'intensité de comptage de rayonnement,
déterminer un seuil limite de foie à partir d'intensités de comptage de rayonnement dans une région frontalière autour du contour de corps, et
rechercher directionnellement les données de sortie de scanner pour comparer des intensités de comptages de rayonnement avec le seuil limite de foie pour identifier la pluralité de premiers points de limite ;

calculer un centroïde du foie à partir des premiers points de limite ;
déterminer une pluralité de seconds points de limite de la rate du patient dans les données de sortie de scanner et calculer un centroïde de la rate à partir des seconds points de limite d'une manière similaire à celle définie ci-dessus pour le foie ;
déterminer une première région d'intérêt correspondant au foie depuis la pluralité déterminée de premiers points de limite et du centroïde du foie ;
déterminer une deuxième région d'intérêt correspondant à la rate depuis la pluralité déterminée de seconds points de limite et du centroïde de la rate ;
déterminer un premier paramètre correspondant à la fonction d'une ou plusieurs des deux ou plus masses tissulaires séparées du patient; dans lequel le premier paramètre est basé au moins en partie sur un premier

attribut associé à la première région d'intérêt et facultativement également basé sur un second attribut associé à la deuxième région d'intérêt ; et
générer en sortie un ou plusieurs parmi une indication graphique d'une valeur du premier paramètre et un rapport de santé associé au premier paramètre pour la présentation sur un écran.

7. Système selon la revendication 6,
dans lequel le processeur matériel est en outre configuré pour détecter une région de moelle osseuse sur la base au moins en partie de l'une ou plusieurs masses tissulaires détectées.

8. Système selon la revendication 6,
dans lequel le paramètre comprend l'un parmi un volume de foie, un volume de rate, une masse hépatique perfusée, un rapport de comptage total, un indicateur de stade, un score péritonéoscopique estimé, un volume de foie normalisé, un volume de rate normalisé, une concentration moyenne la plus élevée, des comptages de foie, un indice foie/rate, un indice foie/moelle osseuse, une longueur de foie, une longueur de rate, des comptages de rate, des comptages de moelle osseuse, et un indice d'activité hépatique.

9. Système selon la revendication 8,
dans lequel les données de sortie de scanner comprennent au moins une ou plusieurs photographies correspondant à des images du patient dans un plan transversal par rapport à un long axe du corps du patient.

10. Système selon l'une quelconque des revendications 6 à 9,
dans lequel le processeur matériel est en outre configuré pour combiner une pluralité de photographies depuis les données d'image, lesdites photographies correspondant à des plans transversaux par rapport à un long axe du corps du patient.

11. Système selon la revendication 6,
dans lequel le paramètre comprend une masse hépatique perfusée.

12. Système selon la revendication 6,
dans lequel le paramètre comprend une représentation de comptages de rayonnement dans la première région d'intérêt.

13. Système selon la revendication 6,
dans lequel le processeur matériel est en outre configuré pour comparer une propriété géométrique de la première région d'intérêt par rapport à la deuxième région d'intérêt.

14. Système selon la revendication 6,
dans lequel le processeur matériel est en outre configuré pour générer et produire en sortie une seconde interface utilisateur, la seconde interface utilisateur configurée pour fournir une fonctionnalité pour que le clinicien entre une commande pour modifier la première région d'intérêt.

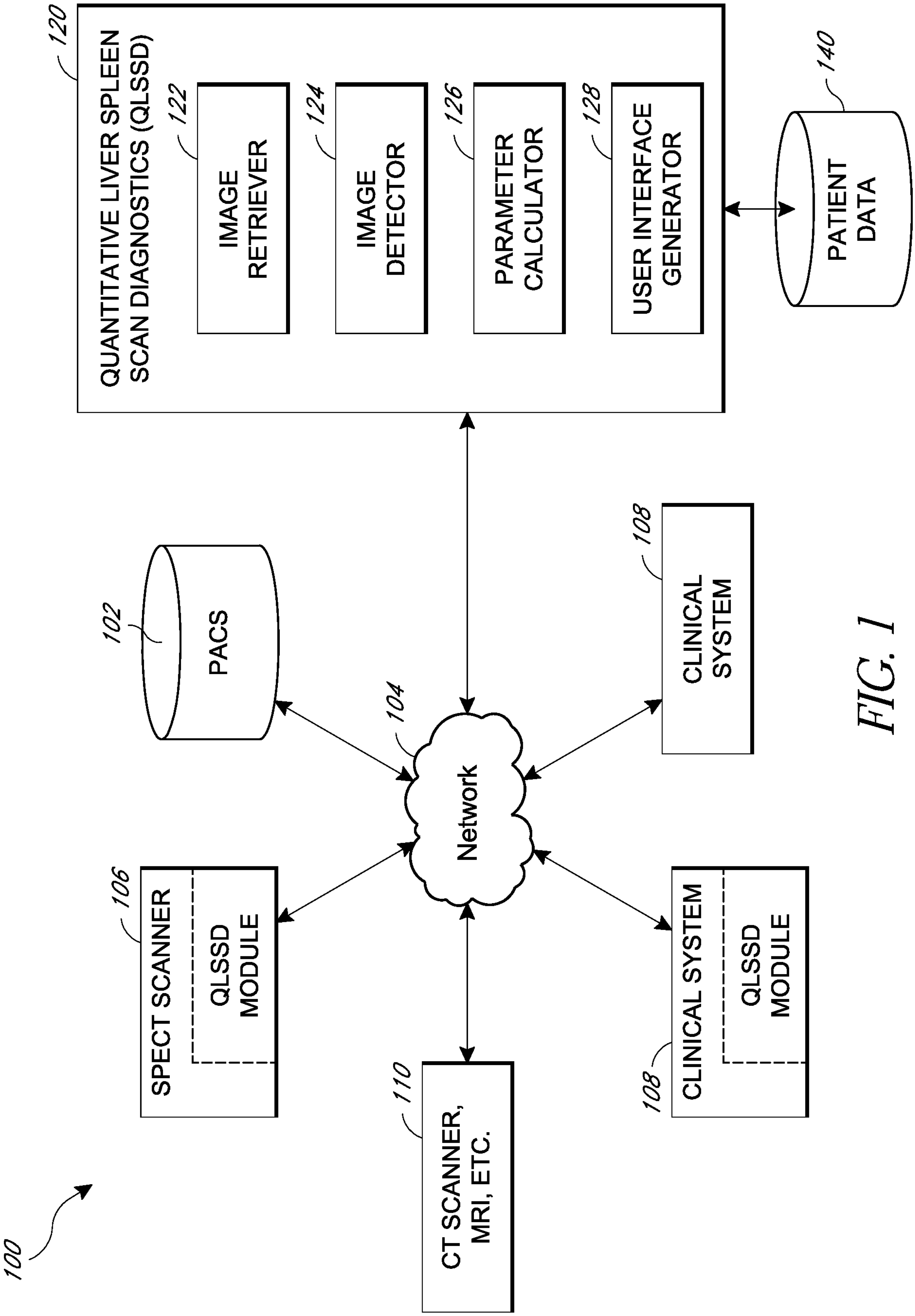

100
120
QUANTITATIVE LIVER SPLEEN SCAN DIAGNOSTICS (QLSSD)
122
IMAGE RETRIEVER
124
IMAGE DETECTOR
126
PARAMETER CALCULATOR
128
USER INTERFACE GENERATOR
140
PATIENT DATA
102
PACS
104
Network
106
SPECT SCANNER
QLSSD MODULE
110
CT SCANNER, MRI, ETC.
108
CLINICAL SYSTEM
QLSSD MODULE
108
CLINICAL SYSTEM

FIG. 1

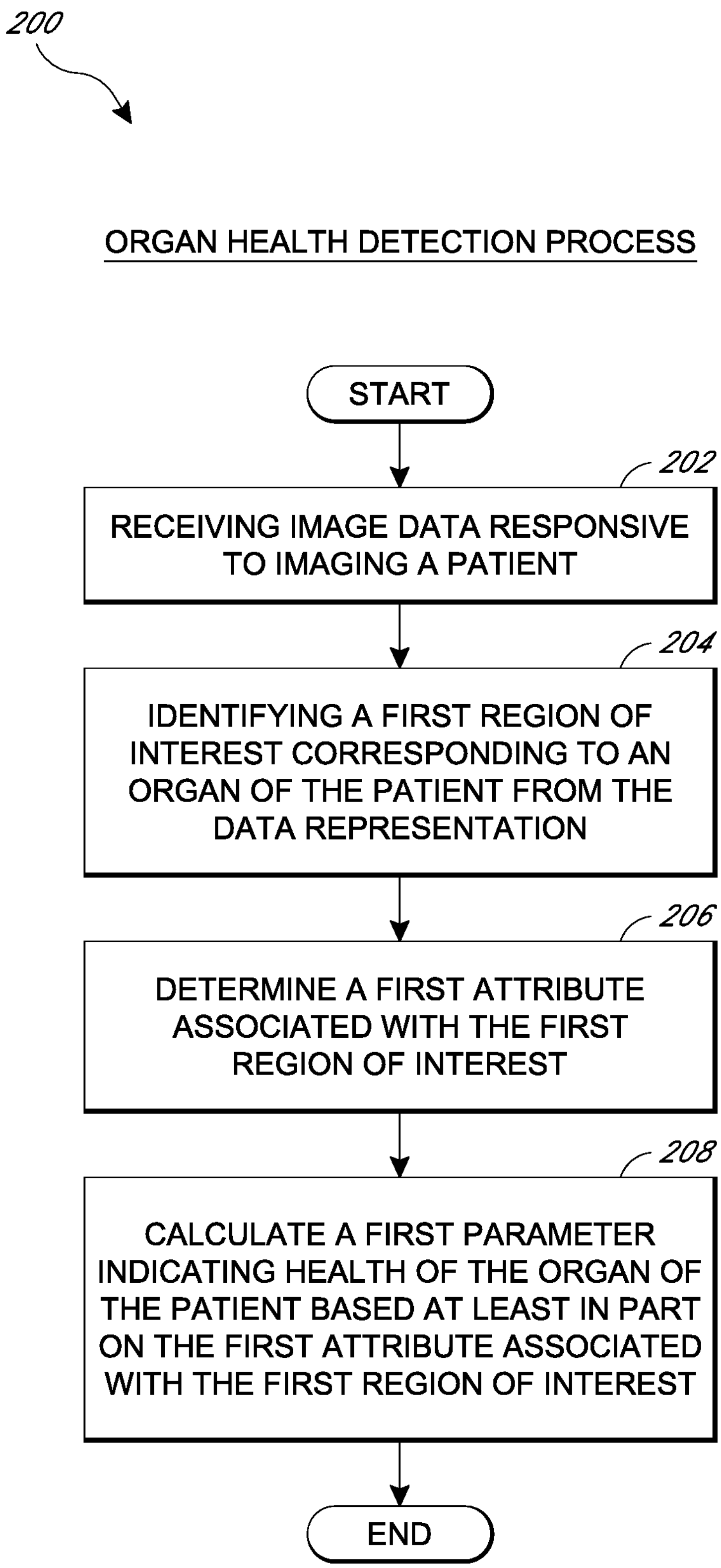

200
ORGAN HEALTH DETECTION PROCESS
START
202
RECEIVING IMAGE DATA RESPONSIVE TO IMAGING A PATIENT
204
IDENTIFYING A FIRST REGION OF INTEREST CORRESPONDING TO AN ORGAN OF THE PATIENT FROM THE DATA REPRESENTATION
206
DETERMINE A FIRST ATTRIBUTE ASSOCIATED WITH THE FIRST REGION OF INTEREST
208
CALCULATE A FIRST PARAMETER INDICATING HEALTH OF THE ORGAN OF THE PATIENT BASED AT LEAST IN PART ON THE FIRST ATTRIBUTE ASSOCIATED WITH THE FIRST REGION OF INTEREST
END

FIG. 2

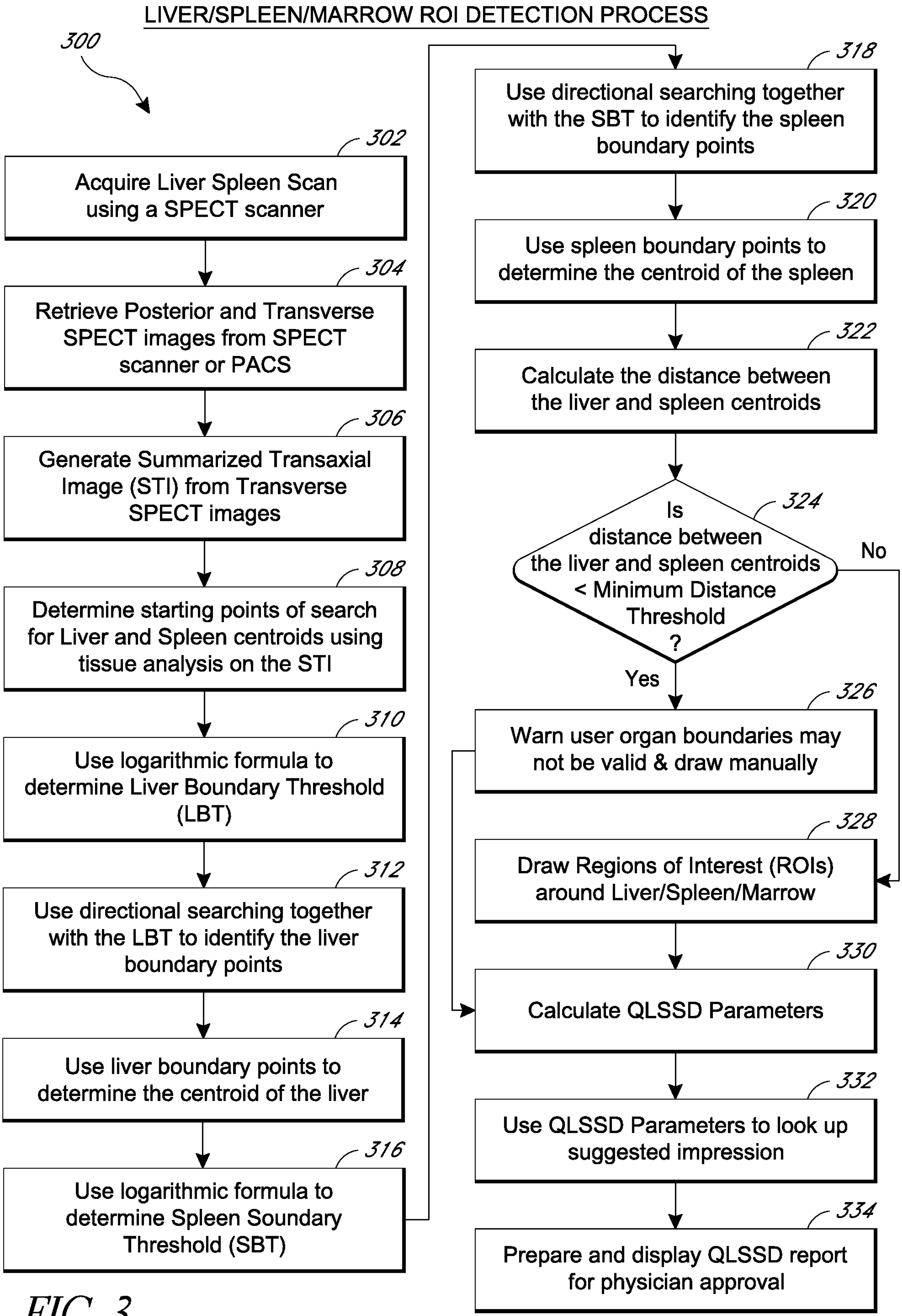

LIVER/SPLEEN/MARROW ROI DETECTION PROCESS
300
302
Acquire Liver Spleen Scan using a SPECT scanner
304
Retrieve Posterior and Transverse SPECT images from SPECT scanner or PACS
306
Generate Summarized Transaxial Image (STI) from Transverse SPECT images
308
Determine starting points of search for Liver and Spleen centroids using tissue analysis on the STI
310
Use logarithmic formula to determine Liver Boundary Threshold (LBT)
312
Use directional searching together with the LBT to identify the liver boundary points
314
Use liver boundary points to determine the centroid of the liver
316
Use logarithmic formula to determine Spleen Soundary Threshold (SBT)
318
Use directional searching together with the SBT to identify the spleen boundary points
320
Use spleen boundary points to determine the centroid of the spleen
322
Calculate the distance between the liver and spleen centroids
324
Is distance between the liver and spleen centroids < Minimum Distance Threshold ?
No
Yes
326
Warn user organ boundaries may not be valid & draw manually
328
Draw Regions of Interest (ROIs) around Liver/Spleen/Marrow
330
Calculate QLSSD Parameters
332
Use QLSSD Parameters to look up suggested impression
334
Prepare and display QLSSD report for physician approval

FIG. 3

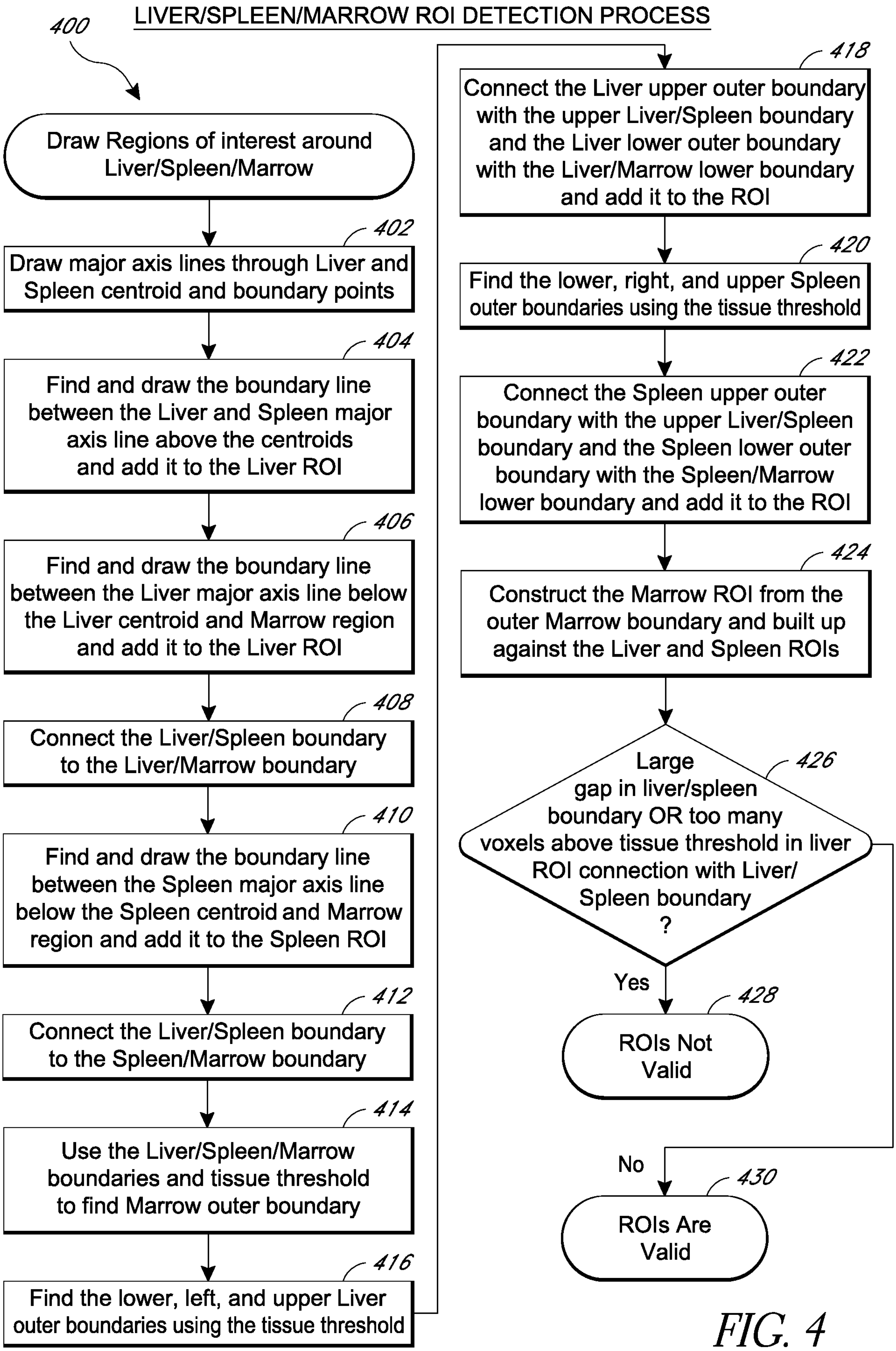

LIVER/SPLEEN/MARROW ROI DETECTION PROCESS
400
Draw Regions of interest around Liver/Spleen/Marrow
402
Draw major axis lines through Liver and Spleen centroid and boundary points
404
Find and draw the boundary line between the Liver and Spleen major axis line above the centroids and add it to the Liver ROI
406
Find and draw the boundary line between the Liver major axis line below the Liver centroid and Marrow region and add it to the Liver ROI
408
Connect the Liver/Spleen boundary to the Liver/Marrow boundary
410
Find and draw the boundary line between the Spleen major axis line below the Spleen centroid and Marrow region and add it to the Spleen ROI
412
Connect the Liver/Spleen boundary to the Spleen/Marrow boundary
414
Use the Liver/Spleen/Marrow boundaries and tissue threshold to find Marrow outer boundary
416
Find the lower, left, and upper Liver outer boundaries using the tissue threshold
418
Connect the Liver upper outer boundary with the upper Liver/Spleen boundary and the Liver lower outer boundary with the Liver/Marrow lower boundary and add it to the ROI
420
Find the lower, right, and upper Spleen outer boundaries using the tissue threshold
422
Connect the Spleen upper outer boundary with the upper Liver/Spleen boundary and the Spleen lower outer boundary with the Spleen/Marrow lower boundary and add it to the ROI
424
Construct the Marrow ROI from the outer Marrow boundary and built up against the Liver and Spleen ROIs
426
Large gap in liver/spleen boundary OR too many voxels above tissue threshold in liver ROI connection with Liver/ Spleen boundary ?
Yes
428
ROIs Not Valid
No
430
ROIs Are Valid

FIG. 4

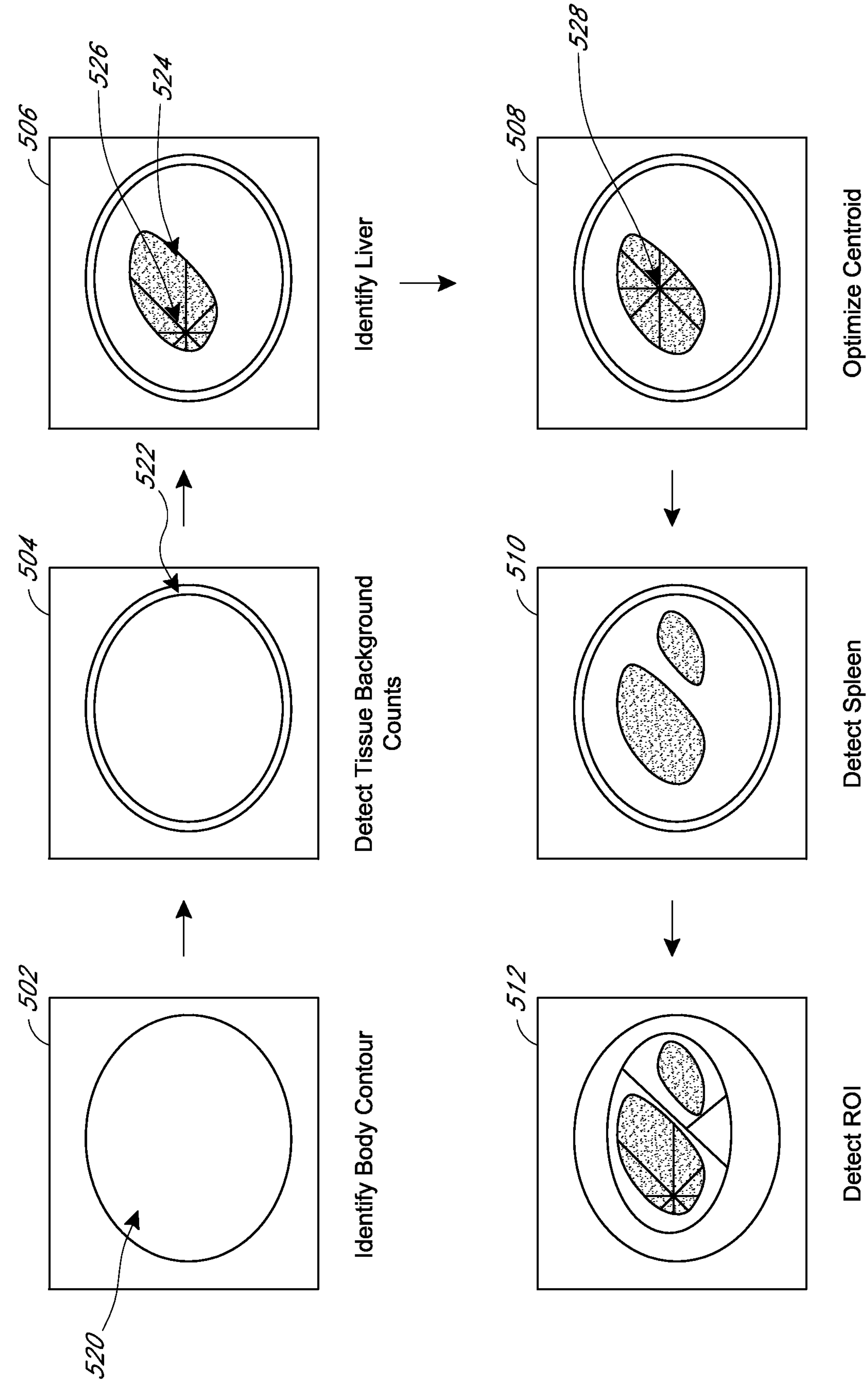

502
520
Identify Body Contour
504
522
Detect Tissue Background Counts
506
526
524
Identify Liver
508
528
Optimize Centroid
510
Detect Spleen
512
Detect ROI

FIG. 5

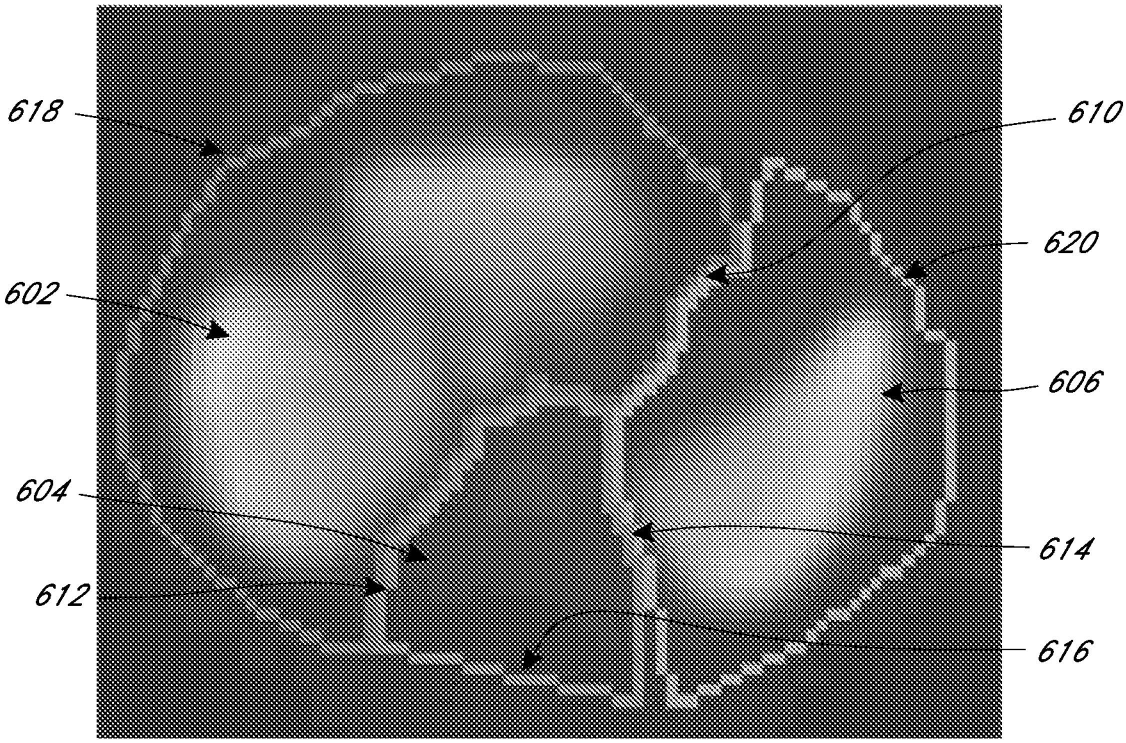


FIG. 6

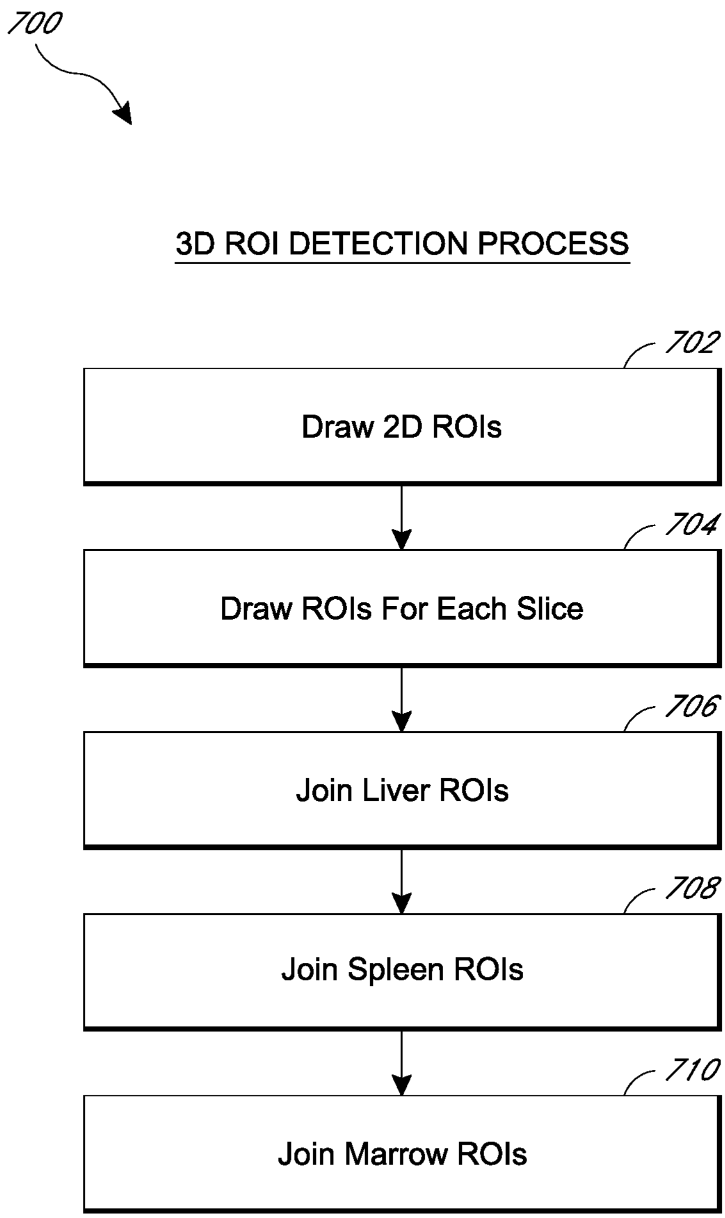

700
3D ROI DETECTION PROCESS
702
Draw 2D ROIs
704
Draw ROIs For Each Slice
706
Join Liver ROIs
708
Join Spleen ROIs
710
Join Marrow ROIs

FIG. 7

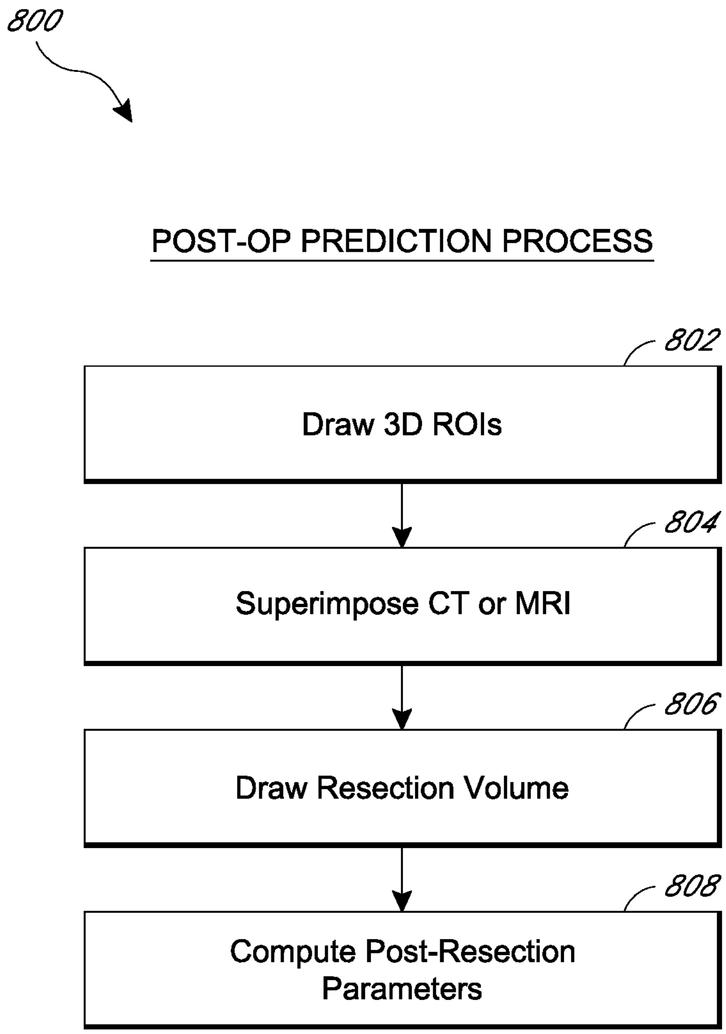

800
POST-OP PREDICTION PROCESS
802
Draw 3D ROIs
804
Superimpose CT or MRI
806
Draw Resection Volume
808
Compute Post-Resection Parameters

FIG. 8

FIG. 9

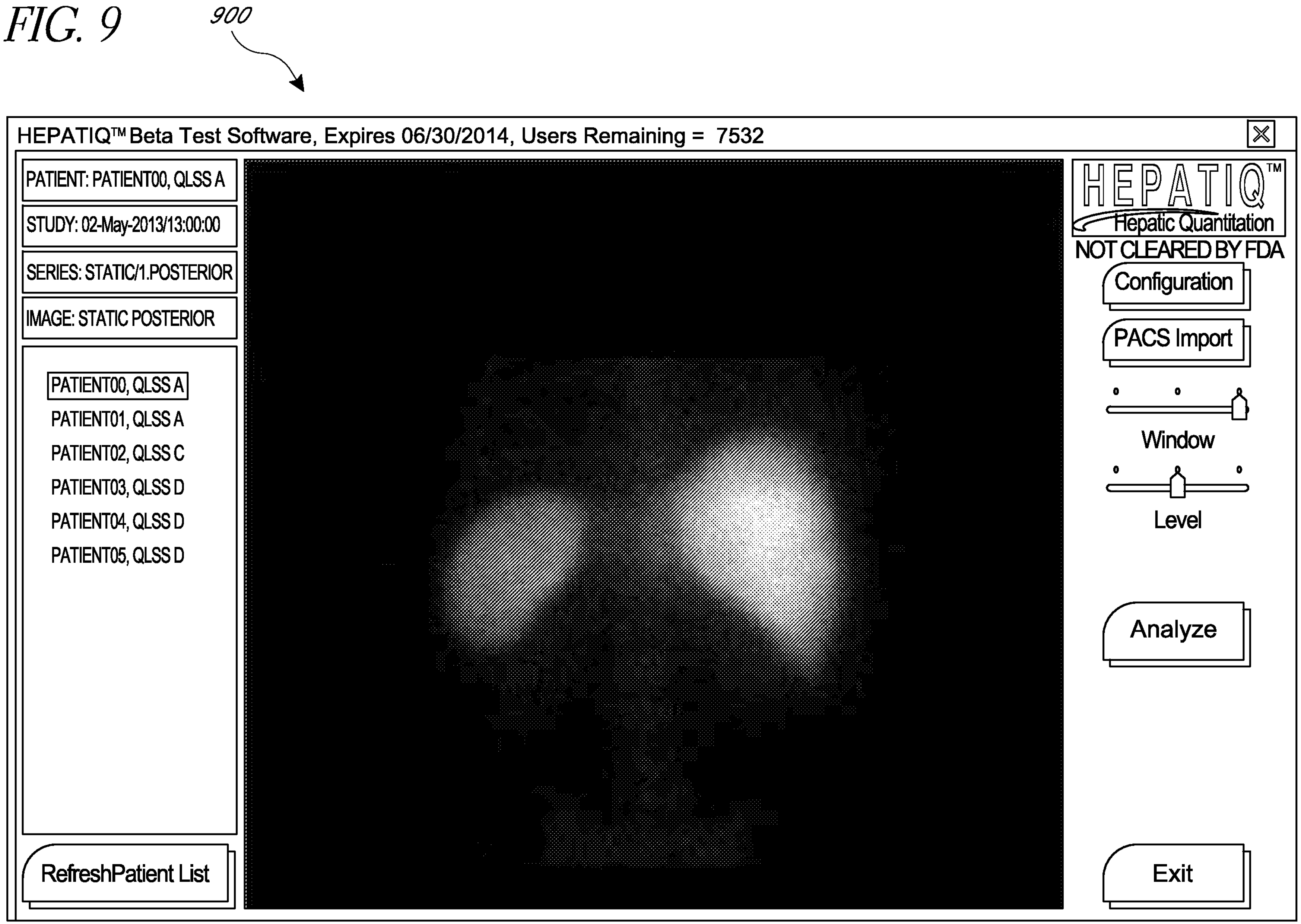

900
HEPATIQ™ Beta Test Software, Expires 06/30/2014, Users Remaining = 7532
PATIENT: PATIENT00, QLSS A
STUDY: 02-May-2013/13:00:00
SERIES: STATIC/1.POSTERIOR
IMAGE: STATIC POSTERIOR
PATIENT00, QLSS A
PATIENT01, QLSS A
PATIENT02, QLSS C
PATIENT03, QLSS D
PATIENT04, QLSS D
PATIENT05, QLSS D
RefreshPatient List
HEPATIQ™
Hepatic Quantitation
NOT CLEARED BY FDA
Configuration
PACS Import
Window
Level
Analyze
Exit

FIG. 10

1000

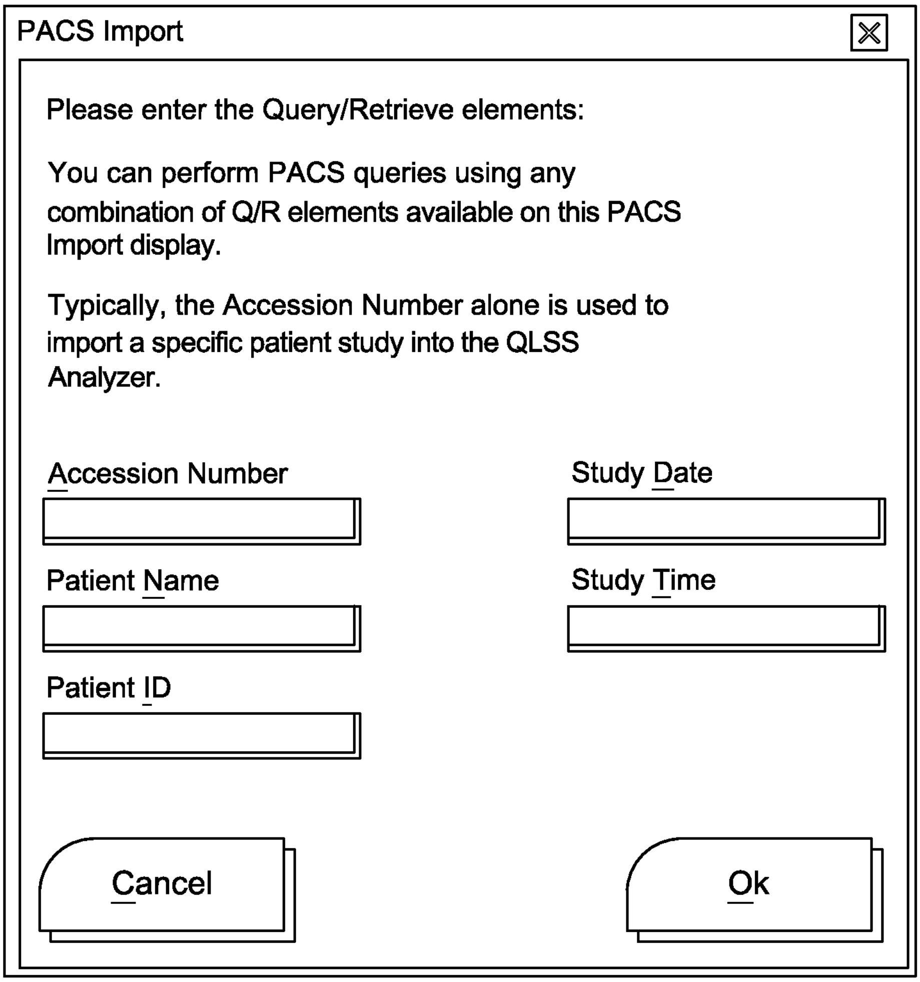

PACS Import
Please enter the Query/Retrieve elements:
You can perform PACS queries using any combination of Q/R elements available on this PACS Import display.
Typically, the Accession Number alone is used to import a specific patient study into the QLSS Analyzer.
Accession Number
Study Date
Patient Name
Study Time
Patient ID
Cancel
Ok

FIG. 11

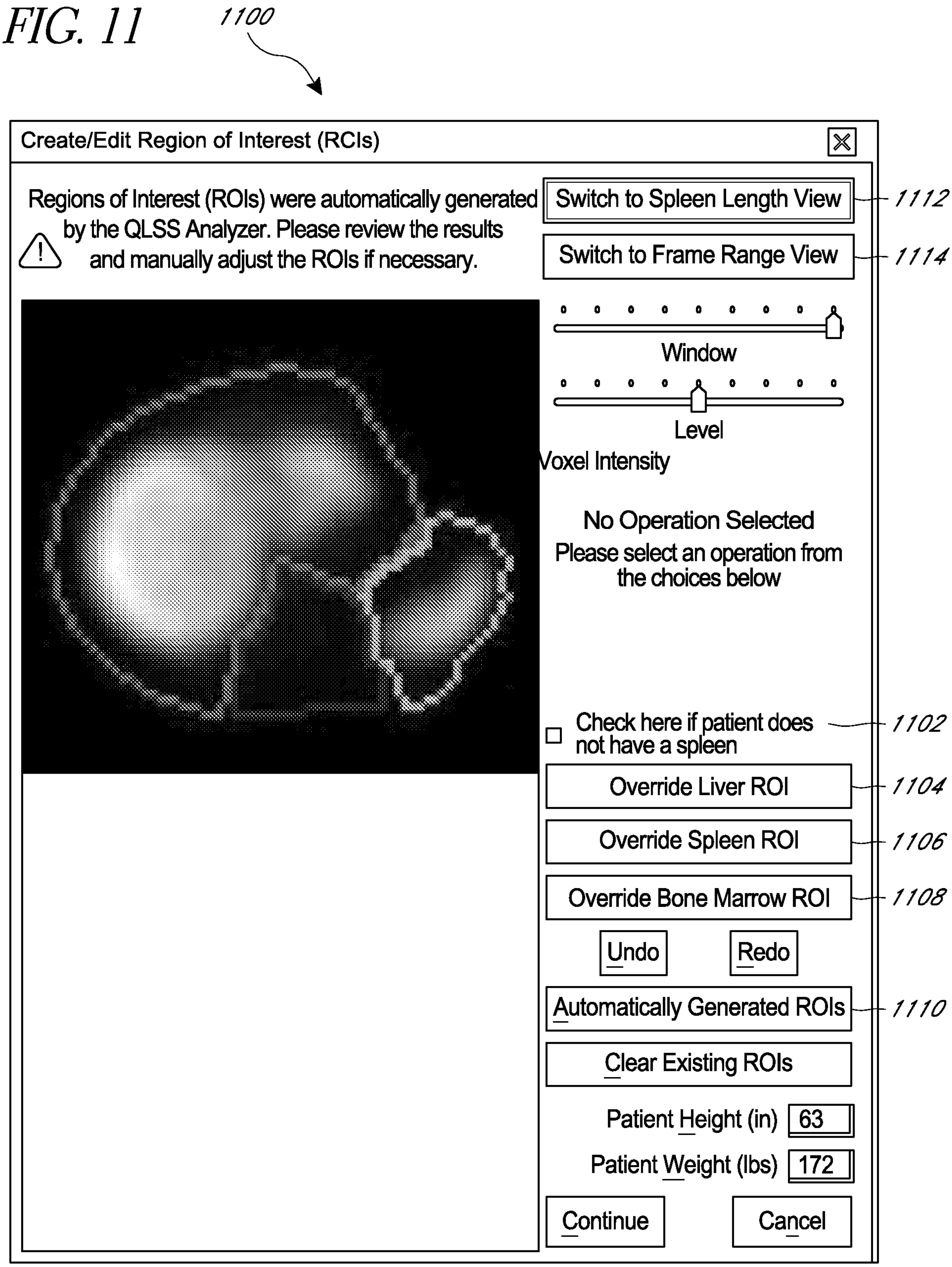

1100
Create/Edit Region of Interest (RCIs)
Regions of Interest (ROIs) were automatically generated by the QLSS Analyzer. Please review the results and manually adjust the ROIs if necessary.
Switch to Spleen Length View
1112
Switch to Frame Range View
1114
Window
Level
Voxel Intensity
No Operation Selected
Please select an operation from the choices below
Check here if patient does not have a spleen
1102
Override Liver ROI
1104
Override Spleen ROI
1106
Override Bone Marrow ROI
1108
Undo
Redo
Automatically Generated ROIs
1110
Clear Existing ROIs
Patient Height (in)
63
Patient Weight (lbs)
172
Continue
Cancel

FIG. 12

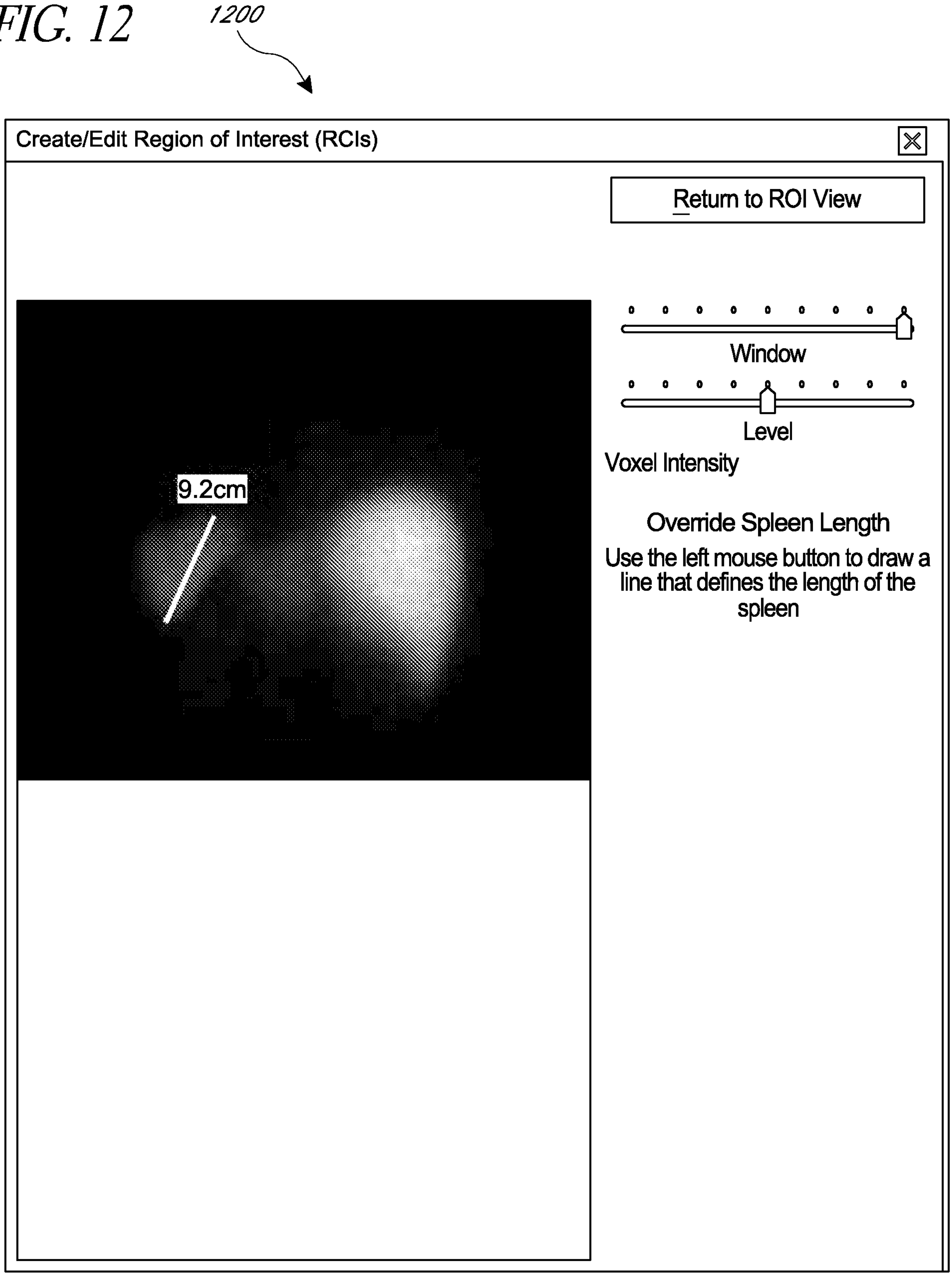

1200
Create/Edit Region of Interest (RCIs)
Return to ROI View
Window
Level
Voxel Intensity
Override Spleen Length
Use the left mouse button to draw a line that defines the length of the spleen
9.2cm

FIG. 13

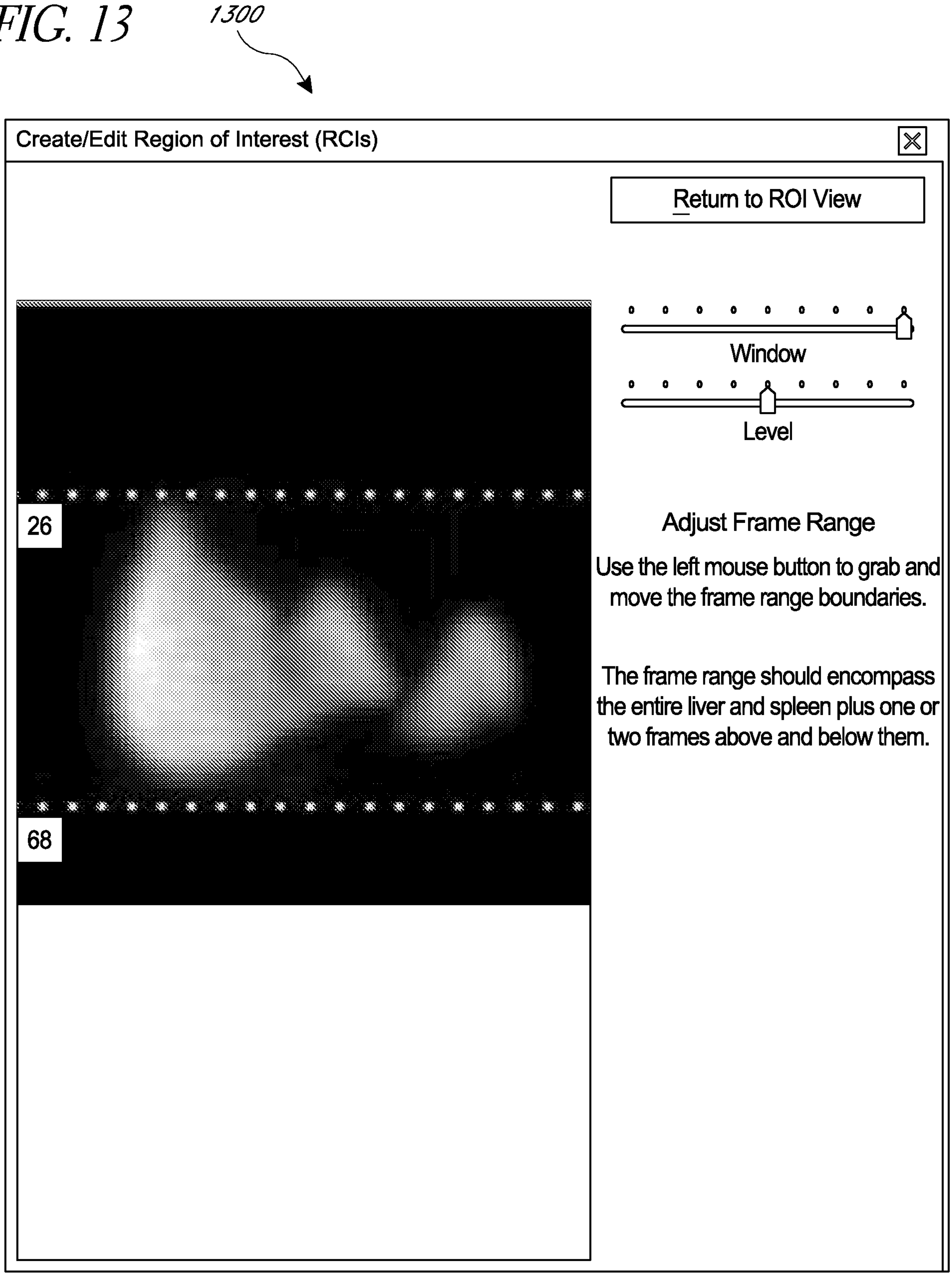
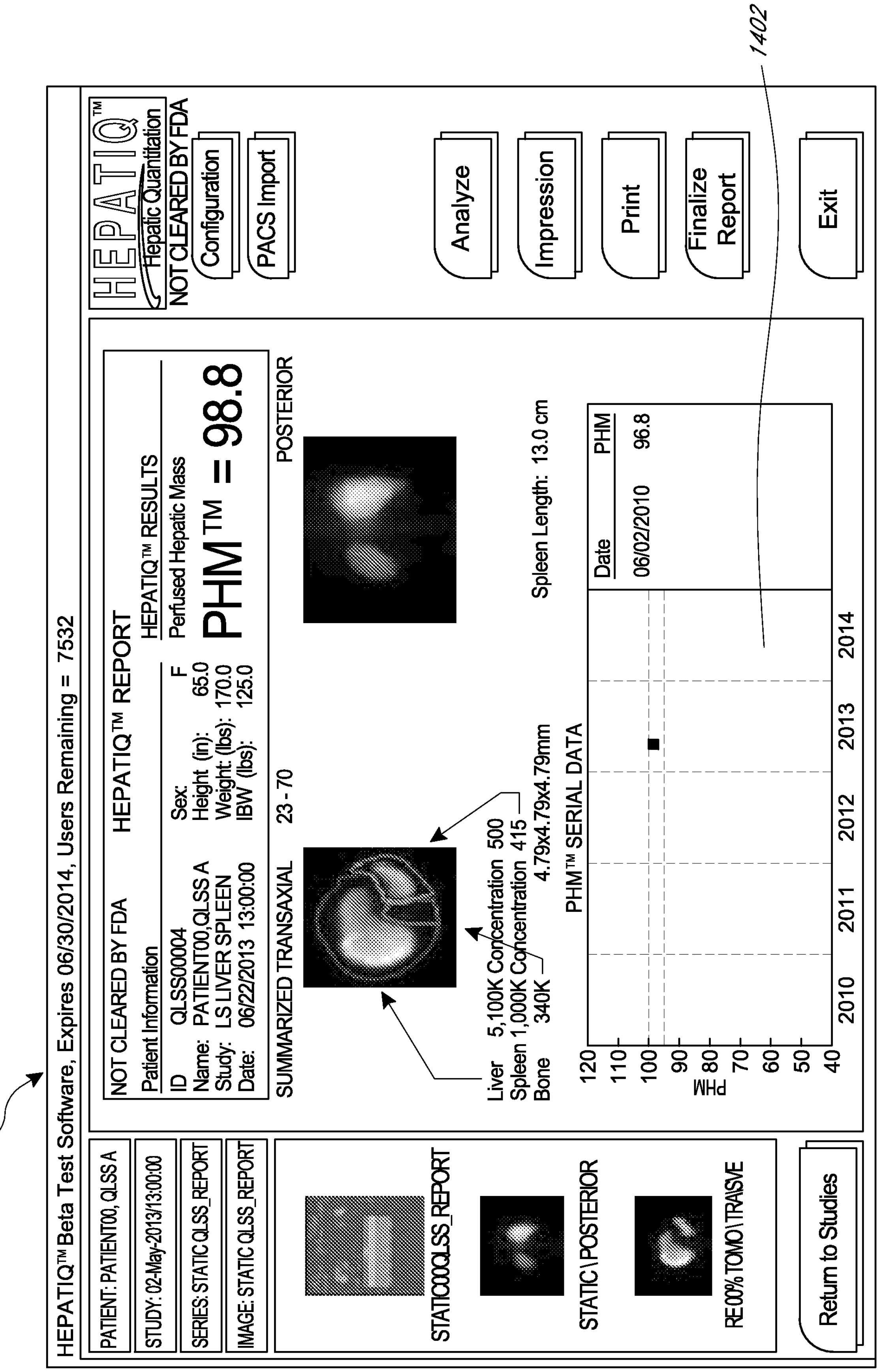

1300
Create/Edit Region of Interest (RCIs)
Return to ROI View
Window
Level
26
68
Adjust Frame Range
Use the left mouse button to grab and move the frame range boundaries.
The frame range should encompass the entire liver and spleen plus one or two frames above and below them.

FIG. 14



1400
1402
HEPATIQ™ Beta Test Software, Expires 06/30/2014, Users Remaining = 7532
PATIENT: PATIENT00, QLSS A
STUDY: 02-May-2013/13:00:00
SERIES: STATIC QLSS_REPORT
IMAGE: STATIC QLSS_REPORT
STATIC00QLSS_REPORT
STATIC\POSTERIOR
RE00% TOMO\TRASVE
Return to Studies
NOT CLEARED BY FDA
HEPATIQ™ REPORT
Patient Information
ID QLSS00004
Name: PATIENT00,QLSS A
Study: LS LIVER SPLEEN
Date: 06/22/2013 13:00:00
Sex: F
Height (in): 65.0
Weight (lbs): 170.0
IBW (lbs): 125.0
HEPATIQ™ RESULTS
Perfused Hepatic Mass
PHM™ = 98.8
SUMMARIZED TRANSAXIAL
23 - 70
POSTERIOR
Liver 5,100K Concentration 500
Spleen 1,000K Concentration 415
Bone 340K
4.79x4.79x4.79mm
Spleen Length: 13.0 cm
PHM™ SERIAL DATA
PHM
120
110
100
90
80
70
60
50
40
2010
2011
2012
2013
2014
Date
PHM
06/02/2010
96.8
HEPATIQ™
Hepatic Quantitation
NOT CLEARED BY FDA
Configuration
PACS Import
Analyze
Impression
Print
Finalize Report
Exit

FIG. 15

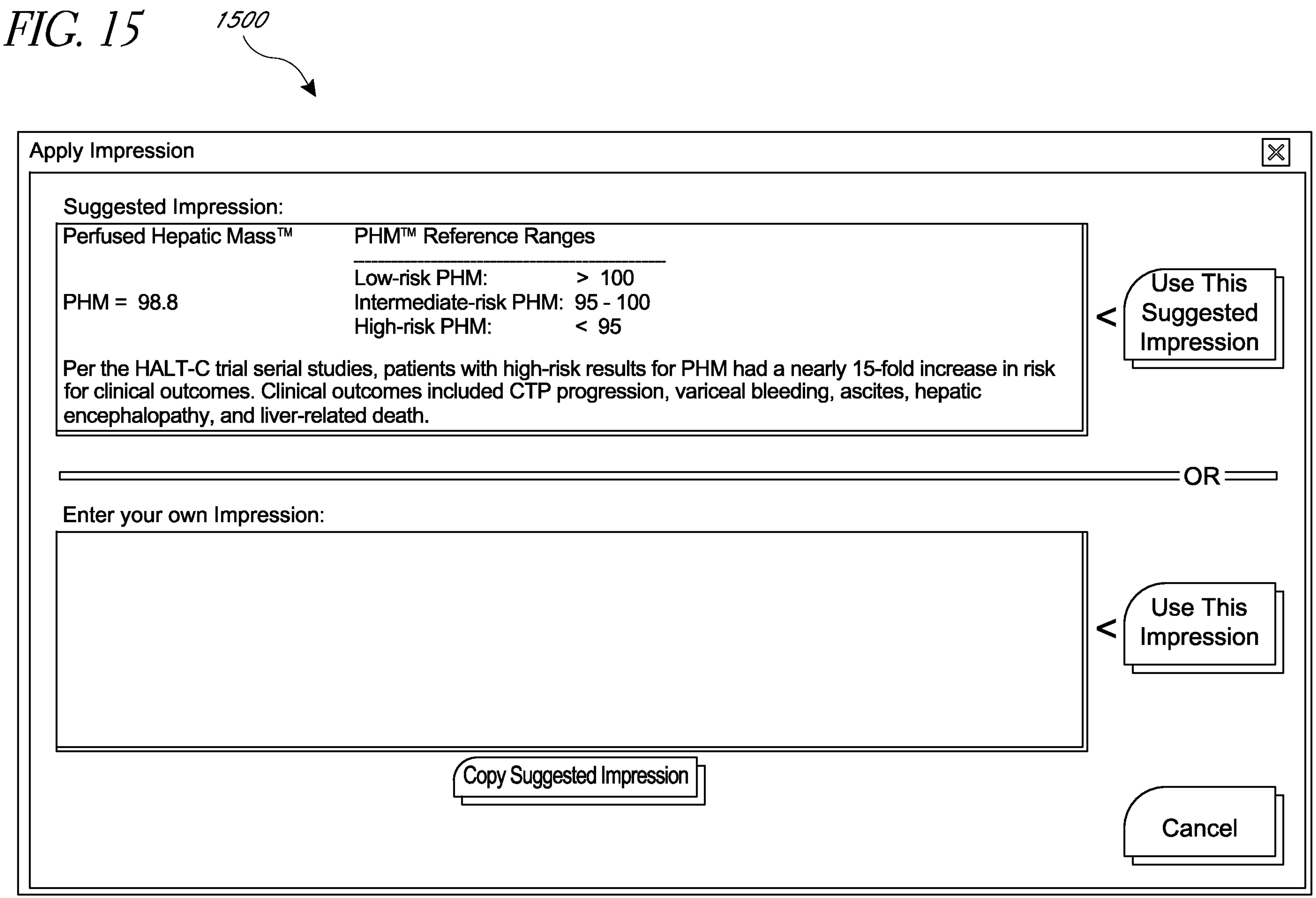

1500
Apply Impression
Suggested Impression:
Perfused Hepatic Mass™
PHM™ Reference Ranges
Low-risk PHM: > 100
PHM = 98.8
Intermediate-risk PHM: 95 - 100
High-risk PHM: < 95
Per the HALT-C trial serial studies, patients with high-risk results for PHM had a nearly 15-fold increase in risk for clinical outcomes. Clinical outcomes included CTP progression, variceal bleeding, ascites, hepatic encephalopathy, and liver-related death.
Use This Suggested Impression
OR
Enter your own Impression:
Use This Impression
Copy Suggested Impression
Cancel

FIG. 16

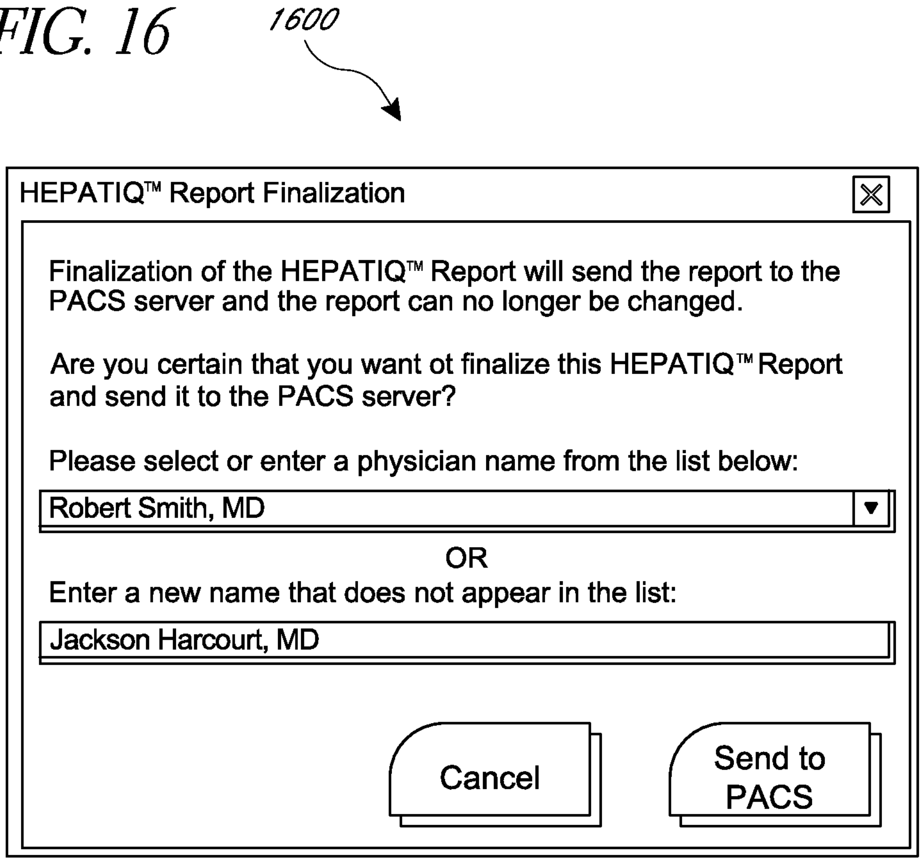

1600
HEPATIQ™ Report Finalization
Finalization of the HEPATIQ™ Report will send the report to the PACS server and the report can no longer be changed.
Are you certain that you want ot finalize this HEPATIQ™ Report and send it to the PACS server?
Please select or enter a physician name from the list below:
Robert Smith, MD
OR
Enter a new name that does not appear in the list:
Jackson Harcourt, MD
Cancel
Send to PACS

FIG. 17

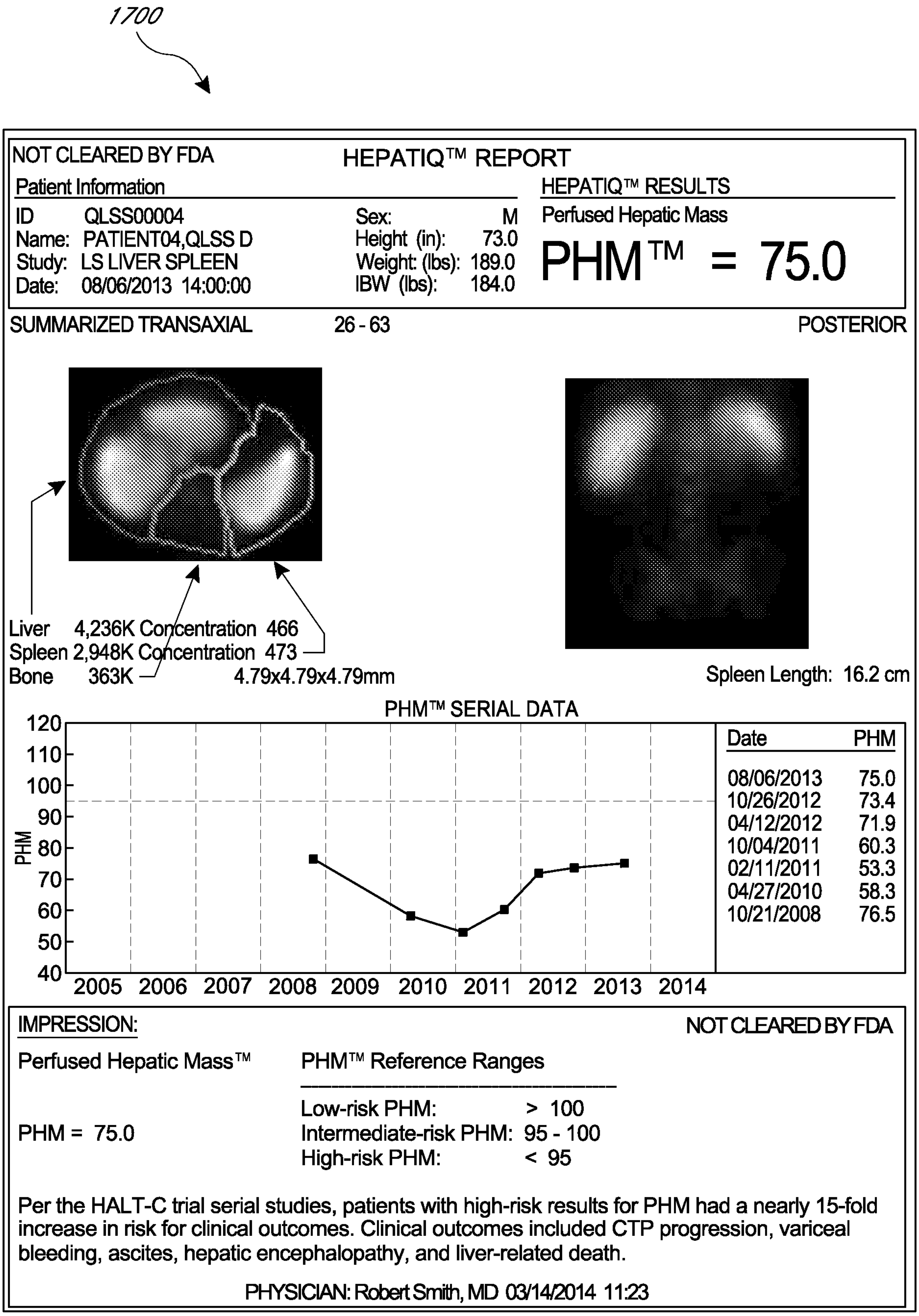
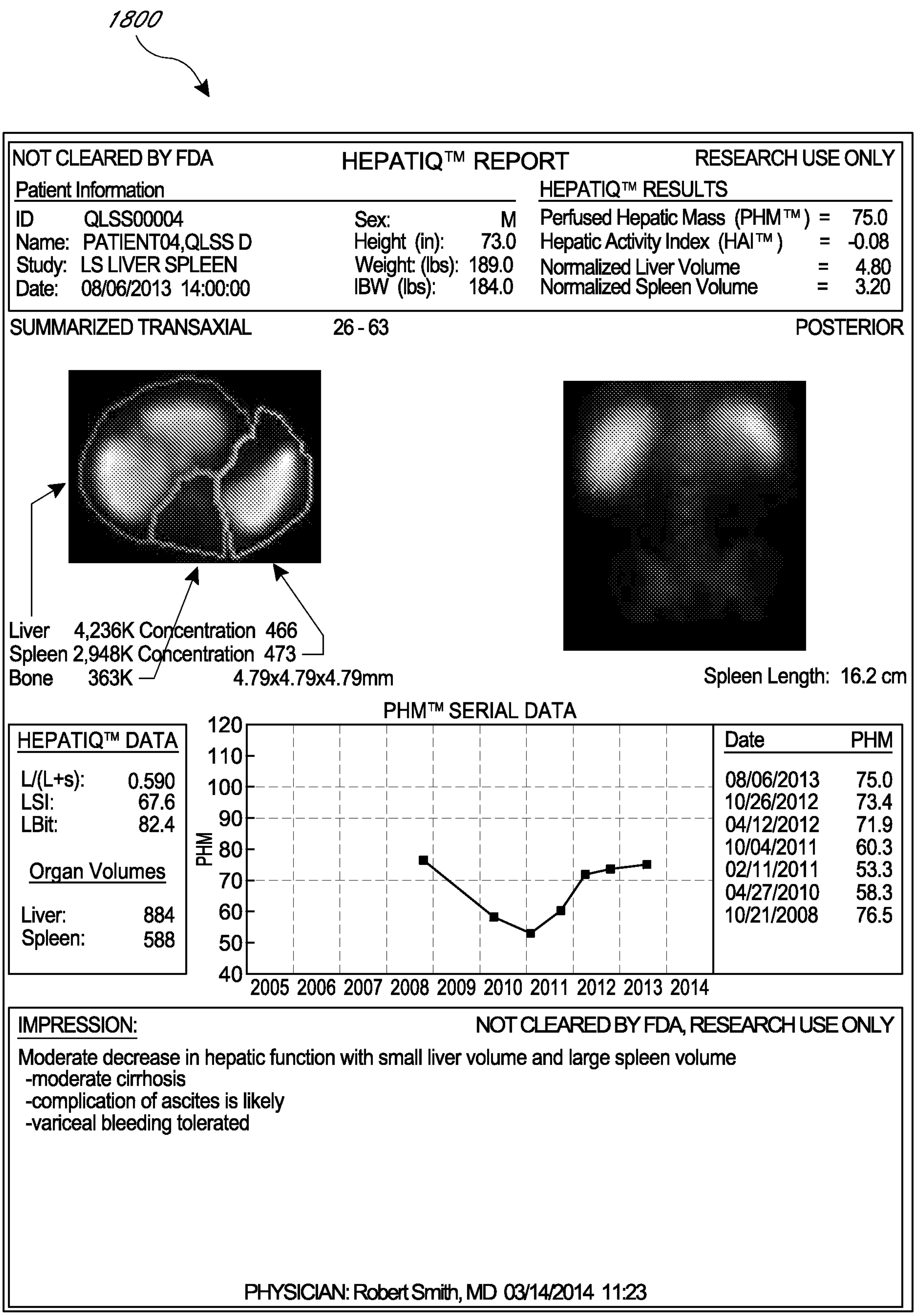

1700
NOT CLEARED BY FDA
HEPATIQ™ REPORT
Patient Information
ID QLSS00004
Name: PATIENT04,QLSS D
Study: LS LIVER SPLEEN
Date: 08/06/2013 14:00:00
Sex: M
Height (in): 73.0
Weight: (lbs): 189.0
IBW (lbs): 184.0
HEPATIQ™ RESULTS
Perfused Hepatic Mass
PHM™ = 75.0
SUMMARIZED TRANSAXIAL
26 - 63
POSTERIOR
Liver 4,236K Concentration 466
Spleen 2,948K Concentration 473
Bone 363K
4.79x4.79x4.79mm
Spleen Length: 16.2 cm
PHM™ SERIAL DATA
PHM
120
110
100
90
80
70
60
50
40
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date PHM
08/06/2013 75.0
10/26/2012 73.4
04/12/2012 71.9
10/04/2011 60.3
02/11/2011 53.3
04/27/2010 58.3
10/21/2008 76.5
IMPRESSION:
NOT CLEARED BY FDA
Perfused Hepatic Mass™
PHM = 75.0
PHM™ Reference Ranges
Low-risk PHM: > 100
Intermediate-risk PHM: 95 - 100
High-risk PHM: < 95
Per the HALT-C trial serial studies, patients with high-risk results for PHM had a nearly 15-fold increase in risk for clinical outcomes. Clinical outcomes included CTP progression, variceal bleeding, ascites, hepatic encephalopathy, and liver-related death.
PHYSICIAN: Robert Smith, MD 03/14/2014 11:23

FIG. 18


1800
NOT CLEARED BY FDA
HEPATIQ™ REPORT
RESEARCH USE ONLY
Patient Information
ID QLSS00004
Name: PATIENT04,QLSS D
Study: LS LIVER SPLEEN
Date: 08/06/2013 14:00:00
Sex: M
Height (in): 73.0
Weight: (lbs): 189.0
IBW (lbs): 184.0
HEPATIQ™ RESULTS
Perfused Hepatic Mass (PHM™) = 75.0
Hepatic Activity Index (HAI™) = -0.08
Normalized Liver Volume = 4.80
Normalized Spleen Volume = 3.20
SUMMARIZED TRANSAXIAL
26 - 63
POSTERIOR
Liver 4,236K Concentration 466
Spleen 2,948K Concentration 473
Bone 363K
4.79x4.79x4.79mm
Spleen Length: 16.2 cm
HEPATIQ™ DATA
L/(L+s): 0.590
LSI: 67.6
LBit: 82.4
Organ Volumes
Liver: 884
Spleen: 588
PHM™ SERIAL DATA
PHM
120
110
100
90
80
70
60
50
40
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date PHM
08/06/2013 75.0
10/26/2012 73.4
04/12/2012 71.9
10/04/2011 60.3
02/11/2011 53.3
04/27/2010 58.3
10/21/2008 76.5
IMPRESSION:
NOT CLEARED BY FDA, RESEARCH USE ONLY
Moderate decrease in hepatic function with small liver volume and large spleen volume
-moderate cirrhosis
-complication of ascites is likely
-variceal bleeding tolerated
PHYSICIAN: Robert Smith, MD 03/14/2014 11:23

REFERENCES CITED IN THE DESCRIPTION

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Non-patent literature cited in the description

- **J. HOEFS et al.** Perfused Kupffer cell mass. *Digestive Diseases and Sciences,* 1995, vol. 40 (3), 552-560 **[0001]**
- **HOEFS et al.** A Novel, Simple Method of Functional Spleen Volume Calculation by Liver-Spleen Scan. *The Journal of Nuclear Medicine,* October 1999, vol. 40 (10 **[0056]**

patsnap

专利名称(译)	用于从肝脏扫描确定肝功能的系统和方法		
公开(公告)号	EP3021753B1	公开(公告)日	2019-08-28
申请号	EP2014747260	申请日	2014-07-16
申请(专利权)人(译)	hepatiq，LLC		
[标]发明人	GHOSH DIPANKAR HOEFS JOHN CARL		
发明人	GHOSH, DIPANKAR HOEFS, JOHN, CARL		
IPC分类号	A61B6/03 A61B6/00 G06T7/60		
CPC分类号	A61B6/037 A61B6/469 A61B6/50 A61B6/5217 G06T7/0014 G06T2207/10108 G06T2207/30056 G06T7/13 G06T7/50 A61B6/032 A61B6/481 A61B6/5205 G06F19/00 G06K9/3233 G06T7/0012 G06T2207/30008		
优先权	61/847313 2013-07-17 US		
其他公开文献	EP3021753A1		
外部链接	Espacenet		

摘要(译)

本文描述的系统和方法确定用于分析患者肝脏健康的客观度量。在一些实施方案中，该系统可包括扫描仪，其可响应于向患者施用放射性化合物而检测辐射计数。此外，该系统可以包括图像检测模块，其可以响应于扫描仪检测到的辐射计数来访问图像数据。图像检测模块可以从图像数据以编程方式识别对应于患者肝脏的第一感兴趣区域。参数计算器模块可以编程地确定与第一感兴趣区域相关联的第一属性，并且至少部分地基于与第一感兴趣区域相关联的第一属性来计算指示患者肝脏健康的第一参数。