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(54) **ULTRASOUND DIAGNOSTIC APPARATUS AND METHOD FOR TRACING MOVEMENT OF TISSUE**

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(57) **ABSTRACT**

An ultrasound diagnostic apparatus includes a transmitting and receiving unit that transmits an ultrasound wave to a target object and receives the ultrasound wave as ultrasound data reflected from the target object including a long axis direction blood vessel. An image generation unit generates an ultrasound image as a sectional image of the blood vessel. A region of interest (ROI) setting unit sets a first ROI on a vertical straight line at a right angle to the long axis direction and a second ROI on a wall of the blood vessel displayed at a designated time. A tracing unit traces movement of tissue in the target object corresponding to the first and second ROIs from the designated time to sequentially following thereafter by a gradient method using a spatial brightness gradient. A second memory unit stores information of the movement of the tissue for a predetermined duration.

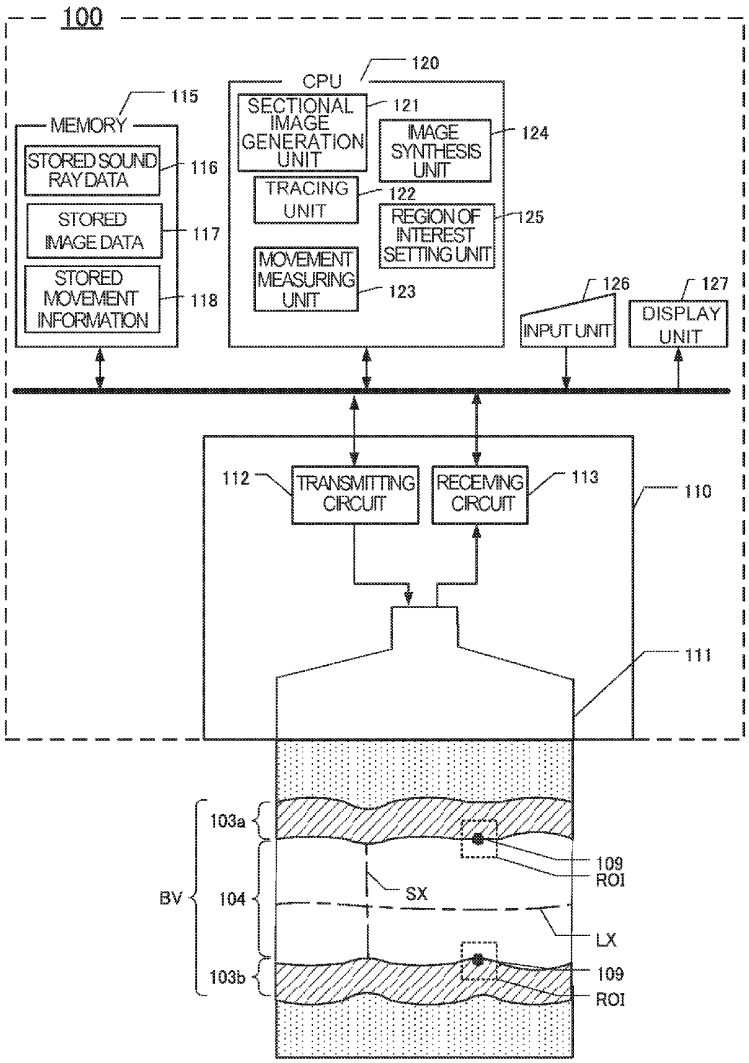


FIG. 1

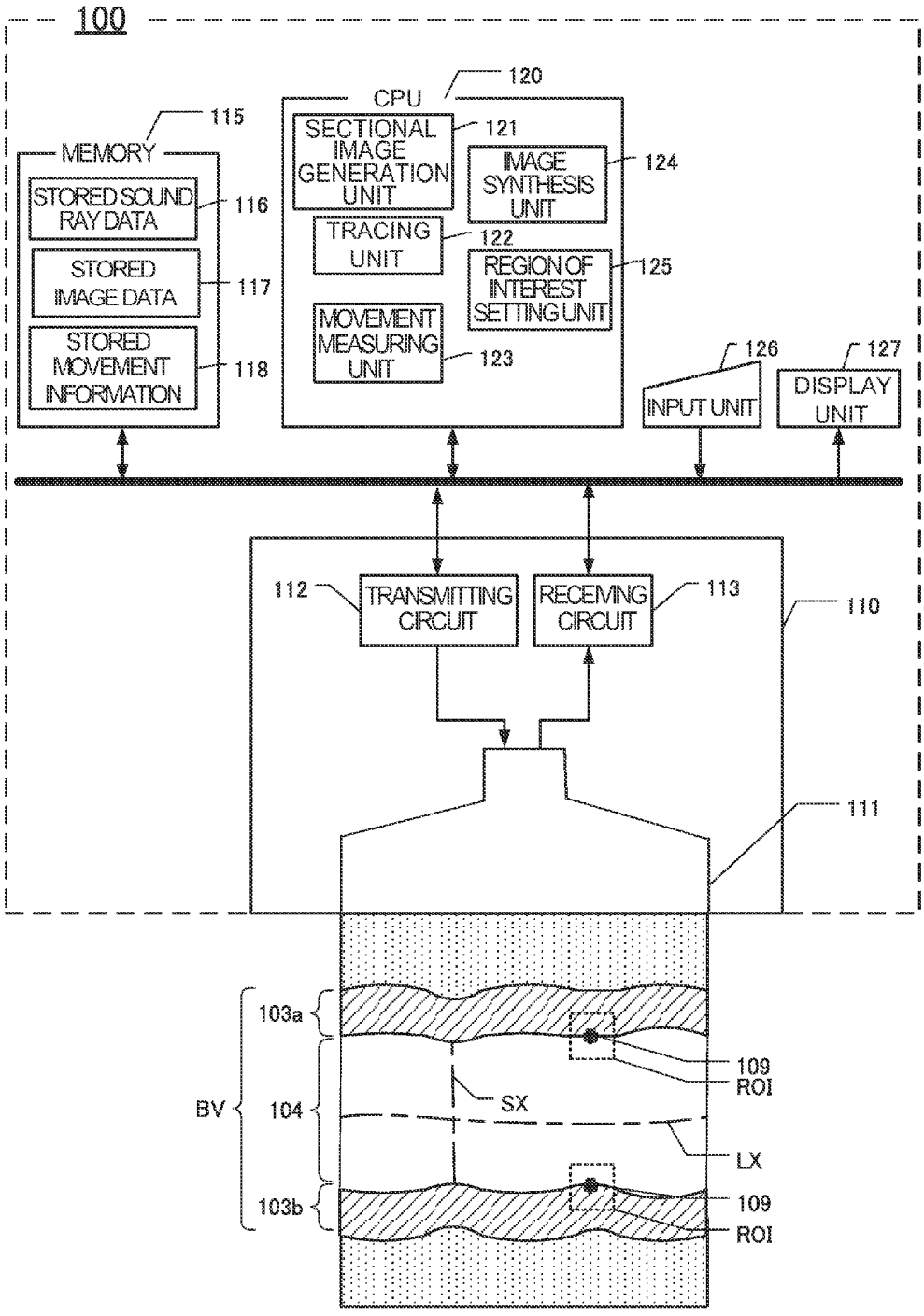
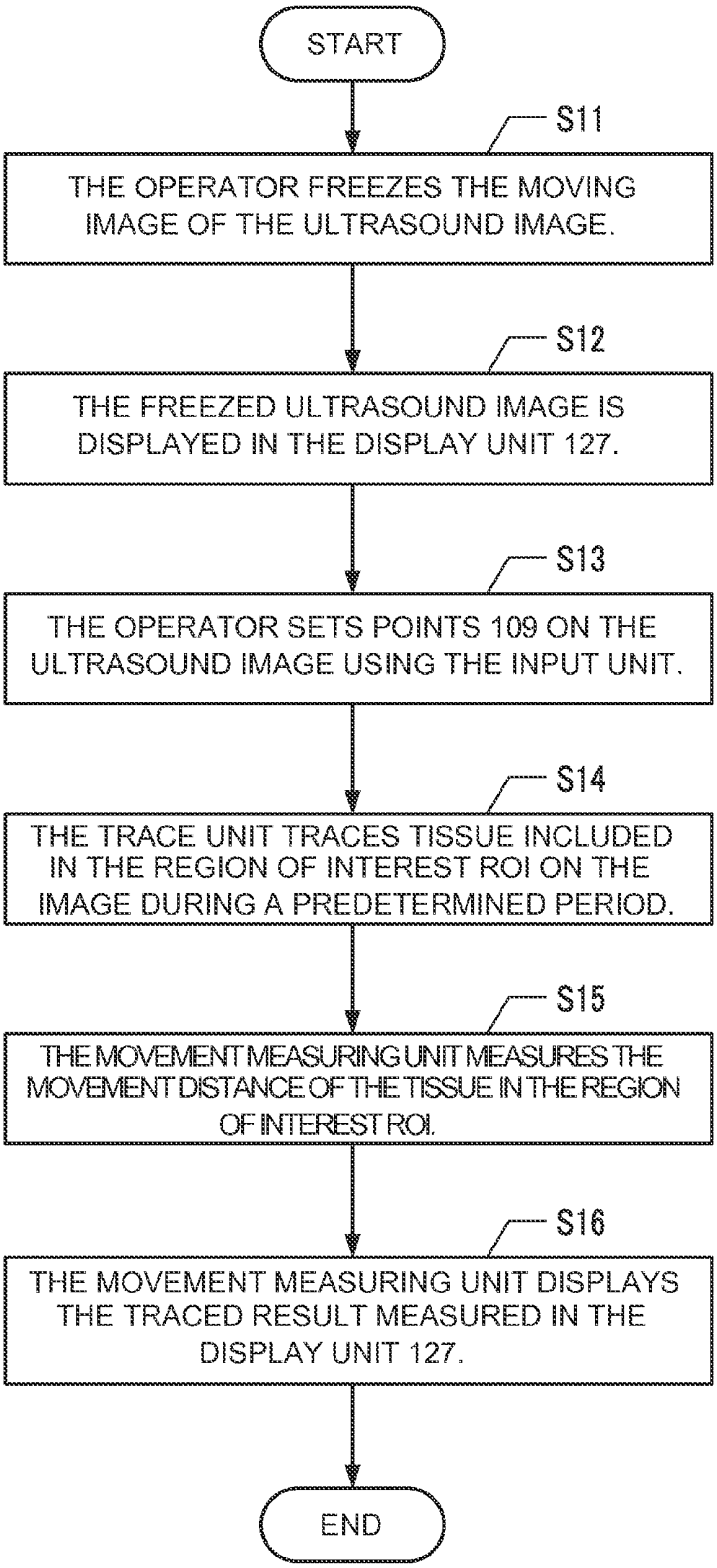

100
CPU
120
MEMORY
115
SECTIONAL IMAGE GENERATION UNIT
121
IMAGE SYNTHESIS UNIT
124
TRACING UNIT
122
REGION OF INTEREST SETTING UNIT
125
MOVEMENT MEASURING UNIT
123
STORED SOUND RAY DATA
116
STORED IMAGE DATA
117
STORED MOVEMENT INFORMATION
118
INPUT UNIT
126
DISPLAY UNIT
127
TRANSMITTING CIRCUIT
112
RECEIVING CIRCUIT
113
110
111
103a
BV
104
103b
109
ROI
SX
LX
109
ROI

FIG. 2


START
S11
THE OPERATOR FREEZES THE MOVING IMAGE OF THE ULTRASOUND IMAGE.
S12
THE FREEZED ULTRASOUND IMAGE IS DISPLAYED IN THE DISPLAY UNIT 127.
S13
THE OPERATOR SETS POINTS 109 ON THE ULTRASOUND IMAGE USING THE INPUT UNIT.
S14
THE TRACE UNIT TRACES TISSUE INCLUDED IN THE REGION OF INTEREST ROI ON THE IMAGE DURING A PREDETERMINED PERIOD.
S15
THE MOVEMENT MEASURING UNIT MEASURES THE MOVEMENT DISTANCE OF THE TISSUE IN THE REGION OF INTEREST ROI.
S16
THE MOVEMENT MEASURING UNIT DISPLAYS THE TRACED RESULT MEASURED IN THE DISPLAY UNIT 127.
END

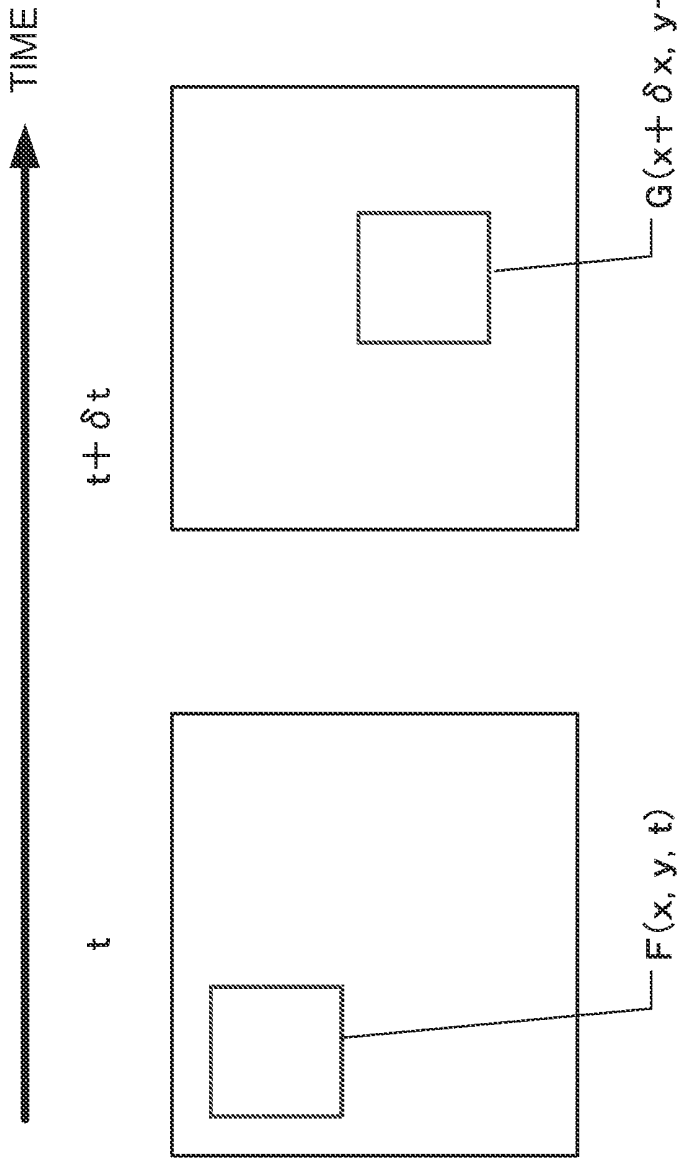


FIG. 3

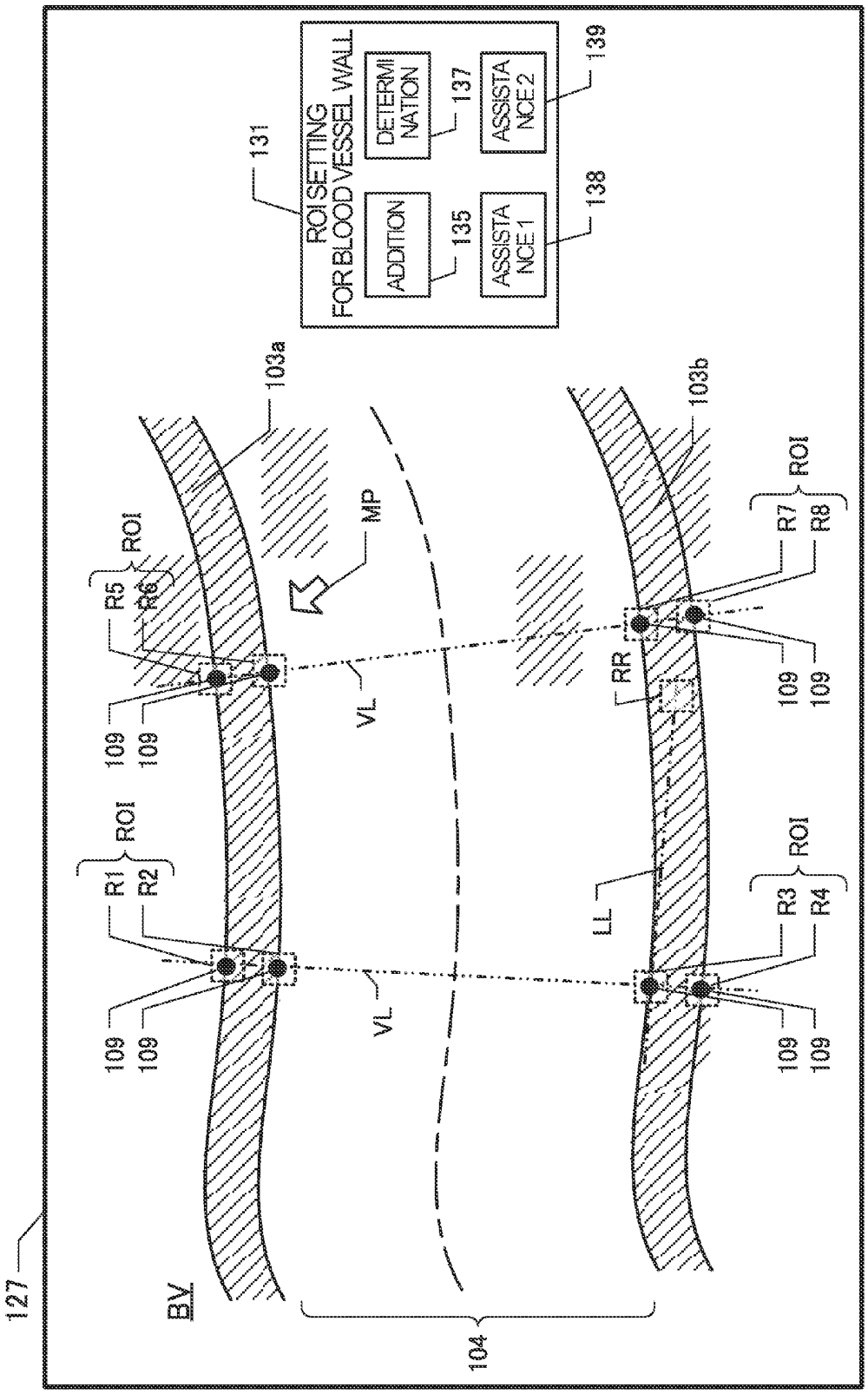

127
131
ROI SETTING FOR BLOOD VESSEL WALL
ADDITION
135
DETERMI NATION
137
ASSISTA NCE 1
138
ASSISTA NCE 2
139
103a
103b
MP
VL
VL
LL
RR
ROI
R1
R2
R3
R4
R5
R6
R7
R8
109
BV
104

FIG. 4

FIG. 5

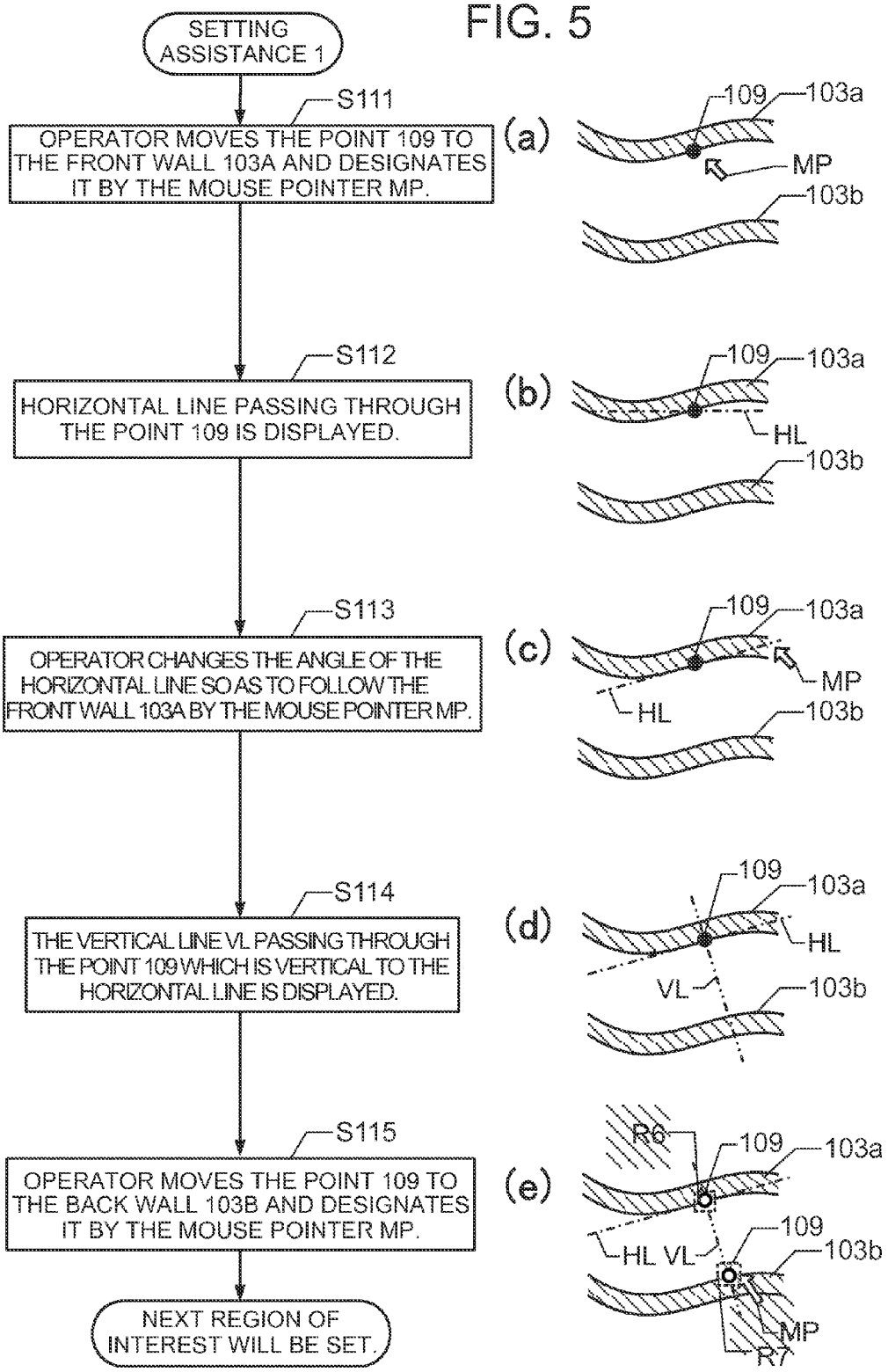
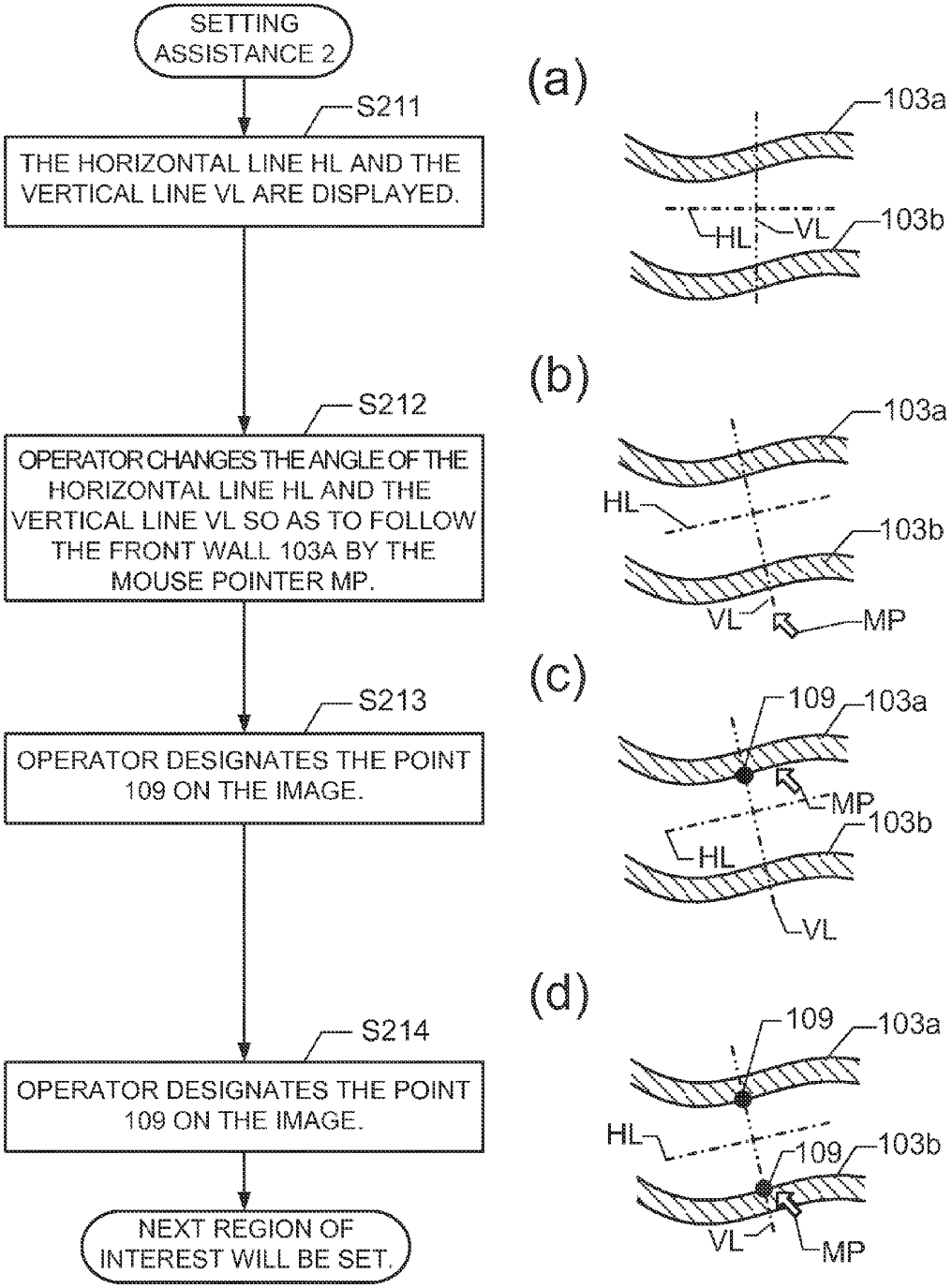

SETTING ASSISTANCE 1
S111
OPERATOR MOVES THE POINT 109 TO THE FRONT WALL 103A AND DESIGNATES IT BY THE MOUSE POINTER MP.
(a)
109
103a
MP
103b
S112
HORIZONTAL LINE PASSING THROUGH THE POINT 109 IS DISPLAYED.
(b)
109
103a
HL
103b
S113
OPERATOR CHANGES THE ANGLE OF THE HORIZONTAL LINE SO AS TO FOLLOW THE FRONT WALL 103A BY THE MOUSE POINTER MP.
(c)
109
103a
MP
HL
103b
S114
THE VERTICAL LINE VL PASSING THROUGH THE POINT 109 WHICH IS VERTICAL TO THE HORIZONTAL LINE IS DISPLAYED.
(d)
109
103a
HL
VL
103b
S115
OPERATOR MOVES THE POINT 109 TO THE BACK WALL 103B AND DESIGNATES IT BY THE MOUSE POINTER MP.
(e)
R6
109
103a
109
HL VL
103b
MP
R7
NEXT REGION OF INTEREST WILL BE SET.

FIG. 6


SETTING ASSISTANCE 2
S211
THE HORIZONTAL LINE HL AND THE VERTICAL LINE VL ARE DISPLAYED.
S212
OPERATOR CHANGES THE ANGLE OF THE HORIZONTAL LINE HL AND THE VERTICAL LINE VL SO AS TO FOLLOW THE FRONT WALL 103A BY THE MOUSE POINTER MP.
S213
OPERATOR DESIGNATES THE POINT 109 ON THE IMAGE.
S214
OPERATOR DESIGNATES THE POINT 109 ON THE IMAGE.
NEXT REGION OF INTEREST WILL BE SET.
(a)
103a
HL
VL
103b
(b)
103a
HL
103b
VL
MP
(c)
109
103a
MP
103b
HL
VL
(d)
109
103a
HL
109
103b
VL
MP

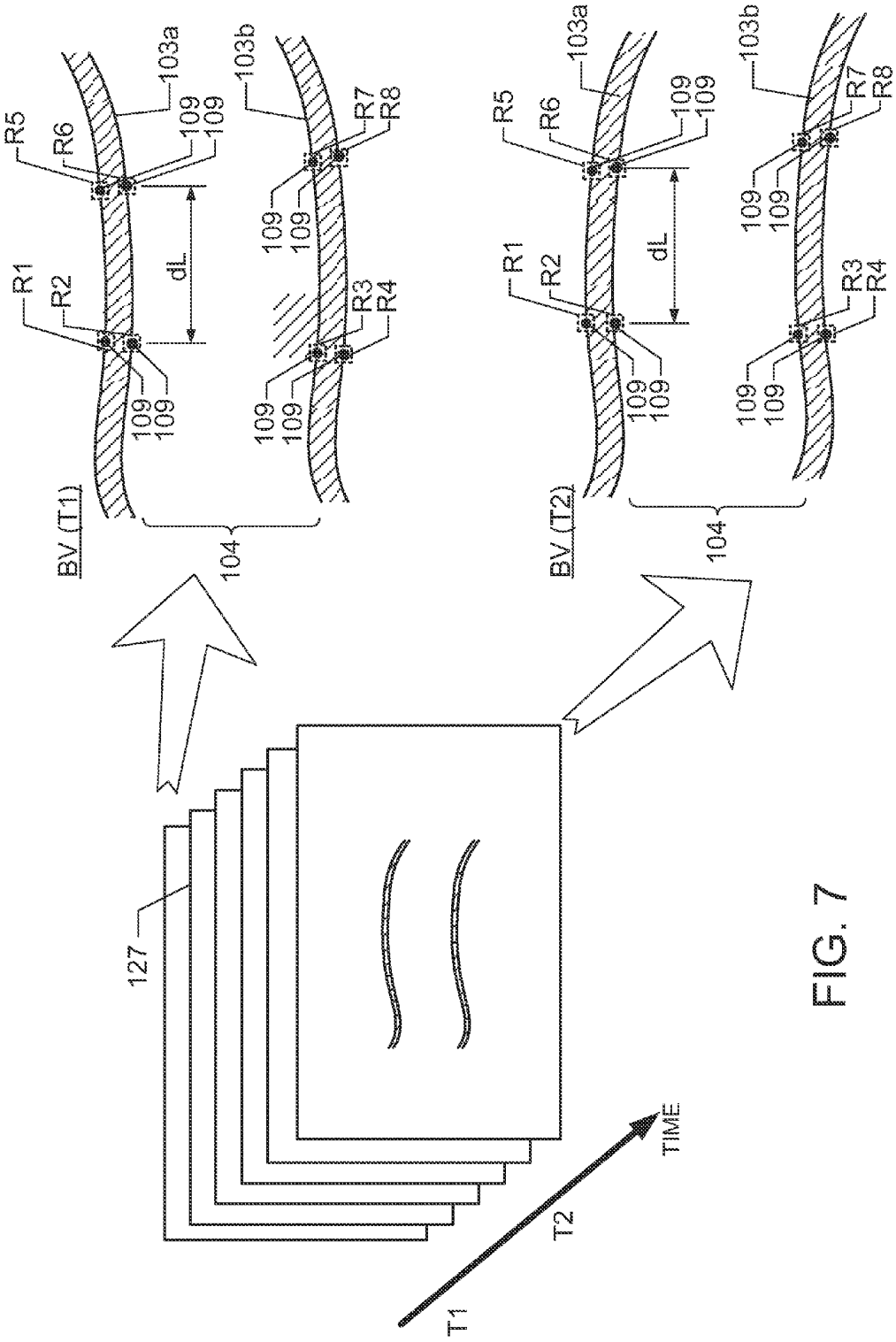

BV (T1)
BV (T2)
103a
103b
R1
R2
R3
R4
R5
R6
R7
R8
109
dL
104
127
T1
T2
TIME

FIG. 7

FIG. 8 (a)

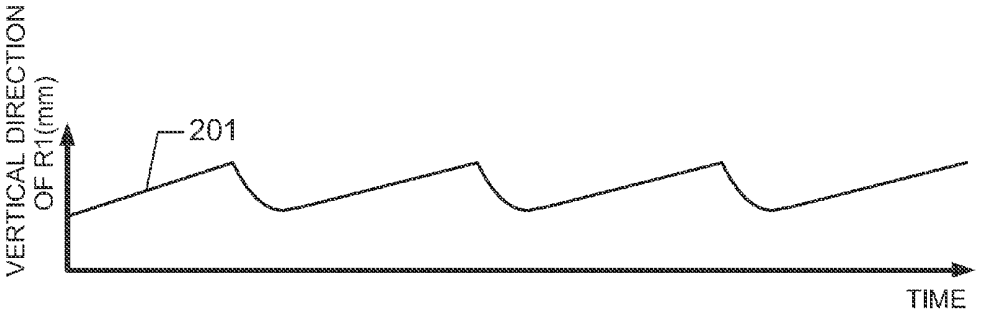


FIG. 8 (b)

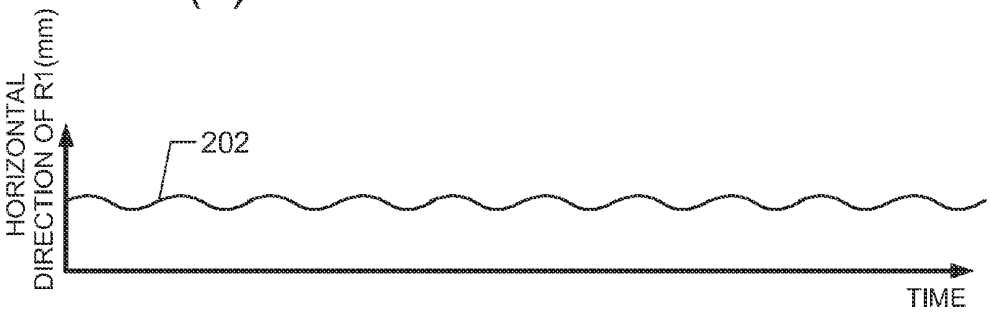


FIG. 8 (c)

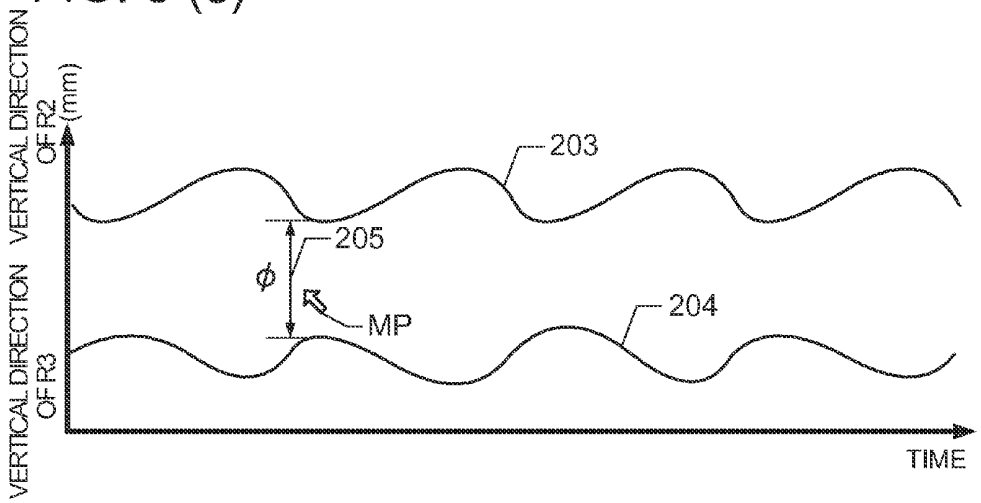


FIG. 9 (a)

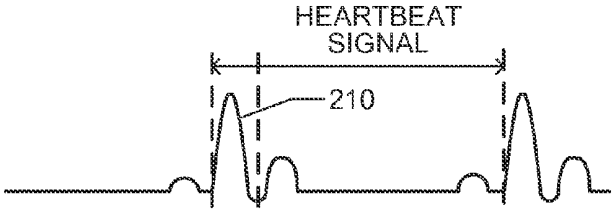


FIG. 9 (b)

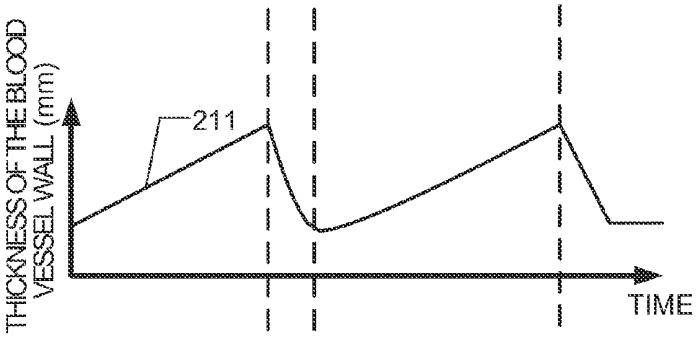


FIG. 9 (c)

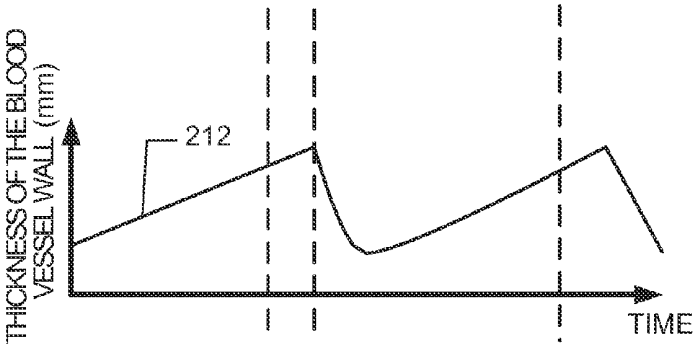
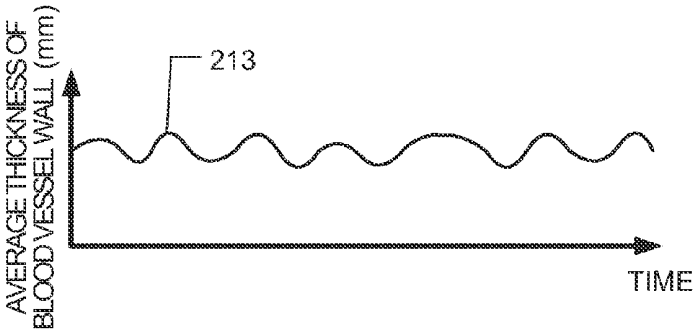


FIG. 9 (d)



ULTRASOUND DIAGNOSTIC APPARATUS AND METHOD FOR TRACING MOVEMENT OF TISSUE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of Japanese Patent Application No. 2010-241316 filed Oct. 27, 2010, which is hereby incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] The embodiments described herein relate to an ultrasound diagnostic apparatus for diagnosing blood vessel using ultrasound.

[0003] In recent years, number of patients diagnosed with circulatory condition, such as cerebral infarction and cardiac infarction, are on the rise. To prevent from such disease, it is important to detect a symptom of arteriosclerosis in its early stage and to improve a lifestyle.

[0004] To diagnose an arterial problem, Japanese unexamined publication 2002-238903A discloses an ultrasound diagnostic apparatus that measures the diameter of blood vessel using B (brightness)-mode image. Japanese unexamined publication 2002-238903A further discloses an ultrasound diagnostic apparatus for tracing the diameter of blood vessel and blood vessel wall in which an operator sets a mark for tracing in the B-mode image displayed in the monitor, and calculating a correlation of the brightness of pixel in a region of interest (ROI) that includes previously setup mark for tracing.

[0005] Unfortunately, the correlation of the brightness of pixel as described in Japanese unexamined publication 2002-238903A may vary the diameter of the blood vessel or the blood vessel wall depending on the image data processing. Also, by setting the region of interest (ROI) on the blood vessel, it is preferred that the inner diameter of the blood vessel or the thickness of the blood vessel wall is displayed.

[0006] It is desirable that the problems described previously are solved.

BRIEF DESCRIPTION OF THE INVENTION

[0007] A first aspect of the ultrasound diagnostic apparatus includes a transmitting and receiving unit for transmitting an ultrasound wave to a target object in sequence and for receiving the ultrasound wave as ultrasound data reflected from a certain region of the target object including a long axis direction blood vessel in sequence; a first memory unit for storing the received ultrasound data in sequence; an image generation unit for generating an ultrasound image as a sectional image of the long axis direction blood vessel based on the received ultrasound data; and a display unit for displaying the ultrasound image generated by the image generation unit.

[0008] The ultrasound diagnostic apparatus includes a region of interest setting unit for setting a first region of interest and a second region of interest on a vertical straight line at a right angle to the long axis direction blood vessel and on a wall of the blood vessel of the ultrasound image displayed in the display unit at a designated time, wherein the region of interest is generated by ultrasound data stored in the first memory unit; a tracing unit for tracing movement of tissue in the target object corresponding to the first region of interest and the second region of interest set in the ultrasound image at the designated time and sequentially following thereafter, by the gradient method using a spatial brightness gradient; and a second memory unit for storing information of the movement of the tissue for a predetermined duration based on the movement of tissue traced by the tracing unit.

[0009] In a second aspect of the ultrasound diagnostic apparatus, the display unit displays a traced result of the movement of the tissue on the vertical straight line and to a horizontal straight line normal to the vertical straight line, based on the information of the movement of the tissue stored in the second memory unit.

[0010] In a third aspect of the ultrasound diagnostic apparatus, the display unit displays the traced result of the distance between the tissues on the vertical straight line, based on the information of the movement of tissue stored in the second memory unit.

[0011] In a fourth aspect of the ultrasound diagnostic apparatus, the region of interest setting unit displays points for indications of the first region of interest and the second region of interest on the display unit.

[0012] In a fifth aspect of the ultrasound diagnostic apparatus, the region of interest setting unit displays a horizontal line in the long axis direction including the first region of interest on the display unit when the first region of interest is set on the vertical straight line, and displays a vertical line normal to the horizontal line including the first region of interest on the display unit when angle of the horizontal line is set. Then an operator can easily set the region of interest.

[0013] In a sixth aspect, the first region of interest includes a first inner wall of the blood vessel on the vertical straight line and the second region of interest includes a second inner wall of the blood vessel on the vertical straight line. The display unit displays a traced result of an inner diameter of the blood vessel identified by the first region of interest and the second region of interest.

[0014] In a seventh aspect, the first region of interest includes a first outer wall of the blood vessel on the vertical straight line and the second region of interest includes a second outer wall of the blood vessel on the vertical straight line. The display unit displays a traced result of an outer diameter of the blood vessel identified by the first region of interest and the second region of interest.

[0015] In an eight aspect, the region of interest setting unit sets a third region of interest and a fourth region of interest on the vertical straight line. The first region of interest includes a first inner wall of the blood vessel on the vertical straight line and the second region of interest includes a second inner wall of the blood vessel on the vertical straight line. The third region of interest includes a first outer wall of the blood vessel and the fourth region of interest includes a second outer wall of the blood vessel. The display unit displays a change in duration of a thickness of the blood vessel identified by the first and the second regions of interest and the third and the fourth regions of interest.

[0016] In a ninth aspect, the region of interest setting unit sets each region of interest corresponding to the first and the second regions of interest, which is in a different position from the first and the second regions of interest in the long axis direction.

[0017] In a tenth aspect, the display unit displays a traced result of an average distance based on the information of the movement of the tissue at the different position in long axis direction stored in the second memory unit. The average distance between the tissues of the target body on the vertical straight line is calculated at a plurality of different positions.

[0018] In an eleventh aspect, the region of interest setting unit sets a new region of interest on the horizontal straight line. The tracing unit traces movement of tissue in the target object corresponding to the region of interest on the horizontal straight line. The display unit displays the points, the first region of interest and the second region of interest when the first region of interest and the region of interest on the horizontal straight line are moved.

[0019] The ultrasound diagnostic apparatus described herein can trace a movement of a target object within the predetermined region, including a blood vessel, by using a gradient method and accurately measure the movement of tissue in the target object.

[0020] Further objects and advantages of the present invention will be apparent from the following description of the preferred embodiments of the invention as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] FIG. **1** is an overall diagram of an ultrasound diagnostic apparatus.

[0022] FIG. **2** is a flowchart showing the method of measuring blood vessel in accordance with a present embodiment.

[0023] FIG. **3** is a diagram explaining the brightness gradient of the grayscale image.

[0024] FIG. **4** is a diagram showing the setup region of interest (ROI) in the blood vessel (BV).

[0025] FIG. **5** shows the first example of setting the ROI with assistance from the region of interest setting unit **125**.

[0026] FIG. **6** shows the second example of setting the ROI with assistance from the region of interest setting unit **125**.

[0027] FIG. **7** shows the sequence of ultrasound image displayed in the display unit **127**.

[0028] FIG. **8** (*a*) shows an example diagram of the traced result of the ROI (R**1**) to the vertical direction, displayed in the display unit **127**.

[0029] FIG. **8** (*b*) shows an example diagram of the traced result of the ROI (R**1**) to the horizontal direction, displayed in the display unit **127**.

[0030] FIG. **8** (*c*) shows an example diagram of the traced result of the ROI (R**2**) and the ROI (R**3**) to the vertical direction, displayed in the display unit **127**.

[0031] FIG. **9** (*a*) is a graph **210** for the heartbeat signal.

[0032] FIG. **9** (*b*) is a graph **211** showing the thickness of the front wall **103***a*.

[0033] FIG. **9** (*c*) is a graph **212** showing the thickness of the front wall **103***a*, which is different from the ROI to the long axis direction in FIG. **9** (*b*).

[0034] FIG. **9** (*d*) is a graph **213** showing the thickness of the average blood vessel wall thickness of the front wall **103***a*.

DETAILED DESCRIPTION OF THE INVENTION

[0035] <Configuration of the Ultrasound Diagnostic Apparatus **100**>

[0036] FIG. **1** is a block diagram showing the configuration of the ultrasound diagnostic apparatus **100**. The ultrasound diagnostic apparatus **100** includes a transmitting and receiving unit **110** connected to a parallel bus, a memory **115**, a CPU (central processing unit) **120**, an input unit **126** for inputting through a mouse or a keyboard and display unit **127** having an LCD unit.

[0037] The transmitting and receiving unit **110** includes an ultrasound probe **111**, a transmitting circuit **112** and a receiving circuit **113**. The ultrasound probe **111** includes a plurality of ultrasound transducers in a 1-dimensional or a 2-dimensional transducer array. The ultrasound transducers transmit ultrasound waves based on applied driving signal to the target object, receive ultrasound echo reflected from the target object, and output a receiving signal.

[0038] The transmitting circuit **112** includes a plurality of channels, and generates a plurality of driving signals applied to each plurality of ultrasound transducers. The transmitting circuit **112** can adjust an amount of delay in the plurality of driving signals so that the ultrasound transmitted from a plurality of ultrasound transducers forms an ultrasound beam thereafter. Also, the transmitting circuit **112** can provide to the ultrasound probe **111***a* plurality of driving signals, set for transmitting an ultrasound transmitted from the plurality of ultrasound transducers all at once to the image region of the target object.

[0039] The receiving circuit **113** includes a plurality of channels, receives a plurality of analog receiving signals outputted from each plurality of ultrasound transducers and amplifies thereof, and converts to digital receiving signals. Moreover, based on a received delay pattern selected from the transmitting and receiving unit **110**, the receiving circuit **113** applies each delay time to a plurality of receiving signals, and processes receiving focus by adding all of the receiving signals. Due to the receiving focus processing, the sound ray data with focused ultrasound echo is formed.

[0040] In this embodiment, the ultrasound probe **111** transmits ultrasound waves from the surface of the target object to a blood vessel BV inside the target object. Also, the ultrasound probe **111** receives an ultrasound echo from the target object, including the blood vessel. The transmitting and receiving unit **110** repeats the transmission of the ultrasound waves and reception of the ultrasound echo, for outputting the sound ray data in sequence. The sound ray data processes logarithm compression, gain adjustment or low-pass filter processing in the receiving circuit **113**, and processes an attenuation correction according to a depth of the reflecting position of ultrasound. The processed sound ray data is sequentially stored in the memory **115** through the parallel bus.

[0041] The memory **115** has capacity for storing a plurality of frames of the sound ray data **116** or a sectional image data **117**, generated by an image generation unit **121**.

[0042] CPU **120** includes the image generation unit **121**, the tracing unit **122**, the movement measuring unit **123**, the image synthesis unit **124** and the region of interest setting unit **125**.

[0043] The image generation unit **121** includes an image data generation function for inputting the sound ray data and generating sectional image data in B-mode. The image generation unit **121** converts the B-mode sectional image data into the sectional image data that complies to the scan method of a normal television signal, performs image processing necessary for gradation process and transmits to an image synthesis unit **124** or a display unit **127**, and sequentially stores the sectional image data etc. into the memory **115**.

[0044] Also, in live mode, the image generation unit **121** converts the directly supplied sound ray data into the sectional image data according to a scanning method, and in freeze mode, the image generation unit **121** converts the sectional image data **117** stored in the memory **115**, into the

sectional image data according to the scanning method. Moreover, during the freeze mode, if the memory **115** is storing the sound ray data **116** instead of the sectional image data **117**, the image generation unit **121** generates the B-mode sectional image data.

[0045] The region of interest setting unit **125** displays the intersection point **109** for indicating the region of interest (ROI) to the ultrasound image using the input unit **126**, such as a mouse. According to the movement of the mouse operated by an operator, the point **109** moves within the display unit **127**. Then, the region of interest setting unit **125** sets the ROI that is the surrounded region including the indicated point **109**, based on the signal from the point **109** indicated by the operator, to the ultrasound image displayed by using the image data supplied from the receiving circuit **113**. The region of interest setting unit **125** automatically sets the size of the ROI. The region of interest setting unit **125** extracts the image data at the ROI. Once the ROI is set, the region of interest setting unit **125** extracts the sectional image data of the ROI corresponding to the sectional image data **117**, which is stored in the memory **115** (or the sound ray data **116** stored in the memory **115**). The sectional image data extracted according to the ROI set by the region of interest setting unit **125** is supplied to the tracing unit **122**.

[0046] Although, the point **109** indicated with a black circle and the ROI indicated in rectangle is displayed in FIG. **1** of the diagram of the blood vessel in the long axis direction in the target object, the ROI does not always need to be indicated in the display unit **127**. Also, if the traced result informs that the blood vessel is moving as a whole from the tracing unit **122**, as explained below, the display unit **127** can display the point **109** and the ROI to trace the movement of the blood vessel as a whole.

[0047] The tracing unit **122** traces which vector direction the ROI is moving to, from the predetermined time. To trace the ROI, a method of calculating the velocity field of the motion object in the moving image (optical flow) is used. There are many methods in an optical flow. According to an experiment, a gradient method was suitable for tracing a blood vessel wall. The gradient method is suitable for tracing minute movements and especially for tracing minute movements of the blood vessel wall. The result of the tracing unit **122** tracing the ROI is transmitted to the image synthesis unit **124**, the movement measuring unit **123** and the memory **115**.

[0048] Also, the tracing unit **122** traces the movement of a whole blood vessel in the long axis direction or rotation. An example case of the blood vessel moving or rotating as a whole would be losing contact between the ultrasound probe **111** and the target object.

[0049] The movement measuring unit **123** measures the movement distance of tissue at a predetermined time based on the movement of tissue in the ROI traced by the tracing unit **122**. Thus, the movement measuring unit **123** can calculate the change in the diameter of the blood vessel or the elasticity of the blood vessel based on the movement distance of tissue. The traced result measured by the movement measuring unit **123** is transmitted to the image synthesis unit **124**, the memory **115** and the display unit **127**. The traced result transmitted to the memory **115** is stored as movement information **118**. The traced result transmitted to the display unit **127** is displayed in real-time as the total amount of movement of tissue inside the ROI.

[0050] The image synthesis unit **124** synthesizes the sectional image data supplied from the image generation unit **121**, the movement information **118** traced by the tracing unit **122** and the traced result measured in the movement measurement unit **123**, and synthesizes two images therewith. Image synthesis unit **124** can retrieve the sound ray data **116** or sectional image data **117**, stored in the memory **115**, on a necessary basis.

[0051] A diagram of a blood vessel in the long axis direction inside the target object as indicated in FIG. **1** is explained below.

[0052] Blood vessel includes a blood vessel wall **103**, which surrounds a blood flow region **104**. Blood vessel wall **103** includes a front wall **103***a*, which is a wall closer to the ultrasound probe **111**, and a back wall **103***b*, which is a wall farther from the ultrasound probe **111**. In FIG. **1**, the ROI set by the region of interest setting unit **125** is positioned on the front wall **103***a* and the back wall **103***b*. The long axis direction LX refers to the blood vessel extending in the longitudinal direction at the center of the blood flow region **104**, and the short axis direction SX refers to the cross-section of the blood vessel (vertical straight line normal to the long axis direction LX).

[0053] <Method for Measuring Blood Vessel>

[0054] FIG. **2** is a flow chart showing the method for measuring the blood vessel.

[0055] In step S**11**, the operator confirms that the moving image of the ultrasound image is stably obtained, and presses a freeze button (not described on figure).

[0056] In step S**12**, when the freeze button is pressed, the sound ray data **116** or the sectional image data **117** acquired during a few seconds after pressing the freeze button is stored in the memory **115**, and the ultrasound image stored in the first frame is displayed in the display unit **127**. The sound ray data **116** or the sectional image data **117** acquired a few seconds after pressing the freeze button can be stored in the memory **115** as well.

[0057] In step S**13**, the operator indicates the point **109** in the ultrasound image displayed on the first frame displayed in the display unit **127** by using the input unit **126** connected by a parallel bus, such as a mouse. The region of interest setting unit **125** sets the ROI to the surrounding region, including the point **109**. The operator can easily set the ROI to the blood vessel inside the target object, which is displayed in the display unit **127**. In this embodiment, at least two or more ROIs should be set.

[0058] In step S**14**, the tracing unit **122** traces the movement of tissue, which includes at least two points of the ROI, using frames of ultrasound images between the initial frame of the ultrasound image and the frame of the ultrasound image after the predetermined duration. The ROI is traced using the gradient method.

[0059] In step S**15**, the movement measuring unit **123** traces, for example, the movement of tissue included at two points of the ROI. For example, if the inner wall of the front wall **103***a* and the inner wall of the back wall **103***b* are the two points of the ROIs, the movement measuring unit **123** is able to understand how the inner diameter of the blood vessel is changing, in comparison to the ultrasound image of the first frame.

[0060] In step S**16**, the display unit **127** displays the traced result, measured by the movement measuring unit **123**, in a graph for example. The display unit **127** is able to display a graph adjacent to the displayed ultrasound image, or display a graph on a separate window.

[0061] <Tracing the ROI by Gradient Method>

[0062] An optical flow method for the tracing unit **122** tracing the movement of tissue in the ROI, at step S**14**, is explained below. In the optical flow method, a characteristic matching method, a method for matching the characteristic of images and calculating the movement, and a gradient method, a method for calculating the movement by calculating the gradient of the contrasting density (brightness) of an image for comparing the contrasting density of the image, is used. An experiment using both the characteristic matching method and the gradient method was performed on the ultrasound image including the blood vessel displayed in the B-mode. As a result, less difference in tracing was found in the gradient method. Thereby the gradient method is explained below.

[0063] As shown in FIG. **3**, the contrasting density image F (p, t) includes a gradient of contrasting density (brightness gradient). The gradient method traces the movement of tissue included in the ROI by using the gradient of contrast.

[0064] As shown in FIG. **3**, an image of contrasting density image "F" at time "t" (p, t) moved with even contrasting density after a minute duration (δ, t), is calculated as contrasting density image G (p+δp, t+δt). The distance of movement is calculated using the following equation:

$$h_0 = 0, \qquad \text{(Eq. 1)}$$

$$h_{k+1} = h_k + \frac{\sum w(p)F'(p+h_k)[G(p) - F(p+h_k)]}{\sum w(p)F'(p+h_k)^2}$$

The movement distance (vector) of tissue in the ROI is calculated by doing the iterative operation of equation 1.

[0065] In equation 1, "h" represents the distance of approximate movement, w (p) represents the weight coefficient, F (p) represents the contrasting density image before the movement, and F' (p) represents the first derivation.

[0066] The gradient method is suitable for tracing minute movements such as movement of the blood vessel wall due to the heartbeat. By tracing the movement of tissue included in the ROI using the gradient method, the minute movement of the blood vessel wall due to the heartbeat can be accurately traced.

[0067] <Setting the ROI>

[0068] FIG. **4** is a diagram showing the ROI in the blood vessel extending in the long axis direction, as displayed in the display unit **127**, which was set by an operator. This is the same method as setting the ROI in the step S**13** of FIG. **2**.

[0069] An operator checks the ultrasound image of the initial frame displayed in the display unit **127**. Then, the operator checks whether the blood vessel extending in the long axis direction is a sectional image that can easily set the ROI, and if the sectional image is an image that can easily set the ROI, the operator clicks the ROI setting button (not described on figure) through the input unit **126**, using the mouse pointer. The region of interest setting unit **125** (refer to FIG. **1**) displays the ROI setting window **131** for the blood vessel wall, on the display unit **127**.

[0070] The ROI setting window **131** for the blood vessel wall includes an adding button **135**, a determination button **137**, a first assistance button **138** and a second assistance button **139**.

[0071] When the adding button **135** is selected with the mouse pointer MP, the point **109** of predetermined size is displayed in the display unit **127**. When the adding button **135** is selected a plurality of times, a plurality of points **109** are displayed in the display unit **127**. In FIG. **4**, eight of the points **109** are displayed in the display unit **127**.

[0072] For each point **109** displayed in the display unit **127**, the operator can move displayed points to an arbitrary position one-by-one using the mouse pointer and can designate the position. In FIG. **4**, the operator designates points **109** on four positions in the long axis direction (short axis direction) of the blood vessel. Based on the designated point **109**, the region of interest setting unit **125** sets the ROIs (R**1** and R**2**) on the outer wall and the inner wall of the front wall **103***a* and sets ROIs R**3** and R**4** on the outer wall and the inner wall of the front wall **103***b*. Also, the operator is designating the point **109** at four positions farther away from the ROIs (R**1** through R**4**) in the long axis direction. Based on the designated points **109**, the region of interest setting unit **125** sets the ROIs R**5** and R**6** on the outer wall and the inner wall of the front wall **103***a*, and sets the ROIs R**7** and R**8** on the outer wall and the inner wall of the back wall **103***b*. Once the operator completes setting all of the regions of interest, the operator selects the determination button **137**. Also, the operator can display the horizontal line or the vertical line for assisting the setting of the ROI, by selecting the first assistance button **138** or the second assistance button **139**. In FIG. **4**, the ROI is displayed in the display unit **127** using dotted lines. However, the point **109** can only be displayed without displaying the ROI.

[0073] When at least one point **109** is designated, the region of interest setting unit **125** sets a new region of interest RR along the horizontal straight line LL extending in the horizontal direction from the point **109**. The horizontal straight line LL and the region of interest RR do not need to be displayed in the display unit **127**. In FIG. **4**, the horizontal straight line LL and the region of interest RR along the horizontal straight line LL are displayed-according to the point **109** on the ROI R**3**. The tracing unit **122** traces the movement of the region of interest R**3** and the newly set region of interest RR. For example, if the ROI R**3** and the region of interest RR are moving with the same size and in the same direction, the tracing unit **122** is able to determine that the blood vessel is moving as a whole. When the tracing unit **122** transmits to the region of interest setting unit **125** and the display unit **127** that the blood vessel is moving as a whole, the region of interest setting unit **125** traces the movement as a whole, to all points **109** and the ROI relating to the points **109**. Thus, even if the blood vessel displaces as a whole, the point **109** and the ROI relating to the point **109** traces the position originally designated or set. Finally, the movement unit **127** traces the vertical straight line VL extending from the point **109** and the ROI relating to the point **109**.

[0074] <Assisting the Setting of the ROI: First Example>

[0075] FIG. **5** is the first example of setting the ROI with assistance from the region of interest setting unit **125** (refer to FIG. **1**). The flowchart on the left side corresponds to the drawing of conditions thereof, indicated on the right side. In the first example of FIG. **5**, the ROI is set on the inner wall of the front wall **103***a* and the inner wall of the back wall **103***b*. Therefore, R**6** and R**7** of the ROI, set in the FIG. **4**, are displayed.

[0076] The operator selects the first assistance button **138** (refer to FIG. **4**), and then selects the adding button **135**. The point **109** is displayed in the display unit **127**.

[0077] In the step S**111**, the operator indicates the point **109** on the inner wall of the front wall **103***a*, which the operator

wants to observe, by moving the mouse pointer. Then, the operator selects the determination button **137**.

[0078] In step S**112**, the region of interest setting unit **125** displays the horizontal line HL, which passes through the point **109** and has a predetermined length with the point **109** as a center. The horizontal line HL is parallel to the horizontal line **127**, and is displayed as a tangent line to the inner wall of the front wall **103***a* in the long axis direction.

[0079] In step S**113**, the operator changes the angle of the horizontal line HL using the mouse pointer MP. Once the angle of the horizontal line HL is changed in such a way that it extends vertically to the front wall **103***a*, the operator selects the determination button **137**.

[0080] In step S**114**, the region of interest setting unit **125** displays the vertical line VL, which passes through the point **109** and is vertical to the horizontal line HL with the angle changed.

[0081] In step S**115**, the operator selects the adding button **135**, displays the point **109** on the display unit **127**, and indicates the point **109** on the inner wall of the back wall **103***b* that the operator wants to observe by moving the mouse pointer MP. At this point, two regions of interests R**6**, R**7** based on two points of the point **109** is set. In order to set three or more regions of interest, the operator continues the operation. If it is not necessary to set more than two regions of interest, the operator selects the determination button **137**.

[0082] If the inner wall of the front wall **103***a* is bent due to the heartbeat, it is difficult to set another point **109** in the vertical direction (to the short axis direction) of the point **109**. Therefore, as mentioned above, the horizontal line HL of the predetermined length with the point **109** as a center is to be displayed, and after changing the angle of the horizontal line HL, the vertical line VL is to be displayed. This sets the ROI R**2** and the ROI R**3** accurately in the vertical direction, therefore the diameter of the blood vessel can be accurately verified.

[0083] In the vertical line (VL) indicated in FIG. **4**, the ROIs R**1**-R**4** are set in the vertical direction accurately. Thus, the thickness of the front wall **103***a* of the blood vessel can be accurately verified based on the ROI R**1** or the ROI R**2**, or the thickness of the back wall **103***b* can be accurately verified based on the ROI R**3** or the ROI R**4**.

[0084] <Assisting the Setting of the ROI: Second Example>

[0085] FIG. **6** is the second example of setting the ROI with assistance from the region of interest setting unit **125** (refer to FIG. **1**). As similar to the first example, the ROI is to be set onto the inner wall of the front wall **103***a* and the inner wall of the back wall **103***b*.

[0086] The operator selects the second assistance button **139** (refer to FIG. **4**).

[0087] In step S**211**, the region of interest setting unit **125** displays the horizontal line HL and the vertical line VL.

[0088] In step S**212**, the operator changes the angle of the horizontal line HL and the vertical line VL using the mouse pointer, and moves the vertical line VL to the position to be observed. By rotating and moving a part of the horizontal line and the vertical line using the mouse pointer, the horizontal line HL and the vertical line VL rotate and move as a whole, while maintaining the right angle.

[0089] In step S**213**, when the operator selects the adding button **135**, the region of interest setting unit **125** displays the point **109** on the display unit **127**. Then the operator moves the point **109** along the inner wall of the front wall **103***a* on the vertical line VL that the operator wants to observe using the mouse pointer MP.

[0090] In step S**214**, when the operator selects the adding button **135**, the point **109** is displayed on the display unit **127**. Then, the operator moves the point **109** to the inner wall of the back wall **103***b* on the vertical line that the operator wants to observe by moving the mouse pointer MP. In order to set three or more ROIs, the operator continues the operation. The operator selects the determination button **137**, if it is not necessary to set more than two ROIs.

[0091] Also, in FIG. **5** or FIG. **6**, the horizontal line HL or the vertical line VL can be drawn directly on the screen of the display unit **127**, which the horizontal line HL or the vertical line VL is displayed, by selecting the first assistance button **138** or the second assistance button **139**.

[0092] <Tracing Information of the ROI>

[0093] FIG. **7** shows the sequence of ultrasound image displayed in the display unit **127** after the point **109** is indicated and the ROI is set. The left side of FIG. **7** shows a plurality of frames of the ultrasound image between the predetermined time T**1** and the predetermined time T**2** being displayed, and the right side of FIG. **7** includes abstracts from the frame sequence taken from the ultrasound image at time T**1** and the ultrasound image at time T**2**.

[0094] The cross-sectional shape of the blood vessel in the long axis direction changes between time T**1** and time T**2** due to the heartbeat. Tissue indicated with the ROIs R**1**-R**8** moves in the horizontal direction (long axis direction) and the vertical direction (short axis direction) respectively. In this embodiment, eight ROIs are set, and by selecting one ROI R**1**, the movement measuring unit **123** can measure the amount of the movement of the ROI R**1** in the vertical direction and the horizontal direction. Also, by selecting at least two ROIs among the eight ROIs, the movement measuring unit **123** can measure the movement information of these two ROIs.

[0095] FIGS. **8**(*a*), **8**(*b*), **8**(*c*), **9**(*a*), **9**(*b*), **9**(*c*), and **9**(*d*) are examples of displaying the traced result measured by the movement measuring unit **123** at step S**16** of FIG. **2**, in a graph. These graphs are displayed based on the movement of the ROIs R**1**-R**8** indicated in FIG. **7**.

[0096] FIG. **8**(*a*)-(*c*) are graphs indicating the traced result of the ROI of the blood vessel.

[0097] FIG. **8**(*a*) is an example of the movement measuring unit **123** displaying the traced result of the ROI R**1** in the vertical direction on the display unit **127**. The vertical axis represents the position (in mm) and the horizontal axis represents time. The graph **201**, displaying the traced result of the ROI R**1** in the vertical direction, indicates that the outer wall of the front wall **103***a*, which also is the ROI R**1**, is largely moving due to the heartbeat.

[0098] FIG. **8**(*b*) is an example of the movement measuring unit **123** displaying the traced result of the ROI R**1** in the horizontal direction on the display unit **127**. The graph **202**, displaying the horizontal direction of the ROI R**1**, indicates that the outer wall of the front wall **103***b* is moving in the horizontal direction due to the heartbeat, and the amount of movement is smaller in comparison to the movement in the vertical direction, as shown in FIG. **8**(*a*).

[0099] FIG. **8**(*c*) is an example of the movement measuring unit **123** displaying the traced result of the ROI R**2** and the ROI R**3** in the vertical direction, on the display unit **127**. ROI R**2** is the inner wall of the front wall **103***a*, and the ROI R**3** is the inner wall of the back wall **103***b*. The graph **203**, display-

ing the vertical direction of the ROI R2, indicates that the inner wall of the front wall **103***a* is moving due to the heartbeat, and the graph **204**, displaying the vertical direction of the ROI R3, indicates that the inner wall of the back wall **103***b* is moving due to the heartbeat. Also, since the ROI R2 and the ROI R3 are placed on the vertical direction (short axis direction) to the blood vessel. The difference between the graph **203** and the graph **204** being equals to the inner diameter of the blood vessel. By displaying the inner diameter index **205** and the operator moving the inner diameter index **205** using the mouse pointer, it is possible for the movement measuring unit **123** to display the inner diameter of the blood vessel for an arbitrary time.

[0100] FIG. **9**(*a*)-(*d*) are graphs displaying the thickness of blood vessel wall, which is one of the traced results.

[0101] FIG. **9**(*a*) is the graph **210** of the heartbeat signal. The heartbeat signal is displayed by placing the sensor (not described on figure) on the target object thereof.

[0102] FIG. **9**(*b*) is an example of the movement measuring unit **123** displaying the difference between the ROI R1 and the ROI R2 in the vertical direction, which corresponds to the thickness of the front wall **103***a*, on the display unit **127** in the graph **211**. The graph **211**, which is the thickness of the front wall **103***a*, is displayed by synchronizing to the graph **210** of the heartbeat signal.

[0103] FIG. **9**(*c*) is an example of the movement measuring unit **123** displaying the difference between the ROI R5 the ROI R6 in the vertical direction, which corresponds to the thickness of the front wall **103***a*, on in the display unit **127**. The graph **212**, which is the thickness of the front wall **103***a*, is displayed by synchronizing to the graph **210** of the heartbeat signal. As displayed in FIG. **7**, the ROI R2 and the ROI R6 are positioned at the distance dL away from the long axis direction. Thus, the thickness of the blood vessel due to the heartbeat is different. By comparing the graph **211** and the graph **212**, the change in time between the graph **211** and the graph **212** can be calculated. Therefore, the pulse wave velocity (PWV), a parameter for arteriosclerosis, can be calculated as well.

[0104] FIG. **9**(*d*) is an example of the movement measuring unit **127** displaying the graph **213**, which indicates the movement measuring unit **123** displaying the average thickness of blood vessel wall of the front wall **103***a*. In FIG. **7**, the movement measuring unit **123** measured the thickness of the front wall **103***a* with the ROI (R1) and the ROI (R2), and the thickness of the front wall **103***a* with the ROI (R5) and the ROI (R6). The graph **213** of the average blood vessel wall thickness is obtained by measuring the thickness of the front wall **103***a* at plurality of places including these two points and calculating the average of the front wall **103***a*.

[0105] The embodiment described herein includes the movement measuring unit **123** displaying the change in the thickness of the blood vessel wall and the change in the inner diameter of the blood vessel. These embodiments may be carried out by means of a variety of changes, such as measuring the change of the outer diameter of the blood vessel and that of the cross-section area of the blood vessel. Also, as mentioned in FIG. **9**(*a*), if the heartbeat or the blood pressure is measured, the movement measuring unit **123** can measure the stiffness parameter or the blood vessel wall diameter direction average elasticity.

[0106] Many widely different embodiments of the invention may be configured without departing from the spirit and the scope of the present invention. It should be understood that the present invention is not limited to the specific embodiments described in the specification, except as defined in the appended claims.

1. An ultrasound diagnostic apparatus comprising:
- a transmitting and receiving unit configured to transmit an ultrasound wave to a target object in sequence and to receive the ultrasound wave as ultrasound data reflected from a certain region of the target object including a long axis direction blood vessel in sequence;
- a first memory unit configured to store the received ultrasound data in sequence;
- an image generation unit configured to generate an ultrasound image as a sectional image of the long axis direction blood vessel based on the received ultrasound data;
- a display unit configured to display the ultrasound image generated by the image generation unit;
- a region of interest setting unit configured to set a first region of interest on a vertical straight line at a right angle to the long axis direction blood vessel and a second region of interest on a wall of the blood vessel of the ultrasound image displayed in the display unit at a designated time, wherein the regions of interest are generated by ultrasound data stored in the first memory unit;
- a tracing unit configured to trace movement of tissue in the target object corresponding to the first region of interest and the second region of interest from the designated time to sequentially following thereafter, by a gradient method using a spatial brightness gradient; and
- a second memory unit configured to store information of the movement of the tissue for a predetermined duration based on the movement of the tissue traced by the tracing unit.

2. The ultrasound diagnostic apparatus according to the claim **1**, wherein the display unit is configured to display a traced result of the movement of the tissue on the vertical straight line or on a horizontal straight line normal to the vertical straight line based on the information of the movement of the tissue stored in the second memory unit.

3. The ultrasound diagnostic apparatus according to the claim **1**, wherein the display unit is configured to display a traced result of a distance between at least two tissues on the vertical straight line based on the information of the movement of the tissue stored in the second memory unit.

4. The ultrasound diagnostic apparatus according to the claim **1**, wherein the region of interest setting unit is configured to display points as indications of the first region of interest and the second region of interest on the display unit, and to set the first region of interest and the second region of interest including the points when the points are indicated.

5. The ultrasound diagnostic apparatus according to the claim **1**, wherein the region of interest setting unit is configured to display a horizontal line in the long axis direction including the first region of interest on the display unit when the first region of interest is set on the vertical straight line, and to display the vertical line normal to the horizontal line including the first region of interest on the display unit when angle of the horizontal line is set.

6. The ultrasound diagnostic apparatus according to the claim **1**, wherein the first region of interest includes a first inner wall of the blood vessel on the vertical straight line and the second region of interest includes a second inner wall of the blood vessel on the vertical straight line,

the display unit configured to display a traced result of an inner diameter of the blood vessel identified by the first region of interest and the second region of interest.

7. The ultrasound diagnostic apparatus according to the claim **2**, wherein the first region of interest includes a first inner wall of the blood vessel on the vertical straight line and the second region of interest includes a second inner wall of the blood vessel on the vertical straight line,

the display unit configured to display a traced result of an inner diameter of the blood vessel identified by the first region of interest and the second region of interest.

8. The ultrasound diagnostic apparatus according to the claim **3**, wherein the first region of interest includes a first inner wall of the blood vessel on the vertical straight line and the second region of interest includes a second inner wall of the blood vessel on the vertical straight line,

the display unit configured to display a traced result of an inner diameter of the blood vessel identified by the first region of interest and the second region of interest.

9. The ultrasound diagnostic apparatus according to the claim **4**, wherein the first region of interest includes a first inner wall of the blood vessel on the vertical straight line and the second region of interest includes a second inner wall of the blood vessel on the vertical straight line,

the display unit is configured to display a traced result of an inner diameter of the blood vessel identified by the first region of interest and the second region of interest.

10. The ultrasound diagnostic apparatus according to the claim **5**, wherein the first region of interest includes a first inner wall of the blood vessel on the vertical straight line and the second region of interest includes a second inner wall of the blood vessel on the vertical straight line,

the display unit is configured to display a traced result of an inner diameter of the blood vessel identified by the first region of interest and the second region of interest.

11. The ultrasound diagnostic apparatus according to the claim **1**, wherein the first region of interest includes a first outer wall of the blood vessel on the vertical straight line and the second region of interest includes a second outer wall of the blood vessel on the vertical straight line,

the display unit is configured to display a traced result of an outer diameter of the blood vessel identified by the first region of interest and the second region of interest.

12. The ultrasound diagnostic apparatus according to the claim **2**, wherein the first region of interest includes a first outer wall of the blood vessel on the vertical straight line and the second region of interest includes a second outer wall of the blood vessel on the vertical straight line,

the display unit is configured to display a traced result of an outer diameter of the blood vessel identified by the first region of interest and the second region of interest.

13. The ultrasound diagnostic apparatus according to the claim **3**, wherein the first region of interest includes a first outer wall of the blood vessel on the vertical straight line and the second region of interest includes a second outer wall of the blood vessel on the vertical straight line,

the display unit is configured to display a traced result of an outer diameter of the blood vessel identified by the first region of interest and the second region of interest.

14. The ultrasound diagnostic apparatus according to the claim **4**, wherein the first region of interest includes a first outer wall of the blood vessel on the vertical straight line and the second region of interest includes a second outer wall of the blood vessel on the vertical straight line,

the display unit is configured to display a traced result of an outer diameter of the blood vessel identified by the first region of interest and the second region of interest.

15. The ultrasound diagnostic apparatus according to the claim **5**, wherein the first region of interest includes a first outer wall of the blood vessel on the vertical straight line and the second region of interest includes a second outer wall of the blood vessel on the vertical straight line,

the display unit is configured to display a traced result of an outer diameter of the blood vessel identified by the first region of interest and the second region of interest.

16. The ultrasound diagnostic apparatus according to the claim **1**, wherein the region of interest setting unit is configured to set a third region of interest and a fourth region of interest on the vertical straight line,

the first region of interest includes a first inner wall of the blood vessel on the vertical straight line and the second region of interest includes a second inner wall of the blood vessel on the vertical straight line, the third region of interest includes a first outer wall of the blood vessel and the fourth region of interest includes a second outer wall of the blood vessel,

the display unit is configured to display a change in duration of a thickness of the blood vessel identified by the first and second regions of interest and the third and fourth regions of interest.

17. The ultrasound diagnostic apparatus according to the claim **1**, wherein the region of interest setting unit is configured to set a plurality of regions of interest corresponding to the first and second regions of interest, the plurality of regions of interest are at different positions than the first and second regions of interest in the long axis direction.

18. The ultrasound diagnostic apparatus according to the claim **17**, wherein the display unit is configured to display a traced result of an average distance based on the information of the movement of the tissue at the different positions in long axis direction stored in the second memory unit, the average distance between at least two tissues of the target object on the vertical straight line is calculated at a plurality different positions.

19. The ultrasound diagnostic apparatus according to the claim **4**, wherein the region of interest setting unit is configured to set a new region of interest on a horizontal straight line, and the tracing unit is configured to trace the movement of the tissue in the target object corresponding to the new region of interest on the horizontal straight line,

the display unit configured to display the points, the first region of interest, and the second region of interest when the first region of interest and the new region of interest are moved.

20. A method for tracing movement of tissue, the method comprising:

transmitting an ultrasound wave to a target object in sequence;

receiving the ultrasound wave as ultrasound data reflected from a certain region of the target object including a long axis direction blood vessel in sequence;

storing the received ultrasound data in sequence;

generating an ultrasound image as a sectional image of the long axis direction blood vessel based on the received ultrasound data;

displaying the ultrasound image;

setting a first region of interest on a vertical straight line at a right angle to the long axis direction blood vessel and a second region of interest on a wall of the blood vessel of the displayed ultrasound image at a designated time;

tracing movement of tissue in the target object corresponding to the first region of interest and the second region of interest from the designated time to sequentially following thereafter by a gradient method using a spatial brightness gradient; and

storing information of the movement of the tissue for a predetermined duration based on the traced movement of the tissue.

* * * * *

专利名称(译)	用于追踪组织运动的超声诊断设备和方法		
公开(公告)号	US20120108971A1	公开(公告)日	2012-05-03
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[标]申请(专利权)人(译)	美山KOJI 小笠原雅文		
申请(专利权)人(译)	美山KOJI 小笠原雅文		
当前申请(专利权)人(译)	通用电气医疗系统全球性技术公司，有限责任公司		
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发明人	MIYAMA, KOJI OGASAWARA, MASAFUMI		
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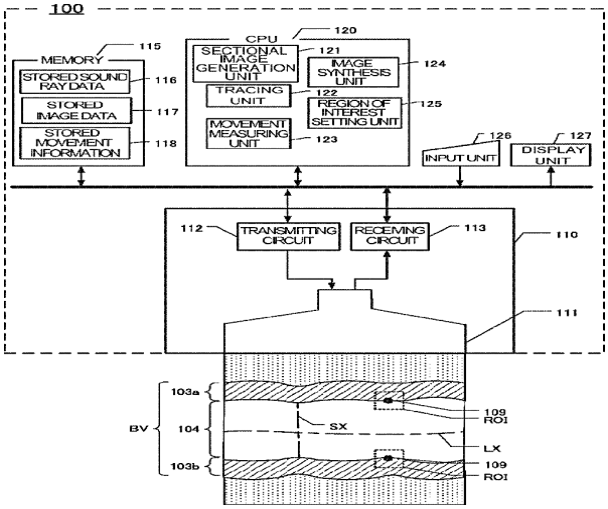
摘要(译)

超声波诊断装置包括发送和接收单元，该发送和接收单元将超声波发送到目标对象，并且接收超声波作为从包括长轴方向血管的目标对象反射的超声波数据。图像生成单元生成超声图像作为血管的截面图像。感兴趣区域（ROI）设置单元在垂直直线上设置与长轴方向成直角的第一ROI和在指定时间显示的血管壁上的第二ROI。跟踪单元通过使用空间亮度梯度的梯度方法跟踪对应于第一和第二ROI的目标对象中的组织从指定时间到其后顺序跟随的移动。第二存储器单元存储组织运动的信息达预定的持续时间。