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

ULTRASCHALLHERZBEURTEILUNG VON HERZEN MIT MEDIALER ACHSKRÜMMUNG UND TRANSVERSALER EXZENTRIZITÄT

ÉVALUATION CARDIAQUE ÉCHOGRAPHIQUE DE COEURS AVEC COURBURE D'AXE MÉDIAN ET EXZENTRICITÉ TRANSVERSALE

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(56) References cited:  
**EP-A1- 2 397 076 WO-A1-2006/024970**  
**WO-A1-2011/121493 JP-A- 2012 029 722**  
**US-A1- 2002 072 672 US-A1- 2005 075 567**

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## Description

**[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.

**[0003]** WO 2011/121493 A1 relates to a medical diagnostic system that analyzes and displays ECG lead data for cardiac assessment, in which a bullseye chart comprising concentric circles subdivided into segments corresponding to different circumferential regions around the heart and at different levels in relation to the apex is filled in with ECG data. The ECG bullseye chart may be compared with an ultrasound bullet scorecard filled in with data derived from ultrasound images.

**[0004]** Referring now to WO 2006/024970 A1, it is there disclosed a diagnostic ultrasound system for detecting abnormalities of the left ventricle of the heart, in which a sequence of images including the mitral valve is acquired and processed to identify the location of the mitral valve in each of the images in the sequence. A graphic is displayed with the images depicting the location of the mitral valve in the current image and in each of the preceding images of the sequence. The image and graphic can be viewed in real time to discern the effects of conduction delay and infarction of the left ventricle.

**[0005]** US 2002/072672 A1 describes an ultrasonic diagnostic imaging system in which ultrasonic cardiac image information is acquired and segmented by automatic border detection. The segmented ultrasonic information is used to display regional wall motion over time. The segmented information may be presented in a color-coded representation, or entered automatically as qualitative or quantitative measures on a scorecard of cardiac performance.

**[0006]** 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 US Pat. 6,491,636 (Chenal et al.) and the heart model processor described in US Pat. US Pat. 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 (multi-planar 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.

**[0007]** This object is solved by the independent claims. Preferred embodiments are defined in the dependent claims.

**[0008]** 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 including that of 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.

**[0009]** 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 opposite walls of the myocardium, and a display for displaying a heart chamber image in a plane of the curved medial axis.

**[0010]** 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.

**[0011]** In the drawings:

FIGURE 1 illustrates standard ASE views of a heart at end diastole and end systole.

FIGURE 2a illustrates the intersection of the planes of the left ventricular chamber in two standard views.

FIGURE 2b a three dimensional mesh of the left ventricle with control points for editing.

FIGURE 3a illustrates the medial axis and control points of longitudinal and transverse cardiac images for a uniformly symmetrical heart shape.

FIGURE 3b illustrates the medial axis and control points of longitudinal and transverse cardiac images for a heart with a longitudinally curved shape.

FIGURE 3c illustrates the medial axis and control points of longitudinal and transverse cardiac images for a heart with an eccentric transverse shape.

FIGURE 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.

FIGURE 4 shows three cardiac images of hearts with longitudinal curvature.

FIGURE 5 shows the same heart data after correction with curved MPRs in accordance with the principles of the present invention.

FIGURE 6 illustrates animation of the transition from planar to curved MPRs of a heart in accordance with the present invention.

FIGURE 7 illustrates the intersection of MPR planes of a right ventricular chamber in two standard views.

FIGURE 8 illustrates in block diagram form an ultrasound system constructed in accordance with the principles of the present invention.

**[0012]** 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.

**[0013]** FIGURE 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, MA) 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 FIGURE 1. Similarly, borders can be automatically traced for other features of the heart, such as the right ventricle.

**[0014]** The three standard view planes intersect each other at a common medial axis of the LV at relative rotational angles of approximately 0°, 60° and 100°. The intersection of two of the standard view planes is illustrated in FIGURE 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 FIGURE 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 FIGURE 2b. The points where the different border tracings intersect each other are marked as a, b, c in the drawing. While the FIGURE 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 FIGURE 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 FIGURE 2b illustrates, the borders of the different view planes are all spatially interrelated 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.

**[0015]** With images of a longitudinally straight and uniformly symmetrical heart these editing problems generally do not arise. FIGURE 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 FIGURE 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.

**[0016]** Not all hearts are ideally shaped for this image analysis, however. FIGURE 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.

**[0017]** FIGURE 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.

**[0018]** In accordance with the principles of the present invention, these problems are mitigated by plotting a curved medial axis 200 as shown in FIGURE 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 FIGURE 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 FIGURE 3d. Compared with FIGURE 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 FIGURE 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 FIGURE 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 FIGURE 3a, and will enable heart measurements which are closer to those which a diagnosing physician is seeking.

**[0019]** 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 FIGURES 4 and 5. In FIGURE 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 FIGURES 5a, b, and c, 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 FIGURE 5 are less irregular and lend themselves more readily to diagnosis and measurement.

**[0020]** It is important that the diagnosing physician rec-

ognize that the processed images of FIGURE 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 FIGURE 6. The image on the left side of FIGURE 6 is the image of FIGURE 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 FIGURE 6 is that of FIGURE 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 FIGURE 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.

**[0021]** As explained for the left ventricle, the present disclosure can be used for other heart chambers, such as the right ventricle (RV), as well. FIGURES 7A and 7B show examples of using a curved MPR plane for a curved right ventricle. The AP4 view in FIGURE 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 1 (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.

**[0022]** FIGURE 7B shows a short axis view of the right ventricle in FIGURE 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.

**[0023]** FIGURE 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  $f_{tr}$  generated by a central controller 28.

**[0024]** 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.

**[0025]** 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 US Pat. 6,013,032 (Savord) and US Pat. 6,375,617 (Fraser). 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. Patent No. 5,833,613. The central controller 28 provides filter weights and decimation con-

trol 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.

**[0026]** 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 US Pat. 6,692,438. 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. patent 6,186,950.

**[0027]** 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 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. patent 5,720,291, and in U.S. patents 5,474,073 and 5,485,842. 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 US Pat. 6,443,896 (Detmer).

**[0028]** 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.

This may be done by fully automated means as described in US Pat. 6,491,636, or by assisted automatic border detection as described in the aforementioned US patent publication no. US2005/0075567. The data and images produced by the QLAB processor are displayed on a display 52.

**[0029]** 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.

**[0030]** 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.

## 40 Claims

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

an ultrasound probe (112); and  
a processor (50) configured to cause the system to:

acquire, using the probe, three dimensional ultrasound image datasets including datasets of a heart; and  
produce image data of a myocardium (60) and a heart chamber,  
**characterized in that** the processor (50) is further configured to cause the system to:

delineate a curved medial axis (200) of the heart chamber between a longitu-

- dinally separated apex (230) and valve plane (220) that is evenly positioned between opposite walls of the heart chamber; and display a heart chamber image in a curved plane defined by the curved medial axis (200).
2. The ultrasonic diagnostic imaging system of Claim 1, wherein the processor (50) is further configured to cause the system to display a long axis heart chamber image in a curvilinear slice that passes through the curved medial axis (200).
  3. The ultrasonic diagnostic imaging system of Claim 1, wherein the processor (50) is further configured to cause the system to create a short axis view (222) normal to the curved medial axis (200).
  4. The ultrasonic diagnostic imaging system of Claim 1, wherein the processor (50) is further configured to cause the system to delineate a myocardial border 210, 212, 214, 232, 234, 236).
  5. The ultrasonic diagnostic imaging system of Claim 4, wherein the processor (50) is further configured to cause the system to delineate a long axis myocardial border (210, 212, 214).
  6. The ultrasonic diagnostic imaging system of Claim 5, wherein the processor (50) 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 (50) is further configured to cause the system to delineate a short axis myocardial border (232, 234, 236).
  8. The ultrasonic diagnostic imaging system of Claim 7, wherein the processor (50) is further configured to cause the system to delineate editing control points (a, b, c, d, e, f) on lines (202) emanating from the curved medial axis (200) and intersecting the short axis myocardial border.
  9. The ultrasonic diagnostic imaging system of Claim 1, wherein the processor (50) is further configured to cause the system to stretch the myocardium (60) 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 (50) is further configured to cause the system to produce a heart chamber image with the curved medial axis (200) and a heart chamber image with the curved medial axis (200) straightened.
  11. The ultrasonic diagnostic imaging system of Claim 10, wherein the processor (50) is further configured to cause the system to produce a sequence of heart chamber images over which the curved medial axis (200) changes to a straightened medial axis.
  12. The ultrasonic diagnostic imaging system of Claim 1, wherein the processor (50) is further configured to cause the system to show a sequence of ultrasound images over which the curved medial axis (200) changes to a straightened medial axis is played as an animation.
  13. A method useful for diagnosing a patient by ultrasonic cardiac imaging comprising:
    - acquiring a sequence of three dimensional image datasets of a heart; and
    - extracting a long axis view of a myocardium (60) and a heart chamber,
    - characterized in that** the method further comprises delineating a curved medial axis (200) of the heart chamber between an apex (230) and valve plane (220) which is evenly spaced between opposite walls of the heart chamber.
  14. The method of Claim 13, further comprising:
    - extracting a short axis view (222) of the myocardium (60) which is in a plane substantially orthogonal to the curved medial axis (200); and
    - locating editing control points (a, b, c, d, e, f) on a border of the myocardium in the short axis view which are on lines (202) passing through the curved medial axis.
  15. The method of Claim 14, further comprising:
    - stretching the myocardium (60) in the short axis view (222) to a more rounded appearance.

#### Patentansprüche

1. Ultraschalldiagnose-Bildgebungssystem zur kardiologischen Diagnose, das Folgendes umfasst:

eine Ultraschallsonde (112); und  
einen Prozessor (50), der konfiguriert ist, um das System zu Folgendem zu veranlassen:

unter Verwenden der Sonde, Aufnehmen dreidimensionaler Ultraschallbilddatensätze, einschließlich von Datensätzen eines Herzens; und  
Erzeugen von Daten eines Myokards (60) und einer Herzkammer,  
**dadurch gekennzeichnet, dass** der Prozessor (50) weiter konfiguriert ist, um das

- System zu Folgendem zu veranlassen:
- Abgrenzen einer gekrümmten medialen Achse (200) der Herzkammer zwischen einem längs getrennten Apex (230) und einer Klappenebene (220), die gleichmäßig zwischen entgegengesetzten Wänden der Herzkammer positioniert ist; und  
Anzeigen eines Herzkammerbilds in einer gekrümmten Ebene, die von der gekrümmten medialen Achse (200) definiert ist.
2. Ultraschalldiagnose-Bildgebungssystem nach Anspruch 1, wobei der Prozessor (50) weiter konfiguriert ist, um das System zu veranlassen, ein Längsachsen-Herzkammerbild in einem kurvilinearen Slice, der durch die gekrümmte mediale Achse (200) durchgeht, anzuzeigen. 5
  3. Ultraschalldiagnose-Bildgebungssystem nach Anspruch 1, wobei der Prozessor (50) weiter konfiguriert ist, um das System zu veranlassen, eine Kurzachsenansicht (222) senkrecht zu der gekrümmten medialen Achse (200) anzulegen. 10
  4. Ultraschalldiagnose-Bildgebungssystem nach Anspruch 1, wobei der Prozessor (50) weiter konfiguriert ist, um das System zu veranlassen, eine Myokardgrenze (210, 212, 214, 232, 234, 236) abzugrenzen. 15
  5. Ultraschalldiagnose- Bildgebungssystem nach Anspruch 4, wobei der Prozessor (50) weiter konfiguriert ist, um das System zu veranlassen, eine Längsachsen-Myokardgrenze (210, 212, 214) abzugrenzen. 20
  6. Ultraschalldiagnose-Bildgebungssystem nach Anspruch 5, wobei der Prozessor (50) weiter konfiguriert ist, um das System zu veranlassen, eine Vielzahl von Editiersteuerpunkten um die Längsachsen-grenze zu lokalisieren. 25
  7. Ultraschalldiagnose-Bildgebungssystem nach Anspruch 4, wobei der Prozessor (50) weiter konfiguriert ist, um das System zu veranlassen, eine Kurzachsen-Myokardgrenze (232, 234, 236) abzugrenzen. 30
  8. Ultraschalldiagnose-Bildgebungssystem nach Anspruch 7, wobei der Prozessor (50) weiter konfiguriert ist, um das System zu veranlassen, Editiersteuerpunkte (a, b, c, d, e, f) auf Linien (202) abzugrenzen, die von der gekrümmten medialen Achse (200) ausgehen und die Kurzachsen-Myokardgrenze schneiden. 35
  9. Ultraschalldiagnose-Bildgebungssystem nach Anspruch 1, wobei der Prozessor (50) weiter konfiguriert ist, um das System zu veranlassen, das Myokard (60) in den Bilddaten zu strecken, um ein Bild eines kreisförmigeren Myokards zu erzeugen. 40
  10. Ultraschalldiagnose-Bildgebungssystem nach Anspruch 1, wobei der Prozessor (50) weiter konfiguriert ist, um das System zu veranlassen, eine Herzkammerbild mit der gekrümmten medialen Achse (200) und ein Herzkammerbild mit der gekrümmten medialen Achse (200) geradegerichtet zu erzeugen. 45
  11. Ultraschalldiagnose-Bildgebungssystem nach Anspruch 10, wobei der Prozessor (50) weiter konfiguriert ist, um das System zu veranlassen, eine Abfolge von Herzkammerbildern zu erzeugen, über der sich die gekrümmte mediale Achse (200) in eine geradegerichtete mediale Achse ändert. 50
  12. Ultraschalldiagnose-Bildgebungssystem nach Anspruch 1, wobei der Prozessor (50) weiter konfiguriert ist, um das System zu veranlassen, eine Abfolge von Ultraschallbildern zu zeigen, über der sich die gekrümmte mediale Achse (200) in eine geradegerichtete mediale Achse, die als eine Animation abgespielt wird, ändert. 55
  13. Verfahren, das zum Diagnostizieren eines Patienten durch kardiologische Ultraschallbildgebung nützlich ist, das Folgendes umfasst:  
Erfassen einer Abfolge dreidimensionaler Bild-datensätze eines Herzens; und  
Extrahieren einer Längsachsenansicht eines Myokards (60) und einer Herzkammer, **dadurch gekennzeichnet, dass** das Verfahren weiter das Abgrenzen einer gekrümmten medialen Achse (200) der Herzkammer zwischen einem Apex (230) und einer Klappenebene (220), die gleichmäßig zwischen entgegengesetzten Wänden der Herzkammer beabstandet ist, umfasst. 60
  14. Verfahren nach Anspruch 13, das weiter Folgendes umfasst:  
Extrahieren eine Kurzachsenansicht (222) des Myokards (60), die in einer Ebene liegt, die im Wesentlichen zu der gekrümmten medialen Achse (200) orthogonal ist; und  
Lokalisieren von Editiersteuerpunkten (a, b, c, d, e, f) auf einer Grenze des Myokards in der Kurzachsenansicht auf Linien (202), die durch die gekrümmte mediale Achse hindurchgehen. 65
  15. Verfahren nach Anspruch 14, das weiter Folgendes umfasst: Strecken des Myokards (60) in der Kurz-

achsenansicht (222) zu einem gerundeteren Aussehen.

## Revendications

1. Système d'imagerie de diagnostic ultrasonique pour un diagnostic cardiaque comprenant :

une sonde ultrasonique (112) ; et un processeur (50) configuré pour amener le système à :

acquérir, en utilisant la sonde, des ensembles de données d'images ultrasoniques tridimensionnels comportant des ensembles de données d'un coeur ; et produire des données d'image d'un myocarde (60) et d'une chambre cardiaque, **caractérisé en ce que** le processeur (50) est en outre configuré pour amener le système à :

définir un axe médian incurvé (200) de la chambre cardiaque entre une pointe longitudinalement séparée (230) et un plan valvulaire (220) qui est uniformément positionné entre les parois opposées de la chambre cardiaque ; et afficher une image de chambre cardiaque dans un plan incurvé défini par l'axe médian incurvé (200).

2. Système d'imagerie de diagnostic ultrasonique selon la revendication 1, dans lequel le processeur (50) est en outre configuré pour amener le système à afficher une image de chambre cardiaque à axe long dans une tranche curviligne qui passe à travers l'axe médian incurvé (200).

3. Système d'imagerie de diagnostic ultrasonique selon la revendication 1, dans lequel le processeur (50) est en outre configuré pour amener le système à créer une vue de l'axe court (222) normalement à l'axe médian incurvé (200).

4. Système d'imagerie de diagnostic ultrasonique selon la revendication 1, dans lequel le processeur (50) est en outre configuré pour amener le système à délimiter un bord du myocarde (210, 212, 214, 232, 234, 236).

5. Système d'imagerie de diagnostic ultrasonique selon la revendication 4, dans lequel le processeur (50) est en outre configuré pour amener le système à délimiter un bord de myocarde à axe long (210, 212, 214).

6. Système d'imagerie de diagnostic ultrasonique selon la revendication 5, dans lequel le processeur (50) est en outre configuré pour amener le système à localiser une pluralité de points de commande d'édition autour du bord à axe long.

7. Système d'imagerie de diagnostic ultrasonique selon la revendication 4, dans lequel le processeur (50) est en outre configuré pour amener le système à délimiter un bord du myocarde à axe court (232, 234, 236).

8. Système d'imagerie de diagnostic ultrasonique selon la revendication 7, dans lequel le processeur (50) est en outre configuré pour amener le système à délimiter des points de commande d'édition (a, b, c, d, e, f) sur des lignes (202) émanant de l'axe médian incurvé (200) et coupant le bord du myocarde à axe court.

9. Système d'imagerie de diagnostic ultrasonique selon la revendication 1, dans lequel le processeur (50) est en outre configuré pour amener le système à étirer le myocarde (60) dans les données d'images pour produire une image d'un myocarde plus circulaire.

10. Système d'imagerie de diagnostic ultrasonique selon la revendication 1, dans lequel le processeur (50) est en outre configuré pour amener le système à produire une image de la chambre cardiaque avec l'axe médian incurvé (200) et une image de la chambre cardiaque avec l'axe médian incurvé (200) redressé.

11. Système d'imagerie de diagnostic ultrasonique selon la revendication 10, dans lequel le processeur (50) est en outre configuré pour amener le système à produire une séquence d'images de la chambre cardiaque sur laquelle l'axe médian incurvé (200) passe à un axe médian redressé.

12. Système d'imagerie de diagnostic ultrasonique selon la revendication 1, dans lequel le processeur (50) est en outre configuré pour amener le système à montrer une séquence d'images ultrasonores sur laquelle l'axe médian incurvé (200) passe à un axe médian redressé en jouant le tout comme une animation.

13. Procédé utile pour le diagnostic d'un patient par imagerie cardiaque ultrasonique, comprenant :

l'acquisition d'une séquence d'ensembles de données d'images tridimensionnelles d'un coeur ; et l'extraction d'une vue d'axe long d'un myocarde (60) et d'une chambre cardiaque,

**caractérisé en ce que** le procédé comprend en outre la délimitation d'un axe médian incurvé (200) de la chambre cardiaque entre une pointe (230) et un plan valvulaire (220) qui est uniformément espacé entre les parois opposées de la chambre cardiaque. 5

14. Procédé selon la revendication 13, comprenant en outre :

l'extraction d'une vue d'axe court (222) du myocarde (60) qui se trouve dans un plan sensiblement orthogonal à l'axe médian incurvé (200) ; et 10

la localisation de points de commande d'édition (a, b, c, d, e, f) sur un bord du myocarde dans la vue d'axe court qui sont sur des lignes (202) passant à travers l'axe médian incurvé. 15

15. Procédé selon la revendication 14, comprenant en outre : 20

l'étirage du myocarde (60) dans la vue d'axe court (222) pour obtenir un aspect plus arrondi.

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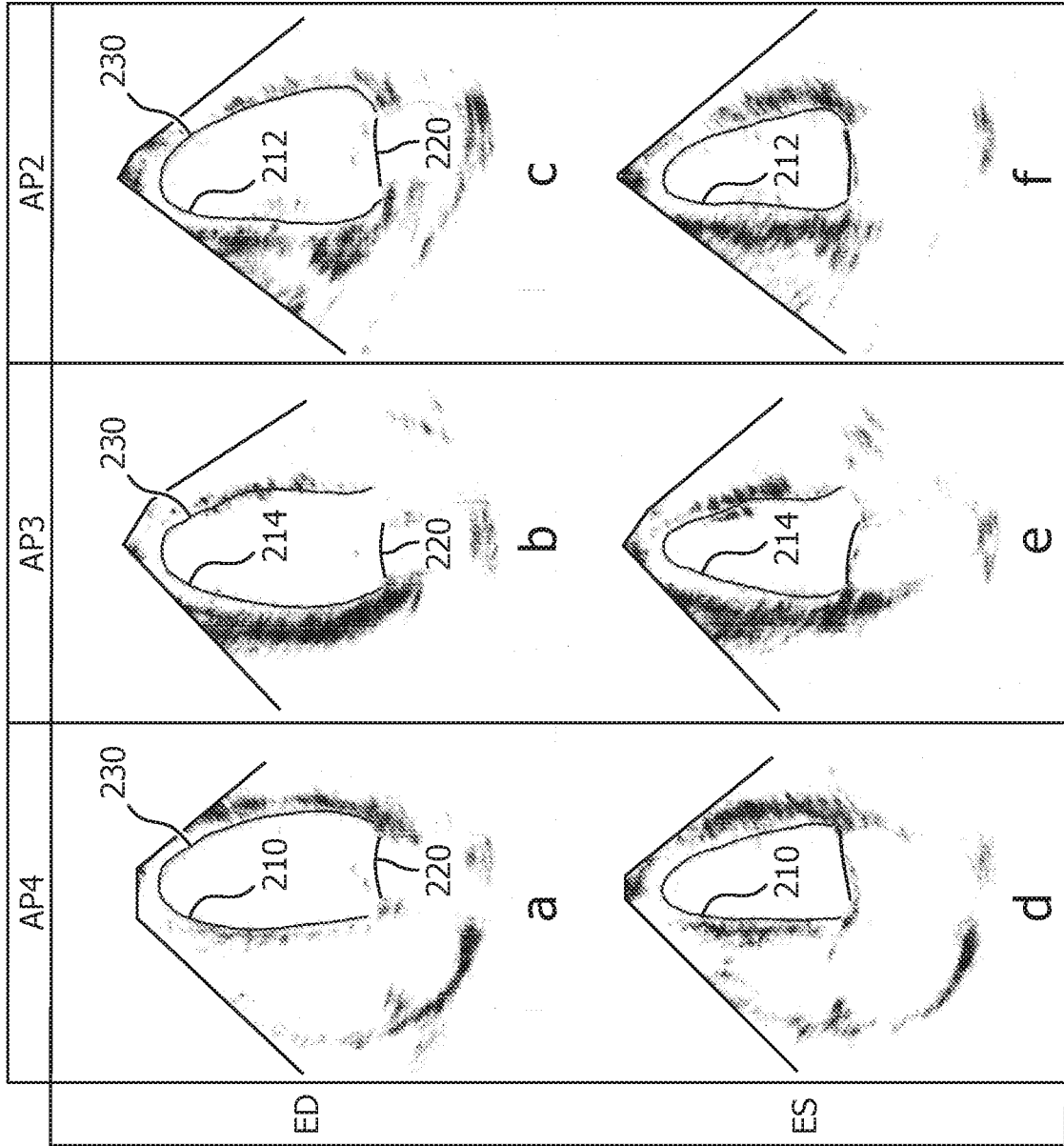


FIG. 1

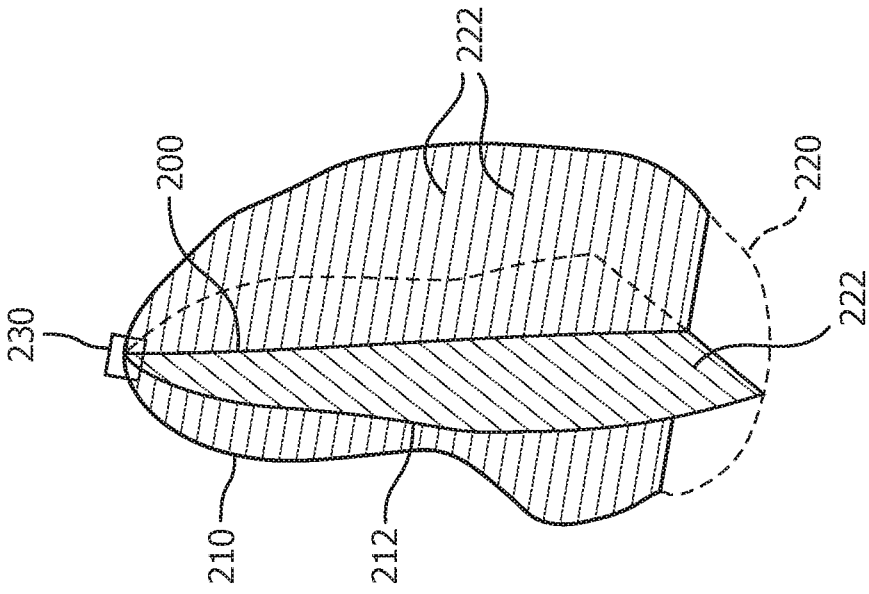


FIG. 2a

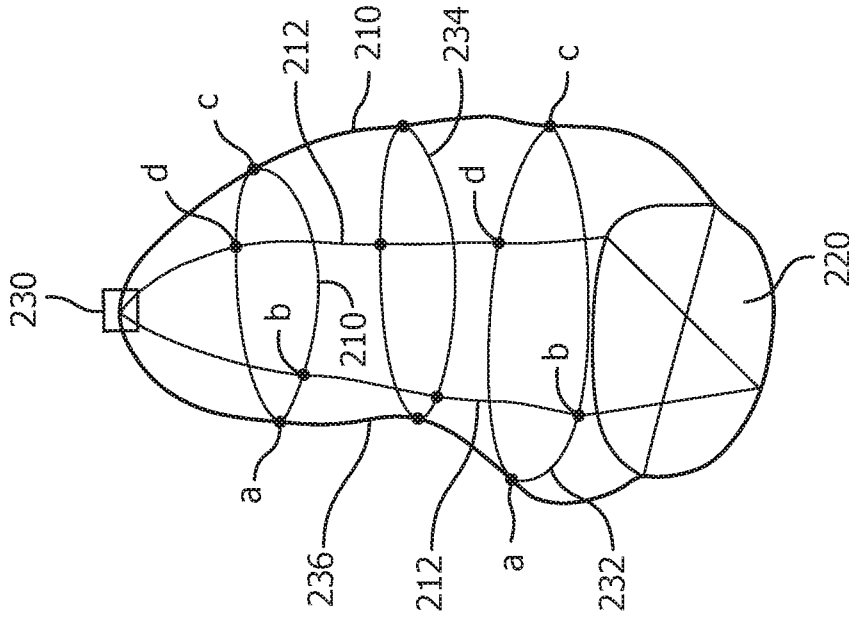


FIG. 2b

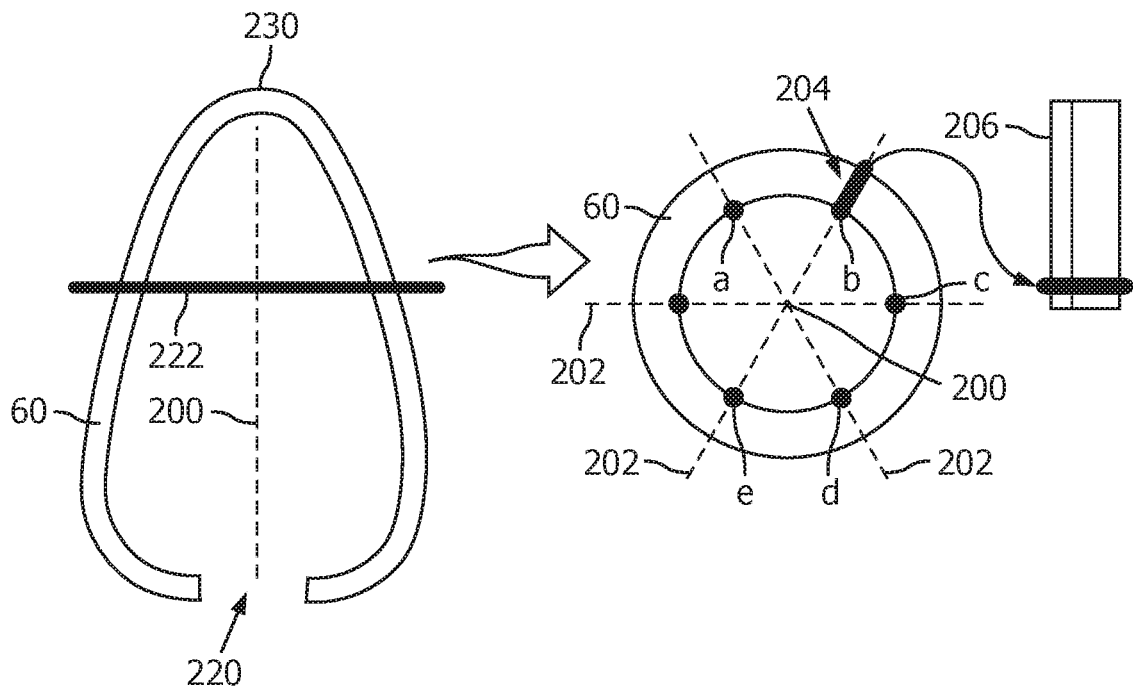


FIG. 3a

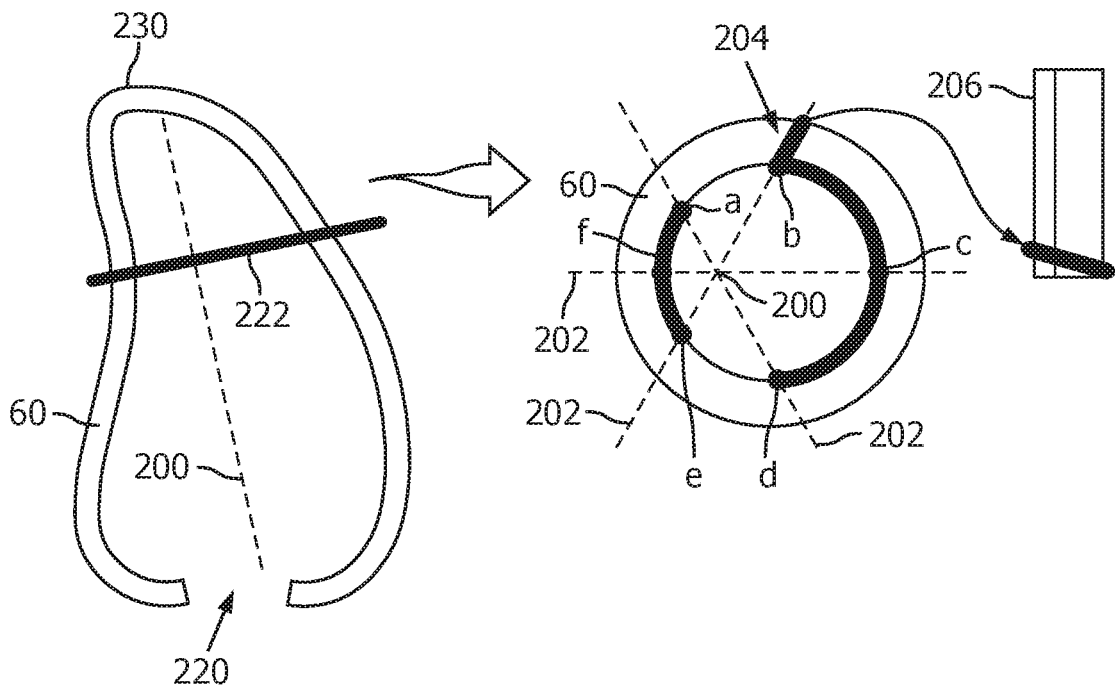


FIG. 3b

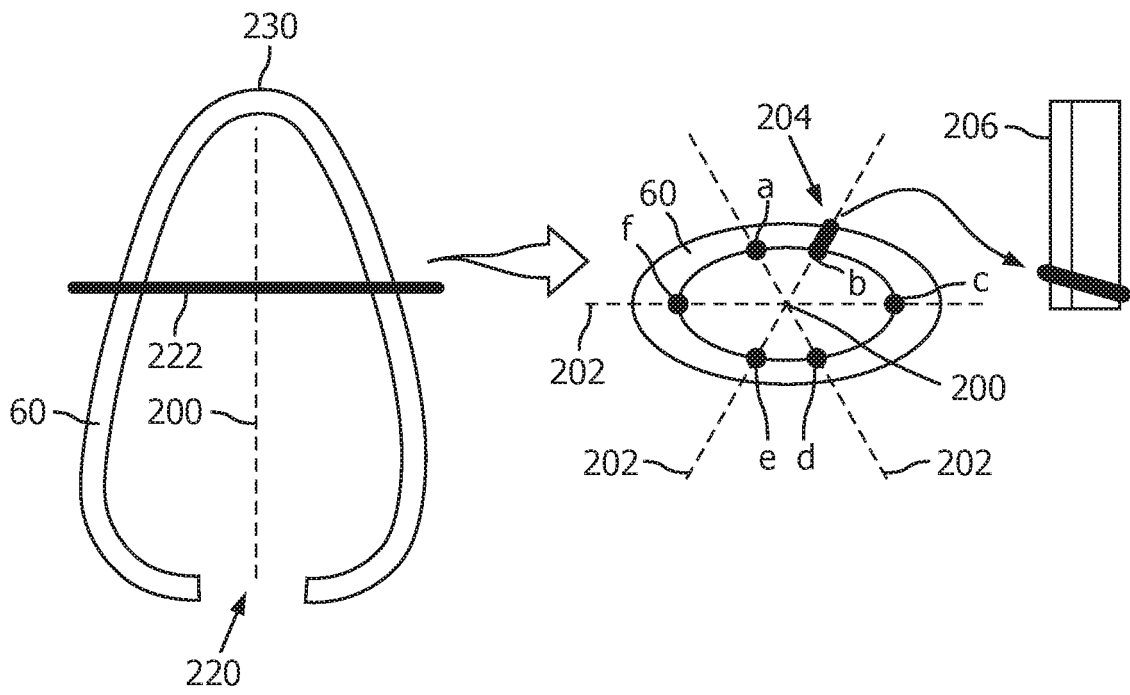


FIG. 3c

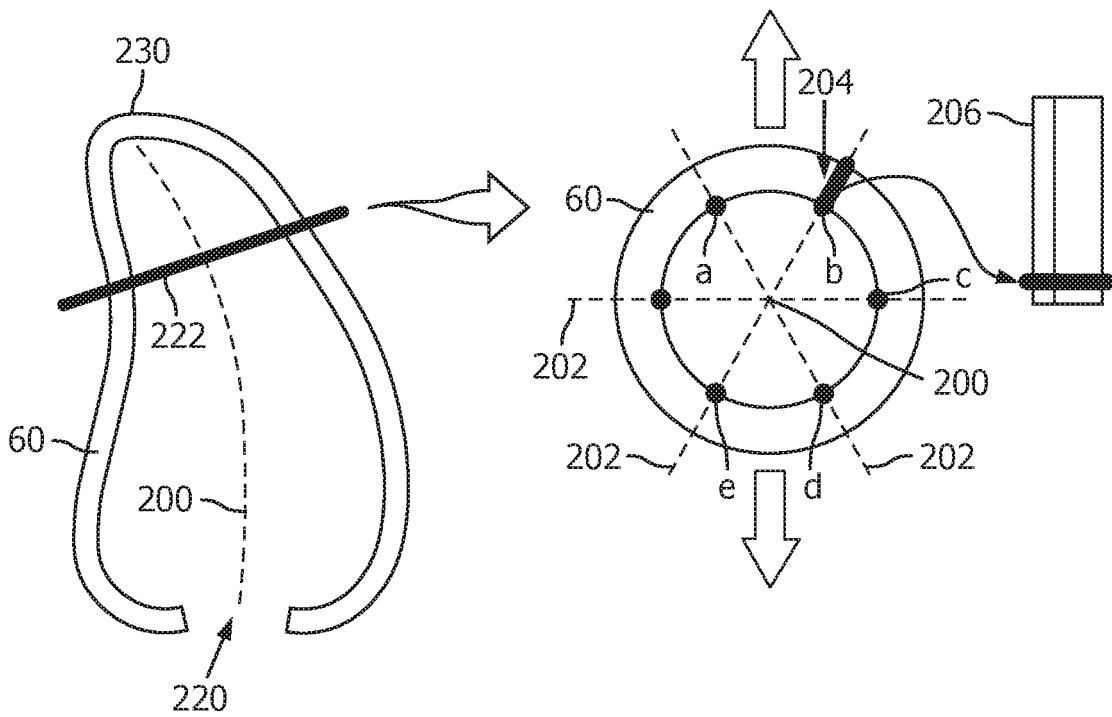
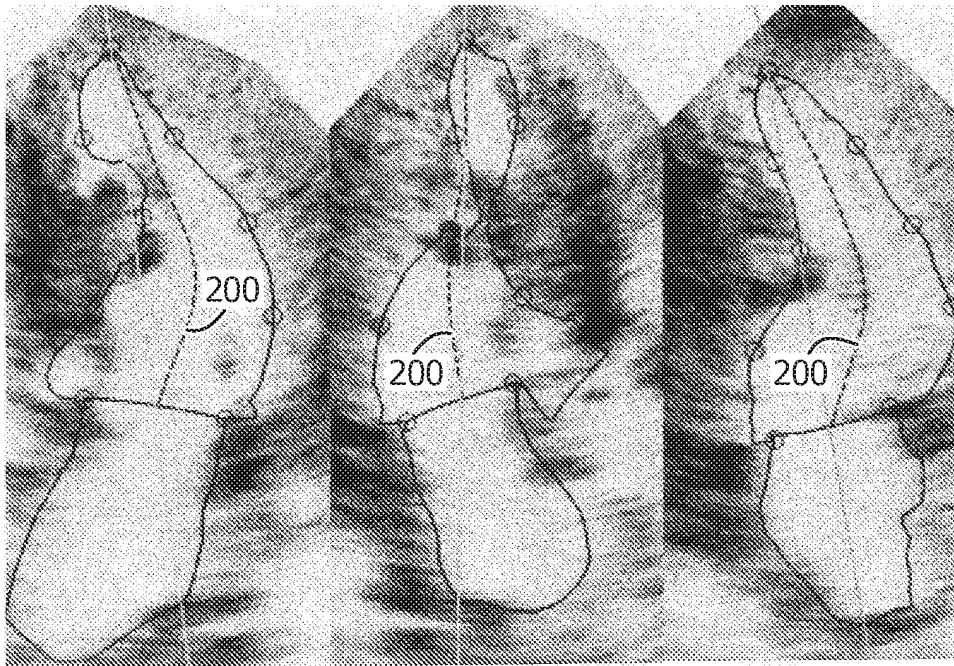


FIG. 3d

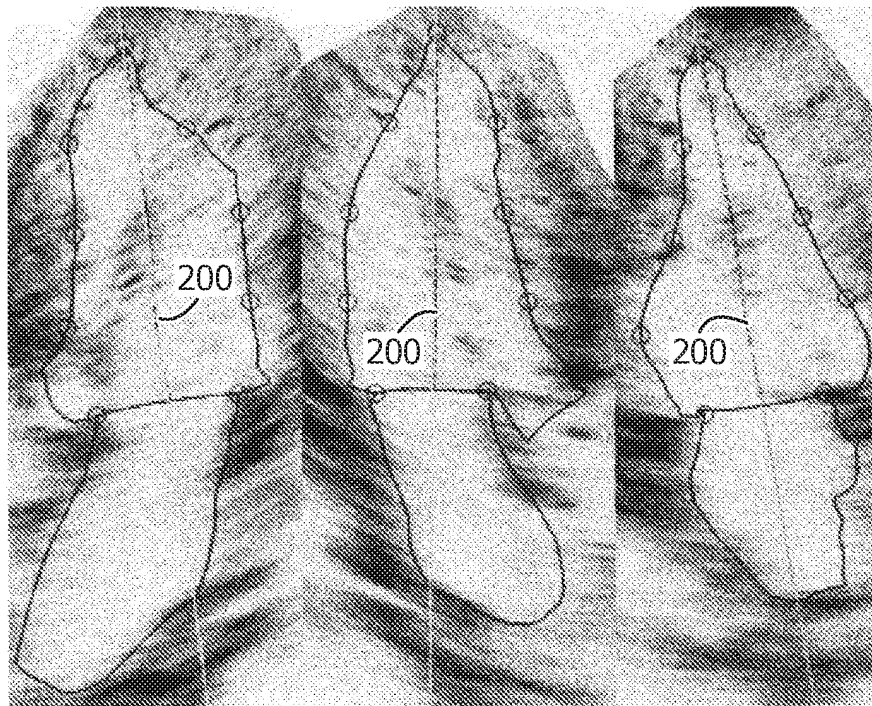


a

b

c

FIG. 4



a

b

c

FIG. 5

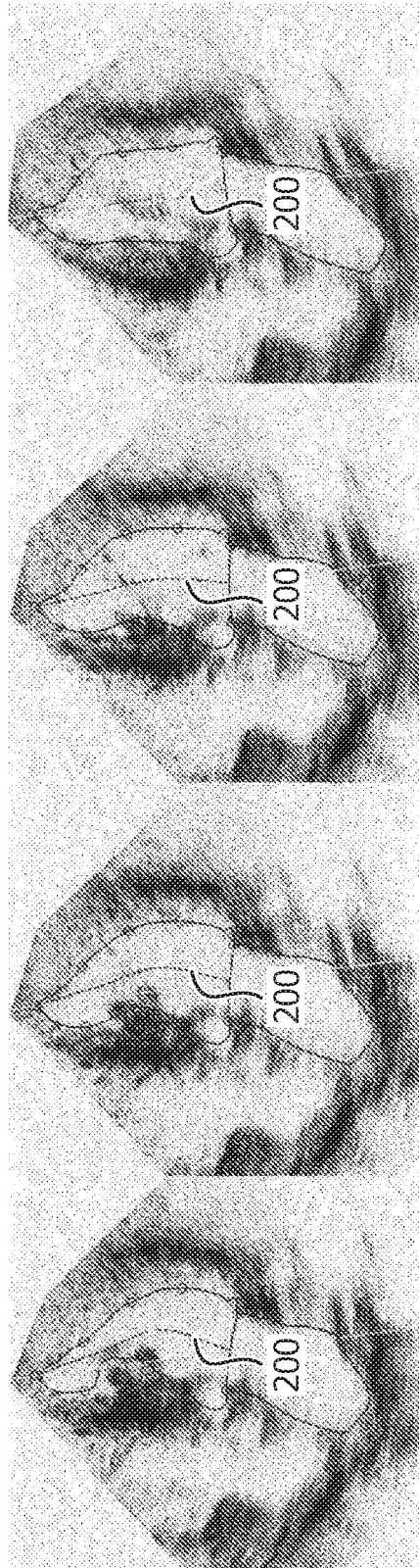


FIG. 6

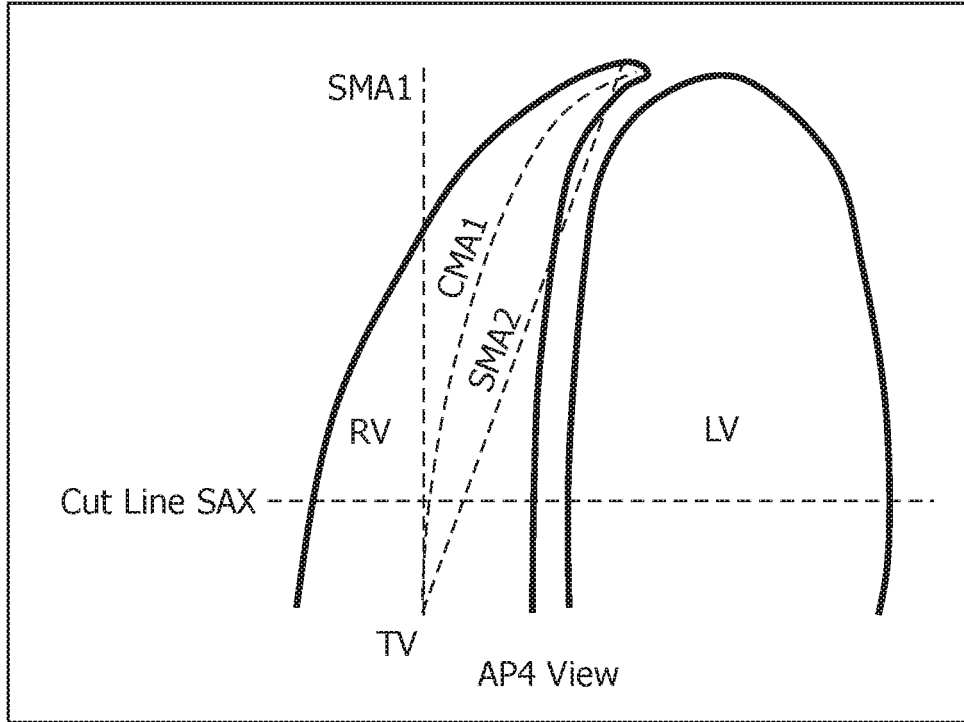


FIG. 7a

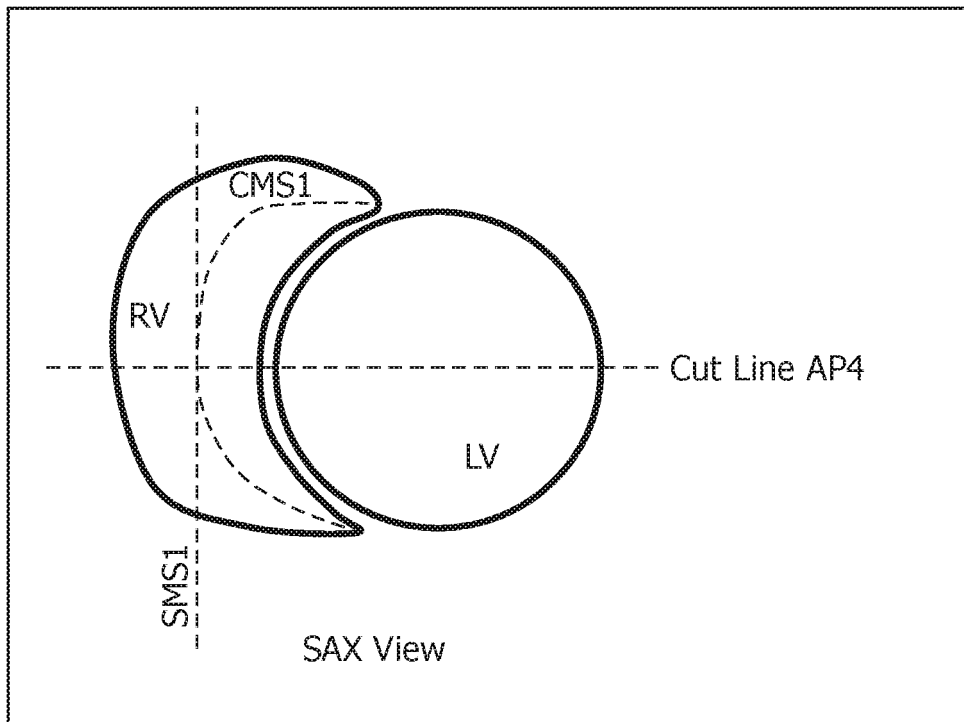


FIG. 7b

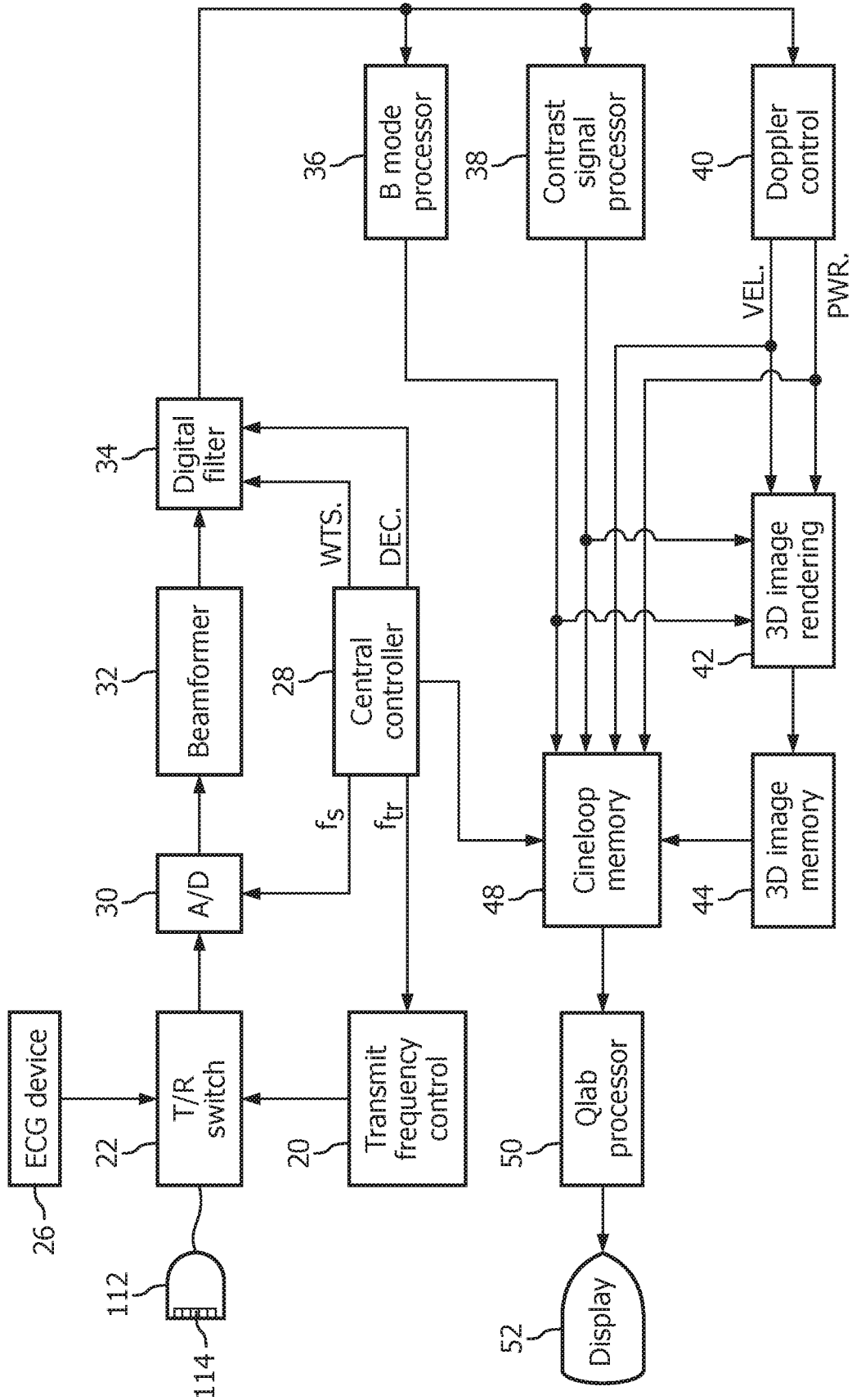


FIG. 8

**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

- WO 2011121493 A1 [0003]
- WO 2006024970 A1 [0004]
- US 2002072672 A1 [0005]
- US 6491636 B, Chenal [0006] [0028]
- US 7101164 B, Weese [0006]
- US 20100189317 A, Lehmann [0006]
- US 6013032 A, Savord [0025]
- US 6375617 B, Fraser [0025]
- US 5833613 A [0025]
- US 6692438 B [0026]
- US 6186 A [0026]
- US 950 A [0026]
- US 5720291 A [0027]
- US 5474073 A [0027]
- US 5485842 A [0027]
- US 6443896 B, Detmer [0027]
- US 20050075567 A [0028]
- US 2005054898 W [0028]

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外部链接	<a href="#">Espacenet</a>		

摘要(译)

超声成像系统通过在心尖和二尖瓣平面之间绘制腔室的纵向内侧轴作为均匀分布在心肌相对壁之间的曲线，从而产生更多的左心室心脏诊断图像。横向图像平面正交于弯曲的中间轴放置，控制点在短轴视图中位于围绕中间轴均匀分布并从中间轴发出的线上。如果短轴视图是椭圆形的腔室，则将横向图像拉伸以使心脏具有更圆的外观，从而可以更好地定位编辑控制点。

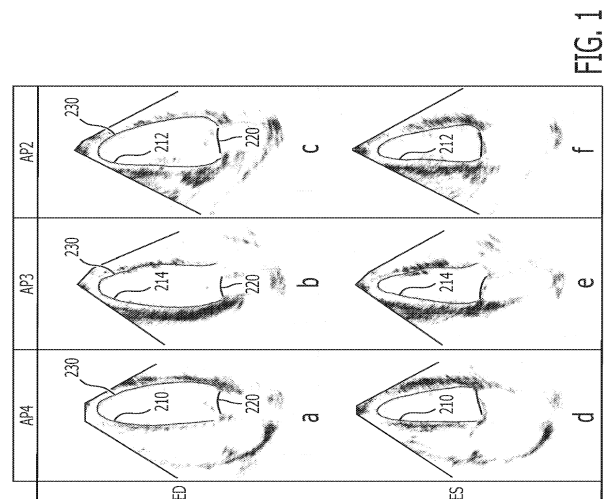


FIG. 1