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(54) **AUTOMATED DOPPLER VELOCIMETRY USING A LOW-COST TRANSDUCER**

AUTOMATISIERTE DOPPLER-GESCHWINDIGKEITSMESSUNG MIT EINEM KOSTENGÜNSTIGEN SCHALLKOPF

VÉLOCIMÉTRIE DOPPLER AUTOMATISÉE À L'AIDE D'UN TRANSDUCTEUR BON MARCHÉ

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to examining a volume of interest for a body vessel and, more particularly, to using ultrasound for the examining.

BACKGROUND OF THE INVENTION

[0002] Assessing the well being of fetus is a very important clinical practice in pregnancy care. Currently, the most prevalent ways for doctors to assess fetal well-being are the analysis of fetal heart rate using a cardiotocograph (CTG) and the assessment of maternal and fetal blood vessel flows using ultrasound Doppler. Ultrasound Doppler waveform analysis of specific blood flows of fetus and mother is part of established medical practice, and a standard recommendation in various clinical guidelines for the diagnosis and assessment of high-risk pregnancies (type-2 diabetes, hypertension or pre-eclampsia in mother and IUGR - intra-uterine growth restriction of fetus). One of the main aims of routine antenatal care is to identify the "at risk" fetus in order to clinically intervene, thereby reducing the incidence of perinatal morbidity and mortality. Some of the vessels useful in the assessment of fetal well-being are: the umbilical artery, the middle cerebral artery, the ductus venosus, and the (left and right) uterine arteries and umbilical veins.

[0003] Ultrasound scanners have become indispensible in the monitoring of pregnancies worldwide. They currently provide the best option to monitor the growth and development of the fetus. Duplex ultrasound scanners provide ultrasound pulsed wave Doppler in addition to the regular scan. Color and power Doppler are newer additions to the range of scanners that provide for vascular imaging. Color Doppler, in particular, is commonly provided, resulting in what is often called a "triplex" scanner.

[0004] Doppler exams typically require a great degree of skill to obtain a clinically useful measurement. For example, correct orientation of the probe with respect to the vessel is essential to ensure that the beam-flow angle is less than 60 degrees. Errors in measurements are amplified when angles of greater than 60 degrees are used in the determination of velocities. The standard workflow on a clinical ultrasound scanner allows a sonographer to determine the orientation of the probe with respect to the vessel using a standard B-mode and Color Flow display. The spectral Doppler measurements are then obtained thus ensuring that the measured velocities are correct.

[0005] The use of ultrasound in vascular applications to perform Doppler velocimetry requires availability of skilled personnel.

[0006] US 6 503 202 B1 discloses a medical diagnostic ultrasound method and system for automated flow analysis. Multiple cross-sectional areas along a vessel are determined automatically and a processor locates an abnormality as a function of the multiple cross-sectional areas, such as identifying a cross-sectional area that is a threshold amount less than an average cross sectional area. The abnormal area is highlighted on the display to assist with a medical diagnosis.

SUMMARY OF THE INVENTION

[0007] In emerging market countries such as India, the shortage of specialists limits the availability and access to ultrasound. Hence, an automated method of acquiring and evaluating Doppler signals for clinical diagnosis (without requiring the user to interpret an ultrasound scan image) would be useful to non-radiologists such as OB/GYN or cardiologists who are the primary treatment providers.

[0008] In addition, a low-cost system is essential to provide an attractive solution in emerging market environments. Devices that are currently available in the market for antenatal check-ups and labor are the ultrasound and CTG machines. However, both of these devices are relatively expensive.

[0009] There exists a need for low-cost, easy-to-use solution to provide Doppler velocimetry to screen and monitor high risk pregnancies.

[0010] The present invention is directed to addressing one or more of the above-discussed concerns. The invention is defined by the independent claims 1, 11 and 12. In accordance with the present invention, an ultrasound probe is designed for carrying out a series of steps automatically and without need for user intervention. These steps include examining, using ultrasound, a volume for body vessels present; and, if one or more vessels are found in the examining, selecting, for fluid-flow analysis, a vessel from among the one or more vessels. This probe can be engineered for low cost, as detailed further herein below.

[0011] In an aspect of the invention, the steps further include generating, for the analysis, information particular to the selected vessel.

[0012] In another aspect, the generated information includes a quantitative characteristic of a waveform. The waveform is representative of magnitude, over time, of velocity of fluid in the selected vessel.

[0013] In a further aspect, the steps include the examining, selecting, and generating, and further include performing the analysis of the generated information. A further included step is: subject to a result based on the analysis, providing, based on the generated information, an indication as to normality of fluid flow in the selected vessel.

[0014] In a still further aspect, the steps include the examining and selecting, and further include, at least until the providing is performed, repeating a sequence of steps for, with the selected vessel serving as a current vessel, each next vessel from among the vessels found. The steps of the sequence are: the selecting, the generating,

performing the analysis, and the providing.

[0015] In yet another aspect, the steps include classifying the selected vessel based on the generated information, with the providing being subject to a result of the classifying.

[0016] In a supplementary aspect, prior to the examining, a target vessel within a vessel category is designated, the category being based on physiology. Based on the generated information, it is determined whether the selected vessel matches the target vessel.

[0017] In a related aspect, the examining and selecting is followed by using ultrasound to generate information particular to the selected vessel and providing, based on the generated information, an indication as to normality of fluid flow in the selected vessel.

[0018] In a different aspect the probe is implemented as a hand-held, stand-alone device. In a still different aspect, the probe includes one or more integrated circuits.

[0019] From an alternative aspect, the probe includes a two-dimensional transducer comprising elements for examining, using ultrasound, a volume for body vessels present. The elements are arranged at a spacing of at least one wavelength of ultrasound emitted from the elements in the examining.

[0020] In an associated aspect, the probe is configured for automatically drawing a conclusion based upon a result of the examining.

[0021] In a sub-aspect, the drawing comprises deciding, based on the examining, as to normality of fluid flow in a vessel found in the examining.

[0022] In one other sub-aspect, the probe is configured for selecting, for fluid-flow analysis, from among one or more vessels found in the examining, the drawing being based on a result of the analysis.

[0023] In a yet further sub-aspect, the probe is configured for the selecting of an artery and for the selecting of a vein.

[0024] In yet another aspect, the probe is configured without electronic focusing of ultrasound and without need for display of an image of any of the vessels.

[0025] In a different, alternative aspect, the elements have respective ultrasound-receiving faces each having a surface area of at least 10 square millimeters.

[0026] In an additional aspect, the faces each have a surface area of at least 25 square millimeters.

[0027] In one further additional aspect, the spacing is a spacing of at least two wavelengths of the ultrasound.

[0028] Details of the ultrasound examination probe are set forth further below, with the aid of the following drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029]

Fig. 1 is a schematic diagram showing, by example, an ultrasound probe, transmit/receive timing diagrams, a volume of interest containing blood vessels, and a blood-flow waveform and respective clinical Doppler indices in accordance with the present invention;

Fig. 2 is a conceptual flow diagram of exemplary signal processing in accordance with the present invention; and

Figs. 3A and 3B are flow charts demonstrating an example of probe operation in accordance with the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

[0030] Fig. 1 depicts, by way of illustrative and non-limitative example, an ultrasound probe 100, transmit/receive timing diagrams 102, 104, and a volume or "volume of interest" 106 containing blood vessels 108, 110, 112. Further depicted are a blood-flow, or "spectral Doppler ultrasound", waveform 114 and respective clinical Doppler indices 116, 118.

[0031] The probe 100 is implementable as an automatic, handheld, stand-alone, self-contained, ultrasound examination device. It has a transducer housing 120 and a handle 122.

[0032] Within the transducer housing 120, a non-phased, two-dimensional transducer 124 is comprised of transducer elements 126, the number of elements being determined by the scan volume and anatomy.

[0033] As seen in FIG. 1 by way example, the number of elements 126 is 32. Thus, with an element size of 10 mm, an approximately 6 cm x 6 cm volume is covered. Flush with a front surface 130 of the housing 120, are ultrasound-receiving faces 132 of the transducer elements 126, the same faces also transmitting, i.e., issuing, ultrasound.

[0034] The total of merely 32 elements 126 stands in stark contrast to the much greater number of elements that would be required in conventional medical imaging to cover the same 6 cm x 6 cm volume.

[0035] In this regard, electronic focusing for medical imaging, as with a phased-array transducer, requires an inter-element spacing of a ½ wavelength, i.e., ½ λ, or less. Doppler ultrasound for imaging can typically range from between 2 x 10^6 and 4 x 10^6 cycles per second (2 to 4 MHz). Ultrasound travels through soft body tissue at a speed of about 1540 meters/second. Wavelength, i.e., λ, is equal to velocity divided by frequency. Here, this is 1540 m/s divided by approximately 2 x 10^6 cycle/s = 0.8 millimeter. Medical ultrasound imaging for a display would therefore require an inter-element spacing of less than 0.4 mm, and an element surface area of less than $(0.4\ mm)^2$ which is less than 0.2 mm^2. Therefore, with a small element size on the order of ½λ, thousands of elements 126 would be required to build a 2D array that, like the one seen in FIG. 1, covers a volume of 6 cm by 6 cm.

[0036] The spacing (size) of elements in FIG. 1 is 10 mm, which, as discussed above, would ordinarily be

more than 12λ of ultrasound used in examining the volume of interest 106 for the blood vessels 108, 110, 112 present.

[0037] More generally, the elements 126, in accordance with what is proposed herein, are spaced apart by more than ½λ, although inter-element spacing 128 may be λ, 2λ or more, as discussed hereinabove. The area of the face 132 is, correspondingly, at least 0.6 square millimeters (mm^2), and may be more, such as 10 mm^2, 25 mm^2, or 100 mm^2 as in FIG. 1.

[0038] Advantageously, the automatic ultrasound device 100 does not rely on display of medical images to reach a diagnosis; but, instead, features an array composed of fewer transducer elements and therefore fewer channels. Thus, cost of production is low, while, by virtue of automatic operation, reliability is maintained. Reliability may even be improved, as when medical examinations must be performed at a quicker pace. The automatic operation also tends to reduce examination time, thereby relieving workload, and making the examination more convenient.

[0039] During Doppler data acquisition, the elements 126 are fired either sequentially, as shown by the timing diagrams 102, 104, or in groups taking care that the acoustic signal from one element does not affect others that are excited at the same time. As seen in Fig. 1, the receive period lags element-by-element the transmit period for a given element, denoted by the number from 1 to 32. The Doppler receive gate is correspondingly positioned in the receive period so as to enable sampling from a corresponding depth within the volume of interest 106.

[0040] On a back surface 134 of the housing 120, so as to face the user, are a number of user-interface, input-output panels which include a top panel 136, a left panel 138 and a right panel 140. An on-off switch 142 and an audio speaker face 144 are disposed in the top panel 136. The left panel 138 frames a function navigation/actuation button 146, a display 148, a Doppler power detection indicator 150, fetal heartbeat acquisition indicator 152, a maternal heartbeat acquisition indicator 154, a normal blood-flow indicator 156, and an abnormal blood-flow indicator 158. The right panel 140 includes three initializing-parameter-entry feedback windows 160, 162, 164.

[0041] Clinical Doppler indices, such as the pulsatility index (PI) 116 and the resistance index (RI) 118 are Doppler angle-independent measures of blood pulsatility. The symbols S, D and A represents, respectively, the peak systolic frequency shift, the end diastolic frequency shift, and one cardiac cycle. This is seen from the blood-flow waveform 114 which is a graph of Doppler frequency, and thus blood flow velocity, versus time.

[0042] The probe 100 can utilize both indices PI and RI in identifying blood vessels and in assessing normality of blood flow. Within the probe 100, control circuitry (not shown), serving as the device of claim 1 or 24, can take the form of one or more integrated circuits (ICs). One or more ICs in accordance with claim 1 or 24 can, alternatively, be configured for installation into existing apparatus such as ultrasound Duplex scanners.

[0043] The signal processing involved in classifying a blood vessel 108-112 found by the probe 100 in the volume of interest 106 is shown, by example, in Fig. 2.

[0044] A blood vessel classifier 200 can be implemented as a k-nearest neighbor (K-NN) classifier, with K = 3 for example.

[0045] The classifier is first used to predict whether the vessel 108-112 is a vein or artery. Various feature inputs to the classifier 200, such as the PI, are used, each of the M types of input corresponding to a dimension in M-dimensional feature space. Another type of input to the classifier is training examples. Each training example corresponds to an actual clinical case, and includes the M feature inputs for that case, defining the example as a particular point, i.e., "example point", in the M-dimensional space. With each example point is associated the respective outcome of "vein" or "artery", depending upon whether that training example actually pertained to a vein or to an artery. The classifier 200 having been initialized with the training examples, a point in M-dimensional space is formed using the feature inputs derived for the blood vessel 108-112 currently being classified. For K = 3, the 3 closest neighbor (example) points are identified. Each neighbor will have as its outcome either the value "artery" or "vein." The majority vote prevails. There are never any ties since 3 is an odd number.

[0046] If the vessel is classified as an artery, the classifier 200 next determines whether it is maternal or fetal, by the same nearest neighbor algorithm. If the blood vessel is a maternal artery, a determination is made as to whether it is a uterine artery. If, on the other hand, the vessel is a fetal artery, a determination is made as to whether it is the umbilical artery. The latter two determinations use the same nearest neighbor algorithm.

[0047] Nearest neighbor classifiers enjoy the benefit of simplicity, although other alternative methods such as neural networks, or support vector machines (SVMs), could be used instead.

[0048] Classifier inputs from the user include the gestational age 204, and a rough, approximate location 208 of the probe on the mother's abdomen. A vascular model 212 in the form of training examples for the classifier 200 is also provided.

[0049] Other inputs come directly or indirectly from the pulse-echo information from received ultrasound 216.

[0050] Directly from the ultrasound 216, an average reflective index estimation 218 is made for the tissue around the probe 100. This index is compared to a predefined reflection index list to determine the position of the probe 100 on the mother's body.

[0051] To form indirect inputs, the ultrasound received is demodulated in a demodulator 220 to extract an ultrasound Doppler signal 224 from the carrier frequency. A fast Fourier transform (FFT) 228 is performed on the Doppler signal 224 to generate a spectrogram, or "FFT-based

sonogram", 230. From the spectrograms 230, one or more relevant spectral profiles 232 are extracted. The term "spectral profile" signifies the part of the sonogram 230 that corresponds to blood flow through an artery or vein. The spectral profile 232 can be approximated as the region between curves corresponding to the maximum and minimum spectral velocities (or spectral frequencies). The spectral breadth 236 of the extracted spectral profile 232 is estimated and provided to the classifier 200. From the spectral profile(s) 232, a curve 240 corresponding to the peak (or, alternatively, the average) spectral velocities is extracted. Specific temporal features 248 are also extracted from the spectral profile(s) 232. These features include, for example, the presence of a notch immediately preceding the pulse in the blood flow waveform 114 of a uterine artery. The PI and RI for the vessel about to be subject to classification 252 are also extracted. In an initialization procedure which precedes examination of the current volume of interest 106, the pulse cycle time estimation 256 is performed based on the spectral profile(s) 232 then extracted.

[0052] Operationally, and as shown in Figs. 3A and 3B, the user, who may be a clinician, midwife, general practitioner, obstetrician/gynecologist or fetal radiologist, inputs, as part of the initialization procedure, a target blood vessel for examination, e.g., left uterine artery (falling within the "uterine artery" blood-vessel physiological category); gestational age; and a rough description of the location the probe will have once initialization ends and the examination begins. Specifically, after actuating the on/off switch 142, the user presses the function navigation/actuation button 146 twice in succession quickly. In response, the first blood vessel choice appears in the display 148. If the choice appearing is not the target blood vessel for examination, the button 146 is pressed once to bring up a new choice in the display 148. This is done repeatedly until the choice displayed is the one for selection. The button 148 is then held down, and the choice is echoed in the initializing-parameter-entry feedback windows 160. Appearing in the display 148 is a choice for gestational age, in months or weeks. In a similar fashion, the user navigates to the correct age, and holds down the button 146, to echo the selection to the window 162. To complete initializing-parameter entry, the same procedure is carried out for the probe location, the selected location being shown in the window 164 (step S304).

[0053] The user now continues with initialization by placing the probe on the mother's abdomen for pulse cycle time estimation 256. The user presses the function navigation/actuation button 146 to launch ultrasound Doppler operation. The transducer will scan depths at each element location to detect blood movement, i.e., Doppler power. If the Doppler power detection indicator 150 lights up, Doppler power in the frequency band of 300-1000 Hz representative of blood flow is detected that is of sufficient magnitude for concluding that a fetal or maternal heart beat can be measured from arterial blood flow. The heart beat rate of the mother is usually lower than the fetal heart beat rate. In addition to the indicator 150, a short beep may be emitted from the audio speaker 144, to alert the user to the onset of detection of Doppler power. Alternatively or in addition, audio feedback of the Doppler signal may come over the audio speaker 144. The probe 100 is held in place for several seconds; if not, the Doppler power drops and a lit indicator light 150 must again be achieved. If, at the end of the several-second period, neither the fetal nor maternal heart beat is detected, the user can move the probe to another location on the mother's abdomen, and can do this repetitively until detection occurs. If the fetal or maternal heart beat is detected, i.e., a body vessel, and in particular an artery, is found, by the signal processing route 220-232, 240, 256, the corresponding fetal heart beat acquisition indicator 152 or maternal heart beat acquisition indicator 154 is lit (step S308). The user, repetitively, moves the probe 100 to a next location on the mother's abdomen until both indicators 152, 154 are lit (step S312), indicating that the pulse cycle time, a clinical Doppler parameter, has been acquired, and extracted, for both the mother and fetus.

[0054] The user now places the probe to check for normality/abnormality of blood flow in a corresponding maternal or fetal vessel which is the target vessel (step S316). If the Doppler power detection indicator 150 does not light up (step S320), Doppler power in the frequency band of 300-1000 Hz representative of blood flow is not detected or is of insufficient magnitude for finding one or more blood vessels. In that case, the user moves or tilts the probe 100 (step S324), until the indicator 150 is lit.

[0055] Once the indicator is lit, the probe 100 is held in place for several seconds to process the volume of interest 106 (step S328).

[0056] Advantageously, this processing occurs automatically and without need for user intervention. Since the display of an image of a blood vessel is not required, no electronic focusing of ultrasound is required. The device is thereby simplified and cost-effective.

[0057] The outcome of the processing may be a green light of the normal blood-flow indicator 156, a red light of the abnormal blood-flow indicator 158, or lack of either light if the blood vessel currently being examined does not match the target vessel. If neither indicator 156, 158 is lit (step S332), processing returns to step S324.

[0058] An example of the processing in step S328 is provided in Fig. 3B. A volume of interest 106, which would change each time the probe 100 is moved or tilted, but which is fixed while the user holds the probe steady, is subject to examination for blood vessels present. In particular, the Doppler power is a frequency band of 300-1000 Hz is computed. This generates a 3-dimensional (3D) representation of vessels 108-112 in the scan volume. The total number of vessels in the scan volume is identified using continuity criteria. For example, for the 8 immediately adjacent pixels, i.e., the 4 side and 4 diagonal pixels, it is assumed that adjacent pixels for which blood flow is detected represent the same blood vessel. Yet, the blood vessels can be mapped in 3D, since the

transducer receive-gates can be set for different depths. In 3D, a least-squares based line-fitting algorithm is used to find the straight line joining the points identified using the continuity criterion. The angle of the straight line from the ultrasound-receiving faces 132 of the transducer elements 126 is then computed. This results in a 3D map from which individual vessels, and their individual orientations, are identifiable. With the orientations identified, spatial features can be determined from the map. For example, in a uterine artery scan the Doppler sample volume is typically placed at the pseudo-intersection of the uterine and iliac arteries. The intersection is determined as the location of the minimum sum of the squared distances between pixels on the vessels (step S336).

[0059] If the vessel map contains no vessels 108-112 (step S340), processing of the current volume of interest 106 is complete, no diagnosis is rendered, and control proceeds to step S332.

[0060] Otherwise, if a vessel 108-112 is detected, a vessel from among those found in the volume of interest 106 is selected for fluid-flow analysis and as a candidate for matching the target vessel (step S344). Any criterion can be used for the selection, since selection of candidates does not end until the target vessel is found or all of the vessels 108-112 in the volume of interest 106 have been processed.

[0061] Information particular to the selected vessel is generated, as seen in FIG. 2 (step S348). The information includes spectral Doppler waveform characteristics (mean frequency estimate, cycle time - time interval between 2 successive peaks, spectral width - width between maximum and minimum frequency envelope at peaks and valleys), time to peak, holder's defect and clinical Doppler indices (such as, S/D, PI and RI), for example.

[0062] Based on the generated information and analysis thereof, the blood vessel classifier 200 classifies the selected vessel (step S352).

[0063] If the classification does not match the target vessel (step S356), and no next vessel from among those found in the volume of interest 106 exists (step S360), control proceeds to step S332.

[0064] Otherwise, if the classification does not match the target vessel, but a next vessel does exist, control branches back to step S344, with that next vessel serving as the selected vessel (step S364).

[0065] If, on the other hand, the classification matches the target vessel, the probe 100 draws a conclusion as to normality of the blood flow in the target, i.e., selected, vessel. In particular and by way of example, the Doppler parameters are compared with nomograms, i.e., tables representing the range of expected Doppler indices as a function of gestational age, to determine whether the flow profile is normal or abnormal (step S368).

[0066] Based on the conclusion, an indication as to normality of the blood flow in the selected vessel is provided by the green light of the normal blood-flow indicator 156 or the red light of the abnormal blood-flow indicator 158 (step S372).

[0067] Although methodology of the present invention can advantageously be applied in providing medical diagnosis for a human or animal subject, the scope of the present invention is not so limited. More broadly, techniques of the present invention are directed to finding, and subjecting to fluid-flow analysis, vessels in body tissue, in vivo, in vitro or ex vivo.

[0068] What is proposed herein pertains to an automated Doppler device for rendering a clinical diagnosis based on a result of analyzing the characteristics of spectral Doppler waveforms. Applications include carotid and renal arteries screening, ABI measurements for detecting peripheral arterial disease (PAD), transcranial, bleed detection in trauma or other hemorrhages in addition to fetal well-being assessment.

[0069] An automatic, stand-alone, hand-held ultrasound blood-vessel examination device requires a reduced number of transducer elements and presents a simplified user interface, without the need for displaying an image of any of the vessels. The probe, in one embodiment, acquires and examines a volume of interest, searches for a target vessel, tests the vessel for normality of blood flow, and reports the diagnosis, all automatically and without need for user intervention. In another embodiment, the probe finds a body vessel in a volume, and extracts a clinical Doppler parameter, all automatically and without need for user intervention.

[0070] While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments.

[0071] For example, more than one target blood vessel can be designated during initialization. These can be processed in the order they are found, or a particular order can be specified during initialization.

[0072] Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. Any reference signs in the claims should not be construed as limiting the scope.

[0073] A computer program can be stored momentarily, temporarily or for a longer period of time on a suitable computer-readable medium, such as an optical storage medium or a solid-state medium. Such a medium is non-transitory only in the sense of not being a transitory, propagating signal, and thus can be realized as register memory, processor cache or RAM, for example.

[0074] A single processor or other unit may fulfill the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

Claims

1. An ultrasound probe (100) comprising a control circuitry configured for carrying out a series of acts, said series comprising:

   a) examining, using ultrasound from the ultrasound probe, a volume to find body vessels present (S336) within the volume; and,
   b) the control circuitry being adapted b1) to select, if one or more vessels are found within the volume in said examining (S340), for fluid-flow analysis a vessel from among said vessels found within the volume (S344), b2) to generate, for said fluid-flow analysis, information particular to the selected vessel (S348), b3) to determine, based on the generated information, whether said selected vessel matches a target vessel (S352,S356), and b4) if the selected vessel matches the target vessel, then b4)(i) to provide, based on the generated information, an indication as to normality of fluid flow in the selected vessel (S368, S372), else b4)(ii) to repeat the selecting, generating, and determining with a next vessel of the vessels found (S360, S364), until there is no further next vessel of the vessels found within the volume,

   wherein said acts of examining, selecting, generating, determining, providing and repeating (i) do not rely on a display of ultrasound scan images, and (ii) are performed automatically and without need for user intervention to interpret an ultrasound scan image, and wherein the control circuitry is further adapted to determine, based on the generated information, whether the selected vessel is a vein or an artery, **characterised in that** the control circuitry is further adapted to determine, if the selected vessel has been determined as an artery, whether the selected vessel is a maternal artery or a fetal artery based on the generated information.

2. The ultrasound probe of claim 1, wherein the generated information comprises a quantitative characteristic (232) of a waveform (114), wherein said waveform is representative of magnitude, over time, of velocity of fluid in said selected vessel.

3. The ultrasound probe of claim 2, wherein said series further comprises performing said fluid-flow analysis of the generated information, and, subject to a result based on said fluid-flow analysis (248, 252), providing, based on said generated information, an indication as to normality of fluid flow in said selected vessel.

4. The ultrasound probe of claim 3, wherein said series further comprises c) at least until said providing is performed, repeating, with said selected vessel serving as a current vessel (S364), step b) for each next vessel from among said vessels found.

5. The ultrasound probe of claim 3, wherein said series further comprises classifying said selected vessel based on said generated information (S352), said providing being subject to a result of said classifying.

6. The ultrasound probe of claim 1, wherein said series further comprises: designating (S304), prior to said examining, the target vessel within a vessel category, said category being based on physiology.

7. The ultrasound probe of claim 1, wherein examining of said series further comprises using the ultrasound (216) to acquire volumetric data to be examined.

8. The ultrasound probe of claim 1, wherein said series further comprises: using the ultrasound to generate information particular to the selected vessel; and providing, based on the generated information, the indication as to normality of fluid flow in said selected vessel (S372).

9. The ultrasound probe of claim 1, wherein the ultrasound probe is implemented as a hand-held (122), stand-alone device.

10. The ultrasound probe of claim 1, wherein the ultrasound probe includes one or more integrated circuits.

11. A computer readable medium for an ultrasound body-fluid-flow analysis probe, said medium comprising instructions executable by a control circuitry of the ultrasound body-fluid flow analysis probe for carrying out a series of acts, said series comprising:

    a) examining, using ultrasound from the ultrasound body-fluid-flow analysis probe, a volume to find body vessels present within the volume; and,
    b) if one or more vessels are found within the volume in said examining, then b1) selecting, for fluid-flow analysis, a vessel from among said vessels found within the volume, b2) generating, for said fluid-flow analysis, information particular to the selected vessel, b3) determining, based on the generated information, whether said selected vessel matches a target vessel, and b4) if the selected vessel matches the target vessel, then b4)(i) providing, based on the generated information, an indication as to normality of fluid flow in the selected vessel, else b4)(ii) repeating the selecting, generating, and determining with a next vessel of the vessels found, until there is no further next vessel of the vessels found within

the volume,

wherein said acts of examining, selecting, generating, determining, providing and repeating (i) do not rely on a display of ultrasound scan images, and (ii) are performed automatically and without need for user intervention to interpret an ultrasound scan image wherein said series furthermore comprises determining, based on the generated information, whether the selected vessel is a vein or an artery, **characterised in that** said series further comprises determining, if the selected vessel has been determined as an artery, whether the selected vessel is a maternal artery or a fetal artery based on the generated information.

12. A method for ultrasound body-fluid-flow analysis, said method comprising: configuring an ultrasound probe comprising a control circuitry for performing, automatically and without need for user intervention to interpret an ultrasound scan image, a series of acts, said series comprising:

a) examining (S336), using ultrasound from the ultrasound probe, a volume to find body vessels present within the volume; and,
b) if one or more vessels are found within the volume in said examining, then b1) selecting, for fluid-flow analysis, a vessel from among said vessels found within the volume, b2) generating, for said fluid-flow analysis, information particular to the selected vessel, b3) determining, based on the generated information, whether said selected vessel matches a target vessel, and b4) if the selected vessel matches the target vessel, then b4)(i) providing, based on the generated information, an indication as to normality of fluid flow in the selected vessel, else b4)(ii) repeating the selecting, generating, and determining with a next vessel of the vessels found, until there is no further next vessel of the vessels found within the volume,

wherein said examining and selecting do not rely on a display of ultrasound scan images, wherein said series furthermore comprises determining, based on the generated information, whether the selected vessel is a vein or an artery, **characterised in that** said series further comprises determining, if the selected vessel has been determined as an artery, whether the selected vessel is a maternal artery or a fetal artery based on the generated information.

Patentansprüche

1. Ultraschallsonde (100) mit einer Steuerungsschaltung, die so konfiguriert ist, dass sie eine Abfolge von Schritten ausführt, wobei gemäß der Abfolge:

a) unter Anwendung von Ultraschall aus der Ultraschallsonde ein Volumen untersucht wird, um innerhalb des Volumens vorhandene Körpergefäße zu ermitteln (S336); und
b) wobei die Steuerungsschaltung so eingerichtet ist, dass sie, b1) wenn ein oder mehrere Gefäße innerhalb des Volumens bei der Untersuchung festgestellt werden (S340), ein Gefäß unter den innerhalb des Volumens ermittelten Gefäßen zur Flüssigkeitsstromanalyse auswählt (S344), b2) für die Flüssigkeitsstromanalyse für das ausgewählte Gefäß spezifische Informationen erzeugt (S348), b3) aufgrund der erzeugten Informationen ermittelt, ob das ausgewählte Gefäß einem Zielgefäß entspricht (S352, S356), und b4) wenn das ausgewählte Gefäß dem Zielgefäß entspricht, dann b4)(i) aufgrund der erzeugten Informationen eine Angabe bezüglich der Normalität des Flüssigkeitsstroms in dem ausgewählten Gefäß bereitstellt (S368, S372), anderenfalls b4)(ii) das Auswählen, Erzeugen und Ermitteln bei einem nächsten Gefäß der ermittelten Gefäße wiederholt (S360, S364), bis kein weiteres nächstes Gefäß der innerhalb des Volumens ermittelten Gefäße mehr vorhanden ist,

wobei die Schritte des Untersuchens, Auswählens, Erzeugens, Ermittelns, Bereitstellens und Wiederholens (i) sich nicht auf eine Darstellung von Ultraschallscanbildern stützen und (ii) automatisch und ohne dass eine Benutzerintervention zur Interpretation eines Ultraschallscanbildes erforderlich ist, ausgeführt werden, und
wobei die Steuerungsschaltung weiterhin so eingerichtet ist, dass sie aufgrund der erzeugten Informationen ermittelt, ob das ausgewählte Gefäß eine Vene oder eine Arterie ist, **dadurch gekennzeichnet, dass** die Steuerungsschaltung weiterhin so eingerichtet ist, dass, wenn sich das ausgewählte Gefäß als eine Arterie erweist, sie aufgrund der erzeugten Informationen ermittelt, ob das ausgewählte Gefäß eine maternale Arterie oder eine fetale Arterie ist.

2. Ultraschallsonde nach Anspruch 1, wobei die erzeugten Informationen eine quantitative Charakteristik (232) einer Wellenform (114) umfassen, wobei die Wellenform für die Höhe der Geschwindigkeit von Flüssigkeit in dem ausgewählten Gefäß im Zeitablauf repräsentativ ist.

3. Ultraschallsonde nach Anspruch 2, wobei die Abfolge weiterhin die Durchführung der Flüssigkeitsstromanalyse der erzeugten Informationen und, in Abhängigkeit eines Ergebnisses aufgrund der Flüssigkeitsstromanalyse (248, 252), das Bereitstellen ei-

ner Angabe hinsichtlich der Normalität des Flüssigkeitsstroms in dem ausgewählten Gefäß aufgrund der erzeugten Informationen umfasst.

4. Ultraschallsonde nach Anspruch 3, wobei gemäß der Abfolge weiterhin c) zumindest bis besagte Bereitstellung erfolgt ist, bei dem als ein aktuelles Gefäß dienenden ausgewählten Gefäß (S364) Schritt b) für jedes nächste Gefäß unter den ermittelten Gefäßen wiederholt wird.

5. Ultraschallsonde nach Anspruch 3, wobei die Abfolge weiterhin das Klassifizieren des ausgewählten Gefäßes aufgrund der erzeugten Informationen umfasst (S352), wobei die Bereitstellung einem Ergebnis besagter Klassifizierung unterliegt.

6. Ultraschallsonde nach Anspruch 1, wobei die Abfolge weiterhin umfasst:

Designieren (S304) des Zielgefäßes innerhalb einer Gefäßkategorie vor besagter Untersuchung, wobei die Kategorie auf Physiologie basiert.

7. Ultraschallsonde nach Anspruch 1, wobei das Prüfen der Abfolge weiterhin das Anwenden des Ultraschalls (216) umfasst, um zu prüfende volumetrische Daten zu erfassen.

8. Ultraschallsonde nach Anspruch 1, wobei die Abfolge weiterhin umfasst:

Anwenden des Ultraschalls, um für das ausgewählte Gefäß spezifische Informationen zu erzeugen; und um aufgrund der erzeugten Informationen die Angabe bezüglich der Normalität des Flüssigkeitsstroms in dem ausgewählten Gefäß bereitzustellen (S372).

9. Ultraschallsonde nach Anspruch 1, wobei die Ultraschallsonde als ein eigenständiges Handheld-Gerät (122) implementiert ist.

10. Ultraschallsonde nach Anspruch 1, wobei die Ultraschallsonde eine oder mehrere integrierte Schaltungen enthält.

11. Computerlesbares Medium für eine Körperflüssigkeitsstromanalysen-Ultraschallsonde, wobei das Medium Instruktionen umfasst, die durch eine Steuerungsschaltung der Körperflüssigkeitsstromanalysen-Ultraschallsonde zur Ausführung einer Abfolge von Schritten ausführbar sind, wobei gemäß der Abfolge:

a) unter Anwendung von Ultraschall aus der Körperflüssigkeitsstromanalysen-Ultraschallsonde ein Volumen untersucht wird, um innerhalb des Volumens vorhandene Körpergefäße zu ermitteln; und
b) wenn ein oder mehrere Gefäße innerhalb des Volumens bei der Untersuchung festgestellt werden, b1) sodann ein Gefäß unter den innerhalb des Volumens ermittelten Gefäßen zur Flüssigkeitsstromanalyse ausgewählt wird, b2) für die Flüssigkeitsstromanalyse für das ausgewählte Gefäß spezifische Informationen erzeugt werden, b3) aufgrund der erzeugten Informationen ermittelt wird, ob das ausgewählte Gefäß einem Zielgefäß entspricht, und b4) wenn das ausgewählte Gefäß dem Zielgefäß entspricht, b4)(i) sodann aufgrund der erzeugten Informationen eine Angabe bezüglich der Normalität des Flüssigkeitsstroms in dem ausgewählten Gefäß bereitgestellt wird, anderenfalls b4)(ii) das Auswählen, Erzeugen und Ermitteln bei einem nächsten Gefäß der ermittelten Gefäße wiederholt wird, bis kein weiteres nächstes Gefäß der innerhalb des Volumens ermittelten Gefäße mehr vorhanden ist,

wobei die Schritte des Untersuchens, Auswählens, Erzeugens, Ermittelns, Bereitstellens und Wiederholens (i) sich nicht auf eine Darstellung von Ultraschallscanbildern stützen und (ii) automatisch und ohne dass eine Benutzerintervention zur Interpretation eines Ultraschallscanbildes erforderlich ist, ausgeführt werden,
wobei gemäß der Abfolge weiterhin aufgrund der erzeugten Informationen ermittelt wird, ob das ausgewählte Gefäß eine Vene oder eine Arterie ist, **dadurch gekennzeichnet, dass**, wenn sich das ausgewählte Gefäß als eine Arterie erweist, gemäß der Abfolge weiterhin aufgrund der erzeugten Informationen ermittelt wird, ob das ausgewählte Gefäß eine maternale Arterie oder eine fetale Arterie ist.

12. Verfahren für eine Ultraschall-Körperflüssigkeitsstromanalyse, wobei das Verfahren die folgenden Schritte umfasst, wonach:

eine Ultraschallsonde so konfiguriert wird, dass sie eine Steuerungsschaltung umfasst, um, automatisch und ohne dass eine Benutzerintervention zur Interpretation eines Ultraschallscanbildes erforderlich ist, eine Abfolge von Schritten auszuführen, wobei gemäß der Abfolge:

a) unter Anwendung von Ultraschall aus der Ultraschallsonde ein Volumen untersucht wird (S336), um innerhalb des Volumens vorhandene Körpergefäße zu ermitteln; und
b) wenn ein oder mehrere Gefäße innerhalb des Volumens bei der Untersuchung fest-

gestellt werden, b1) sodann ein Gefäß unter den innerhalb des Volumens ermittelten Gefäßen zur Flüssigkeitsstromanalyse ausgewählt wird, b2) für die Flüssigkeitsstromanalyse für das ausgewählte Gefäß spezifische Informationen erzeugt werden, b3) aufgrund der erzeugten Informationen ermittelt wird, ob das ausgewählte Gefäß einem Zielgefäß entspricht, und b4) wenn das ausgewählte Gefäß dem Zielgefäß entspricht, b4)(i) sodann aufgrund der erzeugten Informationen eine Angabe bezüglich der Normalität des Flüssigkeitsstroms in dem ausgewählten Gefäß bereitgestellt wird, anderenfalls b4)(ii) das Auswählen, Erzeugen und Ermitteln bei einem nächsten Gefäß der ermittelten Gefäße wiederholt wird, bis kein weiteres nächstes Gefäß der innerhalb des Volumens ermittelten Gefäße mehr vorhanden ist,

wobei das Untersuchen und Auswählen sich nicht auf eine Darstellung von Ultraschallscanbildern stützen,
wobei gemäß der Abfolge weiterhin aufgrund der erzeugten Informationen ermittelt wird, ob das ausgewählte Gefäß eine Vene oder eine Arterie ist, **dadurch gekennzeichnet, dass**, wenn sich das ausgewählte Gefäß als eine Arterie erweist, gemäß der Abfolge weiterhin aufgrund der erzeugten Informationen ermittelt wird, ob das ausgewählte Gefäß eine maternale Arterie oder eine fetale Arterie ist.

Revendications

1. Sonde ultrasonore (100) comprenant un montage de circuits de commande configuré pour réaliser une série d'actions, ladite série comprenant :

a) l'examen, en utilisant des ultrasons provenant de la sonde ultrasonore, d'un volume pour trouver des vaisseaux corporels présents (S336) à l'intérieur du volume ; et,
b) le montage de circuits de commande étant adapté pour b1) sélectionner, si un ou plusieurs vaisseaux sont trouvés à l'intérieur du volume pendant ledit examen (S340), pour une analyse d'écoulement de fluide, un vaisseau parmi lesdits vaisseaux trouvés à l'intérieur du volume (S344), b2) générer, pour ladite analyse d'écoulement de fluide, des informations particulières au vaisseau sélectionné (S348), b3) déterminer, sur la base des informations générées, si ledit vaisseau sélectionné correspond à un vaisseau cible (S352, S356), et b4) si le vaisseau sélectionné correspond au vaisseau cible, alors b4)(i) fournir, sur la base des informations générées, une indication quant à la normalité de l'écoulement de fluide dans le vaisseau sélectionné (S368,S372), sinon b4)(ii) répéter la sélection, la génération, et la détermination avec un vaisseau suivant parmi les vaisseaux trouvés (S360, S364), jusqu'à ce qu'il n'y ait plus de vaisseau suivant parmi les vaisseaux trouvés à l'intérieur du volume,

dans laquelle lesdites actions d'examen, de sélection, de génération, de détermination, de fourniture et de répétition (i) ne dépendent pas d'un affichage des images de balayage ultrasonore, et (ii) sont réalisées automatiquement et sans avoir recours à une intervention d'un utilisateur pour interpréter une image de balayage ultrasonore, et
dans laquelle le montage de circuits de commande est en outre adapté pour déterminer, sur la base des informations générées, si le vaisseau sélectionné est une veine ou une artère, **caractérisée en ce que** le montage de circuits de commande est en outre adapté pour déterminer, si le vaisseau sélectionné a été déterminé comme étant une artère, si le vaisseau sélectionné est une artère maternelle ou une artère foetale sur la base des informations générées.

2. Sonde ultrasonore selon la revendication 1, dans laquelle les informations générées comprennent une caractéristique quantitative (232) d'une forme d'onde (114),
dans laquelle ladite forme d'onde représente une amplitude, au fil du temps, de la vitesse du fluide dans ledit vaisseau sélectionné.

3. Sonde ultrasonore selon la revendication 2, dans laquelle ladite série comprend en outre la réalisation de ladite analyse d'écoulement de fluide des informations générées, et, sous réserve d'un résultat basé sur ladite analyse d'écoulement de fluide (248, 252), la fourniture, sur la bases desdites informations générées, d'une indication quant à la normalité d'écoulement de fluide dans ledit vaisseau sélectionné.

4. Sonde ultrasonore selon la revendication 3, dans laquelle ladite série comprend en outre

c) au moins jusqu'à ce que ladite fourniture soit réalisée, la répétition, avec ledit vaisseau sélectionné servant de vaisseau actif (S364), de l'étape b) pour chaque vaisseau suivant parmi lesdits vaisseaux trouvés.

5. Sonde ultrasonore selon la revendication 3, dans laquelle ladite série comprend en outre la classification dudit vaisseau sélectionné sur la bases desdites informations générées (S352), ladite fourniture dépen-

dant d'un résultat de ladite classification.

6. Sonde ultrasonore selon la revendication 1, dans laquelle ladite série comprend en outre : la désignation (S304), avant ledit examen, du vaisseau cible à l'intérieur d'une catégorie de vaisseau, ladite catégorie étant basée sur la physiologie.

7. Sonde ultrasonore selon la revendication 1, dans laquelle l'examen de ladite série comprend en outre l'utilisation d'ultrasons (216) pour acquérir des données volumétriques à examiner.

8. Sonde ultrasonore selon la revendication 1, dans laquelle ladite série comprend en outre : l'utilisation des ultrasons pour générer des informations propres au vaisseau sélectionné ; et la fourniture, sur la base des informations générées, de l'indication quant à la normalité d'un écoulement de fluide dans ledit vaisseau sélectionné (S372).

9. Sonde ultrasonore selon la revendication 1, dans laquelle la sonde ultrasonore se présente comme un dispositif autonome, à main (122).

10. Sonde ultrasonore selon la revendication 1, dans laquelle la sonde ultrasonore comprend un ou plusieurs circuits intégrés.

11. Support lisible par ordinateur pour une sonde d'analyse d'écoulement de fluide corporel ultrasonore, ledit support comprenant des instructions exécutables par un montage de circuits de commande de la sonde d'analyse d'écoulement de fluide corporel ultrasonore pour réaliser une série d'actions, ladite série comprenant :

a) l'examen, en utilisant des ultrasons provenant de la sonde d'analyse d'écoulement de fluide corporel ultrasonore, d'un volume pour trouver des vaisseaux corporels présents à l'intérieur du volume ; et,
b) si un ou plusieurs vaisseaux sont trouvés à l'intérieur du volume pendant ledit examen, alors b1) la sélection, pour une analyse d'écoulement de fluide, d'un vaisseau parmi lesdits vaisseaux trouvés à l'intérieur du volume, b2) la génération, pour ladite analyse d'écoulement de fluide, d'informations particulières au vaisseau sélectionné, b3) la détermination, sur la base des informations générées, de la correspondance ou non dudit vaisseau sélectionné avec un vaisseau cible, et b4) si le vaisseau sélectionné correspond au vaisseau cible, alors b4)(i) la fourniture, sur la base des informations générées, d'une indication quant à la normalité de l'écoulement de fluide dans le vaisseau sélectionné, sinon b4)(ii) la répétition de la sélection, de la génération, et de la détermination avec un vaisseau suivant parmi les vaisseaux trouvés, jusqu'à ce qu'il n'y ait plus de vaisseau suivant parmi les vaisseaux trouvés à l'intérieur du volume,

dans lequel lesdites actions d'examen, de sélection, de génération, de détermination, de fourniture et de répétition (i) ne dépendent pas d'un affichage des images de balayage ultrasonore, et (ii) sont réalisées automatiquement et sans avoir recours à une intervention d'un utilisateur pour interpréter une image de balayage ultrasonore, et
dans lequel ladite série consiste par ailleurs à déterminer, sur la base des informations générées, si le vaisseau sélectionné est une veine ou une artère, **caractérisé en ce que** ladite série consiste en outre à déterminer, si le vaisseau sélectionné a été déterminé comme étant une artère, si le vaisseau sélectionné est une artère maternelle ou une artère foetale sur la base des informations générées.

12. Procédé pour une analyse d'écoulement de fluide corporel ultrasonore, ledit procédé comprenant :

la configuration d'une sonde ultrasonore comprenant un montage de circuits de commande pour réaliser, automatiquement et sans recourir à une intervention d'un utilisateur pour interpréter une image de balayage ultrasonore, d'une série d'actions, ladite série comprenant :

a) l'examen (S336), en utilisant des ultrasons provenant de la sonde ultrasonore, d'un volume pour trouver des vaisseaux corporels présents à l'intérieur du volume ; et,
b) si un ou plusieurs vaisseaux sont trouvés à l'intérieur du volume pendant ledit examen, alors b1) la sélection, pour une analyse d'écoulement de fluide, d'un vaisseau parmi lesdits vaisseaux trouvés à l'intérieur du volume, b2) la génération, pour ladite analyse d'écoulement de fluide, d'informations particulières au vaisseau sélectionné, b3) la détermination, sur la base des informations générées, de la correspondance ou non dudit vaisseau sélectionné avec un vaisseau cible, et b4) si le vaisseau sélectionné correspond au vaisseau cible, alors b4)(i) la fourniture, sur la base des informations générées, d'une indication quant à la normalité de l'écoulement de fluide dans le vaisseau sélectionné, sinon b4)(ii) la répétition de la sélection, de la génération, et de la détermination avec un vaisseau suivant parmi les vaisseaux trouvés, jusqu'à ce qu'il n'y ait plus de vaisseau suivant parmi les

vaisseaux trouvés à l'intérieur du volume,

dans lequel lesdits examen et sélection ne dépendent pas d'un affichage des images de balayage ultrasonore,
dans lequel ladite série consiste par ailleurs à déterminer, sur la base des informations générées, si le vaisseau sélectionné est une veine ou une artère, **caractérisé en ce que** ladite série consiste en outre à déterminer, si le vaisseau sélectionné a été déterminé comme étant une artère, si le vaisseau sélectionné est une artère maternelle ou une artère foetale sur la base des informations générées.

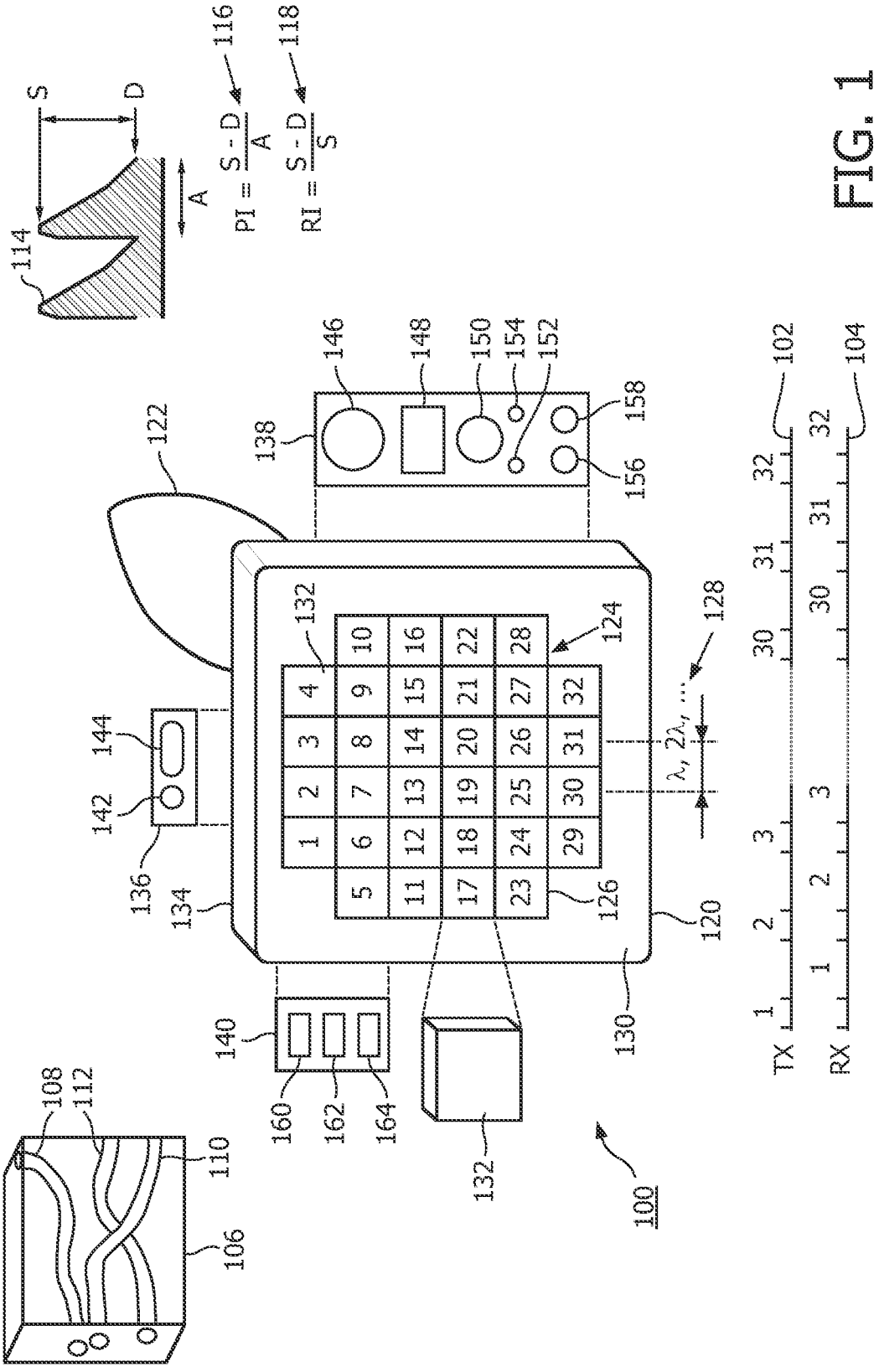
S
D
A
114
116
118
PI = (S - D)/A
RI = (S - D)/S
122
138
146
148
150
154
152
158
156
102
104
32
31
30
3
2
1
TX
RX
144
142
136
134
132
124
126
120
128
130
140
160
162
164
108
112
110
106
100

FIG. 1

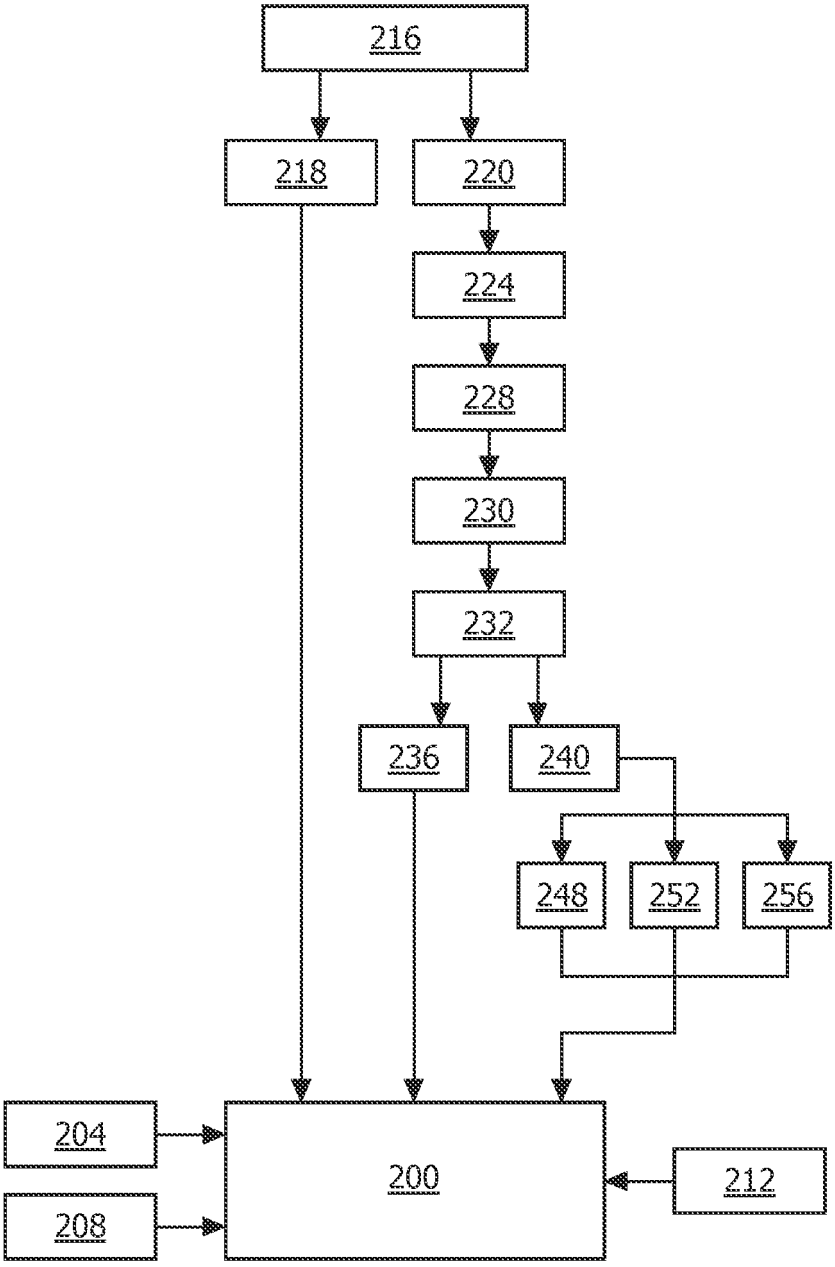

FIG. 2

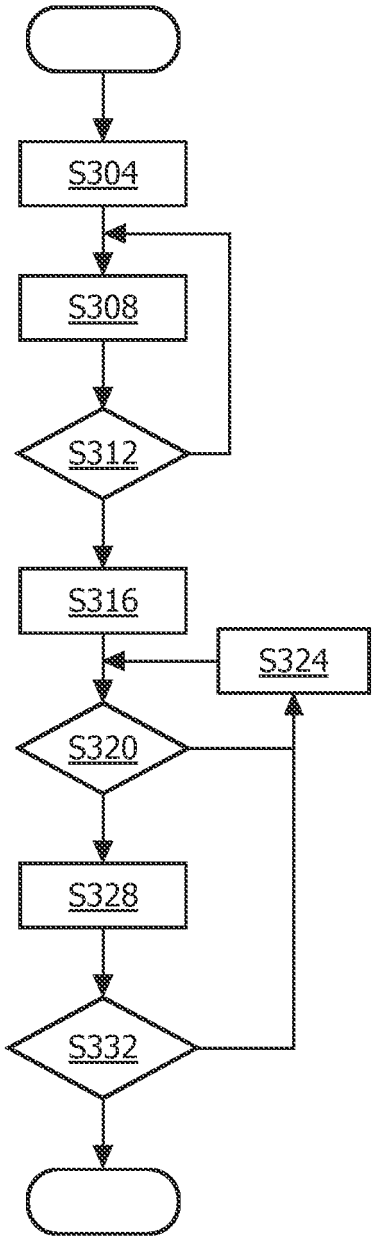
S304
S308
S312
S316
S324
S320
S328
S332

FIG. 3A

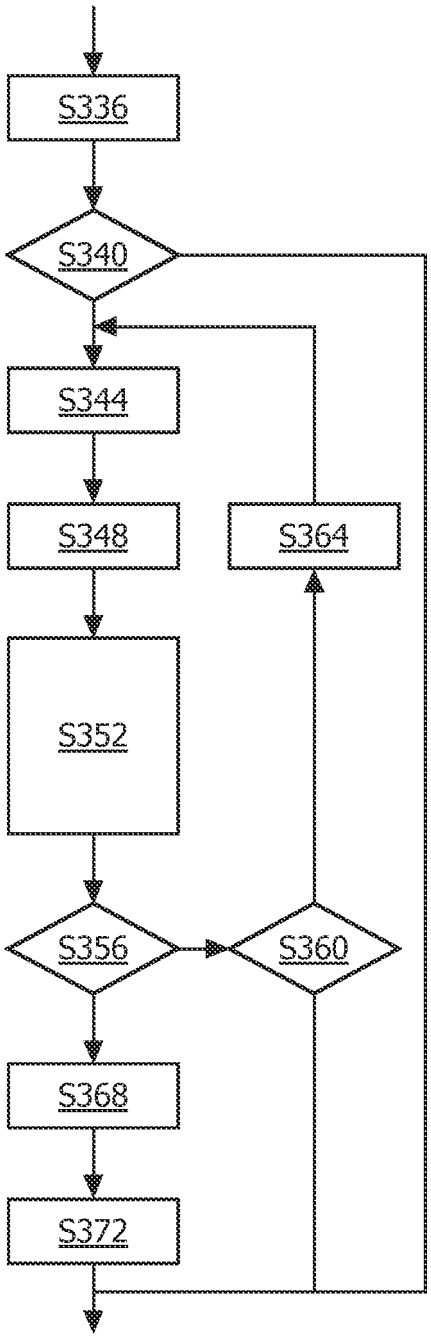
S336
S340
S344
S348
S364
S352
S356
S360
S368
S372

FIG. 3B

REFERENCES CITED IN THE DESCRIPTION

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专利名称(译)	使用低成本传感器的自动多普勒测速仪		
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[标]申请(专利权)人(译)	皇家飞利浦电子股份有限公司		
申请(专利权)人(译)	皇家飞利浦N.V.		
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摘要(译)

自动，独立的手持式超声血管检查装置（100）需要减少数量的换能器元件（126）并且呈现简化的用户界面（136-140），而不需要显示任何图像。船只在一个实施例中，探针获取并检查感兴趣的体积（106），搜索目标血管，测试血管的血流正常性，并自动报告诊断，而无需用户干预。在另一个实施例中，探针在体积中找到身体血管（108-112），并且自动地提取临床多普勒参数，而无需用户干预。