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(54) **ULTRASONIC CARDIAC ASSESSMENT OF HEARTS WITH MEDIAL AXIS CURVATURE AND TRANSVERSE ECCENTRICITY**

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(57) **ABSTRACT**

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An ultrasonic imaging system produces more diagnostic cardiac images of the left ventricle by plotting the longitudinal medial axis of the chamber between the apex and mitral valve plane as a curved line evenly spaced between the opposite walls of the myocardium. Transverse image planes are positioned orthogonal to the curved medial axis with control points positioned in the short axis view on lines evenly spaced around and emanating from the medial axis. If the short axis view is of an oval shaped chamber the transverse image is stretched to give the heart a more rounded appearance resulting in better positioning of editing control points.

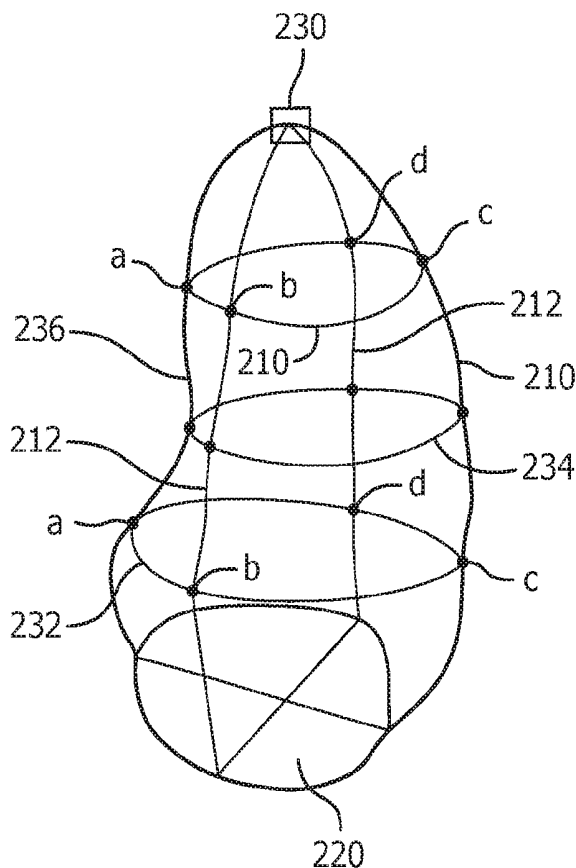
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§ 371 (c)(1),

(2) Date: **May 17, 2018**

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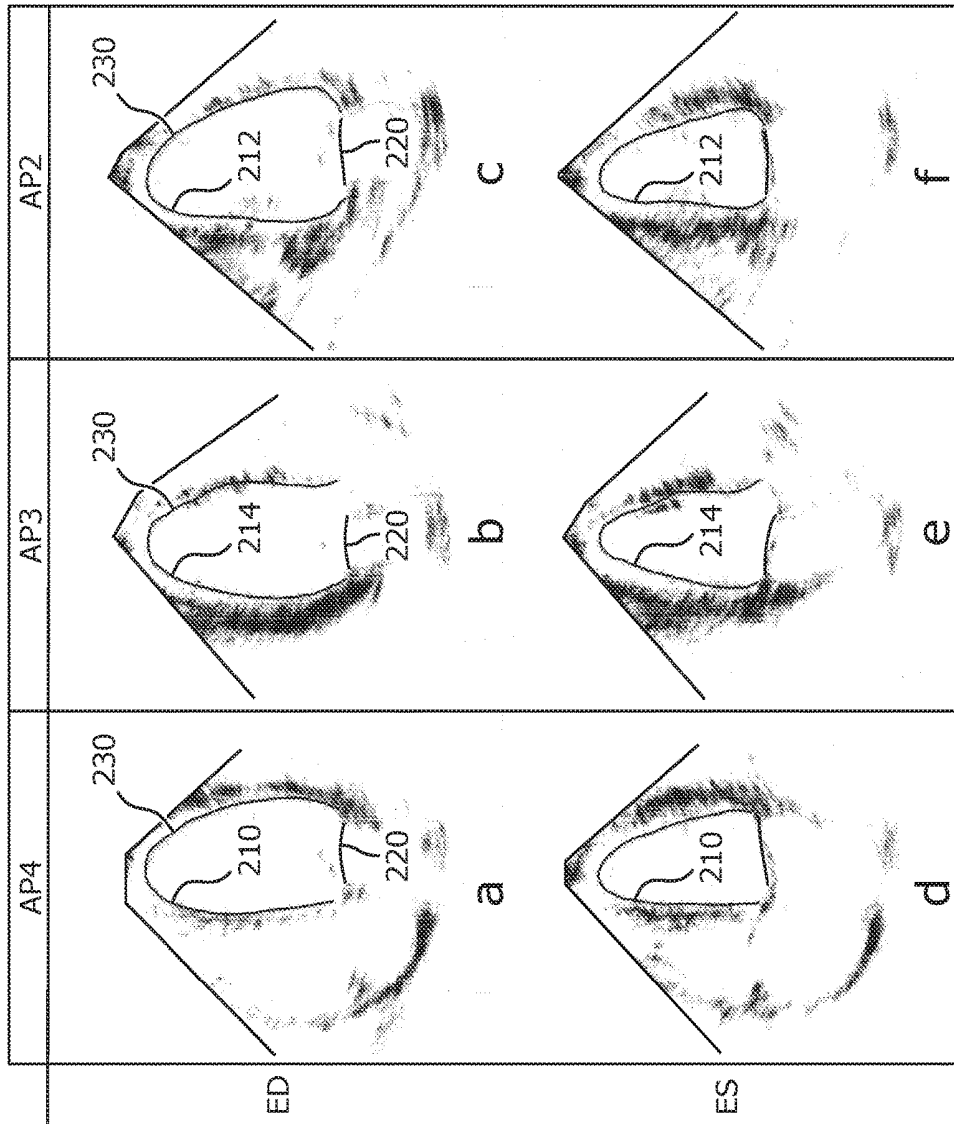


FIG. 1

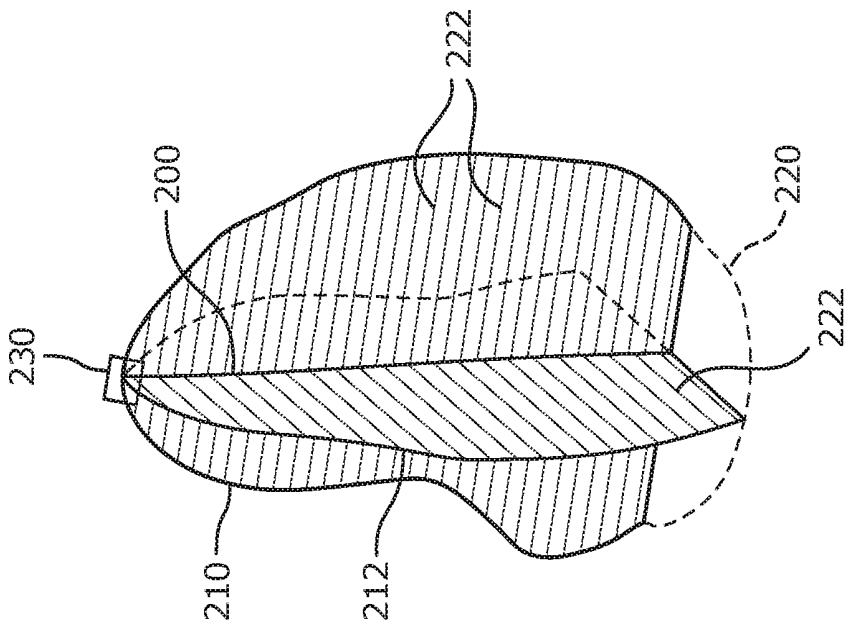


FIG. 2a

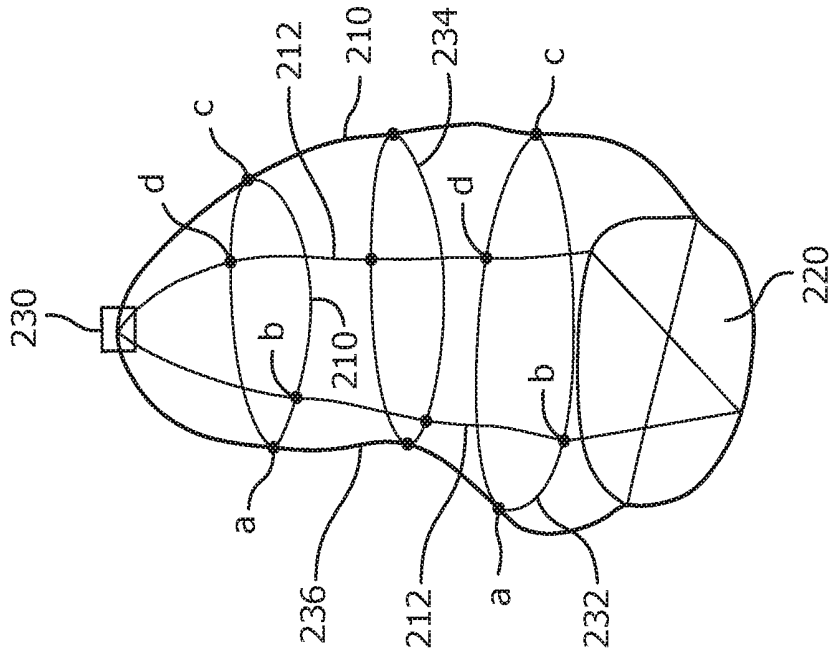


FIG. 2b

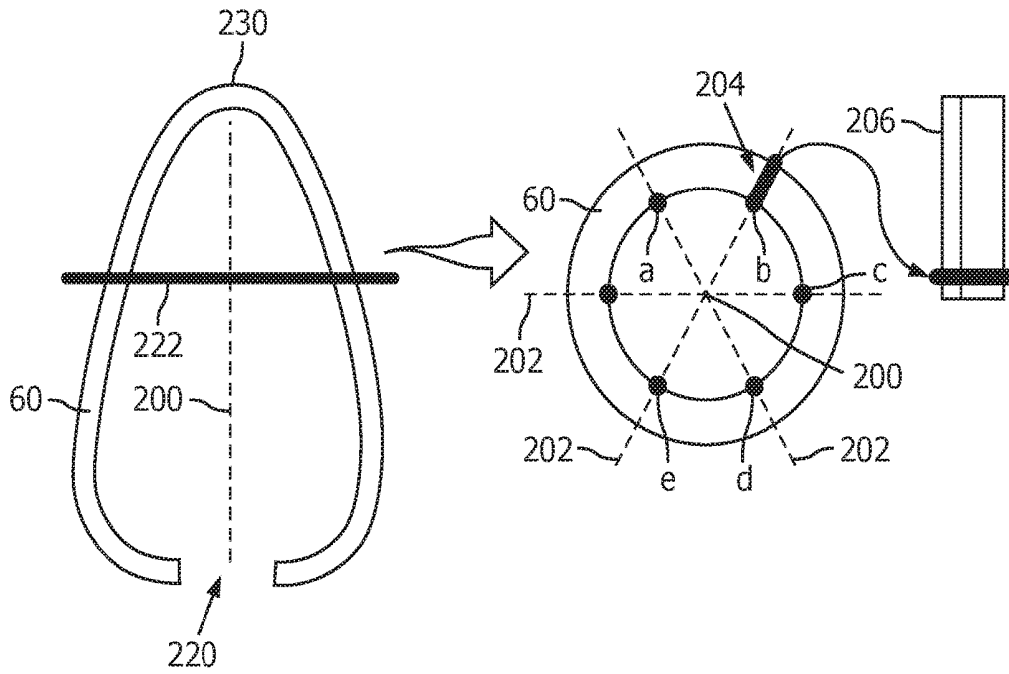


FIG. 3a

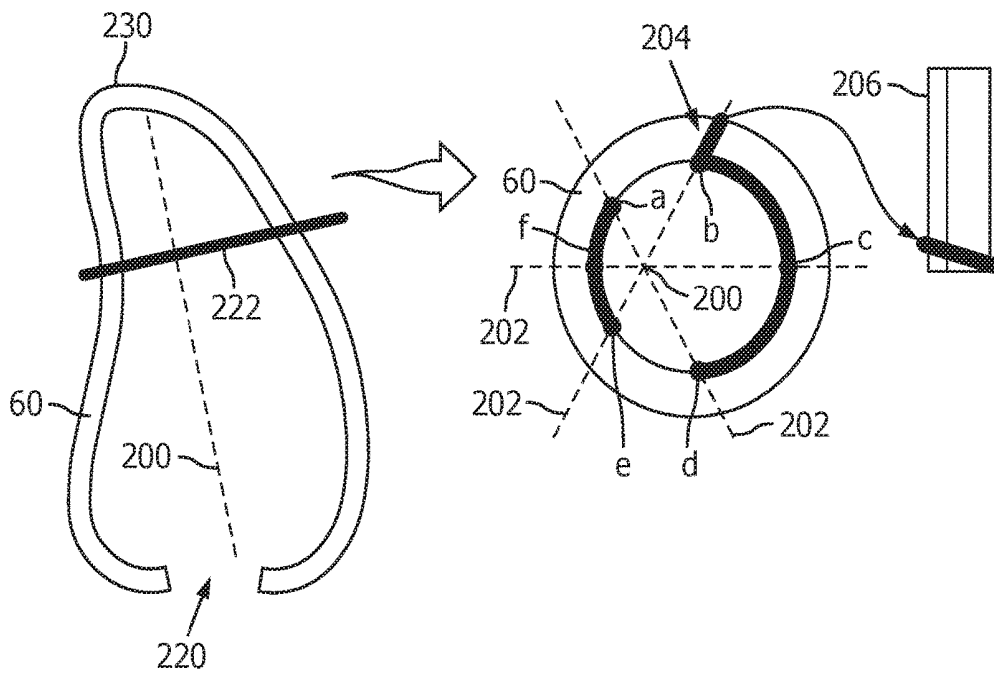


FIG. 3b

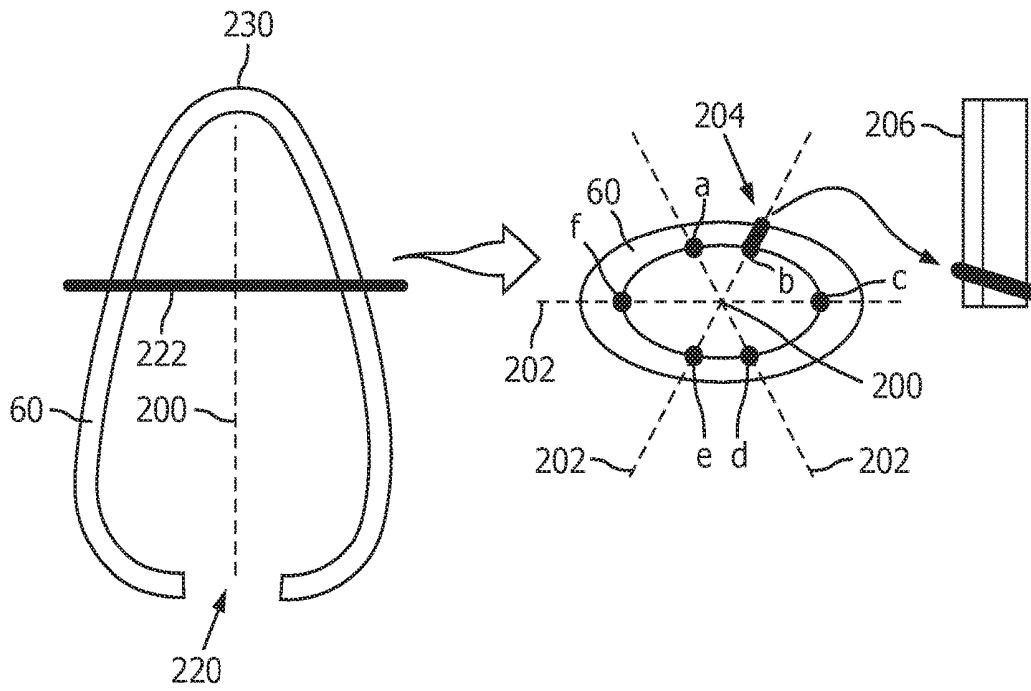


FIG. 3c

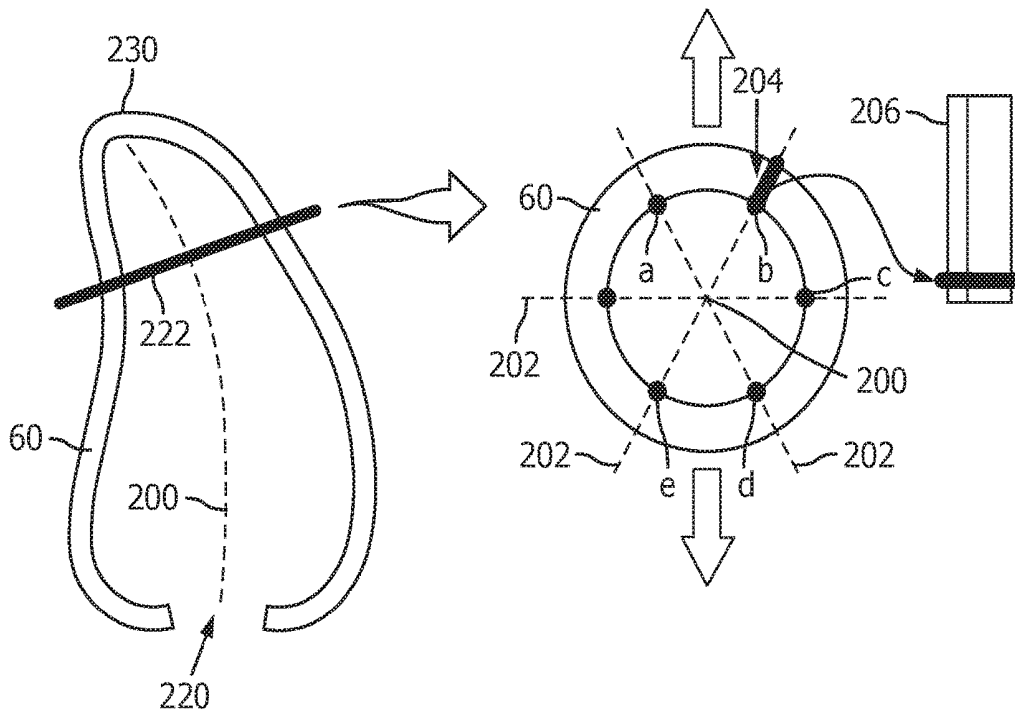
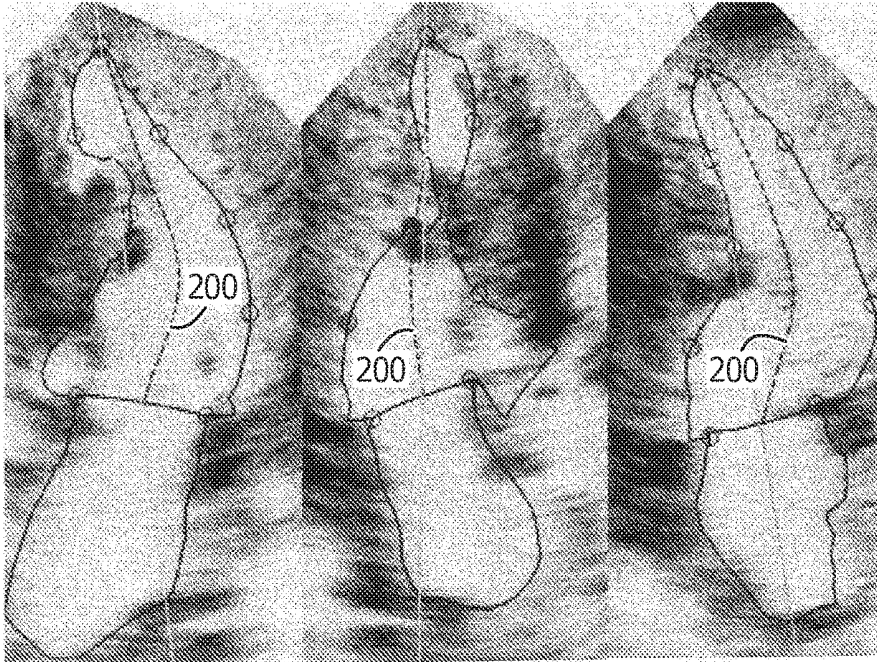


FIG. 3d

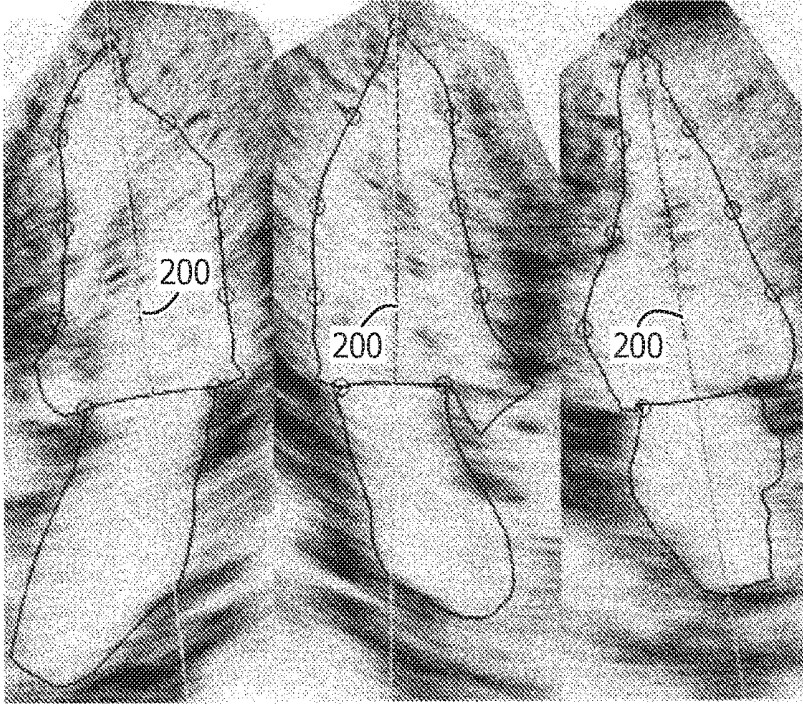


a

b

c

FIG. 4



a

b

c

FIG. 5

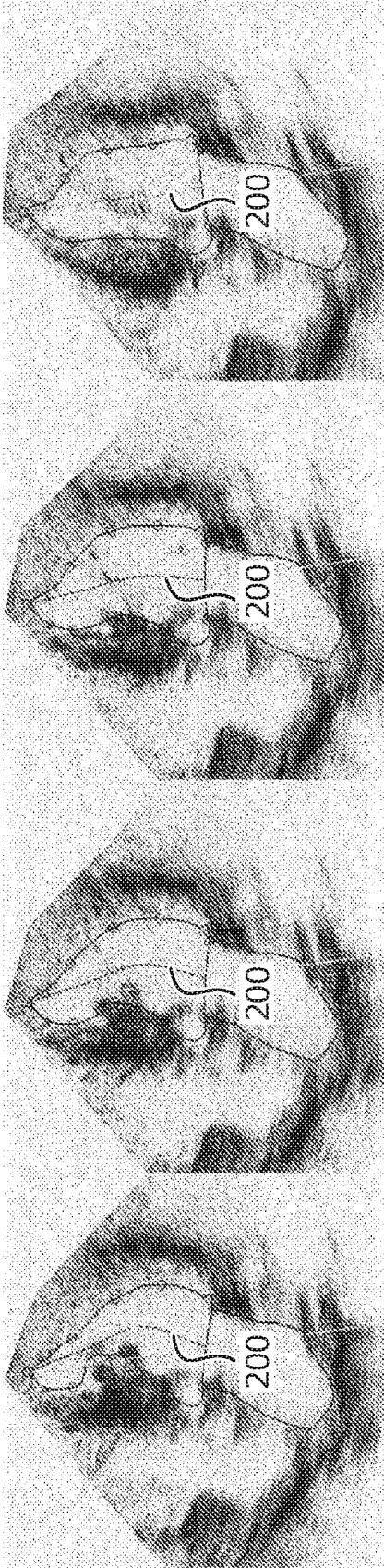


FIG. 6

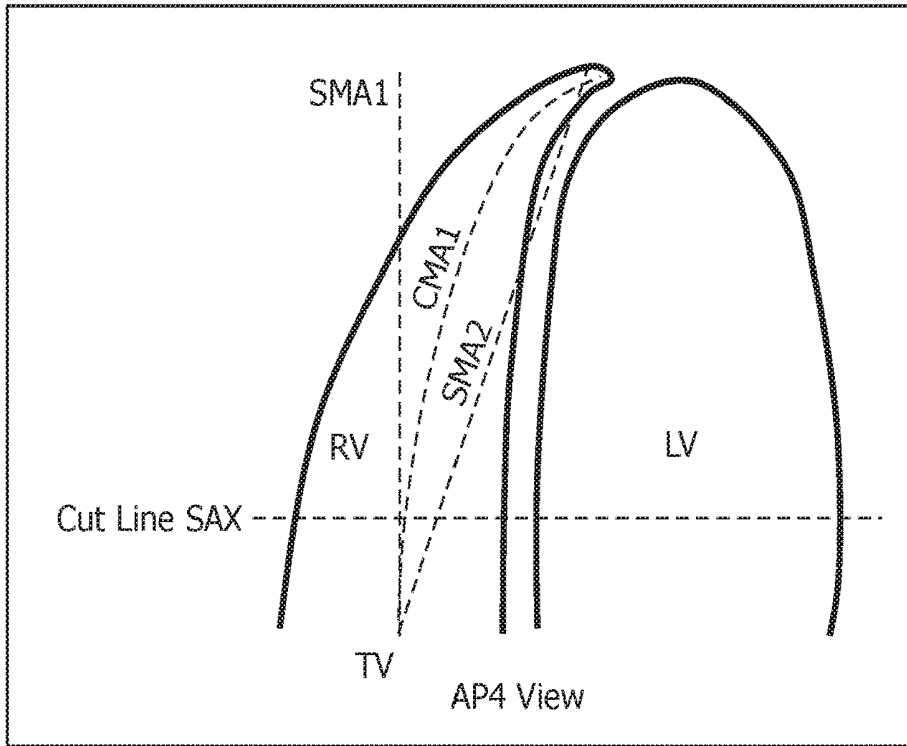


FIG. 7a

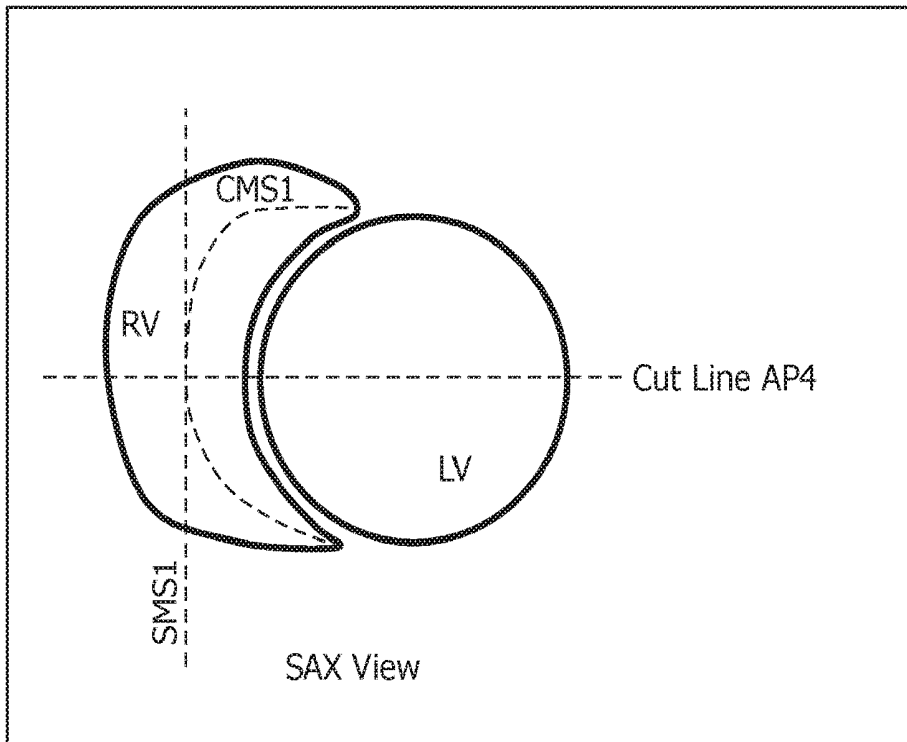


FIG. 7b

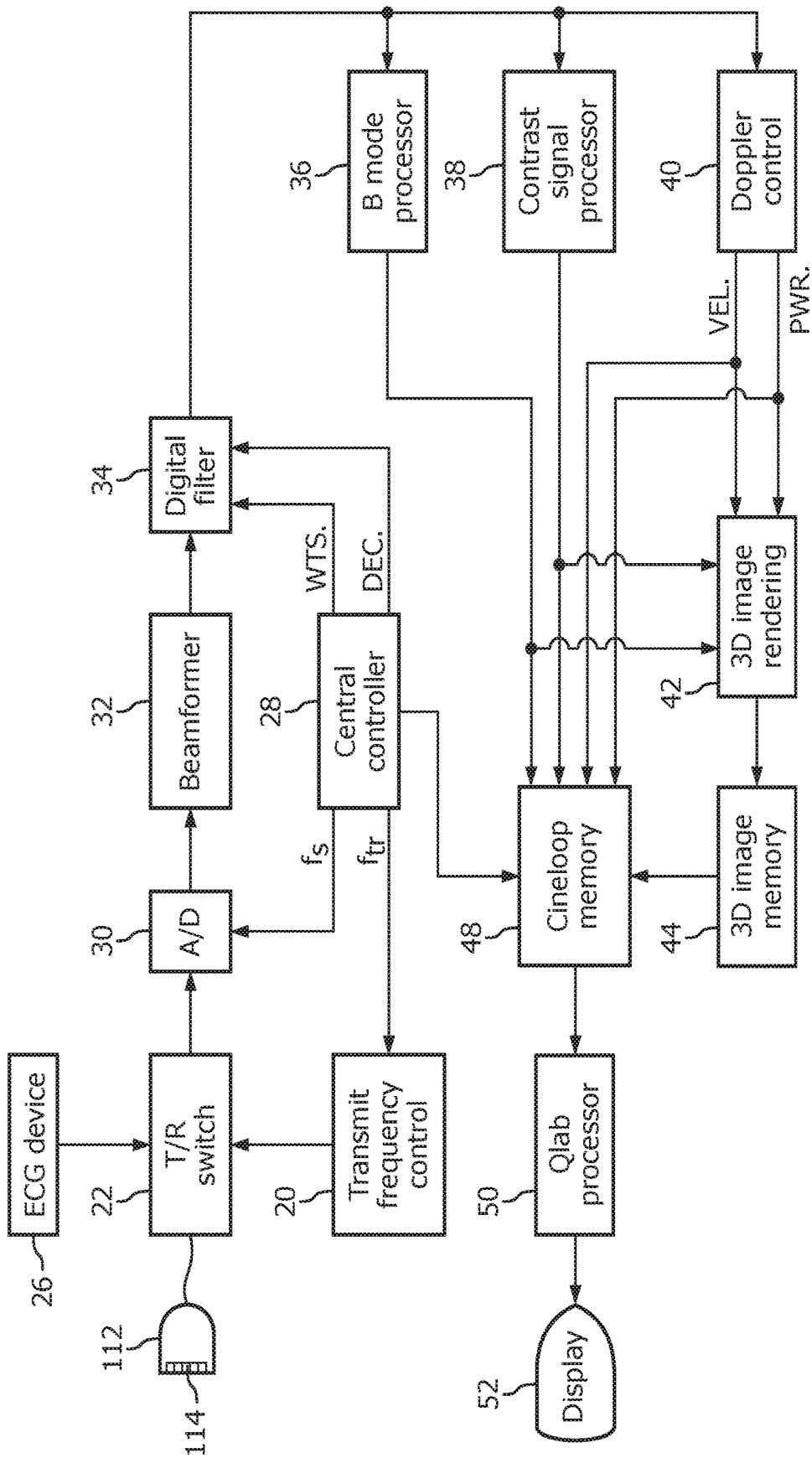


FIG. 8

**ULTRASONIC CARDIAC ASSESSMENT OF  
HEARTS WITH MEDIAL AXIS CURVATURE  
AND TRANSVERSE ECCENTRICITY**

**[0001]** This invention relates to medical diagnostic ultrasound systems and, in particular, to ultrasound systems which perform cardiac assessment of hearts with axial curvature and transverse irregularity.

**[0002]** Ultrasonic imaging is widely used to assess and diagnose the condition of the heart. An ultrasound probe pressed against the body of a patient just below the rib cage and aimed upward to view the heart from its apex. When the heart is fully in view in real time images, a sequence of three dimensional image datasets is acquired over a heart cycle. The three dimensional image data is analyzed by a segmentation processor to identify various features and characteristics of the heart, such as the endothelial border of the left ventricle, ejection fraction, and myocardial motion. Two such processors for cardiac analysis are the automated border detection processor described in U.S. Pat. No. 6,491,636 (Chenal et al.) and the heart model processor described in U.S. Pat. No. 7,101,164 (Weese et al. and US Pat. pub. no. 2010/0189317 (Lehmann et al.)) With analytical tools such as these, the clinician can command the processor to segment the cardiac data over the heart cycle, identifying the valves and chambers of the heart and showing the heart in standard ASE views from which diagnosis proceeds. However, since there is a great variability among patients as to patient size, body habitus, and heart shapes and orientation, the clinician will edit the automatically delineated borders to best fit the anatomical boundaries that the clinician perceives in the images. Two characteristics which pose problems for this editing are a pronounced longitudinal curvature and/or an eccentric transverse shape of the heart. A longitudinal curvature of the left ventricle can preclude an MPR (multiplanar reconstructed) image plane through the three dimensional image data from being able to show an adequate long axis presentation in all of the standard ASE views. Transverse eccentricity of the heart can make border delineation more difficult and edit control spacing less regular. Accordingly it is desirable for an ultrasonic cardiac diagnostic processor to adequately present a long axis view of the heart, with good border orthogonality and edit control spacing in each of the standard ASE views.

**[0003]** In some aspects, the present invention includes ultrasound systems and methods. For example, the present invention can include an ultrasonic diagnostic imaging system for cardiac diagnosis. The system can have instruction thereon, which when executed cause the system to: acquire, using a probe, three dimensional ultrasound image datasets of including the a heart, produce image data of a myocardium and a heart chamber, delineate a curved medial axis of the heart chamber between a longitudinally separated apex and valve plane which that is substantially evenly positioned between opposite walls of the myocardium, and display a heart chamber image in a plane of the curved medial axis.

**[0004]** In certain aspects, the systems of the present invention can include an ultrasonic diagnostic imaging system for cardiac diagnosis that includes a probe configured to acquire three dimensional ultrasound image datasets including a heart, a first processor configured to produce image data of a myocardium and a heart chamber, a second processor configured to delineate a curved medial axis of the heart chamber between a longitudinally separated apex and valve plane that is substantially evenly positioned between oppo-

site walls of the myocardium, and a display for displaying a heart chamber image in a plane of the curved medial axis.

**[0005]** In some aspects, the present invention includes a method of diagnosing a patient by ultrasonic cardiac imaging. The method can include acquiring a sequence of three dimensional image datasets of a heart, extracting a long axis view of a myocardium and heart chamber, and delineating a curved medial axis of the heart chamber between an apex and valve plane which is evenly spaced between opposite walls of the myocardium.

IN THE DRAWINGS

**[0006]** FIG. 1 illustrates standard ASE views of a heart at end diastole and end systole.

**[0007]** FIG. 2a illustrates the intersection of the planes of the left ventricular chamber in two standard views.

**[0008]** FIG. 2b a three dimensional mesh of the left ventricle with control points for editing.

**[0009]** FIG. 3a illustrates the medial axis and control points of longitudinal and transverse cardiac images for a uniformly symmetrical heart shape.

**[0010]** FIG. 3b illustrates the medial axis and control points of longitudinal and transverse cardiac images for a heart with a longitudinally curved shape.

**[0011]** FIG. 3c illustrates the medial axis and control points of longitudinal and transverse cardiac images for a heart with an eccentric transverse shape.

**[0012]** FIG. 3d illustrates the medial axis and control points of longitudinal and transverse cardiac images of a heart corrected for these irregularities in accordance with the principles of the present invention.

**[0013]** FIG. 4 shows three cardiac images of hearts with longitudinal curvature.

**[0014]** FIG. 5 shows the same heart data after correction with curved MPRs in accordance with the principles of the present invention.

**[0015]** FIG. 6 illustrates animation of the transition from planar to curved MPRs of a heart in accordance with the present invention.

**[0016]** FIG. 7 illustrates the intersection of MPR planes of a right ventricular chamber in two standard views.

**[0017]** FIG. 8 illustrates in block diagram form an ultrasound system constructed in accordance with the principles of the present invention.

**[0018]** In accordance with the principles of the present invention, an ultrasonic diagnostic system and method are described which correct for heart curvature and transverse eccentricity in ultrasonic cardiac images. The usual straight-line medial axis is plotted as a curved line evenly spaced between the chamber walls and extending from the apex to mitral valve plane. Transverse eccentricity is reduced by stretching the myocardium in the image to produce a more uniform shape. As a result of these measures, the borders of the cardiac chamber are presented such that chamber walls are more equidistant and orthogonal to the viewing plane, enabling the creation of more complete long axis MPR views and allowing for in-plane edits of transverse MPR planes to represent more equidistant and orthogonal displacement of segmented boundaries and control points. Non-foreshortened long axis MPR views are produced which are curvilinear slices that pass through the curved medial axis. Editing of the control points in one of the standard views will now operate more independently of the

other views and improve the visualization and diagnosis of the interface being delineated.

**[0019]** FIG. 1 illustrates three standard views of a heart from which diagnosis proceeds, and apical four-chamber (AP4) view, an apical three-chamber (AP3) view, and an apical two-chamber (AP2) view. The top three images a, b, and c are of a heart at the end diastole phase, and the bottom three images d, e, and f are of the heart at the end systole phase. Image analysis tools such as the Heart Model, part of the QLAB feature on Philips Healthcare (Andover, Mass.) ultrasound systems, can automatically segment these standard view planes as MPR image planes from volume (3D) data of a heart. The QLAB feature is also capable of automatically tracing borders of the heart in an ultrasound cardiac image, such as the boundary **210**, **212** and **214** of the left ventricle (LV) and the mitral valve plane **220** in these views as illustrated in FIG. 1. Similarly, borders can be automatically traced for other features of the heart, such as the right ventricle.

**[0020]** The three standard view planes intersect each other at a common medial axis of the LV at relative rotational angles of approximately  $0^\circ$ ,  $60^\circ$  and  $100^\circ$ . The intersection of two of the standard view planes is illustrated in FIG. 2a, where the LV plane in the AP4 view, outlined at **210**, is shown intersecting the LV plane of the AP2 view, outlined at **212**, at medial axis **200**. Also shown in FIG. 2a are lines **222** indicating where transverse (short axis) view planes may be reconstructed as MPR images from the volume image data. Since all these two dimensional view planes are extracted from the same volume image data, their heart wall outlines can be organized as a mesh or wire frame model of the three dimensional left ventricular chamber as shown in FIG. 2b. The points where the different border tracings intersect each other are marked as a, b, c in the drawing. While the FIG. 2a drawings represent an ideal case, in practice the 3D image data may not be fully susceptible to identifying the entirety of all of the border tracings **210**, **212**, **232**, **234** and **236** (and others) automatically, or at least not to the complete satisfaction of the diagnosing physician. Thus, the QLAB image diagnosis program creates control points around automatically drawn borders which can be manipulated by the physician to relocate the border tracing relative to the image. When the physician pulls or moves a control point in a view plane with a pointing device such as a trackball or mouse, the border tracing will move to a new position with the control point but remain smoothly connected to adjacent control points, a process known as "rubberbanding." In FIG. 2b intersection points a, b, and c can be used as control points for the illustrated border tracings. A problem arises, however, if the control points are located too close to each other. In such case, the border processing program cannot smoothly reposition the connected border tracing. Instead, the tracing will jump and become unstable as the physician attempt movement of a control point. Furthermore, attempts to reposition a control point in one view plane can affect the position of a tracing and control point in another view plane when the control points are too close together. As FIG. 2b illustrates, the borders of the different view planes are all spatially inter-related by their relation to the common 3D image dataset. Hence it is desirable to have regular, even spacing of the control points so that editing of their position will not cause instability of the tracing or affect the border tracings and control points in other view planes.

**[0021]** With images of a longitudinally straight and uniformly symmetrical heart these editing problems generally do not arise. FIG. 3a illustrates the myocardium **60** of a longitudinally straight and symmetrical heart. Its medial axis **200**, automatically drawn between the apex **230** of the heart and the center of the mitral valve plane **220** at the bottom of the LV, is straight down the center of the LV chamber. A flat view plane that passes through the straight medial axis **200** will capture a complete, non-foreshortened long axis view of the LV. When a transverse view plane **222** is created orthogonal to the medial axis **200**, the symmetrical myocardium **60** will appear approximately circular, as shown on the right side of FIG. 3a. When evenly angularly distributed control point positioning lines **202** are located emanating from the medial axis **200**, their intersection with the heart wall produce evenly distributed control points a, b, c, d, and e. Furthermore the positioning lines are seen to intersect the myocardium orthogonally. This produces the short path **204** through the endocardial border and myocardium, useful for measuring correct myocardial thickness, as illustrated by bar **206**.

**[0022]** Not all hearts are ideally shaped for this image analysis, however. FIG. 3b illustrates the myocardium **60** of a heart with a curved longitudinal shape, a so-called banana-shaped heart. When the medial axis **200** is drawn between the apex **230** and the mitral valve plane **220**, it is seen to be closer to the left side of the heart and further from the right side of the heart as the drawing illustrates. An orthogonally located transverse plane **222** will appear as shown to the right in the drawing, with the medial axis **200** close to the left side of the heart and far from the right side. When the control point positioning lines **202** are drawn emanating from the medial axis **200** their points of intersection with the myocardium **60** are not uniformly distributed around the heart. Control points b, c, and d are widely separated, and points a, f and e are much closer together. When the physician attempts to reposition control point f, it can cause instability and inadvertent repositioning of closely adjacent points a and e. Furthermore, the positioning lines **202** do not intersect the heart wall orthogonally, but at different angles. Measurement of the endocardial border and myocardial thickness are distorted and inaccurate, as illustrated by the tilted positioning line through the bar **206** to the right in the drawing.

**[0023]** FIG. 3c illustrates a condition where the myocardium is not longitudinally curved, but is more transversely oval rather than rounded as shown to the right in the drawing. The oval shape of the myocardium causes the control points a, b and d, e to be too closely spaced and control points c and f to be widely separated from their adjacent control points. While the horizontal control point positioning line intersects the myocardium **60** orthogonally in the short axis view, the intersections of the other positioning lines **202** are not orthogonal, again causing a distortion of the thickness of the myocardium along the positioning lines, as shown at **204** and in bar **206**.

**[0024]** In accordance with the principles of the present invention, these problems are mitigated by plotting a curved medial axis **200** as shown in FIG. 3d. The medial axis **200** is drawn, not as a straight line between the apex **230** and the mitral valve plane **220**, but as a curve which is evenly positioned between the opposite sides of the heart in the view plane as shown in FIG. 3d. The curve may not rigorously follow the heart anatomy, but may be smoothed

by the image processing software into a smooth curve, rather than a jagged and rapidly changing curve. A quadratic curve model is preferred for such smoothly curved axes. The result is illustrated by the smooth medial axis curve **200** on the left side of FIG. **3d**. Compared with FIG. **3b**, the curved medial axis causes orthogonal transverse axis image planes to have a more centrally located medial axis **200** from which evenly spaced control point positioning lines **202** will intersect the myocardium in the short axis more orthogonally, as shown on the right side of FIG. **3d**. This will create a more orthogonal path the myocardium as shown at **204** and by bar **206**, accurately indicating the true myocardial thickness. In accordance with a further aspect of the present invention, any pronounced oval shaping of the myocardium in the short axis view is reduced by “stretching” the myocardium in the image with the image processing software to produce a more rounded shape, as indicated by the arrows on the right side of FIG. **3d**. Centerline-orthogonal affine stretching is preferred for this image processing. When both of these modifications are applied, the transverse view of the heart and its cut planes appear more like those of the ideal heart shape of FIG. **3a**, and will enable heart measurements which are closer to those which a diagnosing physician is seeking.

**[0025]** Since the viewing medium for an ultrasound system is a flat display, the benefit of the medial axis curvature for a long axis view is best presented to the diagnosing physician by sampling the 3D image data to produce a curvilinear slice that passes through the curved medial axis, then straightening the curved image to a flat plane for display. The final image will thus show the medial axis, when displayed, as a straight line. The results of elastic deformation of the curved plane intersecting the curved medial axis may be appreciated by viewing the images of FIGS. **4** and **5**. In FIG. **4**, the medial axis **200** in anatomically correct images of the LV has been curved as discussed above in heart images *a*, *b*, and *c*. When elastic deformation is performed to view the curved planes defined by the curved medial axes **200** as flat planes in the plane of the ultrasound system image display, the LV appears as shown in FIGS. **5a**, **5b**, and **5c**, respectively, with the medial axes shown as straight lines. As the images illustrate, the boundary and area of the LV in the processed images of FIG. **5** are less irregular and lend themselves more readily to diagnosis and measurement.

**[0026]** It is important that the diagnosing physician recognize that the processed images of FIG. **5** are not the anatomically correct images acquired by the ultrasound system, but have been processed to be more susceptible to diagnosis and measurement. In accordance with a further aspect of the present invention, an ultrasound system of the present invention can produce an animation of the change from an image with a curved medial axis image to one in which the curvature has been straightened, as illustrated in FIG. **6**. The image on the left side of FIG. **6** is the image of FIG. **4a**, in which the medial axis has been drawn as a curved line positioned evenly between the opposite side walls of the anatomically correct LV. The image on the right side of FIG. **6** is that of FIG. **5a**, which results from deformation of the curved axis MPR plane to a straight one. The intermediate images between the left and right ends of FIG. **6** illustrate two images produced in a sequence of progressive straightening of the medial axis. When these images (and others) are played to the diagnosing physician by the image processing software as an animation sequence, the physician can readily grasp the image processing effect on the original image on

the left, and observe how it has been changed to the more diagnostic but less anatomically correct image on the right.

**[0027]** As explained for the left ventricle, the present disclosure can be used for other heart chambers, such as the right ventricle (RV), as well. FIGS. **7A** and **7B** show examples of using a curved MPR plane for a curved right ventricle. The AP4 view in FIG. **7A** shows three MPR planes as identified by the dashed lines, referred to as a straight MPR Apical **1** (SMA1), a straight MPR Apical **2** (SMA2), and curved MPR apical (CMA1). The SMA1 is positioned at the center of the tricuspid valve (TV), and further orthogonal to the AP4 view plane and the short-axis view plane (SAX). Here, SMA1 results in a foreshortened view of the RV chamber. Alternatively, SMA2 can be oriented to pass through the TV and the apex of the RV, but this view also results in a foreshortened or inaccurate view of the RV chamber. As shown, the CMA1 plane, which is determined similar to the LV analysis described above, is positioned evenly between walls of the right ventricle and contains both the tricuspid valve and the apex of the RV. FIG. **7B** shows a short axis view of the right ventricle in FIG. **7A**, along with the cut line for the AP4 view. Similar to the problems with SMA1 and SMA2, an MPR plane identified as a straight MPR short-axis **1** (SMS1) is positioned at the center of the right ventricle, but it does not fully slice through the crescent-shaped RV. In contrast, the curved MPR plane, curved MPR short-axis **1** (CMS1), is positioned at the medial axis of the RV as seen in the short-axis view, and it spans from each tip of the crescent-shaped RV.

**[0028]** FIG. **8** illustrates an ultrasound system constructed in accordance with the present invention to process cardiac images with curved medial axes and less oval transverse cross-sections as described above. An ultrasonic probe **112** includes an array **114** of ultrasonic transducers that transmit and receive ultrasonic pulses. The array may be a one dimensional linear or curved array for two dimensional imaging, but preferably it is a mechanically swept one-dimensional array or a two dimensional matrix of transducer elements for electronic beam steering in three dimensions. The three dimensional data sets and images described above are preferably acquired using 3D probe with these array types which are capable of acquiring a 3D data set of the heart. The ultrasonic transducers in the array **114** transmit ultrasonic energy and receive echoes returned in response to this transmission. A transmit frequency control circuit **20** controls the transmission of ultrasonic energy at a desired frequency or band of frequencies through a transmit/receive (“T/R”) switch **22** coupled to the ultrasonic transducers in the array **114**. The times at which the transducer array is activated to transmit signals may be synchronized to an internal system clock (not shown), or may be synchronized to a bodily function such as the heart cycle, for which a heart cycle waveform is provided by an ECG device **26**. When the heartbeat is at the desired phase of its cycle as determined by the waveform provided by ECG device **26**, such as end diastole or end systole, the probe is commanded to acquire an ultrasonic image dataset. With an electronically steered and focused two dimensional array, the 3D datasets can be acquired as a real time sequence of 3D cardiac datasets. The frequency and bandwidth of the ultrasonic energy generated by the transmit frequency control circuit **20** is controlled by a control signal  $f_r$ , generated by a central controller **28**. Echoes from the transmitted ultrasonic energy are received by the transducers in the array **114**, which generate echo

signals that are coupled through the T/R switch **22** and digitized by analog to digital (“A/D”) converters **30** when the system uses a digital beamformer. Analog beamformers may also be used. The A/D converters **30** sample the received echo signals at a sampling frequency controlled by a signal  $f_s$  generated by the central controller **28**. The desired sampling rate dictated by sampling theory is at least twice the highest frequency of the received passband, and might be on the order of at least 30-40 MHz. Sampling rates higher than the minimum requirement are also desirable.

**[0029]** The echo signal samples from the individual transducers in the array **114** are delayed and summed by a beamformer **32** to form coherent echo signals. For 3D imaging with a two dimensional array, it is preferable to partition the beamformer between a microbeamformer located in the probe and the main beamformer in the system mainframe as described in U.S. Pat. No. 6,013,032 (Savord) and U.S. Pat. No. 6,375,617 (Fraser), both of which are incorporated herein by reference. The digital coherent echo signals are then filtered by a digital filter **34**. The digital filter **34** bandpass filters the signals, and can also shift the frequency band to a lower or baseband frequency range. The digital filter could be a filter of the type disclosed in U.S. Pat. No. 5,833,613, for example, which is incorporated herein by reference. The central controller **28** provides filter weights and decimation control variables for the digital filter **34**. Filtered echo signals from tissue are coupled from the digital filter **34** to a B mode processor **36** for conventional B mode processing.

**[0030]** Filtered echo signals of a contrast agent, such as microbubbles, are coupled to a contrast signal processor **38**. Contrast agents are often used to more clearly delineate the endocardial wall in relation to contrast agent in the blood pool of the heart chamber, or to perform perfusion studies of the microvasculature of the myocardium as described in U.S. Pat. No. 6,692,438 for example, which is incorporated herein by reference. The contrast signal processor **38** preferably separates echoes returned from harmonic contrast agents by the pulse inversion technique, in which echoes resulting from the transmission of multiple pulses to an image location are combined to cancel fundamental signal components and enhance harmonic components. A preferred pulse inversion technique is described in U.S. Pat. No. 6,186,950, for instance, which is incorporated herein by reference.

**[0031]** The filtered echo signals from the digital filter **34** are also coupled to a Doppler processor **40** for Doppler processing to produce velocity and power

**[0032]** Doppler signals. The output signals from these processors may be displayed as planar images, and are also coupled to a 3D image processor **42** for the rendering of three dimensional images, which are stored in a 3D image memory **44**. Three dimensional rendering may be performed as described in U.S. Pat. No. 5,720,291, and in U.S. Pat. Nos. 5,474,073 and 5,485,842, all of which are incorporated herein by reference. Method for generating MPR planes are well known, and include turning data from points in a common plane in a volumetric region of the body into an ultrasonic image of that plane, as described, e.g., in U.S. Pat. No. 6,443,896 (Detmer), which is incorporated by reference herein.

**[0033]** The signals from the contrast signal processor **38**, the B mode processor **36** and the Doppler processor **40**, and the three dimensional image signals from the 3D image

memory **44** are coupled to a Cineloop® memory **48**, which stores image data for each of a large number of ultrasonic images. The image data are preferably stored in the Cineloop memory **48** in sets, with each set of image data corresponding to an image obtained at a respective time. The image data in a data set can be used to display a parametric image showing tissue perfusion at a respective time during the heartbeat. The sets of image data stored in the Cineloop memory **48** may also be stored in a permanent memory device such as a disk drive or digital video recorder for later analysis. In this embodiment the image dataset are also coupled to a QLAB processor **50**, where the images are processed to produce curved medial axes of the heart chamber and stretched to reduce oval shapes as described above. The QLAB processor can also process curved MPR images to reproduce them in a flat plane as discussed above, and play an animation of the progressive change from a curved plane view to a flat view of the same plane. The QLAB processor also makes quantified measurements of various aspects of the anatomy in the image and delineates tissue boundaries and borders by automated border tracing as described in US patent publication no. US2005/0075567 and PCT publication no. 2005/054898, all of which are incorporated herein by reference. This may be done by fully automated means as described in U.S. Pat. No. 6,491,636, or by assisted automatic border detection as described in the aforementioned US patent publication no. US2005/0075567, all of which are incorporated herein by reference. The data and images produced by the QLAB processor are displayed on a display **52**.

**[0034]** It will be understood that each block of the block diagram illustrations, and combinations of blocks in the block diagram illustrations, as well any portion of the systems and methods disclosed herein, can be implemented by computer program instructions. These program instructions may be provided to a processor to produce a machine, such that the instructions, which execute on the processor, create means for implementing the actions specified in the block diagram block or blocks or described for the systems and methods disclosed herein. The computer program instructions may be executed by a processor to cause a series of operational steps to be performed by the processor to produce a computer implemented process. The computer program instructions may also cause at least some of the operational steps to be performed in parallel. Moreover, some of the steps may also be performed across more than one processor, such as might arise in a multi-processor computer system. In addition, one or more processes may also be performed concurrently with other processes, or even in a different sequence than illustrated without departing from the scope or spirit of the invention.

**[0035]** The computer program instructions can be stored on any suitable computer-readable hardware medium including, but not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by a computing device. Processors can include hardware such as microprocessors, field programmable gate arrays (FPGAs), integrated circuits, or the like.

1. An ultrasonic diagnostic imaging system for cardiac diagnosis, comprising:

an ultrasound probe; and

a processor configured to cause the system to:

acquire, using the probe, three dimensional ultrasound image datasets including a heart;

produce image data of a myocardium and a heart chamber;

delineate a curved medial axis of the heart chamber between a longitudinally separated apex and valve plane that is substantially evenly positioned between opposite walls of the myocardium; and

display a heart chamber image in a plane defined by the curved medial axis.

2. The ultrasonic diagnostic imaging system of claim 1, wherein the processor is further configured to cause the system to display a long axis heart chamber image in a plane defined by the curved medial axis.

3. The ultrasonic diagnostic imaging system of claim 1, wherein the processor is further configured to cause the system to produce a short axis view normal to the curved medial axis.

4. The ultrasonic diagnostic imaging system of claim 1, wherein the processor is further configured to cause the system to delineate a myocardial border.

5. The ultrasonic diagnostic imaging system of claim 4, wherein the processor is further configured to cause the system to delineate a long axis myocardial border.

6. The ultrasonic diagnostic imaging system of claim 5, wherein the processor is further configured to cause the system to locate a plurality of editing control points around the long axis border.

7. The ultrasonic diagnostic imaging system of claim 4, wherein the processor is further configured to cause the system to delineate a short axis myocardial border.

8. The ultrasonic diagnostic imaging system of claim 7, wherein the processor is further configured to cause the system to delineate editing control points on lines emanating from the curved medial axis and intersecting the short axis myocardial border.

9. The ultrasonic diagnostic imaging system of claim 1, wherein the processor is further configured to cause the system to stretch the myocardium in the image data to produce an image of a more circular myocardium.

10. The ultrasonic diagnostic imaging system of claim 1, wherein the processor is further configured to cause the system to produce a heart chamber image with the curved medial axis and a heart chamber image with the curved medial axis straightened.

11. The ultrasonic diagnostic imaging system of claim 10, wherein the processor is further configured to cause the system to produce a sequence of heart chamber images over which the curved medial axis changes to a straightened medial axis.

12. The ultrasonic diagnostic imaging system of claim 1, wherein the processor is further configured to cause the system to show a sequence of ultrasound images over which the curved medial axis changes to a straightened medial axis is played as an animation.

13. A method of diagnosing a patient by ultrasonic cardiac imaging comprising:

acquiring a sequence of three dimensional image datasets of a heart;

extracting a long axis view of a myocardium and heart chamber; and

delineating a curved medial axis of the heart chamber between an apex and valve plane which is evenly spaced between opposite walls of the myocardium.

14. The method of claim 13, further comprising: extracting a short axis view of the myocardium which is in a plane substantially orthogonal to the curved medial axis; and

locating editing control points on a border of the myocardium in the short axis view which are on lines passing through the curved medial axis.

15. The method of claim 14, further comprising: stretching the myocardium in the short axis view to a more rounded appearance.

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摘要(译)

超声成像系统通过在顶点和二尖瓣平面之间绘制腔室的纵向中轴线作为在心肌的相对壁之间均匀间隔的曲线来产生更多左心室的诊断心脏图像。横向图像平面定位成与弯曲的中轴线正交，其中控制点位于短轴视图中，线条均匀地间隔开并且从中间轴线发出。如果短轴视图是椭圆形腔室，则横向图像被拉伸以使心脏具有更圆润的外观，从而更好地定位编辑控制点。

