



(11) **EP 2 212 716 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention
of the grant of the patent:
26.02.2014 Bulletin 2014/09

(51) Int Cl.:
G01S 15/89 (2006.01) A61B 8/08 (2006.01)

(21) Application number: **08850546.6**

(86) International application number:
PCT/IB2008/054769

(22) Date of filing: **13.11.2008**

(87) International publication number:
WO 2009/063423 (22.05.2009 Gazette 2009/21)

(54) **INTERVENTIONAL NAVIGATION USING 3D CONTRAST-ENHANCED ULTRASOUND**

INTERVENTIONELLE NAVIGATION MITHILFE VON 3D-KONTRASTVERSTÄRKTEM
ULTRASCHALL

NAVIGATION INTERVENTIONNELLE PAR IMAGERIE ULTRASONORE 3D AVEC INJECTION DE
CONTRASTE

(84) Designated Contracting States:
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT
RO SE SI SK TR**

(30) Priority: **16.11.2007 US 988472 P**
12.05.2008 US 52288

(43) Date of publication of application:
04.08.2010 Bulletin 2010/31

(73) Proprietor: **Koninklijke Philips N.V.**
5656 AE Eindhoven (NL)

(72) Inventors:
• **KRUECKER, Jochen**
Briarcliff Manor
New York 10510-8001 (US)
• **XU, Sheng**
Briarcliff Manor
New York 10510-8001 (US)

• **JIANG, Hui**
Briarcliff Manor
New York 10510-8001 (US)

(74) Representative: **van Velzen, Maaïke Mathilde**
Philips
Intellectual Property & Standards
P.O. Box 220
5600 AE Eindhoven (NL)

(56) References cited:
WO-A-96/25881 US-A1- 2006 020 204

- **FENSTER A ET AL: "The use of three-dimensional ultrasound imaging in breast biopsy and prostate therapy" MEASUREMENT, INSTITUTE OF MEASUREMENT AND CONTROL. LONDON, GB, vol. 36, no. 3-4, 1 October 2004 (2004-10-01), pages 245-256, XP004633237 ISSN: 0263-2241**
- **MORIYASU ET AL: "1009" ULTRASOUND IN MEDICINE AND BIOLOGY, NEW YORK, NY, US, vol. 32, no. 5, 1 May 2006 (2006-05-01), page P4, XP005499913 ISSN: 0301-5629**

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

EP 2 212 716 B1

Description

[0001] This invention was made in the performance of a Cooperative Research and Development Agreement with the United States Public Health Service (CRADA No. NCI-NIHCC-01864). The Government of the United States may have certain rights in the invention.

[0002] US 2006/0020204 A1 discloses a method for managing a 3D space in which substantially real-time images are acquired. The substantial real-time images are acquired of an object or a body, wherein prior image data are co-registered to the 3D space from which the substantially real-time images were acquired. A scan probe and a handheld tool are tracked in 3D, and the tracking information from the scan probe is used to fuse images from prior scans of the object or the body to one or more substantially real-time images of the object or the body. The tracking information from the handheld tool is used to control display parameters and manipulative operations on the one or more substantially real-time images.

[0003] The present embodiments relate generally to ultrasound diagnostic imaging systems and more particularly, to an apparatus for interventional navigation using 3D contrast enhanced ultrasound (CEUS).

[0004] Ultrasound imaging is one of the primary image guidance methods for many minimally invasive and interventional procedures. In particular, most needle biopsies and needle-based ablation procedures are guided by ultrasound. The advantages of ultrasound include the real time imaging capability, low cost, flexibility in its application, and the fact that no ionizing radiation is used. However, non-enhanced ultrasound, including the commonly used gray-scale ultrasound image, may not be able to visualize a particular target (e.g., a tumor) with the desired contrast, and in some cases, may not visualize the target at all. In those cases, needle placement becomes very difficult and prone to inaccuracies, since it involves imaging the target using a different modality, and "mentally" transferring the tumor location into the real time ultrasound image based on anatomical landmarks near the tumor identified in both imaging modalities. The result may be false-negative biopsies, failed tumor therapy, and in general, poor therapeutic outcomes.

[0005] Contrast enhanced ultrasound (CEUS) imaging is another form of ultrasound imaging that refers to ultrasound imaging after intra-venous injection of an ultrasound contrast agent (such as Definite®, Bristol-Myers Squibb). On modern ultrasound scanners, specific imaging modes have been implemented to take advantage of the non-linear acoustic response of contrast agents, thus only highlighting tissue with contrast uptake. The resulting image is called "contrast image" and has a very different appearance compared to non-contrast images. It is also possible to image tissue after contrast injection in regular grayscale mode. In the later instance, the resulting image is called the "tissue image" and looks similar to grayscale images obtained without contrast injection, showing only a small enhancement in areas of contrast uptake.

[0006] It is noted that CEUS can provide superior visualization of tumors, vascularity, and other tissues of interest compared to non-contrast enhanced ultrasound imaging. However, the contrast enhancement after bolus injection is a transient phenomenon, and typically disappears after a few minutes. Such a time limitation of a few minutes is often insufficient time to perform a desired procedure (e.g., such as placing a needle for biopsy or ablation). In other words, for guidance during interventional procedures such as needle placement for biopsy and ablation, the time window of the contrast enhancement is insufficient in comparison to the time required to perform the interventional procedure. A second injection of the contrast agent is possible to prolong the enhancement effect, but this may still be insufficient to complete the desired procedure.

[0007] Additional limitations of prior techniques associated with use of a pre-acquired CEUS volume alone include, for example, the position of a subsequent acquired real time ultrasound tissue image during the interventional procedure relative to the pre-acquired CEUS volume is unknown and needs to be estimated, thus being prone to inaccuracy. Furthermore, tissue motion complicates an estimation of target location based upon a pre-acquired CEUS volume.

[0008] Accordingly, an improved method and system for overcoming the problems in the art is desired.

Figure 1 is a partial block diagram view of a system for implementing a system for interventional navigation using 3D contrast-enhanced ultrasound according to one embodiment of the present disclosure;

Figure 2 is a partial block diagram view illustrating transformations between various coordinate systems relevant to the apparatus for interventional navigation using 3D CEUS, according to embodiments of the present disclosure;

Figure 3 is a display view illustrating the side-by-side display of real time tissue and corresponding CEUS multi-planar reconstruction (MPR) image views according to one embodiment of the present disclosure; and

Figure 4 is a display view illustrating the display of real time tissue and corresponding CEUS MPR images views with semi-transparent overlay according to another embodiment of the present disclosure.

[0009] In the figures, like reference numerals refer to like elements. In addition, it is to be noted that the figures may not be drawn to scale.

[0010] The embodiments of the present disclosure provide a system to utilize contrast-enhanced ultrasound imaging (CEUS) for image guidance during interventional procedures according to claim 1. In particular, the embodiments of the

present disclosure advantageously enable a system for using CEUS to improve targeting accuracy in interventional procedures without having to modify the workflow or switch to a different imaging modality entirely.

[0011] The system, as disclosed herein, includes a spatial tracking system configured to track the position of an ultrasound probe. Use of the tracking system enables determination of the location of a 3D CEUS volume at the beginning of an interventional procedure. In one embodiment, a 3D tissue volume is also acquired simultaneously with the 3D CEUS volume, as discussed further herein below. Thereafter, during the interventional procedure, spatial tracking of the ultrasound probe enables joint display of a current real time ultrasound tissue image with a corresponding CEUS multi-planar reconstruction (MPR), wherein the corresponding MPR is derived from the initial 3D CEUS volume. Tissue motion between the initial 3D CEUS acquisition and the real time ultrasound tissue imaging is corrected by image-based registration between the real time ultrasound tissue image and the 3D ultrasound tissue volume co-acquired with the initial 3D CEUS volume. The joint display of (i) a corresponding MPR derived from the initial CEUS volume and (ii) real time non-contrast ultrasound tissue image advantageously enables joint visualization of a needle position and target location, and thus enables guidance of the needle into the target for the duration of the interventional procedure, subsequent to expiration of the enhancement effect of the contrast agent.

[0012] Turning now to the drawings, Figure 1 is a block diagram view of a system 10 for interventional navigation using 3D contrast-enhanced ultrasound according to one embodiment of the present disclosure. System 10 comprises an ultrasound scanner (US) 12 equipped and/or coupled with an ultrasound imaging probe 14. In one embodiment, the ultrasound scanner 12 comprises, for example, an iU22 ultrasound scanner commercially available from Philips Medical Systems. Imaging probe 14 comprises any suitable 3D ultrasound imaging probe. In addition, ultrasound scanner 12 includes a scanner display 16. Furthermore, ultrasound scanner 12 is configured for simultaneous acquisition of contrast and tissue images. Ultrasound scanner 12 is further configured for transferring images in real-time, for example, via data streaming, to workstation 18. For example, transferring images in real-time can be accomplished using an iU22 ultrasound scanner with Digital Navigation Link software. While illustrated as separate from the ultrasound scanner 12, workstation 18 may also be integrated in and part of the ultrasound scanner 12.

[0013] Referring still to Figure 1, workstation 18 includes a workstation display 20. In operation, the ultrasound scanner 12, probe 14, and workstation 18 are used in conjunction with a patient 22 having an anatomy that is subject to a given ultrasound diagnosis and/or a corresponding treatment or medical procedure, wherein the patient 22 is positioned upon a patient table 24. Ultrasound scanner 12 is configured to acquire contrast and tissue ultrasound images, for example, in a "side by side mode" corresponding to an interleaved acquisition of contrast and tissue frames, and sends both acquired images to the workstation 18. Software is executed by workstation 18 to accommodate the workflow as discussed further herein.

[0014] The system 10 for interventional navigation using 3D contrast-enhanced ultrasound also includes position tracking according to the embodiments of the present disclosure. System 10 is enhanced by integration with an external position tracking system (TS) 26. The external position tracking system 26 includes a tracking field generator 28 which is configured for producing a tracking field, generally designated by reference numeral 30. A sensor 32 is coupled to the ultrasound probe 14, wherein responsive to the sensor being located within a range of sensing field 30, the sensor's position and orientation can be tracked by the tracking system 26. In one embodiment, workstation 18 is coupled to tracking system 26 and configured to communicate tracking information and/or provide tracking instructions between workstation 18 and tracking system 26 according to the requirements of a given interventional navigation or implementation. Tracking system 26 can comprise any suitable tracking system, for example, such as the electro-magnetic "Aurora" system by Northern Digital Inc., of Waterloo, Canada. In another embodiment, tracking system 26 includes an optical tracking system, in which tracking field generator 28 comprises, for example, a camera, for optically tracking the ultrasound probe 14 within the tracking field 30 corresponding to an optical field of view. Such an optical tracking system may comprise, for example, a "Polaris" system by Northern Digital Inc., of Waterloo, Canada.

[0015] In system 10 of Figure 1, the external position tracking system (TS) 26 is set up next to or proximate the patient 22. A 6 degree-of-freedom (6DoF) position sensor (S) 32 is coupled to the ultrasound probe 14, and the tracking field generator 28 is positioned such that the probe position can be tracked within tracking field 30.

[0016] Workstation 18 also includes software contained on computer readable medium and loaded in a memory thereof, wherein the software includes instructions executable by a processor of the workstation to (i) acquire and store at least one 3D CEUS volume, together with the volume's tracking system coordinates provided by the sensor 32, and (ii) acquire and process tracking sensor coordinates in real time, and using the real-time tracking sensor coordinates for computing and displaying multi-planar reconstructions (MPRs) of the at least one acquired and stored 3D CEUS volume, such that the corresponding MPR shows the same tissues as the latest acquired real time tissue image.

[0017] In one embodiment, the ultrasound scanner 12 is configured to acquire and transmit a CEUS image/volume and a tissue image/volume simultaneously. In such an embodiment, the software of workstation 18 further includes instructions executable by the processor of the workstation 18 to (iii) acquire and store simultaneously acquired 3D CEUS volumes and 3D tissue volumes, together with the corresponding volumes' tracking system coordinates provided by the sensor 32; and (iv) acquire and process tracking sensor coordinates in real time, and use the real time tracking

sensor coordinates for image-based registration of the non-contrast real time tissue image with the 3D tissue volume acquired simultaneously with the 3D CEUS volume, wherein a resulting registration transformation is used for computing and displaying MPRs of the initial acquired and stored 3D CEUS volume, such that the CEUS MPR shows the same tissues as the latest acquired real time tissue image.

[0018] In one embodiment, the system comprises using an ultrasound scanner 12 capable of acquiring real time 3D images in contrast and tissue mode, and capable of streaming (i.e., transferring in real time) the image data to the workstation 18 (or other system, for example, via a suitable communication network). In conjunction with this embodiment, the system assumes that a patient is able to follow breathing commands and is further able to produce reproducible breath holds. Furthermore, software running on workstation 18 is configured to communicate with various hardware (e.g., tracking system, ultrasound scanner, etc.) using real time electronic data transfer.

[0019] In one example of workflow, a patient 22 being presented for an ultrasound-guided needle ablation is positioned on an examination table 24. Position sensor 32 is attached to the ultrasound probe 14. The transmitter/receiver 28 of tracking system 26 is positioned close to the patient 22 such that the ultrasound probe 14 with attached position sensor 32 is in the field of view 30 of the transmitter/receiver 28 during the necessary ultrasound imaging for the procedure. The ultrasound scanner 12 is initially configured or set to contrast imaging mode, and an intra-venous bolus injection of contrast agent is administered to the patient 22. Upon the contrast enhancement becoming visible in the ultrasound image displayed on display 16, a three-dimensional (3D) CEUS scan covering the tumor or area of interest is then acquired. The 3D CEUS volume and corresponding probe position data is transferred to the navigation workstation 18. For subsequent imaging after the contrast enhancement has disappeared, the real time 2D or 3D ultrasound tissue images and corresponding probe position data are continuously transferred (i.e., streamed) to the workstation 18. Based on the current probe position, the location of the current ultrasound tissue image relative to the initially acquired 3D CEUS image (also referred to as a pre-acquired 3D CEUS image) is calculated. On the workstation display 20, the current real-time ultrasound tissue image is displayed jointly with the corresponding multi-planar reconstruction (MPR) (or other visualization) of the CEUS image. This allows localizing the needle in the real time tissue image, and localizing the tumor in the CEUS image, and thus enabling guidance of the needle into the tumor, wherein the tumor may not be visible in the real time tissue image alone.

[0020] Figure 2 is a partial block diagram view illustrating transformations between various coordinate systems relevant to the system for interventional navigation using 3D contrast-enhanced ultrasound of Figure 1, according to embodiments of the present disclosure. In particular, Figure 2 is an illustration of transformations between the coordinate systems of a 2D ultrasound image, a 3D ultrasound image, the tracking sensor attached to the ultrasound probe, and the tracking system. In one embodiment, Figure 2 illustrates the relationship of transformations between the 6 DoF position sensor, the tracking system, and the corresponding ultrasound frame.

[0021] The transformation T_{tracking} describes a current position and orientation (otherwise referred to as a "pose") of the tracking sensor 14 relative to the tracking system (26,28). In other words, the transformation T_{tracking} describes the relationship between the coordinate system of tracking system C_{tracking} and the coordinate system of the tracking sensor C_{sensor} . The transformation T_{tracking} is provided by the tracking system and is acquired by the workstation 18, for example, continuously in real time or as required for a given implementation of the interventional procedure according to the embodiments of the present disclosure. The transformation $T_{\text{calibration}}$ describes the relationship between the coordinate system $C_{3\text{DUS}}$ of the 3D ultrasound image (i.e., voxel coordinates) and the coordinate system C_{sensor} of the tracking sensor 38 attached to the probe 14. The transformation $T_{\text{calibration}}$ is determined in a one-time calibration procedure and remains fixed for a given tracking sensor 32 rigidly attached to the ultrasound probe 14, subject to being re-calibrated upon replacement of and/or change in the sensor and/or probe. Lastly, the transformation $T_{2\text{DUS} \rightarrow 3\text{DUS}}$ describes the relationship between the coordinate system $C_{2\text{DUS}}$ of a 2D ultrasound image and the coordinate system $C_{3\text{DUS}}$ of the 3D ultrasound image (i.e., voxel coordinates). That is, the transformation between coordinate systems for tracked 2D and 3D ultrasound image acquisition is given by $T_{2\text{DUS} \rightarrow 3\text{DUS}}$. In summary, the transformation $T_{2\text{DUS} \rightarrow 3\text{DUS}}$ transforms 2D image pixel coordinates to 3D image voxel coordinates, $T_{\text{calibration}}$ transforms 3D image voxel coordinates into sensor coordinates, and T_{tracking} transforms sensor coordinates into tracking system coordinates. Note that T_{tracking} is the real time pose information of the sensor 32 provided by the tracking system (26,28).

[0022] According to one embodiment, CEUS image acquisition is as follows. After contrast injection, the navigation software on the workstation requests the sonographer to find a probe position that visualizes the tumor target in 3D CEUS mode. All 3D images from the scanner and all position data from the sensor are continuously streamed to the workstation. When an appropriate image has been acquired and confirmed on the workstation, the image will be stored on the workstation along with the corresponding probe position T_{tracking} , 3DCEUS given by the tracking sensor. The reference coordinate system assigned to the 3D CEUS volume is that of the tracking system, which is immobile throughout the procedure. Using the illustration in Figure 2, the transformation from 3D CEUS voxel coordinates to tracking system coordinates is given by:

$$\mathbf{T}_{3DCEUS} = \mathbf{T}_{\text{calibration}} \cdot \mathbf{T}_{\text{tracking, 3DCEUS}}$$

[0023] In addition, the embodiments of the present disclosure provide image guidance as follows. After 3D CEUS acquisition, the ultrasound scanner is switched to 2D imaging mode for image guidance. The transformation $\mathbf{T}_{2DUS \rightarrow 3DUS}$ between the 2D image coordinates and 3D image coordinates is known based on the imaging algorithms on the ultrasound scanner. Thus, using the current tracking data $\mathbf{T}_{\text{tracking}}$ from the tracking sensor, the position of the current 2D ultrasound tissue image within the CEUS reference image acquired with $\mathbf{T}_{\text{tracking, 3DCEUS}}$, can be determined using the transformation:

$$\begin{aligned} \mathbf{T}_{2DUS \rightarrow 3DCEUS} &= \mathbf{T}_{2DUS \rightarrow 3DUS} \cdot \mathbf{T}_{\text{calibration}} \cdot \mathbf{T}_{\text{tracking}} \cdot (\mathbf{T}_{3DCEUS})^{-1} \\ &= \mathbf{T}_{2DUS \rightarrow 3DUS} \cdot \mathbf{T}_{\text{calibration}} \cdot \mathbf{T}_{\text{tracking}} \cdot (\mathbf{T}_{\text{tracking, 3DCEUS}})^{-1} \cdot (\mathbf{T}_{\text{calibration}})^{-1} \end{aligned}$$

[0024] The workstation will use this relationship to extract- in real time - the MPR from the 3D CEUS image that corresponds to the current pose of the 2D tissue image. In one embodiment, both images are displayed side-by-side, or in another embodiment, displayed using semi-transparent overlay with user-determined transparency, on the workstation display 20. Figure 3 in an illustrative view of the side-by-side display 36 of real time tissue image 38, showing an inserted needle 40, and display 42 of the corresponding MPR 44 from the pre-acquired CEUS volume, showing the target 46 highlighted by the contrast enhancement. Figure 4 is an illustrative view of a semi-transparent overlay 48 of the same tissue and contrast image, as indicated in Figure 4 by reference numeral 50.

[0025] According to another embodiment, the system is configured for acquisition of multiple 3D CEUS volumes. That is, during the 3D CEUS volume acquisition, rather than storing on the workstation 18 only a single volume showing the contrast-enhance tissue of interest, a time series of volumes and their corresponding position information are also stored. The system can then ascertain the dynamics of contrast uptake (e.g., in-flow and out-flow), which are also diagnostically valuable indicators. The system is further configured for (a) co-displaying not just a single CEUS MPR with the real time tissue image, but co-displaying multiple MPRs of the entire time-series as a "movie". In addition, the system is also configured for (b) processing the time-series data to create a volumetric map of diagnostically relevant parameters, such as the in-flow time constant, and then co-displaying an MPR of this parameter MAP with the real time tissue image during the interventional procedure.

[0026] In another embodiment, the system is configured for using alternate target visualization. That is, rather than co-displaying or over-laying an MPR of the 3D CEUS volume with the tissue image, a target volume-of-interest (VOI) is segmented from the 3D CEUS volume after CEUS acquisition. Such a target VOI includes, for example, a sphere covering the area of strongest tissue enhancement in the 3D CEUS volume. In this embodiment, during the interventional procedure, only the appropriate cross-section of the VOI, as determined by the current tracking position, would be superimposed on the real time tissue image.

[0027] In another embodiment, the system is configured for using real time 3D imaging during guidance. That is, instead of using 2D imaging for guidance, the system uses real time 3D imaging. In this case, rather than generating MPRs, other means of visualization are used, such as maximum intensity projections (MIPs). The MIP projections can be computed using the same set of transformations as described in the embodiments herein above.

[0028] In yet another embodiment, the system is configured for non-real time 3D CEUS acquisition. In this embodiment, for example, if real time 3D CEUS is not available, the reference CEUS volume can also be generated by tracking a 2D ultrasound probe, streaming to the workstation all 2D image frames and corresponding tracking data, obtaining a "sweep" over the target area after contrast injection, and reconstructing the 3D CEUS volume based on the acquired 2D images and tracking data.

[0029] In a further embodiment, the system is configured for use of image-based registration for motion correction. In this embodiment, the above described joint display of real time tissue image and corresponding 3D CEUS MPR is only accurate if the patient, or the organ being imaged, does not move between acquisition of the 3D CEUS volume and of the real time tissue image. To enhance the accuracy in the presence of tissue motion, the system according to the embodiments of the present invention is further configured for example, one of the following motion correction methods. A first motion correction method includes simultaneous acquisition of the 3D CEUS image with a 3D tissue image. This motion correction method makes use of a simultaneous dual-mode acquisition and visualization, for example, as is available in real time 2D on modern scanners such as Philips iU22, and which enables non-real time simultaneous 3D acquisition as described above. A second motion correction method includes an image-based registration of a current 2D tissue image (or the last N 2D tissue images, with N is small, e.g. < 10) with the 3D tissue image acquired simultaneously

with the 3D CEUS image. The tracking coordinates associated with the 2D images serve as a starting position for the registration (i.e. assuming no organ motion). The registration itself can utilize various optimizers and similarity measures, such as the Gauss-Newton optimizer and sum-of-squared-differences similarity measure. The result of the registration is the transformation $T_{2DUS \rightarrow 3Dtissue}$. Since the 3D CEUS and tissue images were acquired simultaneously, their coordinate systems are identical, and the same transformation can be used to transform current 2D coordinates into 3D CEUS coordinates.

[0030] As discussed herein, the system according to the embodiments of the present disclosure use a spatial tracking system to track the position of an ultrasound probe and for image guidance in interventional procedures during contrast-enhanced ultrasound imaging (CEUS). At the beginning of an interventional procedure, a three-dimensional (3D) CEUS volume is acquired simultaneously with a regular 3D ultrasound tissue image. During the procedure, spatial tracking of the ultrasound probe enables joint display of the current real time ultrasound tissue image with the corresponding multi-planar reconstruction (MPR) from the 3D CEUS volume acquired at the beginning of the procedure (also referred to herein as the pre-acquired 3D CEUS volume). Tissue motion between 3D CEUS acquisition obtained at the beginning of the procedure and real time imaging obtained subsequent or after the beginning of the procedure is corrected by image-based registration between the real time 3D tissue image and a 3D tissue image co-acquired with the 3D CEUS at the beginning of the procedure. The joint display of pre-acquired CEUS, and more particularly, a multi-planar reconstruction (MPR) of the pre-acquired CEUS, wherein the MPR corresponds to a given tissue image in real time, and real time non-contrast ultrasound enables joint visualization of needle position and target location, and thus enables guidance of the needle into the target. As previously discussed, CEUS can provide superior visualization of tumors, vascularity, and other tissues of interest compared to non-contrast enhanced ultrasound imaging. By itself, contrast enhancement after bolus injection is a transient phenomenon and typically disappears after a few minutes. For guidance during interventional procedures such as needle placement for biopsy and ablation, the time window of the transient phenomenon of contrast enhancement alone is insufficient. However, the embodiments of the present disclosure advantageously provide a system and method that overcomes this limitation.

[0031] Accordingly, by now it will be appreciated that a method for interventional navigation using 3D contrast-enhanced ultrasound (CEUS) imaging as disclosed herein comprises: acquiring a reference 3D CEUS volume and tracking information for a desired portion of an anatomy that is subject to an interventional procedure with an instrument, wherein the acquiring takes place during a useful lifetime of a contrast enhancement agent administered to the desired portion of the anatomy; acquiring real-time tracked tissue images during the interventional procedure; generating at least one corresponding contrast-enhanced ultrasound image multiplanar reconstruction (CEUS MPR) for at least one of the acquired real-time tracked tissue images during the interventional procedure as a function of the reference 3D CEUS volume and tracking information; displaying at least one of the acquired real-time tracked tissue images, wherein the displayed real-time tracked tissue image includes at least an image of the instrument within the desired portion of the anatomy; and displaying the at least one corresponding contrast-enhanced ultrasound image multiplanar reconstruction (CEUS MPR) that corresponds to the displayed real-time tracked tissue image, wherein the CEUS MPR image includes a contrast enhanced MPR image obtained from the reference 3D CEUS volume and includes a target volume of interest, thereby providing a concurrent display of contrast enhanced image information and tissue image information useful for the interventional navigation at least subsequent to the expiration of the contrast enhancement useful lifetime.

[0032] According to another embodiment, acquisition of the reference 3D CEUS volume includes concurrent acquisition of at least one tracked 3D ultrasound contrast image and tissue image pair. In addition, the at least one tracked 3D ultrasound contrast and tissue image pair comprise an initial ultrasound contrast image and a corresponding initial tissue image captured substantially concurrently and automatically registered to one another.

[0033] In another embodiment, the interventional procedure includes a first portion thereof that occurs prior to expiration of the contrast enhancement useful lifetime and a second portion thereof that occurs subsequent expiration of the contrast enhancement useful lifetime. In a further embodiment, the at least one corresponding contrast-enhanced ultrasound image multiplanar reconstruction is spatially registered with a corresponding one of the acquired real-time tracked tissue images. In another embodiment, the real-time tracked tissue image and the corresponding CEUS MPR are displayed adjacent to one another. In yet another embodiment, the real-time tracked tissue image and the corresponding CEUS MPR reference image are displayed together on a single display. In the latter instance, the real-time tracked tissue image and the corresponding CEUS MPR can further be displayed in an overlaying arrangement such that one image overlays the other image. Still further, the overlaying arrangement can comprise one image being semi-transparent with respect to the other image.

[0034] According to another embodiment, instead of generating at least one corresponding contrast-enhanced ultrasound image multiplanar reconstruction (CEUS MPR) for at least one of the acquired real-time tracked tissue images during the interventional procedure, and instead of displaying the acquired real-time tracked tissue images, the system is configured for: generating a maximum intensity projection (MIP) as a function of the at least one pair of acquired tracked 3D real-time ultrasound contrast and tissue images; displaying a maximum intensity projection (MIP) of at least one of the acquired real-time tracked 3D tissue images, wherein the displayed real-time tracked tissue image MIP

includes at least an image of the instrument within the desired portion of the anatomy; and displaying the at least one corresponding contrast-enhanced ultrasound image maximum intensity projection (CEUS MIP) that corresponds to the displayed MIP of the at least one acquired real-time tracked 3D tissue image, wherein the CEUS MIP image includes a contrast enhanced MIP image from a target volume of interest, thereby providing a concurrent display useful for the interventional navigation at least subsequent to the expiration of the contrast enhancement useful lifetime.

[0035] In another embodiment, in the absence of real-time 3D ultrasound, the reference 3D CEUS volume is acquired by tracking a 2D ultrasound probe, acquiring a series of 2D contrast and tissue image frames and corresponding tracking data while sweeping the tracked 2D ultrasound probe over the desired portion of the anatomy after contrast enhancement agent administration, streaming the acquired series of 2D contrast and tissue images and corresponding tracking data to a workstation, and reconstructing the reference 3D CEUS volume at the workstation based upon the acquired 2D contrast and tissue images and corresponding tracking data.

[0036] In yet another embodiment, acquiring the reference 3D CEUS volume includes using a spatial tracking system configured to track a position of an ultrasound probe used in acquiring the reference 3D CEUS volume, wherein the tracking system enables determination of a location and orientation of the reference 3D CEUS volume; and wherein the tracking system is further configured to track the acquired tissue images during the interventional procedure. The system is further configured to: correcting for tissue motion within the desired portion of the anatomy which may occur between (i) a time of the acquisition of the reference 3D CEUS volume, and (ii) a time of the acquisition of the at least one real-time tracked tissue image. Still further, correcting tissue motion includes using an image-based registration between (a) the real-time tracked 3D tissue image and (b) the ultrasound tissue image of the tracked 3D ultrasound contrast and tissue image pair.

[0037] According to another embodiment, acquiring the reference 3D CEUS volume and tracking information includes acquiring a time series of 3D CEUS volumes and corresponding tracking information, and wherein generating the at least one corresponding CEUS MPR image includes generating a time series of CEUS MPR images, and wherein displaying the acquired real-time tracked tissue images and displaying the at least one corresponding CEUS MPR images comprises co-displaying the CEUS MPR images with the real-time tissue images as time-series data. The system is further configured to processing the time-series data to create a volumetric map of diagnostically relevant parameters, and co-displaying the volumetric map with (i) the CEUS MPR images and (ii) the real-time tissue images. In addition, the diagnostically relevant parameters can include at least an in-flow time constant of the contrast agent.

[0038] In yet another embodiment, the system is further configured to segmenting the target volume of interest from the reference 3D CEUS volume, wherein the target volume of interest comprises an areas of strongest tissue enhancement; and displaying a corresponding cross-section segment of the target volume of interest, instead of displaying the at least one corresponding contrast-enhanced ultrasound image multiplanar reconstruction (CEUS MPR), that corresponds to the displayed real-time tracked tissue image, and superimposing the corresponding cross-section segment of the target volume of interest on the displayed real-time tracked tissue image.

[0039] According to an example, a method for interventional navigation using 3D contrast-enhanced ultrasound (CEUS) imaging comprises: acquiring a reference 3D CEUS volume and tracking information for a desired portion of an anatomy that is subject to an interventional procedure with an instrument, wherein the acquiring takes place during a useful lifetime of a contrast enhancement agent administered to the desired portion of the anatomy, wherein acquisition of the reference 3D CEUS volume includes concurrent acquisition of at least one tracked 3D ultrasound contrast image and tissue image pair; acquiring real-time tracked tissue images during the interventional procedure; generating at least one corresponding contrast-enhanced ultrasound image multiplanar reconstruction (CEUS MPR) for at least one of the acquired real-time tracked tissue images during the interventional procedure as a function of the reference 3D CEUS volume and tracking information, wherein the at least one corresponding contrast-enhanced ultrasound image multiplanar reconstruction is spatially registered with a corresponding one of the acquired real-time tracked tissue images; displaying the acquired real-time tracked tissue images, wherein the displayed real-time tracked tissue image includes at least an image of the instrument within the desired portion of the anatomy; and displaying the at least one corresponding contrast-enhanced ultrasound image multiplanar reconstruction (CEUS MPR) that corresponds to the displayed real-time tracked tissue image, wherein the CEUS MPR image includes a contrast enhanced MPR image obtained from the reference 3D CEUS volume and includes a target volume of interest, thereby providing a concurrent display of contrast enhanced image information and tissue image information useful for the interventional navigation at least subsequent to the expiration of the contrast enhancement useful lifetime.

[0040] As discussed herein, the embodiments of the present disclosure can be applied in ultrasound-based image guidance of diagnostic and therapeutic medical procedures. For example, the embodiments of the present disclosure can improve needle guidance for biopsy and ablation procedures. In addition, the embodiments of the present disclosure advantageously overcome limitations and disadvantages in current ultrasound-based procedure guidance, such as, limited visualization or no visualization of some tumors/targets; poor accuracy in execution of the procedure if target location is estimated based on a pre-acquired modality (other than pre-acquired CEUS as disclosed with respect to the embodiments of the present disclosure); and brief duration of contrast enhancement in CEUS imaging which is insufficient

for execution of a given interventional procedure.

[0041] Although only a few exemplary embodiments have been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the novel teachings and advantages of the embodiments of the present disclosure. Accordingly, all such modifications are intended to be included within the scope of the embodiments of the present disclosure as defined in the following claims. In the claims, means-plus-function clauses are intended to cover the structures described herein as performing the recited function.

[0042] In addition, any reference signs placed in parentheses in one or more claims shall not be construed as limiting the claims. The word "comprising" and "comprises," and the like, does not exclude the presence of elements or steps other than those listed in any claim or the specification as a whole. The singular reference of an element does not exclude the plural references of such elements and vice-versa. One or more of the embodiments may be implemented by means of hardware comprising several distinct elements, and/or by means of a suitably programmed computer. In a device claim enumerating several means, several of these means may be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to an advantage.

Claims

1. A system (10) for interventional navigation using 3D contrast-enhanced ultrasound, CEUS, imaging, the system comprising:

an ultrasound imaging device (12) configured to i) acquire a reference 3D CEUS volume and tracking information for a desired portion of an anatomy (22) that is subject to an interventional procedure with an instrument (40), wherein the ultrasound imaging device is further configured to acquire the reference 3D CEUS volume and tracking information during a useful lifetime of a contrast enhancement agent administered to the desired portion of the anatomy, wherein the acquisition of the reference 3D CEUS volume includes concurrent acquisition of at least one tracked 3D ultrasound contrast image and tissue image pair, ii) acquire real-time tracked tissue images (38) during the interventional procedure, and iii) generate at least one corresponding contrast-enhanced ultrasound image multiplanar reconstruction, CEUS MPR, (44) for at least one of the acquired real-time tracked tissue images during the interventional procedure as a function of the reference 3D CEUS volume and tracking information; and

a display (16,20) coupled to the ultrasound imaging device and configured to display i) the acquired real-time tracked tissue images, wherein the displayed real-time tracked tissue images include at least an image of the instrument within the desired portion of the anatomy, and ii) at least one corresponding contrast-enhanced ultrasound image multiplanar reconstruction, CEUS MPR, that corresponds to the displayed real-time tracked tissue image, wherein the CEUS MPR image includes a contrast enhanced MPR image obtained from the reference 3D CEUS volume and includes a target volume of interest, thereby providing a concurrent display of contrast enhanced image information and tissue image information useful for the interventional navigation at least subsequent to the expiration of the contrast enhancement useful lifetime.

2. The system of claim 1, further wherein the at least one tracked 3D ultrasound contrast and tissue image pair comprise an initial ultrasound contrast image and a corresponding initial tissue image captured substantially concurrently and automatically registered to one another.

3. The system of claim 1, wherein the ultrasound imaging device is further configured to operate during the interventional procedure that includes a first portion thereof that occurs prior to expiration of the contrast enhancement useful lifetime and a second portion thereof that occurs subsequent expiration of the contrast enhancement useful lifetime.

4. The system of claim 1, wherein the at least one corresponding contrast enhanced ultrasound image multiplanar reconstruction is spatially registered with a corresponding one of the acquired real-time tracked tissue images.

5. The system of claim 1, wherein the real-time tracked tissue image and the corresponding CEUS MPR are displayed adjacent to one another.

6. The system of claim 1, wherein the real-time tracked tissue image and the corresponding CEUS MPR reference image are displayed together on a single display.

7. The system of claim 6, further wherein the real-time tracked tissue image and the corresponding CEUS MPR are displayed in an overlaying arrangement such that one image overlays the other image.
8. The system of claim 7, still further wherein the overlaying arrangement comprises one image being semi-transparent with respect to the other image.
9. The system of claim 1, wherein the ultrasound imaging device is further configured to acquire the reference 3 D CEUS volume by using a spatial tracking system configured to track a position of an ultrasound probe used in acquiring the reference 3D CEUS volume, wherein the tracking system enables determination of a location and orientation of the reference 3D CEUS volume; and wherein the spatial tracking system is further configured to track the acquired tissue images during the interventional procedure.
10. The system of claim 9, wherein the ultrasound imaging device is further configured to correct for tissue motion within the desired portion of the anatomy which may occur between i) a time of the acquisition of the reference 3D CEUS volume, and ii) a time of the acquisition of the at least one real-time tracked tissue image.
11. The system of claim 10, wherein correcting for tissue motion includes using an image based registration between a) the real-time tracked 3D tissue image and b) the ultrasound tissue image of the tracked 3D ultrasound contrast and tissue image pair.
12. The system of claim 1, wherein the ultrasound imaging device is further configured to acquire the reference 3D CEUS volume and tracking information by acquiring a time series of 3D CEUS volumes and corresponding tracking information, and to generate the at least one corresponding CEUS MPR image by generating a time series of CEUS MPR images, and wherein the display is further configured to display the acquired real-time tracked tissue images and the at least one corresponding CEUS MPR images by co-displaying the CEUS MPR images with the real-time tissue images as time-series data.
13. The system of claim 12, further comprising:
means for processing the time-series data to create a volumetric map of diagnostically relevant parameters, and co-displaying the volumetric map with i) the CEUS MPR images and ii) the real-time tissue images.
14. The system of claim 13, wherein the diagnostically relevant parameters include at least an in-flow time constant of the contrast agent.

Patentansprüche

1. System (10) zur interventionellen Navigation mithilfe von Bildgebung mit kontrastverstärktem 3D-Ultraschall, CEUS, wobei das System Folgendes umfasst:
- eine Ultraschall-Bildgebungsvorrichtung (12), die so konfiguriert ist, dass sie
i) ein 3D-Referenz-CEUS-Volumen und Tracking-Informationen für einen gewünschten Teil einer Anatomie (22) erfasst, die einem Eingriff mit einem Instrument (40) unterzogen wird, wobei die Ultraschall-Bildgebungsvorrichtung ferner so konfiguriert ist, dass sie das 3D-Referenz-CEUS-Volumen und die Tracking-Informationen während der Lebensdauer eines kontrastverstärkenden Mittels erfasst, das dem gewünschten Teil der Anatomie verabreicht wird, wobei die Erfassung des 3D-Referenz-CEUS-Volumens die gleichzeitige Erfassung von zumindest einem Paar aus verfolgtem 3D-Ultraschallkontrastbild und Gewebebild umfasst,
ii) in Echtzeit verfolgte Gewebebilder (38) während des Eingriffs erfasst und
iii) zumindest eine entsprechende kontrastverstärkte multiplanare Ultraschallbildrekonstruktion, CEUS MPR, (44) für zumindest eines der erfassten, in Echtzeit verfolgten Gewebebilder während des Eingriffs abhängig von dem 3D-Referenz-CEUS-Volumen und den Tracking-Informationen erzeugt, und
- eine Anzeige (16, 20), die mit der Ultraschall-Bildgebungsvorrichtung verbunden und so konfiguriert ist, dass sie Folgendes anzeigt:

- i) die erfassten, in Echtzeit verfolgten Gewebebilder, wobei die erfassten, in Echtzeit verfolgten Gewebebilder zumindest ein Bild des Instruments in dem gewünschten Teil der Anatomie enthalten, und
 ii) zumindest eine entsprechende kontrastverstärkte multiplanare Ultraschallbildrekonstruktion, CEUS MPR, die dem angezeigten, in Echtzeit verfolgten Gewebebild entspricht, wobei das CEUS-MPR-Bild ein kontrastverstärktes MPR-Bild enthält, das aus dem 3D-Referenz-CEUS-Volumen erzielt wurde und ein interessierendes Zielvolumen enthält, wodurch eine gleichzeitige Anzeige von kontrastverstärkten Bildinformationen und Gewebebildinformationen geschaffen wird, die für die interventionelle Navigation zumindest im Anschluss an den Ablauf der Kontrast verstärkenden Wirkung von Nutzen ist.
2. System nach Anspruch 1, wobei das zumindest eine Paar aus verfolgtem 3D-Ultraschallkontrast- und Gewebebild ferner ein Ausgangsultraschallkontrastbild und ein entsprechendes Ausgangsgewebebild umfasst, die im Wesentlichen gleichzeitig erfasst und automatisch zueinander registriert werden.
3. System nach Anspruch 1, wobei die Ultraschall-Bildgebungsvorrichtung ferner so konfiguriert ist, dass sie während des Eingriffs arbeitet, der einen ersten Abschnitt, der vor dem Ablauf der Kontrast verstärkenden Wirkung stattfindet, und einen zweiten Abschnitt umfasst, der nach dem Ablauf der Kontrast verstärkenden Wirkung stattfindet.
4. System nach Anspruch 1, wobei die zumindest eine entsprechende kontrastverstärkte multiplanare Ultraschallbildrekonstruktion zu einem entsprechenden der erfassten, in Echtzeit verfolgten Gewebebilder räumlich registriert wird.
5. System nach Anspruch 1, wobei das in Echtzeit verfolgte Gewebebild und die entsprechende CEUS MPR nebeneinander angezeigt werden.
6. System nach Anspruch 1, wobei das in Echtzeit verfolgte Gewebebild und das entsprechende CEUS-MPR-Referenzbild zusammen auf einer einzigen Anzeige angezeigt werden.
7. System nach Anspruch 6, wobei ferner das in Echtzeit verfolgte Gewebebild und die entsprechende CEUS MPR in einer überlagerten Anordnung angezeigt werden, sodass ein Bild das andere Bild überlagert.
8. System nach Anspruch 7, wobei ferner die überlagerte Anordnung umfasst, dass ein Bild halbtransparent hinsichtlich des anderen Bildes ist.
9. System nach Anspruch 1, wobei die Ultraschall-Bildgebungsvorrichtung ferner so konfiguriert ist, dass sie das 3D-Referenz-CEUS-Volumen mithilfe eines Systems zum räumlichen Tracking erfasst, das so konfiguriert ist, dass es die Position eines Schallkopfes verfolgt, der bei der Erfassung des 3D-Referenz-CEUS-Volumens verwendet wird, wobei das Tracking-System die Ermittlung der Lage und Ausrichtung des 3D-Referenz-CEUS-Volumens ermöglicht und wobei das System zum räumlichen Tracking ferner so konfiguriert ist, dass es die erfassten Gewebebilder während des Eingriffs verfolgt.
10. System nach Anspruch 9, wobei die Ultraschall-Bildgebungsvorrichtung ferner so konfiguriert ist, dass sie Gewebebewegungen in dem gewünschten Teil der Anatomie, die zwischen i) dem Zeitpunkt der Erfassung des 3D-Referenz-CEUS-Volumens und ii) dem Zeitpunkt der Erfassung des zumindest einen, in Echtzeit verfolgten Gewebebildes auftreten können, korrigiert.
11. System nach Anspruch 10, wobei die Korrektur von Gewebebewegungen die Verwendung einer bildbasierten Registrierung a) des in Echtzeit verfolgten 3D-Gewebebildes zu b) dem Ultraschall-Gewebebild des Paares aus verfolgtem 3D-Ultraschallkontrastbild und Gewebebild umfasst.
12. System nach Anspruch 1, wobei die Ultraschall-Bildgebungsvorrichtung ferner so konfiguriert ist, dass sie das 3D-Referenz-CEUS-Volumen und die Tracking-Informationen erfasst, indem sie eine Zeitreihe von 3D-CEUS-Volumen und entsprechende Tracking-Informationen erfasst, und dass sie das zumindest eine entsprechende CEUS-MPR-Bild erzeugt, indem sie eine Zeitreihe von CEUS-MPR-Bildern erzeugt, und wobei die Anzeige ferner so konfiguriert ist, dass sie die erfassten, in Echtzeit verfolgten Gewebebilder und das zumindest eine entsprechende CEUS-MPR-Bild anzeigt, indem sie die CEUS-MPR-Bilder zusammen mit den Echtzeit-Gewebebildern als Zeitreihendaten anzeigt.
13. System nach Anspruch 12, das ferner Folgendes umfasst:

Mittel zur Verarbeitung der Zeitreihendaten, um eine volumetrische Abbildung von diagnostisch relevanten Parametern zu erstellen und die volumetrische Abbildung zusammen mit i) den CEUS-MPR-Bildern und ii) den Echtzeit-Gewebebildern anzuzeigen.

- 5 **14.** System nach Anspruch 13, wobei die diagnostisch relevanten Parameter zumindest eine Zuflusszeitkonstante des Kontrastmittels einschließen.

Revendications

- 10 **1.** Système (10) de navigation interventionnelle par imagerie ultrasonore 3D à contraste renforcé, CEUS, le système comprenant :

un dispositif d'imagerie ultrasonore (12) conçu pour

i) acquérir un volume CEUS 3D de référence et des informations de repérage pour une partie souhaitée d'une anatomie (22) qui est soumise à une procédure interventionnelle avec un instrument (40), le dispositif d'imagerie ultrasonore étant conçu en outre pour acquérir le volume CEUS 3D de référence et les informations de repérage pendant une durée de vie utile d'un agent de renforcement de contraste administré à la partie souhaitée de l'anatomie, dans lequel l'acquisition du volume CEUS 3D de référence comprend l'acquisition concourante d'au moins une paire d'image ultrasonore 3D contrastée de suivi et d'image de tissu,

ii) acquérir des images de tissu de suivi en temps réel (38) pendant la procédure interventionnelle, et

(iii) générer au moins une reconstruction multiplanaire d'image ultrasonore à contraste renforcé correspondante, MPR CEUS, (44) pour au moins une des images de tissu de suivi en temps réel acquises lors de la procédure interventionnelle en fonction du volume CEUS 3D de référence et des informations de repérage ; et

un écran d'affichage (16, 20) couplé au dispositif d'imagerie ultrasonore et conçu pour afficher

i) les images de tissu de suivi en temps réel acquises, les images de tissu de suivi en temps réel affichées comprenant au moins une image de l'instrument au sein de la partie souhaitée de l'anatomie, et

ii) au moins une reconstruction multiplanaire d'image ultrasonore à contraste renforcé correspondante, MPR CEUS, qui correspond à l'image de tissu de suivi en temps réel affichée, l'image MPR CEUS comprenant une image MPR à contraste renforcé obtenue à partir du volume CEUS 3D de référence et comprenant un volume cible d'intérêt, pour ainsi afficher simultanément des informations d'image à contraste renforcé et des informations d'image de tissu utiles pour la navigation interventionnelle au moins après l'expiration de la durée de vie utile du renforcement du contraste.

2. Système selon la revendication 1, dans lequel la au moins une paire d'image ultrasonore 3D contrastée de suivi et d'image de tissu comprend une image ultrasonore contrastée initiale et une image initiale de tissu correspondante capturées sensiblement simultanément et alignées automatiquement l'une par rapport à l'autre.

3. Système selon la revendication 1, dans lequel le dispositif d'imagerie ultrasonore est conçu en outre pour fonctionner lors de la procédure interventionnelle qui comprend une première partie qui a lieu avant l'expiration de la durée de vie utile du renforcement du contraste et une seconde partie qui a lieu après l'expiration de la durée de vie utile du renforcement du contraste.

4. Système selon la revendication 1, dans lequel la au moins une reconstruction multiplanaire d'image ultrasonore à contraste renforcé correspondante est alignée spatialement avec une image correspondante des images de tissu de suivi en temps réel acquises.

5. Système selon la revendication 1, dans lequel l'image de tissu de suivi en temps réel et la MPR CEUS correspondante sont affichées l'une à côté de l'autre.

6. Système selon la revendication 1, dans lequel l'image de tissu de suivi en temps réel et l'image MPR CEUS de référence correspondante sont affichées ensemble sur un seul écran d'affichage.

7. Système selon la revendication 6, dans lequel l'image de tissu de suivi en temps réel et la MPR CEUS correspondante sont affichées selon un agencement de chevauchement de façon qu'une image recouvre l'autre image.
8. Système selon la revendication 7, dans lequel l'agencement de chevauchement comprend une image qui est semi-transparente par rapport à l'autre image.
9. Système selon la revendication 1, dans lequel le dispositif d'imagerie ultrasonore est conçu en outre pour acquérir le volume CEUS 3D de référence au moyen d'un système de suivi spatial conçu pour suivre la position d'une sonde ultrasonore utilisée pour acquérir le volume CEUS 3D de référence, dans lequel le système de suivi permet la détermination d'un emplacement et d'une orientation du volume CEUS 3D de référence ; et dans lequel le système de suivi spatial est conçu en outre pour suivre les images de tissu acquises lors de la procédure interventionnelle.
10. Système selon la revendication 9, dans lequel le dispositif d'imagerie ultrasonore est conçu en outre pour corriger les mouvements du tissu au sein de la partie souhaitée de l'anatomie qui peuvent se produire entre i) un moment de l'acquisition du volume CEUS 3D de référence, et ii) un moment de l'acquisition de la au moins une image de tissu de suivi en temps réel.
11. Système selon la revendication 10, dans lequel la correction des mouvements du tissu comprend l'utilisation d'un alignement basé sur les images entre a) l'image 3D de tissu de suivi en temps réel et b) l'image ultrasonore de tissu de la paire d'image ultrasonore 3D contrastée de suivi et d'image de tissu.
12. Système selon la revendication 1, dans lequel le dispositif d'imagerie ultrasonore est conçu en outre pour acquérir le volume CEUS 3D de référence et les informations de repérage par l'acquisition d'une série temporelle de volumes CEUS 3D et d'informations de repérage correspondantes, et pour générer la au moins une image MPR CEUS correspondante par la génération d'une série temporelle d'images MPR CEUS, et dans lequel l'écran d'affichage est conçu en outre pour afficher les images de tissu de suivi en temps réel acquises et la au moins une image MPR CEUS correspondante par le co-affichage des images MPR CEUS avec les images de tissu en temps réel sous la forme de données de série temporelle.
13. Système selon la revendication 12, comprenant en outre :
des moyens pour traiter les données de série temporelle afin de créer une carte volumétrique de paramètres appropriés pour le diagnostic et pour co-afficher la carte volumétrique avec i) les images MPR CEUS et ii) les images de tissu en temps réel.
14. Système selon la revendication 13, dans lequel les paramètres appropriés pour le diagnostic comprennent au moins une constante temporelle en flux de l'agent de contraste.

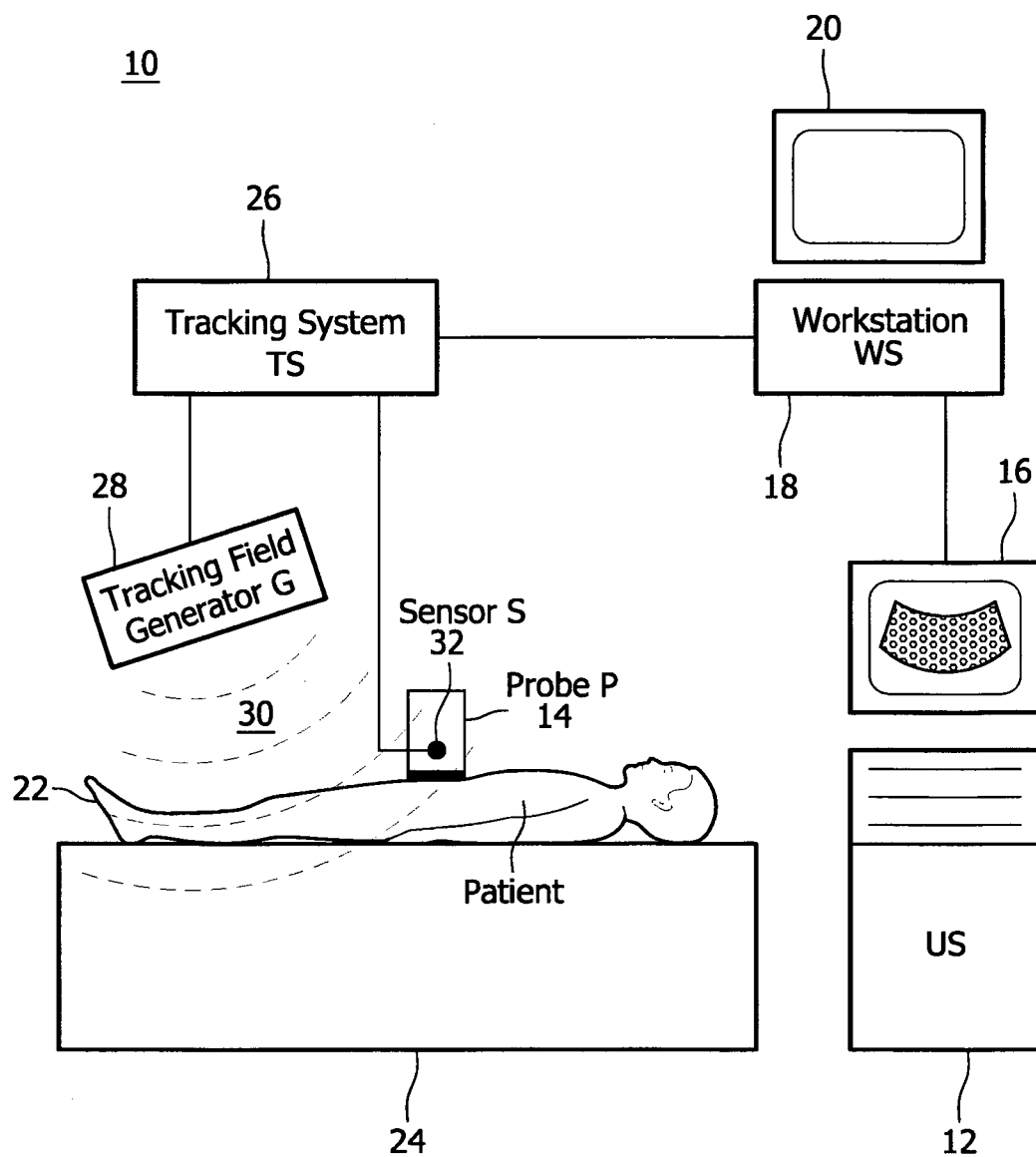


FIG. 1

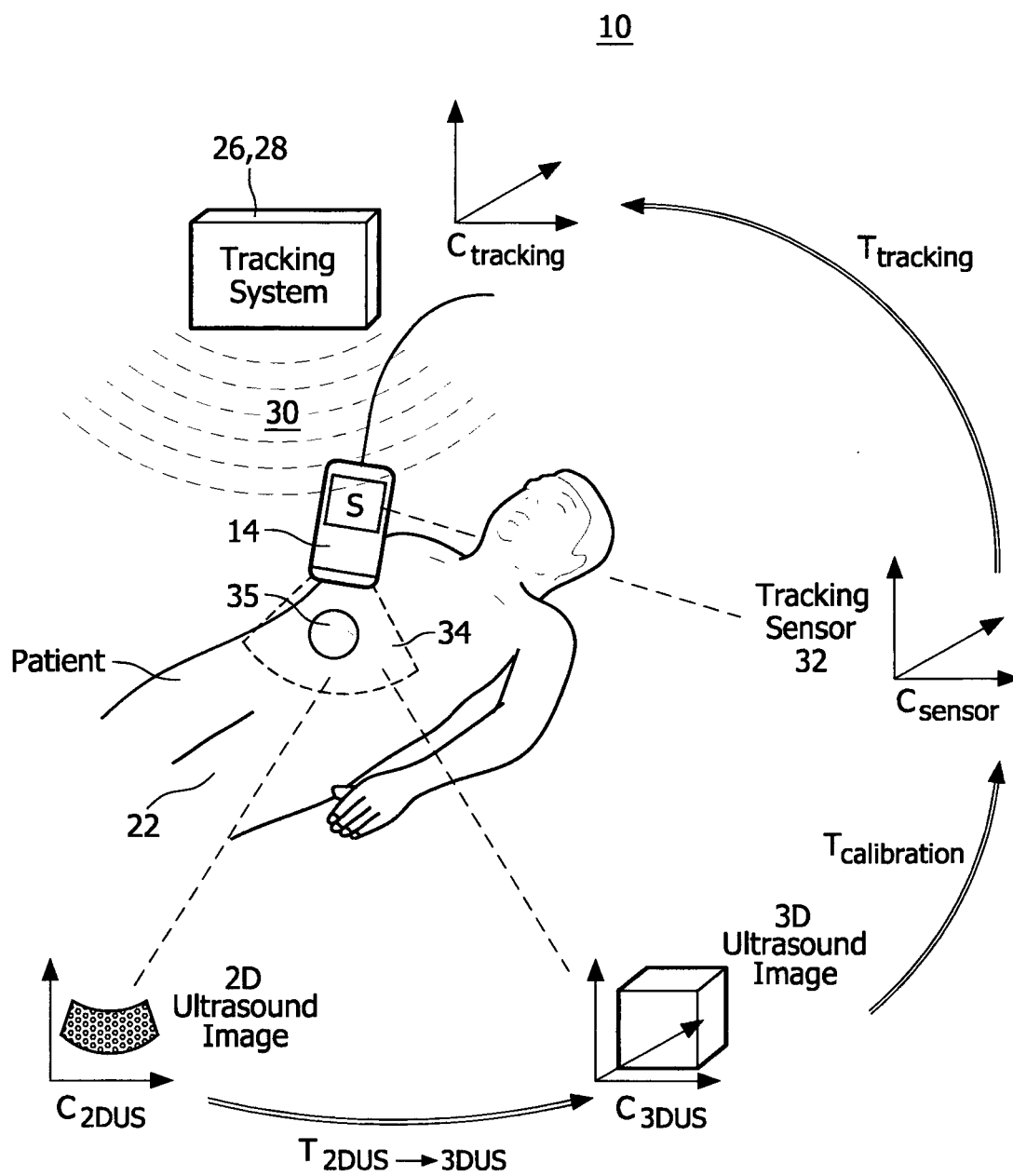


FIG. 2

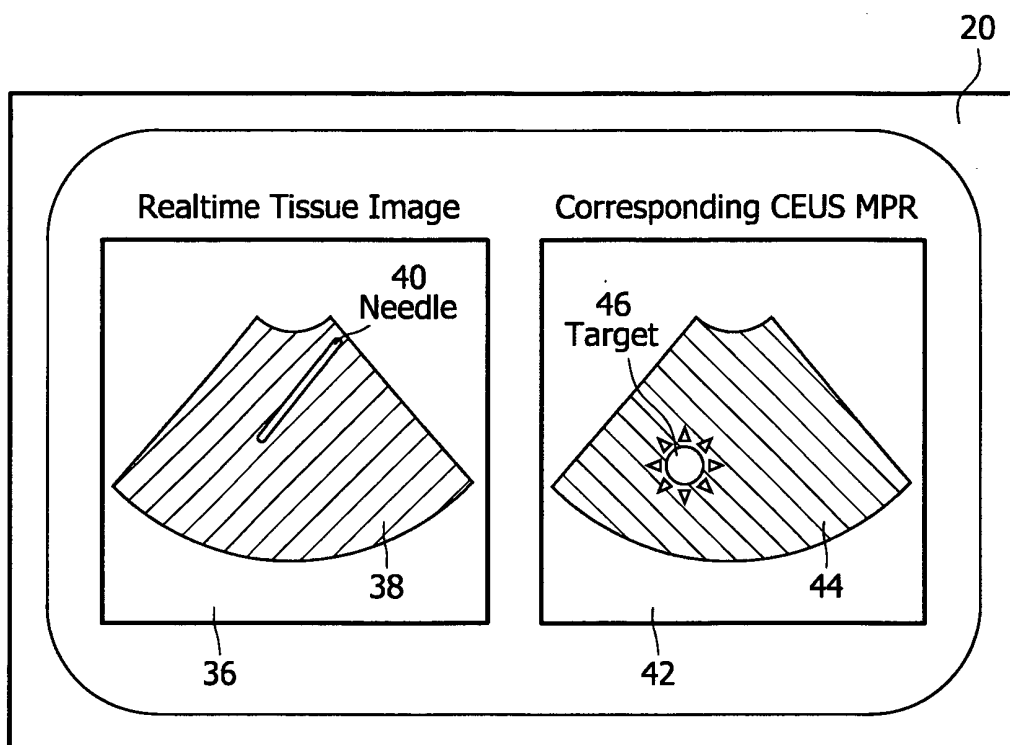


FIG. 3

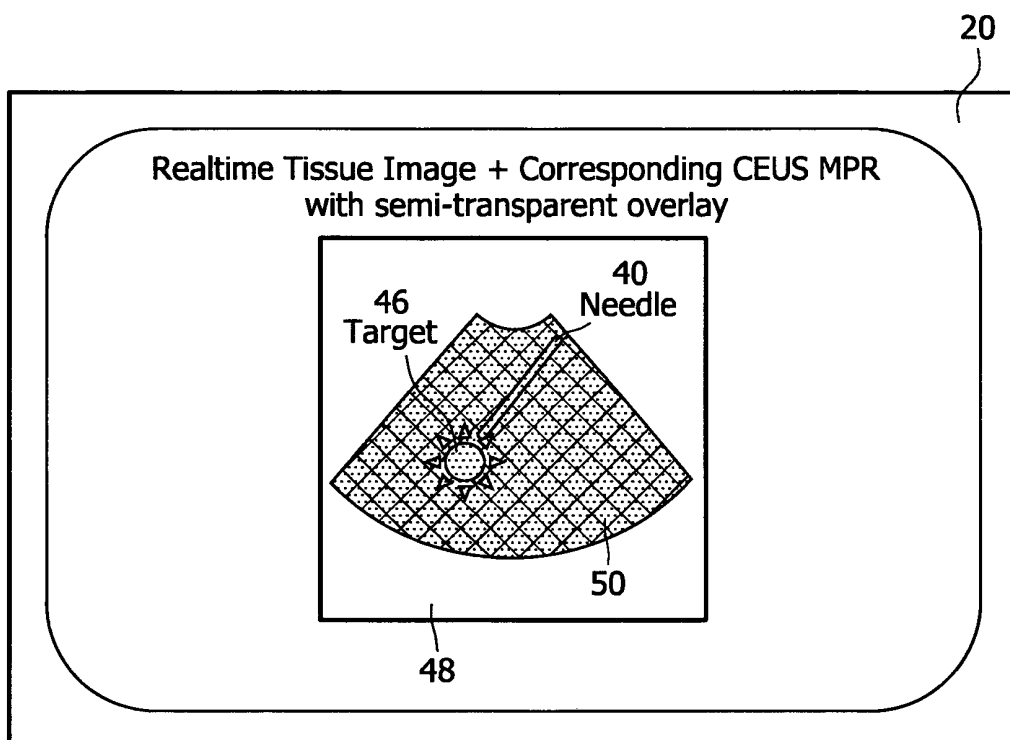


FIG. 4

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 20060020204 A1 [0002]

专利名称(译)	使用3D对比增强超声的介入导航		
公开(公告)号	EP2212716B1	公开(公告)日	2014-02-26
申请号	EP2008850546	申请日	2008-11-13
[标]申请(专利权)人(译)	皇家飞利浦电子股份有限公司		
申请(专利权)人(译)	皇家飞利浦电子N.V.		
当前申请(专利权)人(译)	皇家飞利浦N.V.		
[标]发明人	KRUECKER JOCHEN XU SHENG JIANG HUI		
发明人	KRUECKER, JOCHEN XU, SHENG JIANG, HUI		
IPC分类号	G01S15/89 A61B8/08		
CPC分类号	G01S15/899 A61B8/0833 A61B8/4245 A61B8/4263 G01S7/52074 G01S7/52098 G01S15/8993		
优先权	61/052288 2008-05-12 US 60/988472 2007-11-16 US		
其他公开文献	EP2212716A1		
外部链接	Espacenet		

摘要(译)

一种使用3D对比度增强超声 (CEUS) 成像 (10) 的介入导航的方法包括获取参考3D CEUS体积并跟踪用于使用器械 (40) 进行介入手术的解剖结构 (22) 的期望部分的信息，在给予解剖结构的造影增强剂的使用寿命期间。在介入过程期间获取实时跟踪的组织图像 (38)。另外，生成用于所获取的实时跟踪的组织图像中的至少一个的对应的CEUS多平面重建 (MPR) (44)。获取的实时跟踪组织图像中的至少一个与对应的CEUS MPR一起显示 (20)。所显示的实时跟踪的组织图像至少包括在解剖结构的期望部分内的器械的图像，并且CEUS MPR对应于所显示的实时跟踪的组织图像。CEUS MPR图像包括从参考3D CEUS体积获得的对比度增强的MPR图像，并且包括感兴趣的目标体积 (46)，从而提供对于介入导航有用的对比度增强图像信息和组织图像信息的并发显示，至少后续到对比度增强使用寿命到期。

