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(54) **MAGNETIC RESONANCE SYSTEM AND PROGRAM**

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USPC **600/413**; 600/419

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(57)

ABSTRACT

A magnetic resonance system configured to repeatedly execute imaging sequences each having a first RF pulse for flipping each spin in a region containing blood, and a data acquisition sequence acquiring data of the blood from the region is provided. The magnetic resonance system includes a storage unit configured to store a correspondence relation between a contrast between the blood and a background tissue, a first time taken from the first RF pulse to the data acquisition sequence, and a second time taken from a completion of an imaging sequence to a start of a next imaging sequence, first determining means configured to determine the first time used, and second determining means configured to determine the second time used.

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A61B 5/026 (2006.01)

G01R 33/38 (2006.01)

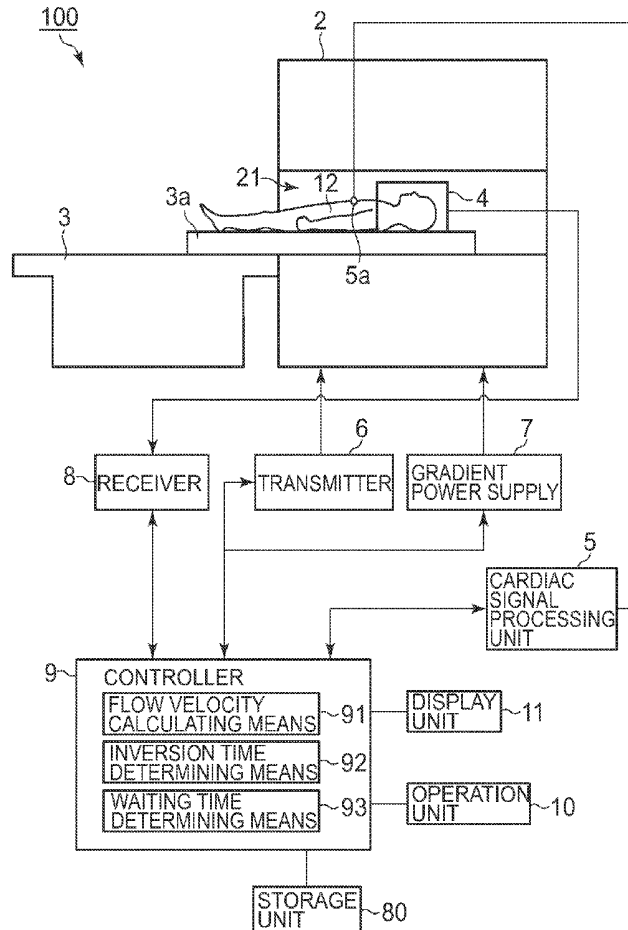
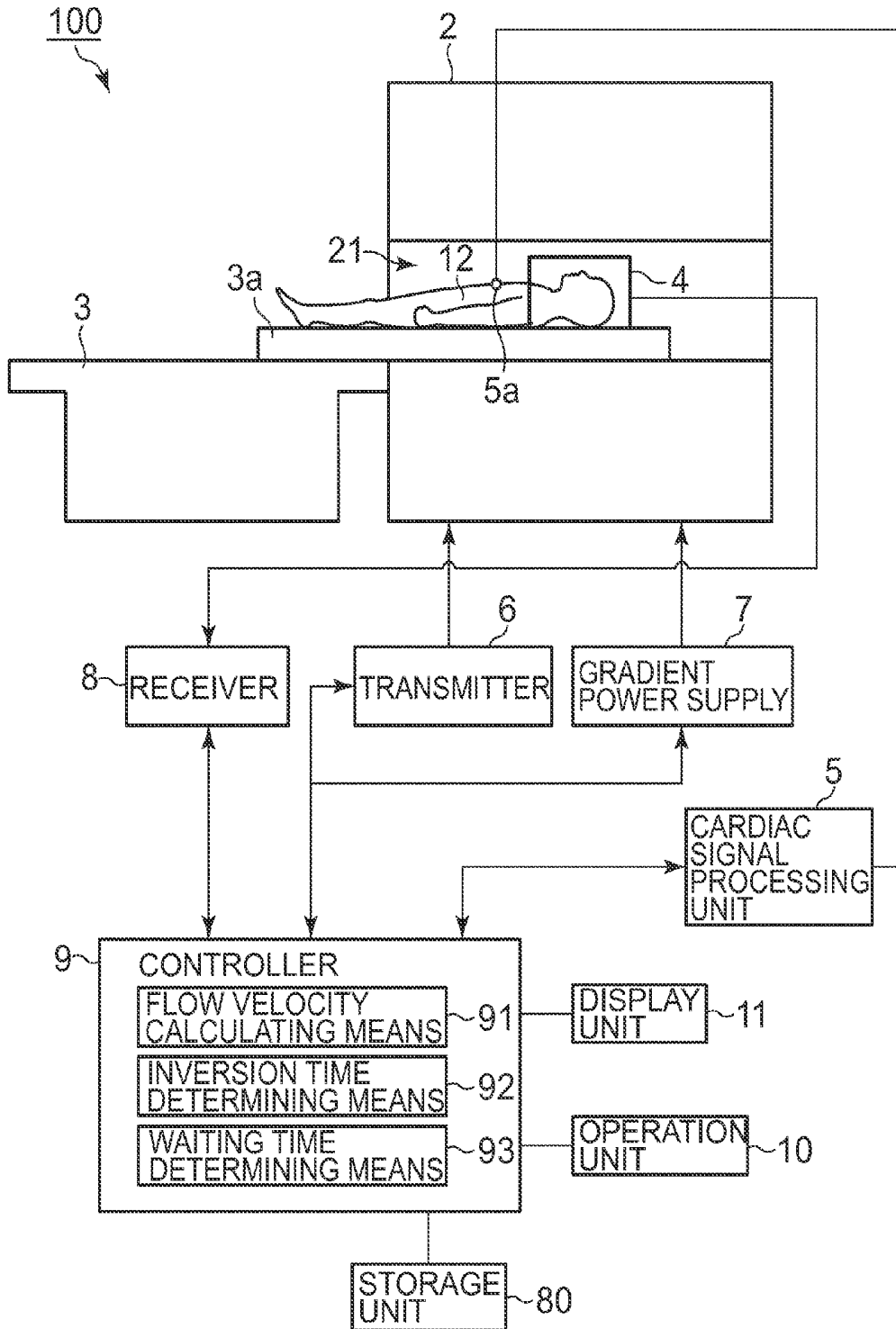


FIG. 1



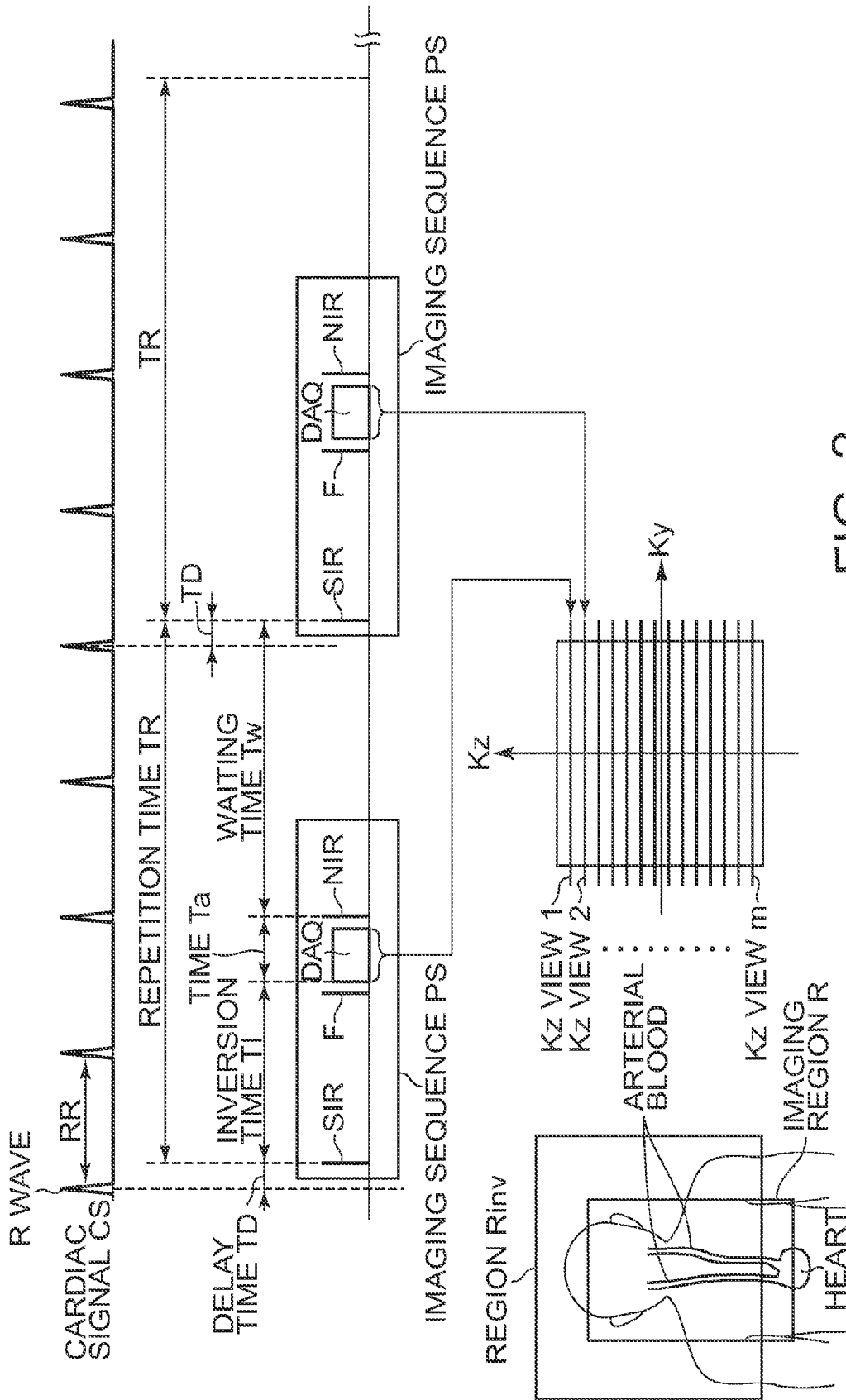


FIG. 2

FIG. 3

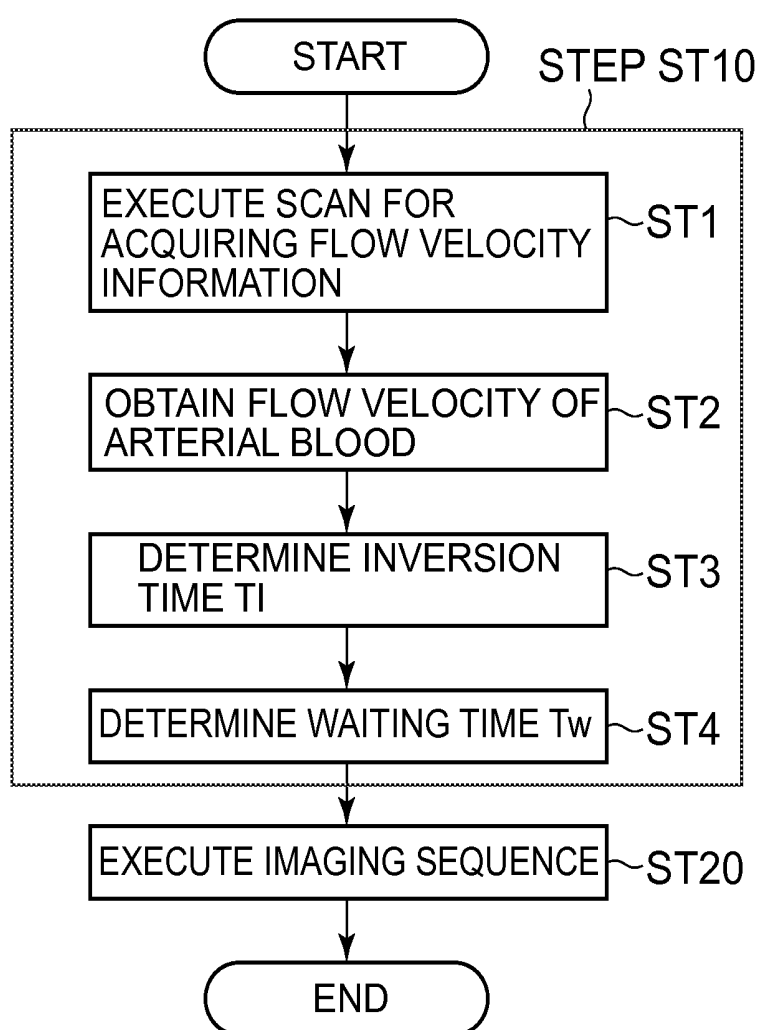


FIG. 4

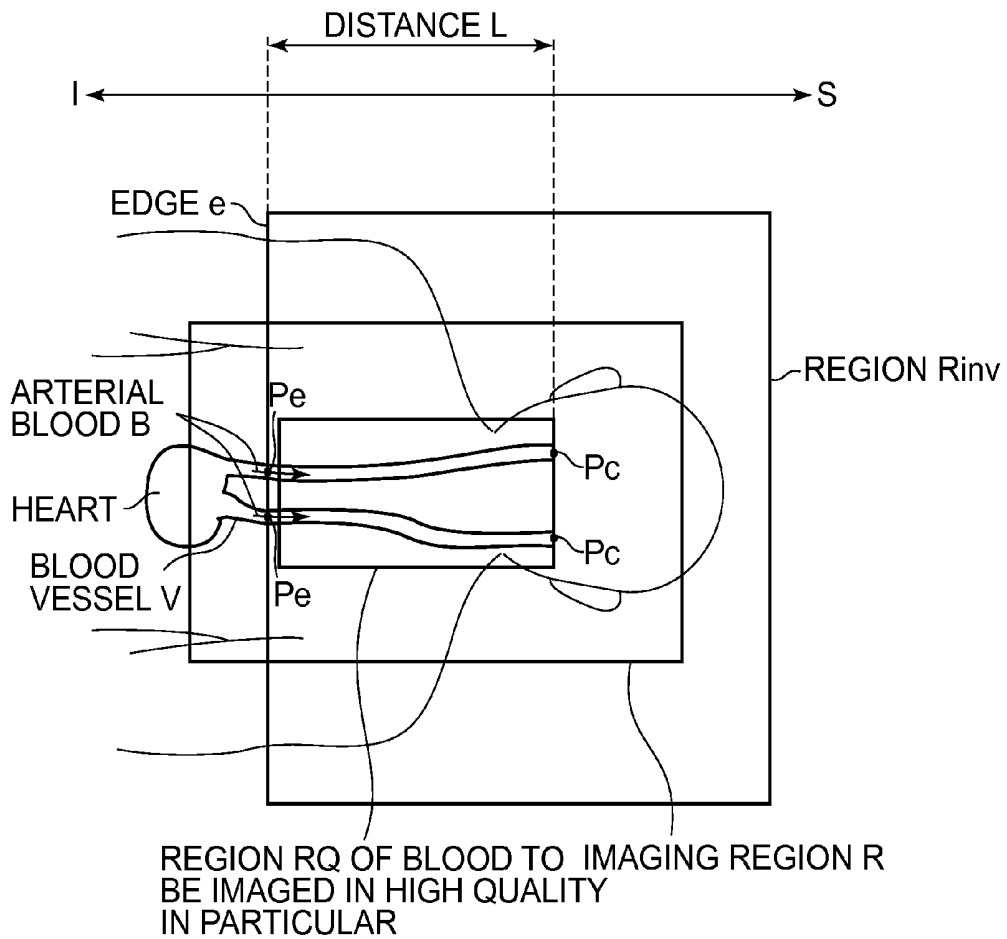


FIG. 5

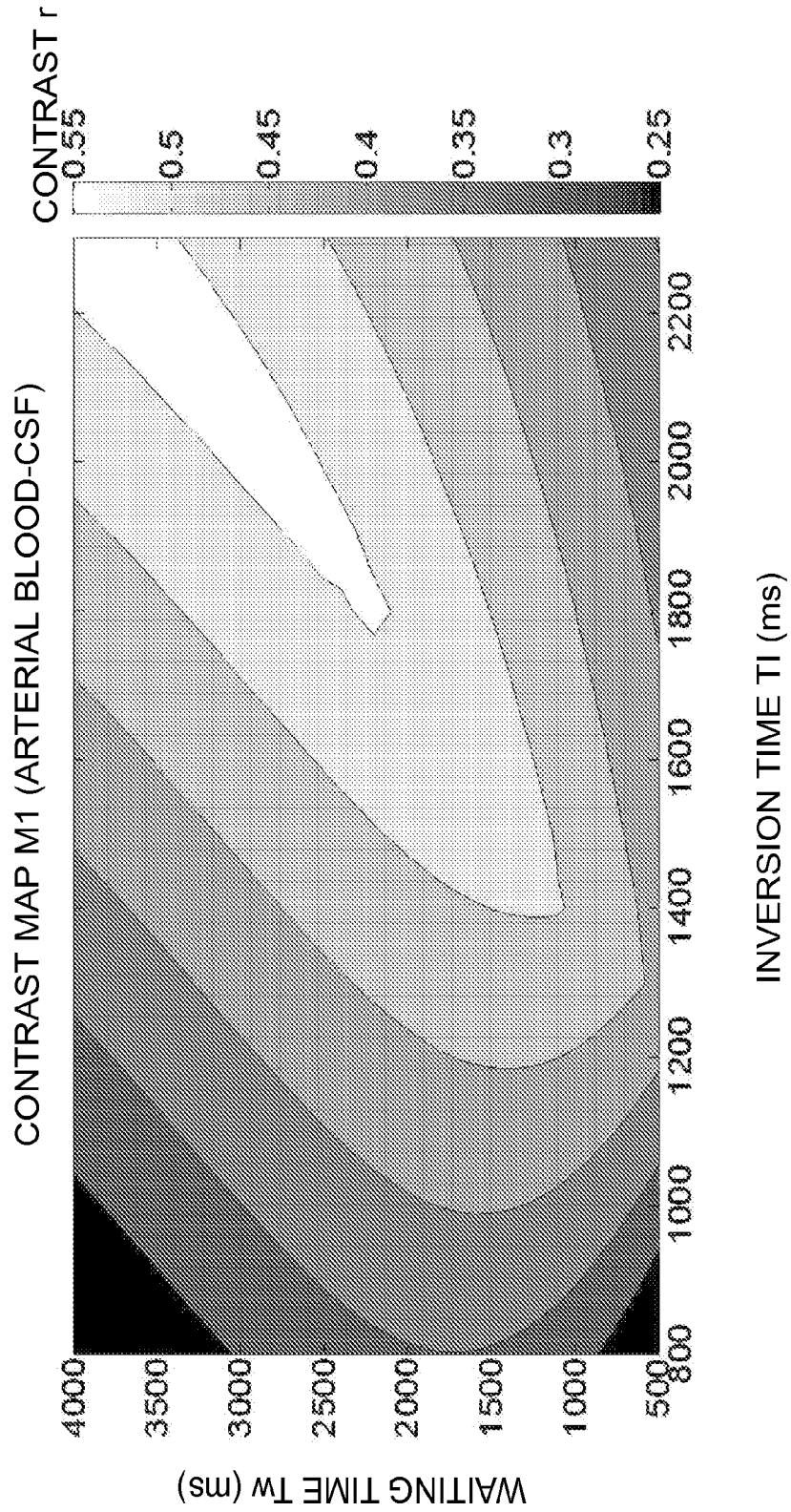


FIG. 6

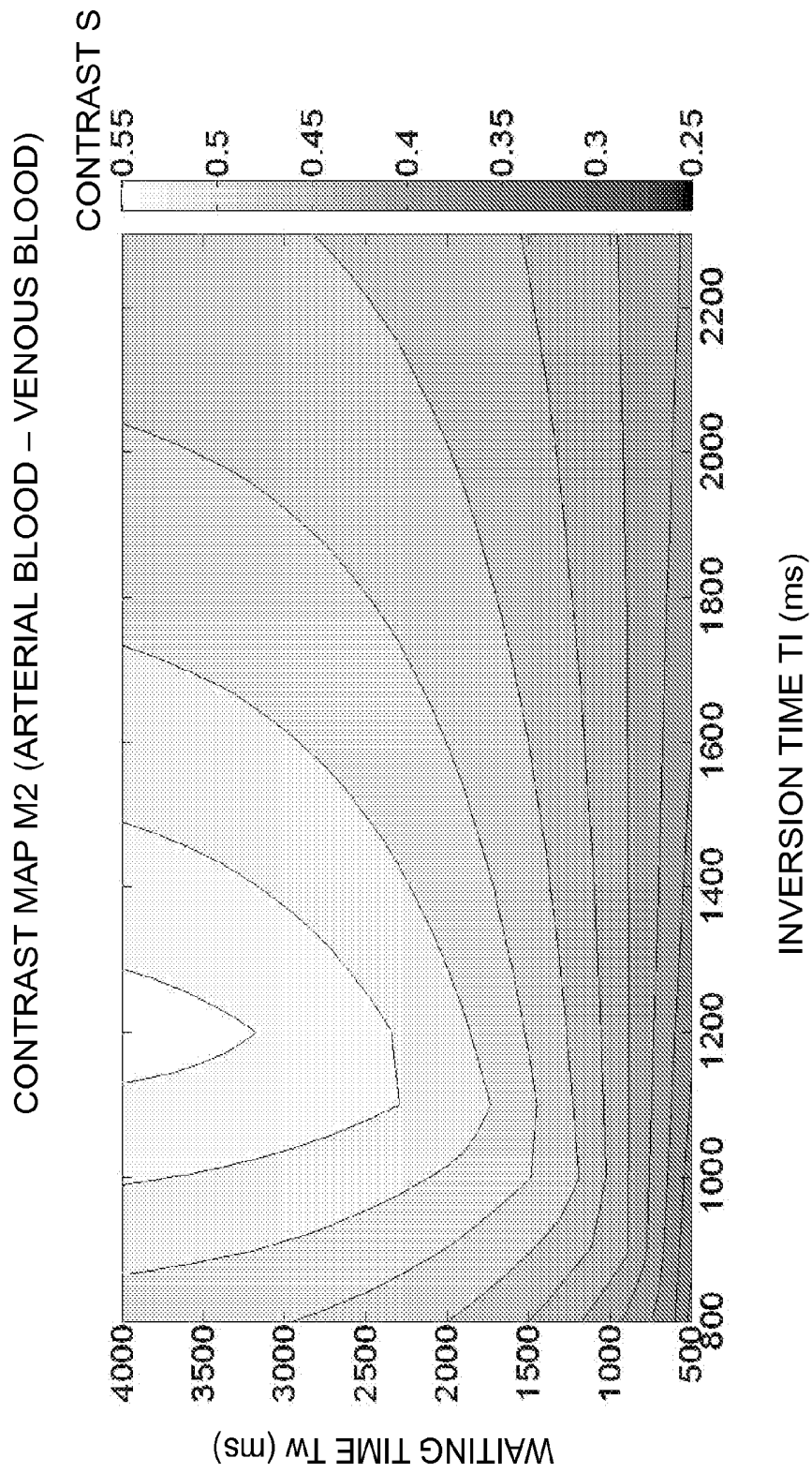


FIG. 7

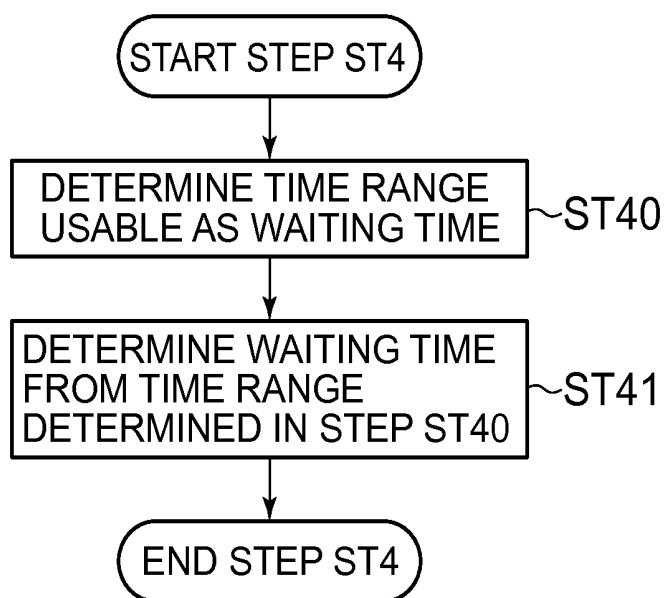


FIG. 8

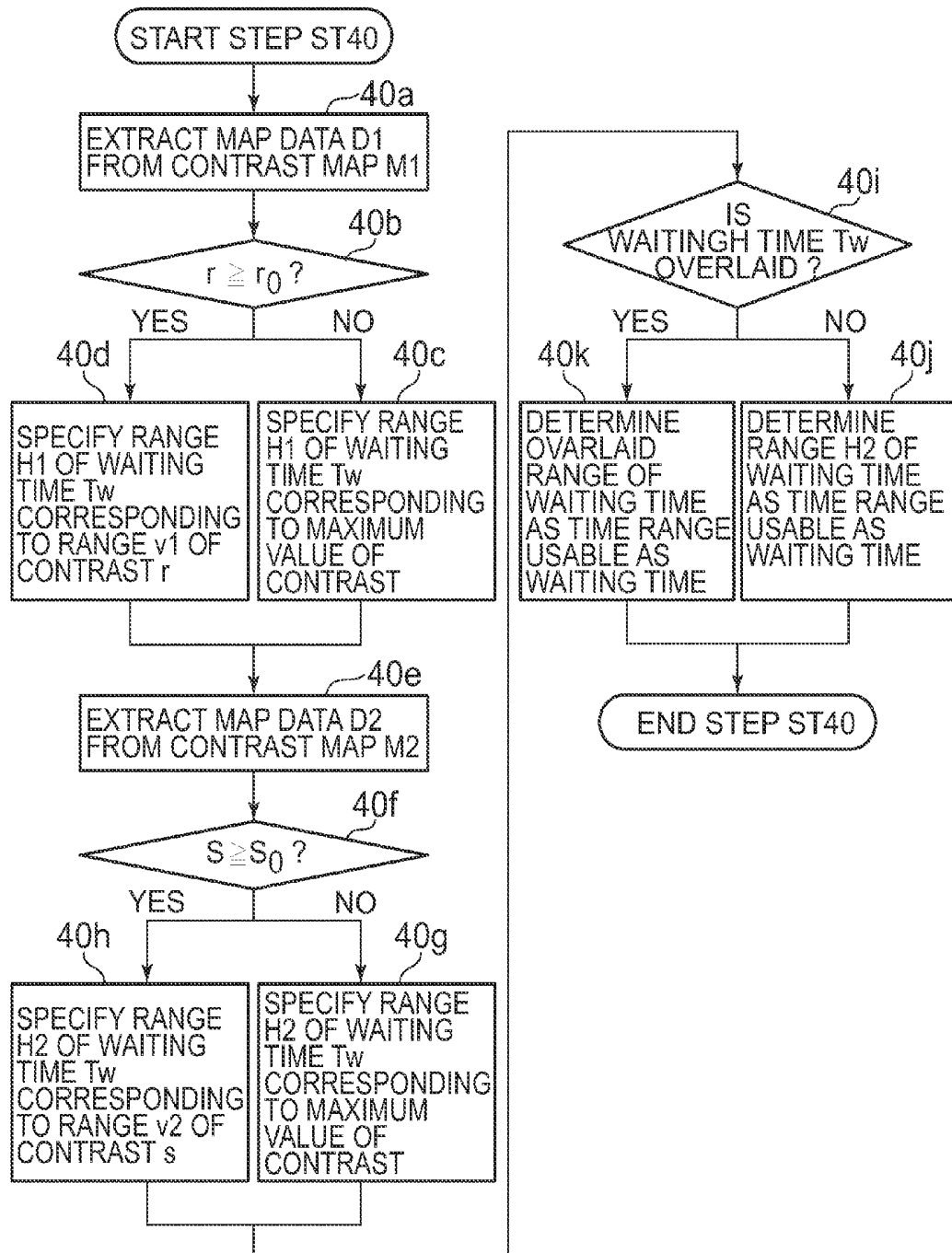


FIG. 9

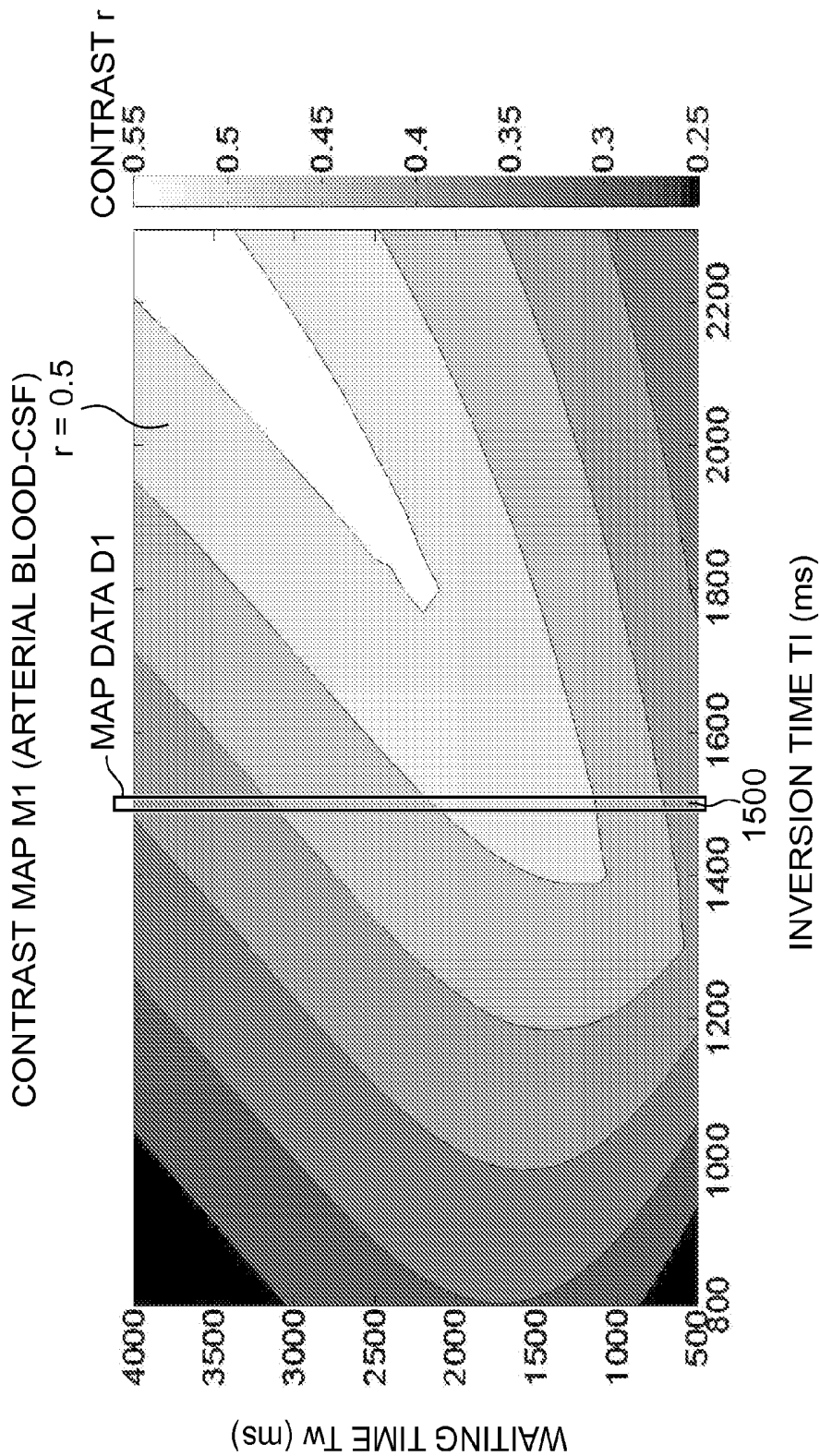


FIG. 10

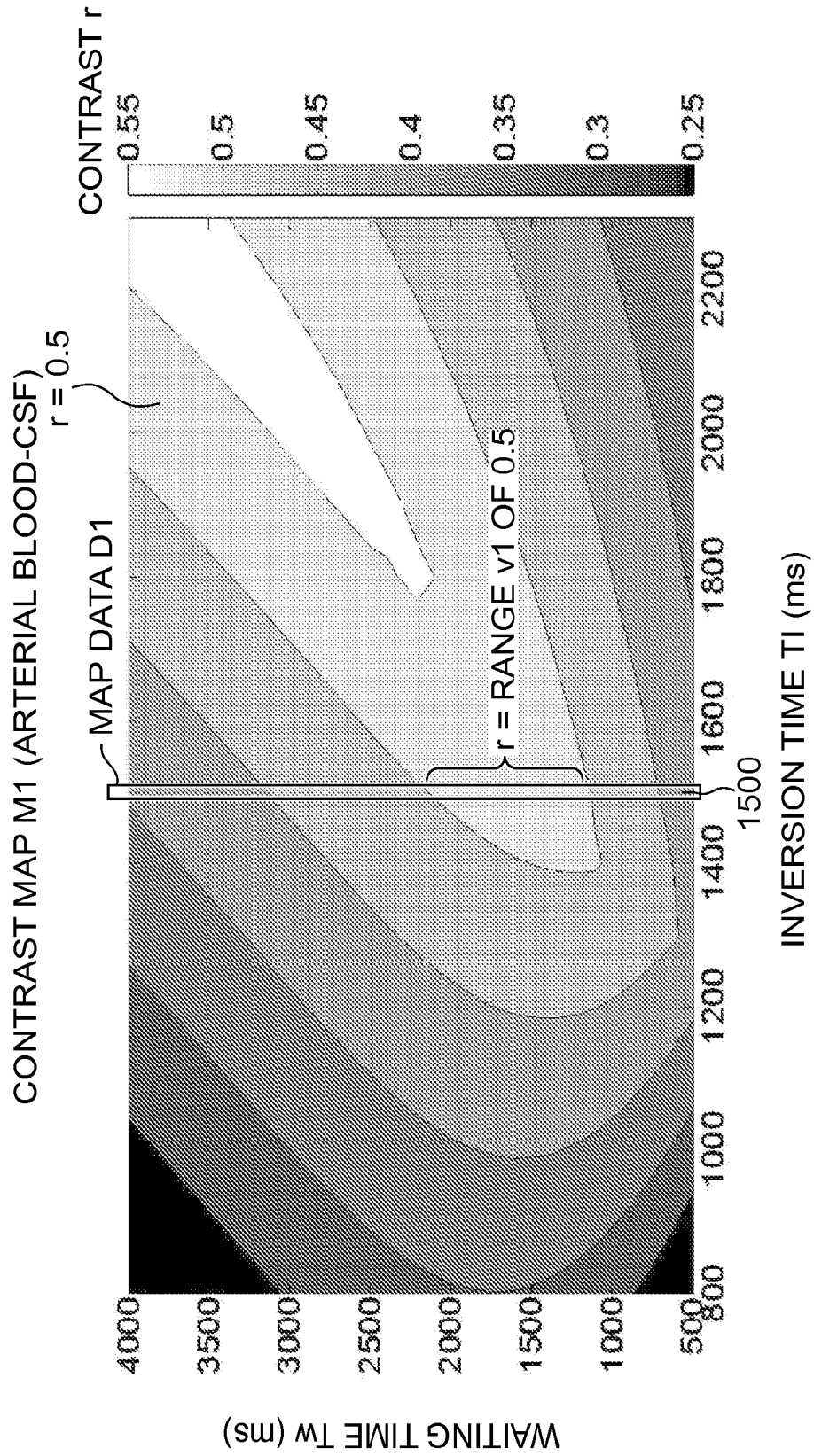


FIG. 11

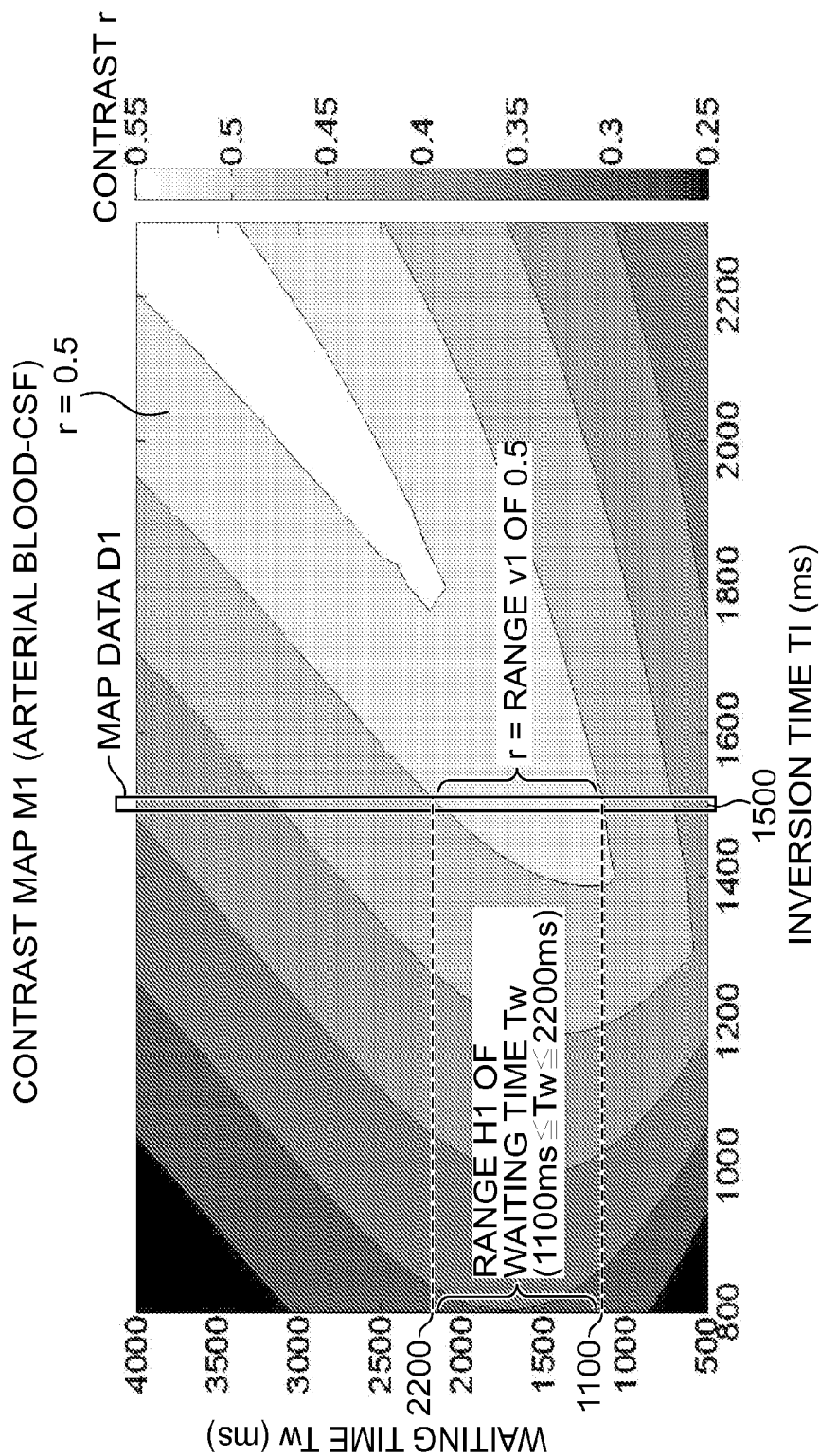


FIG. 12

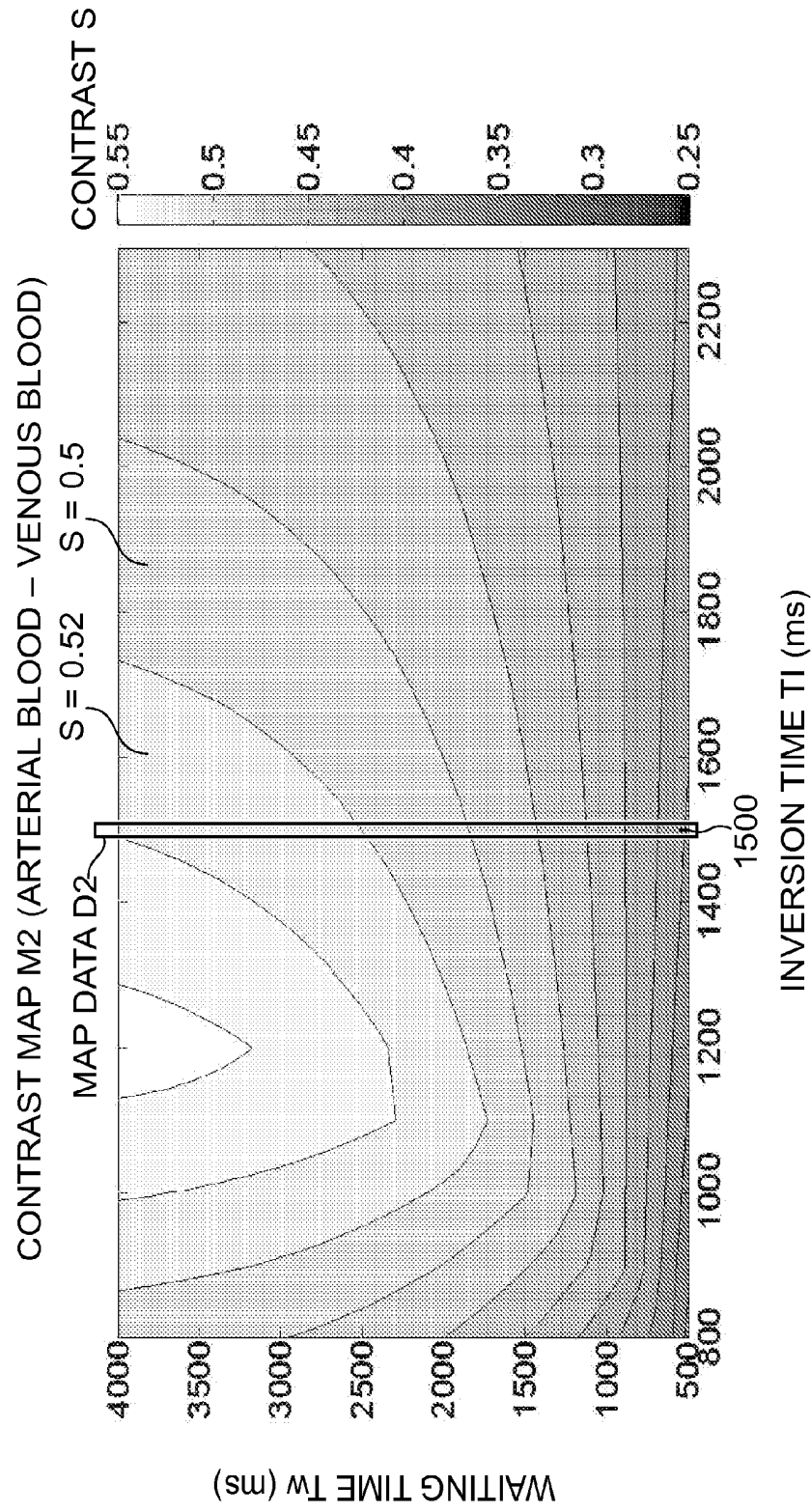


FIG. 13

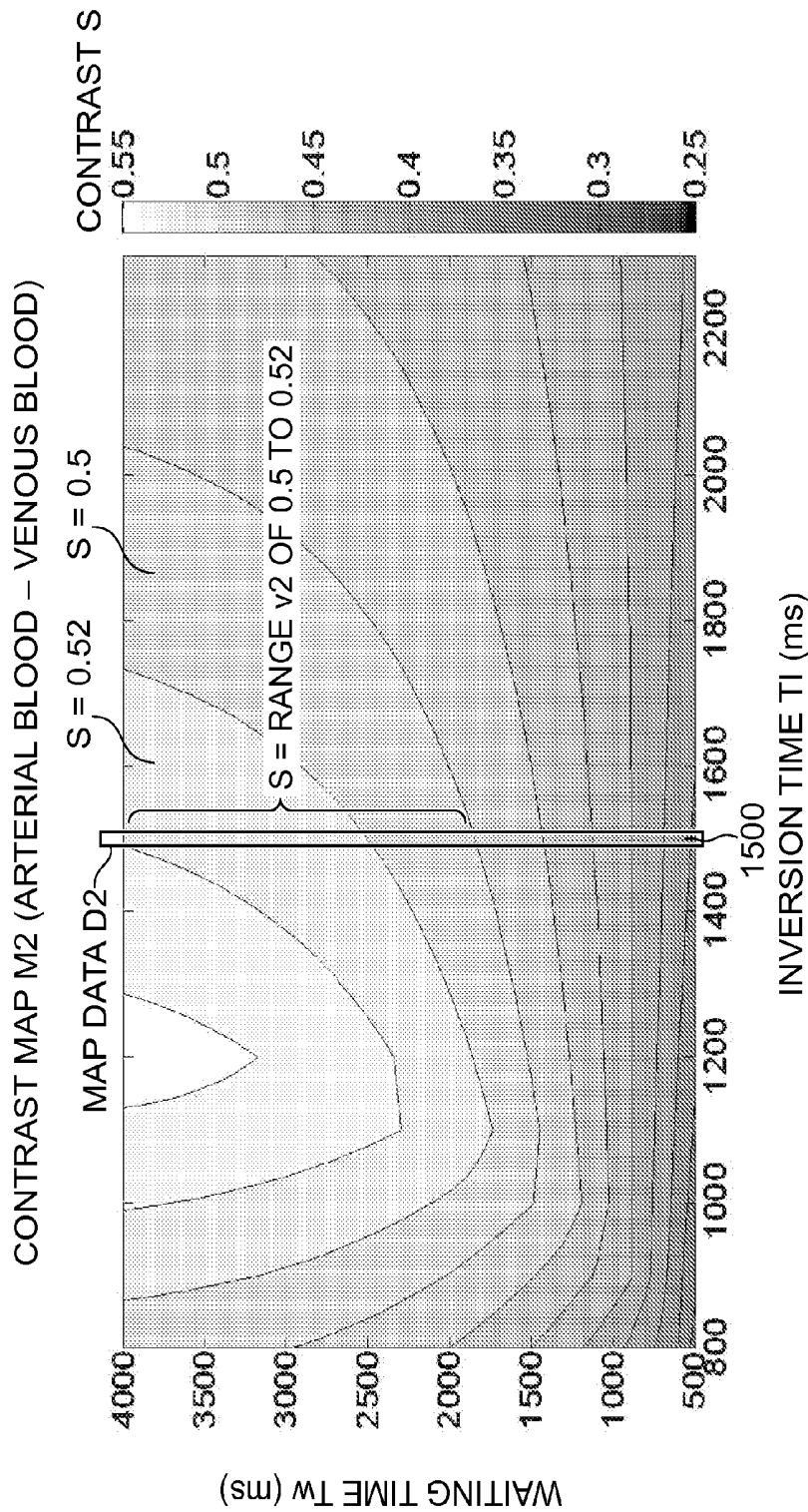


FIG. 14

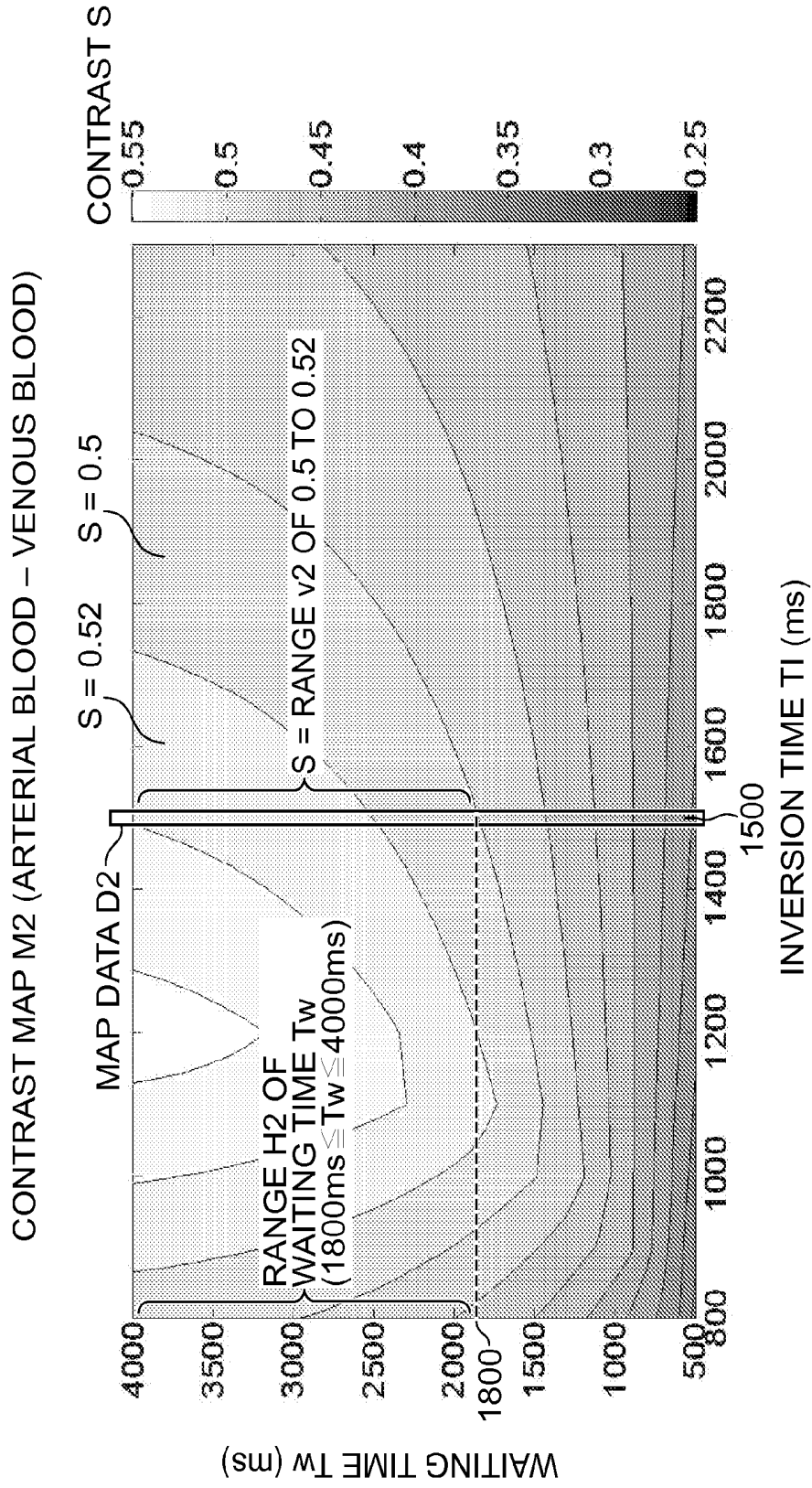


FIG. 15

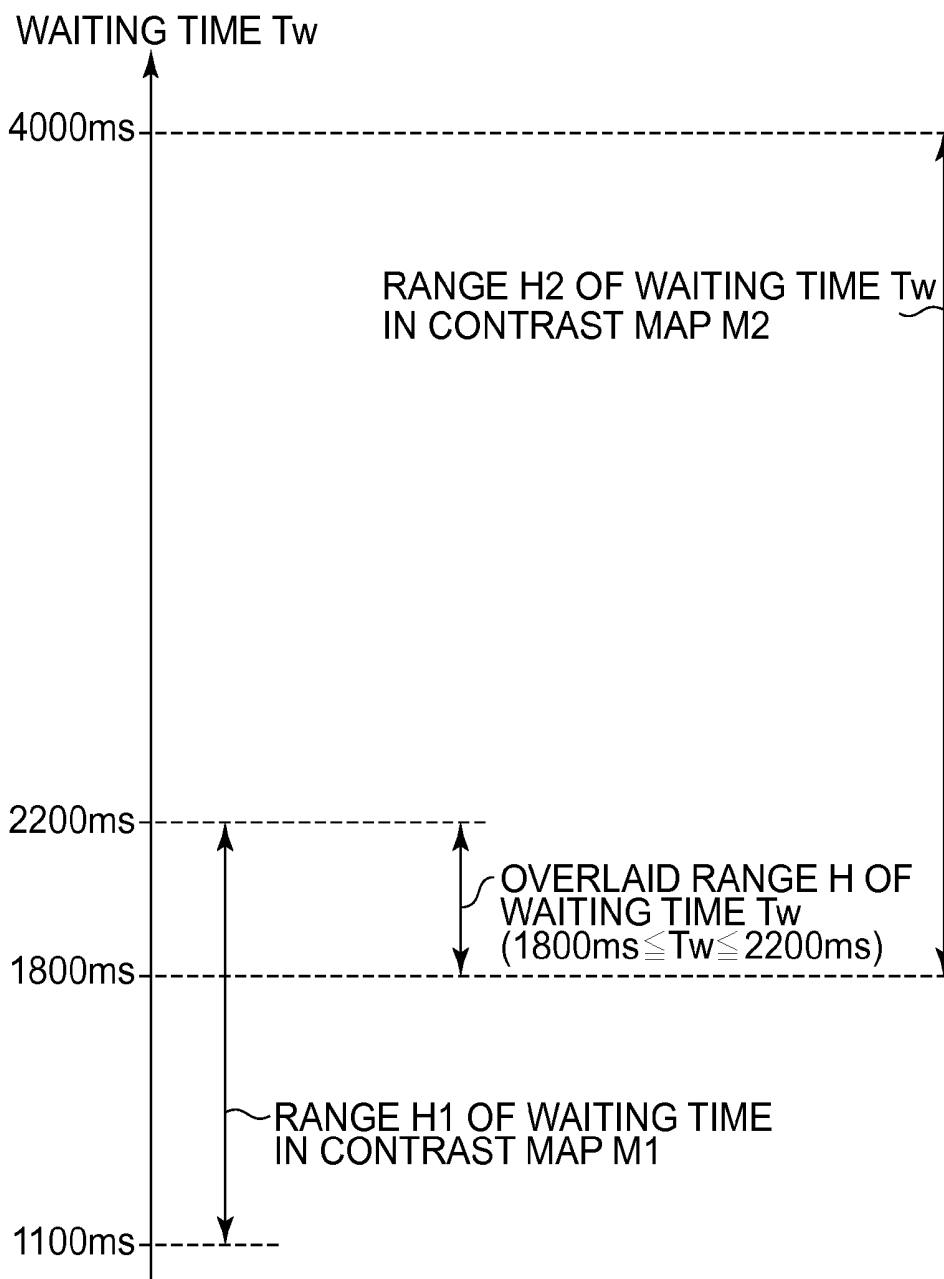


FIG. 16

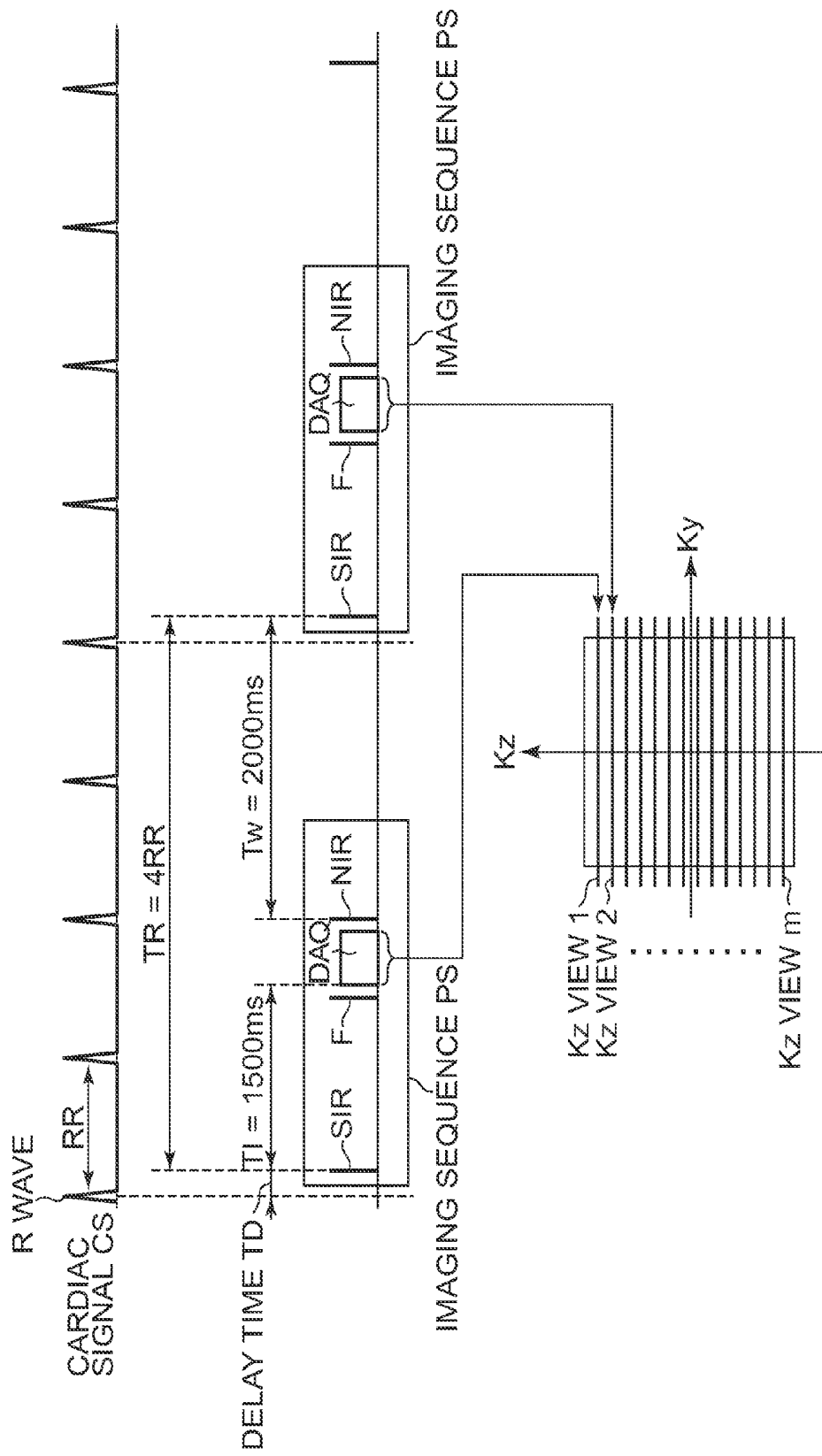


FIG. 17

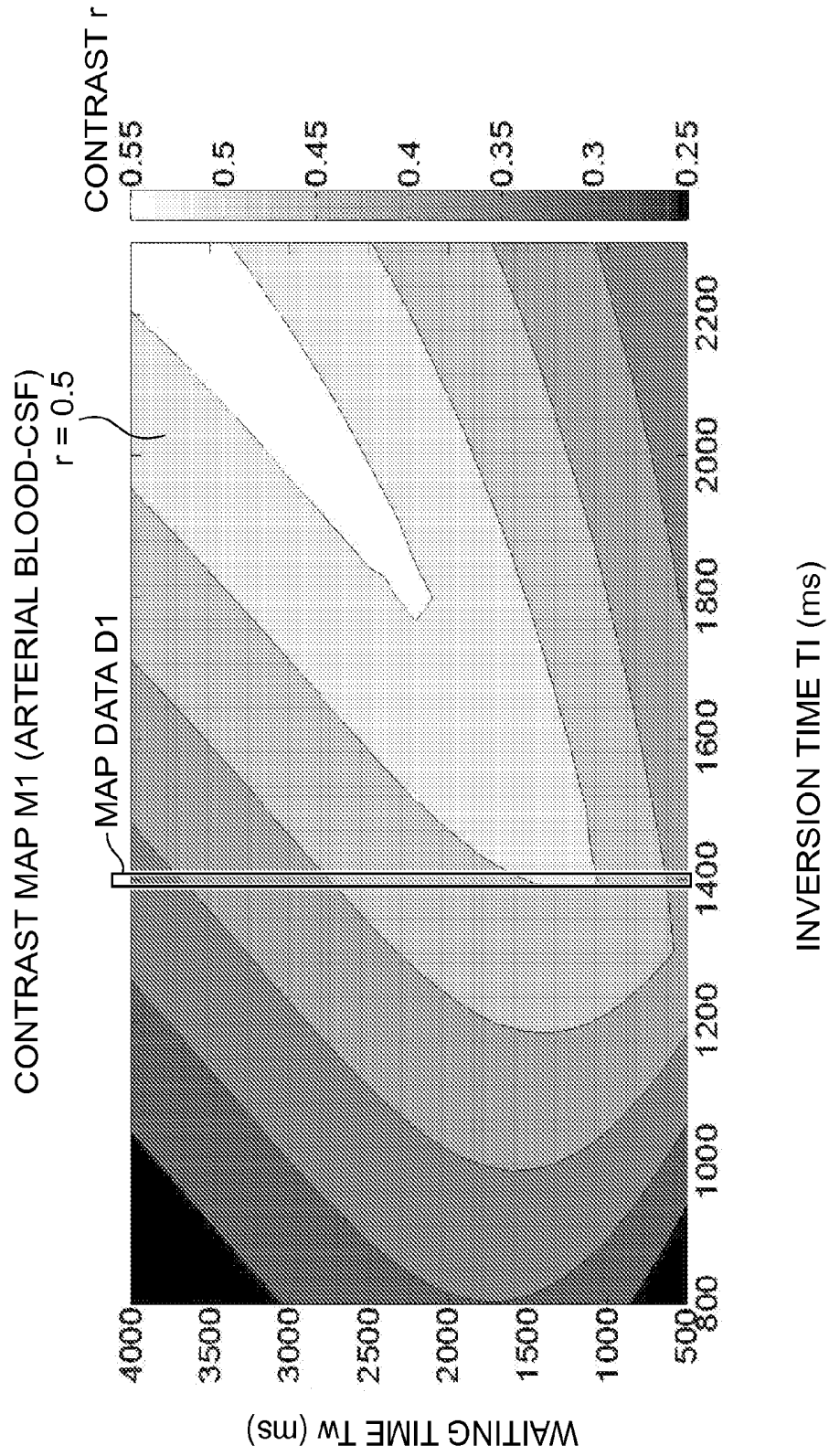


FIG. 18

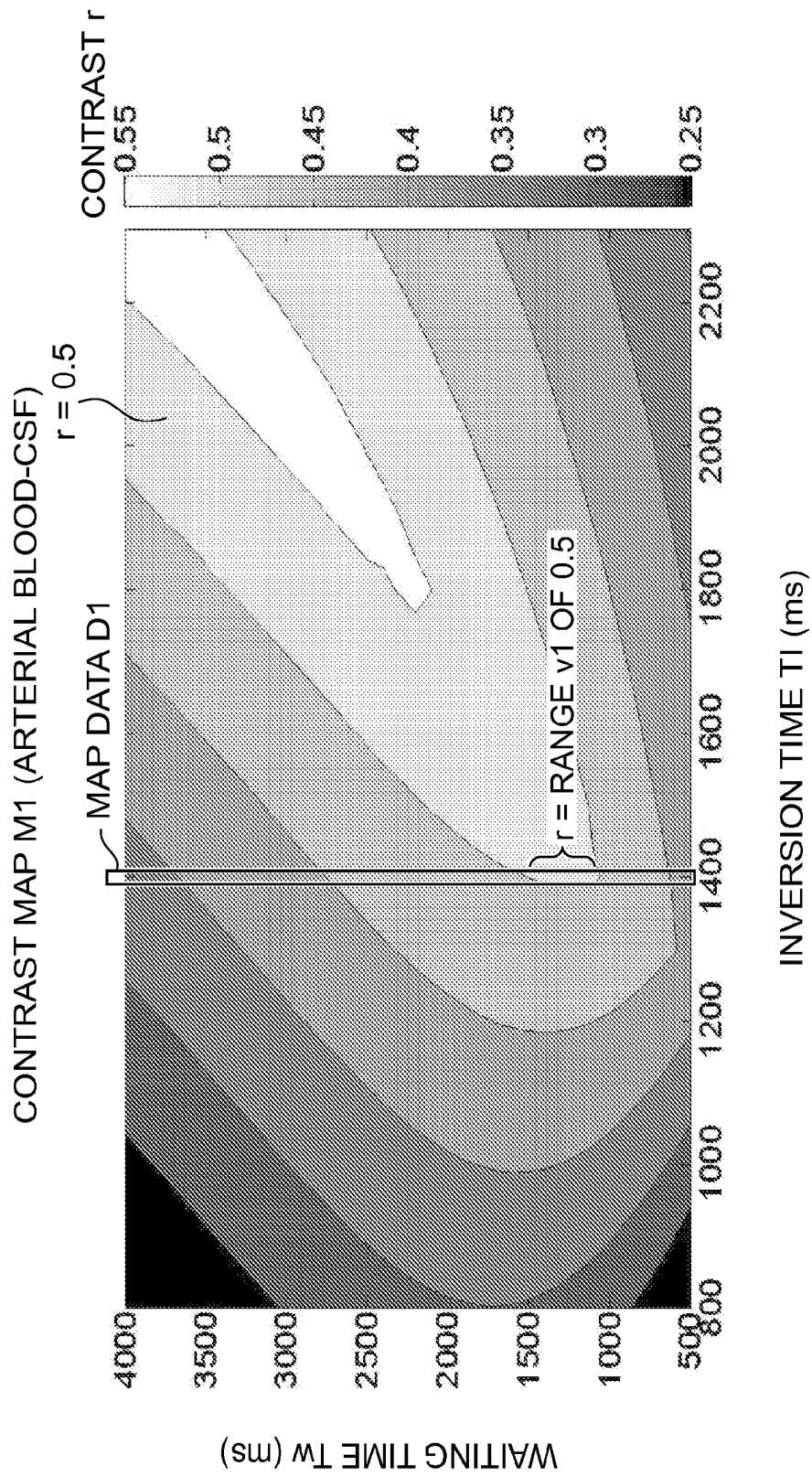


FIG. 19

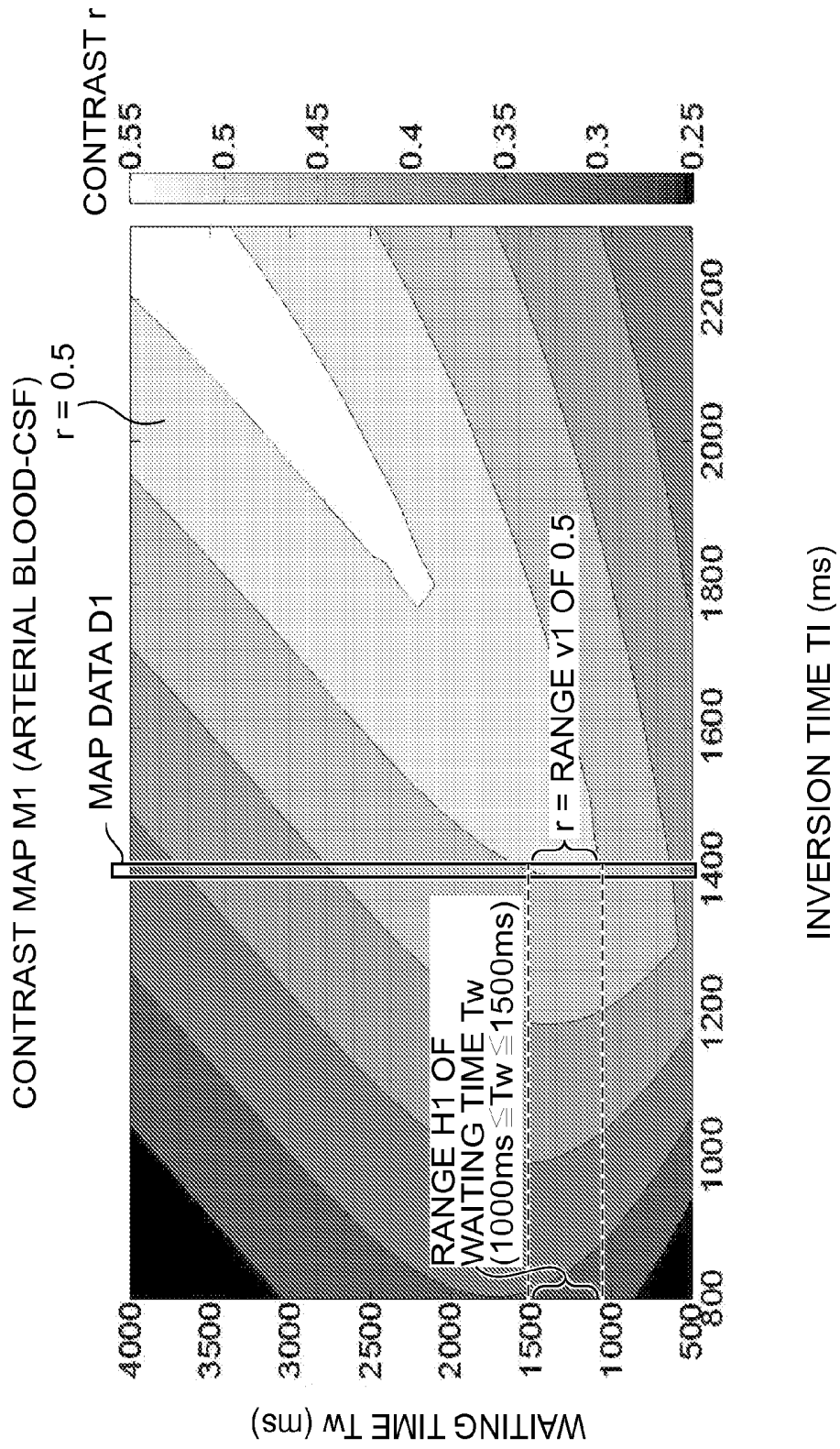


FIG. 20

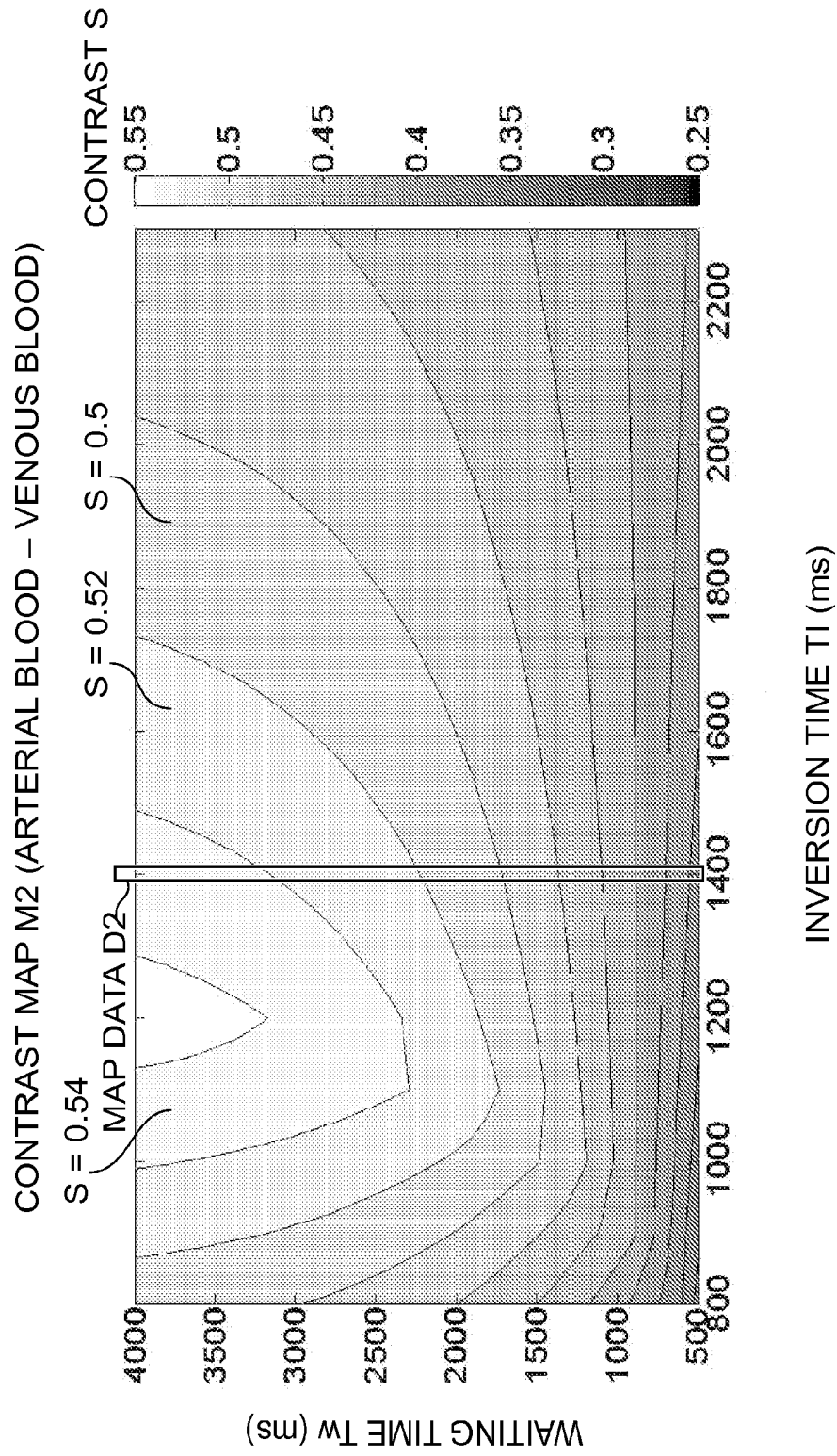


FIG. 21

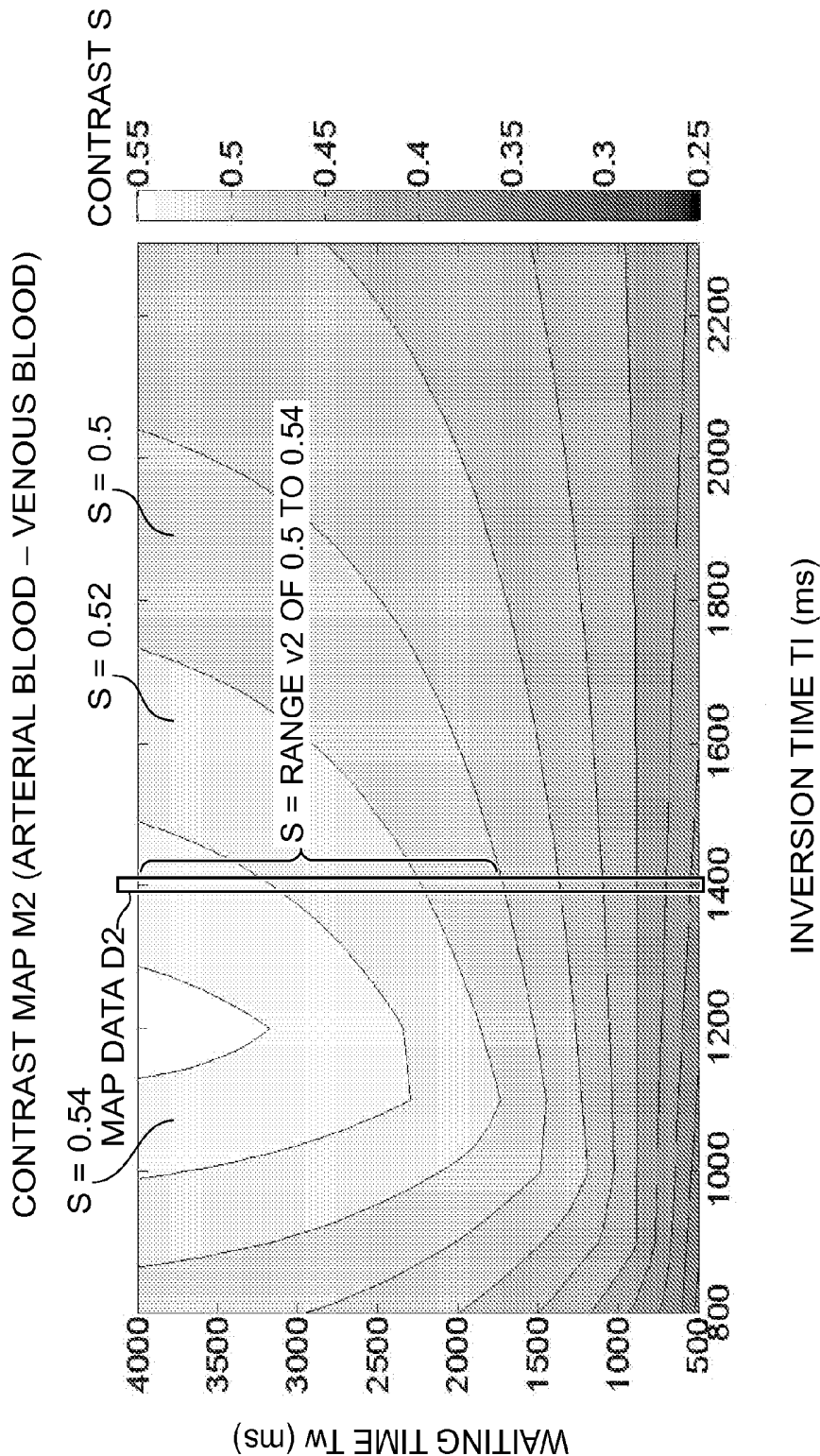


FIG. 22

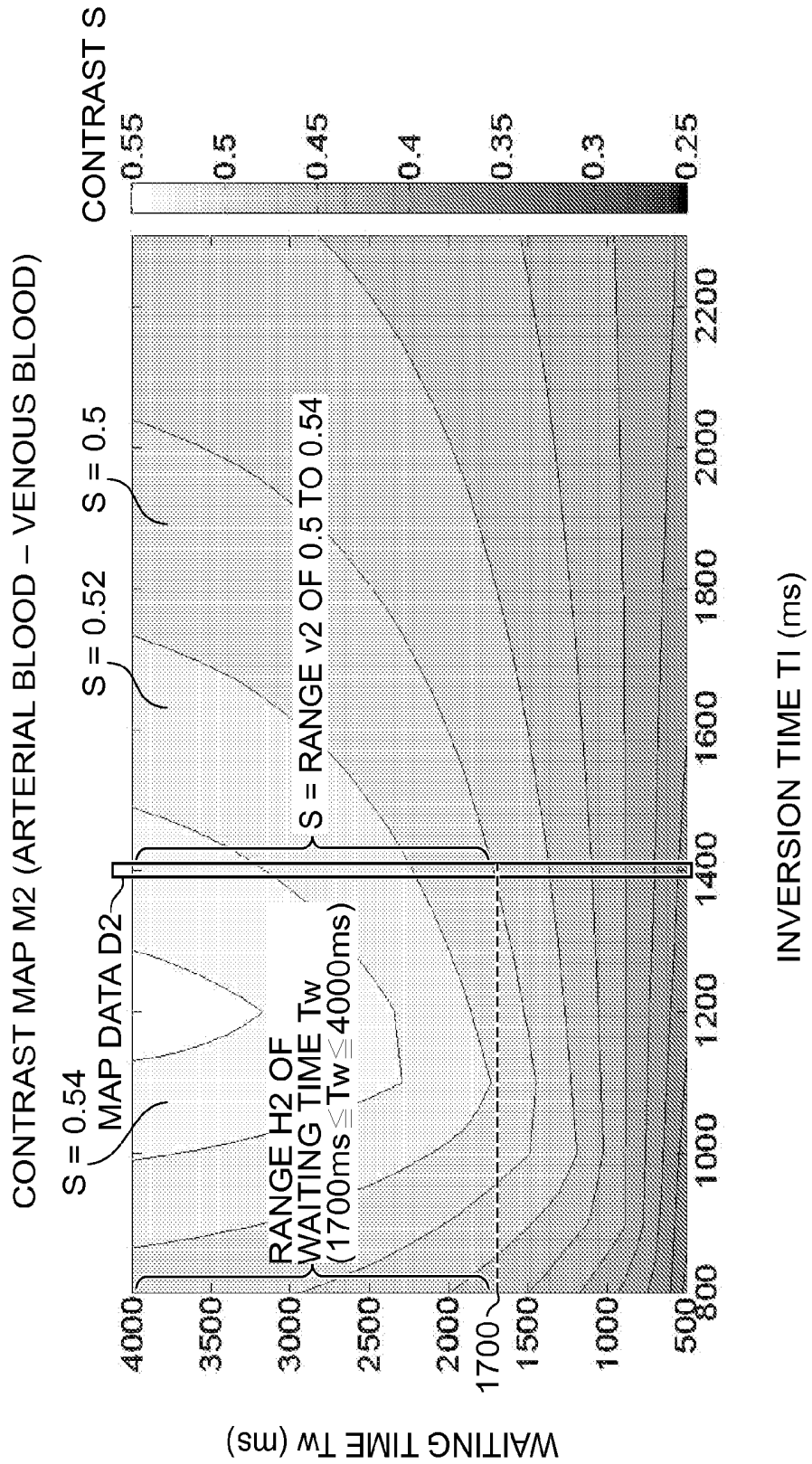


FIG. 23

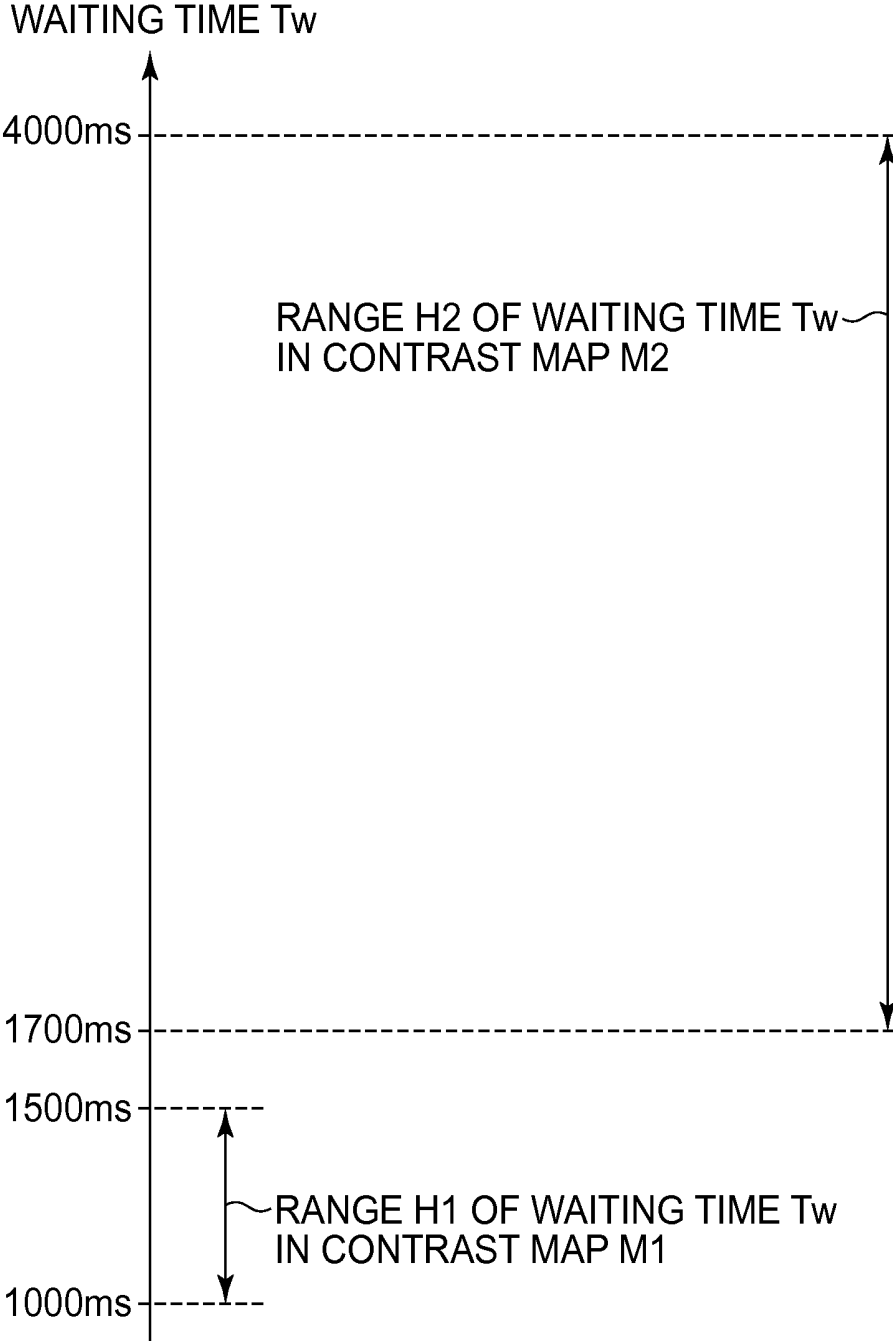


FIG. 24

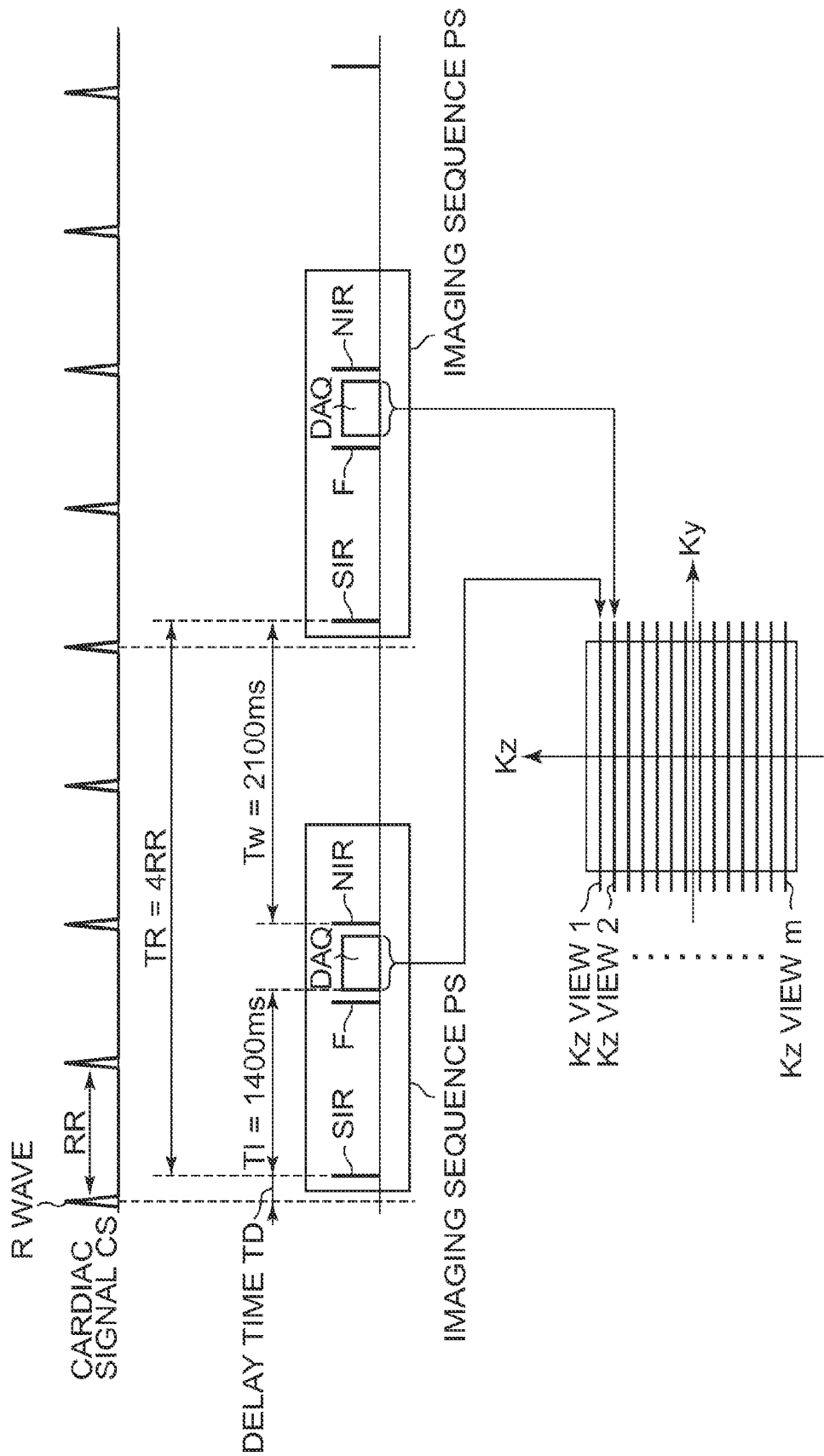


FIG. 25

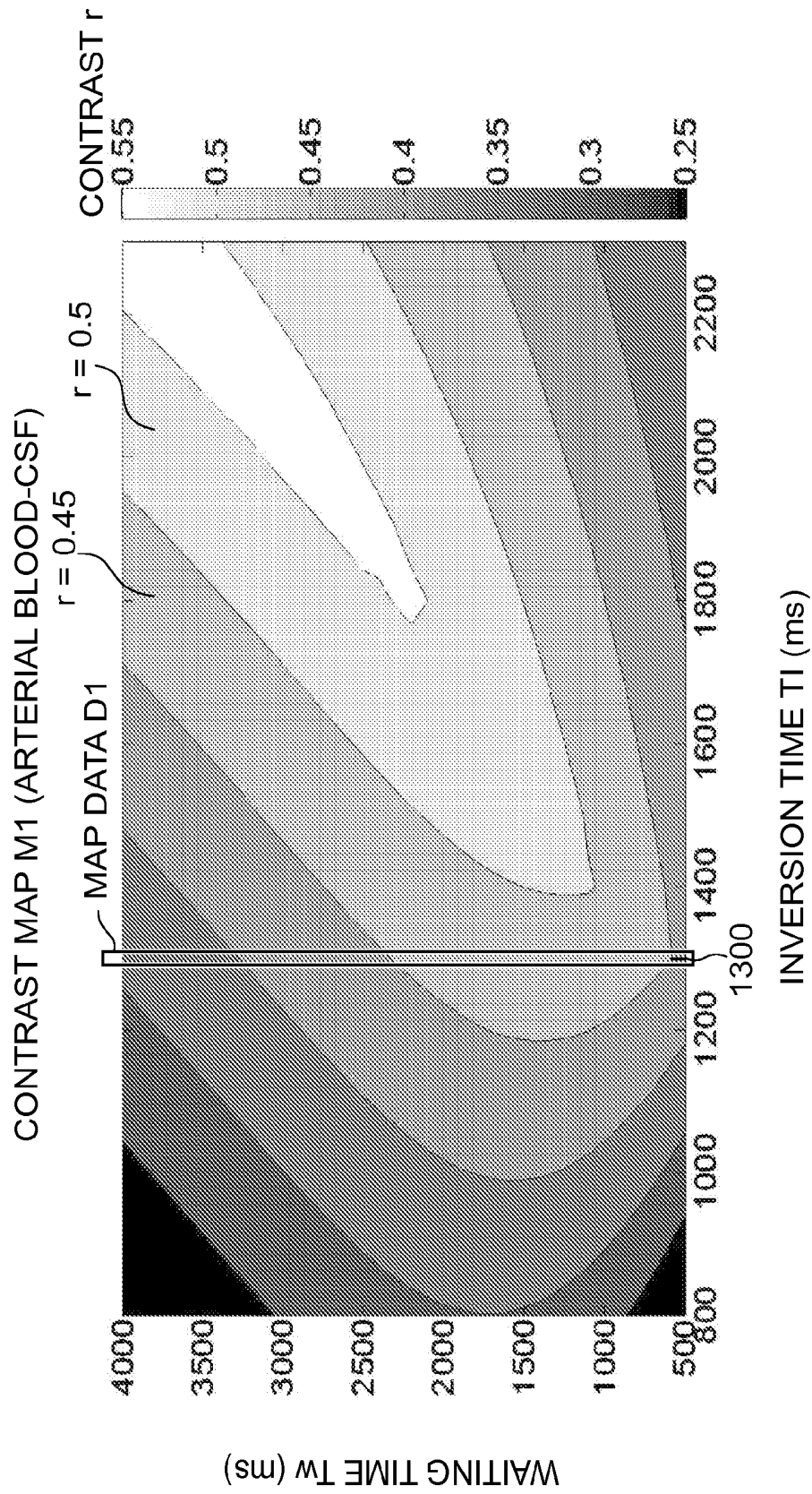


FIG. 26

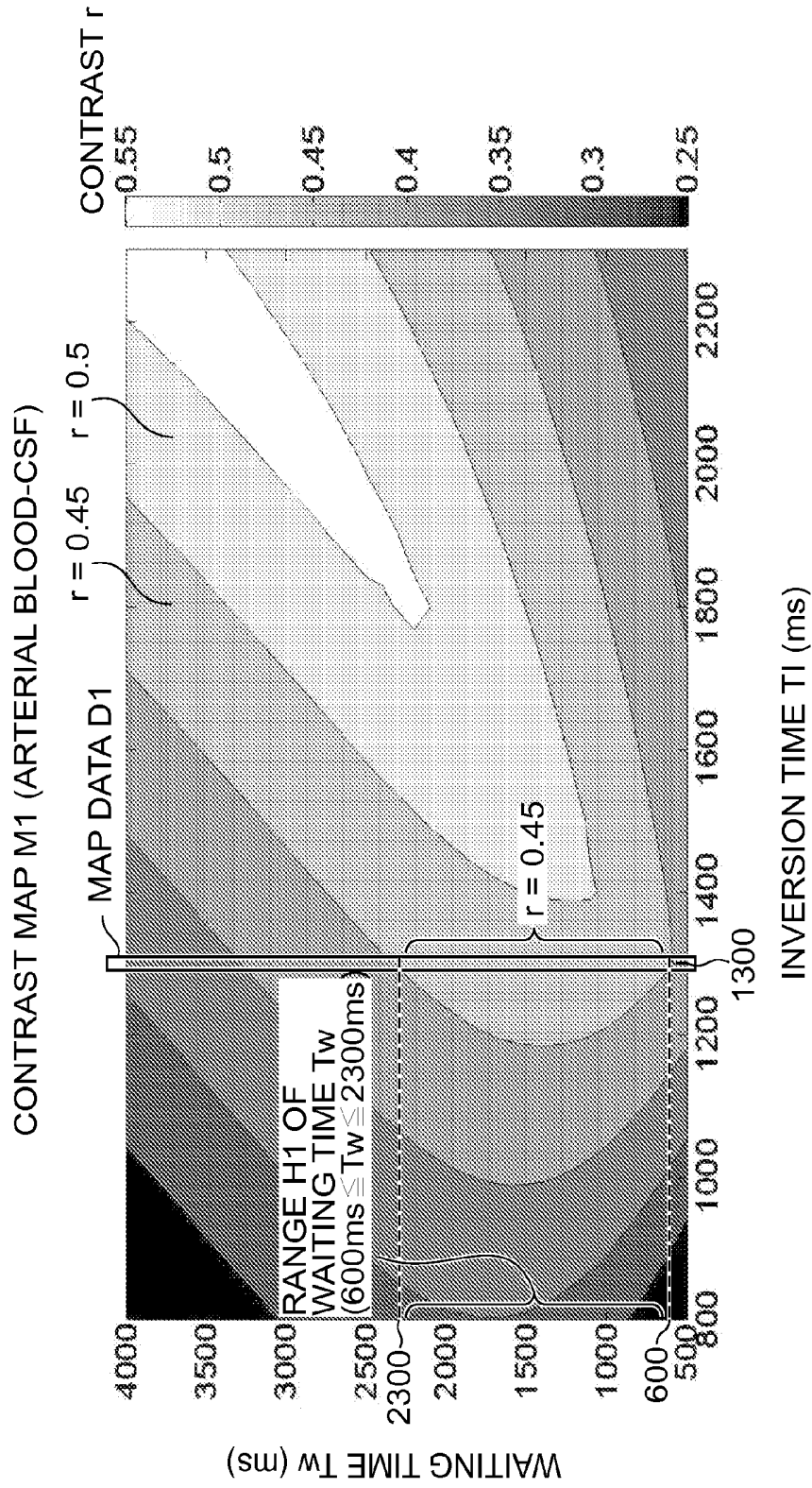


FIG. 27

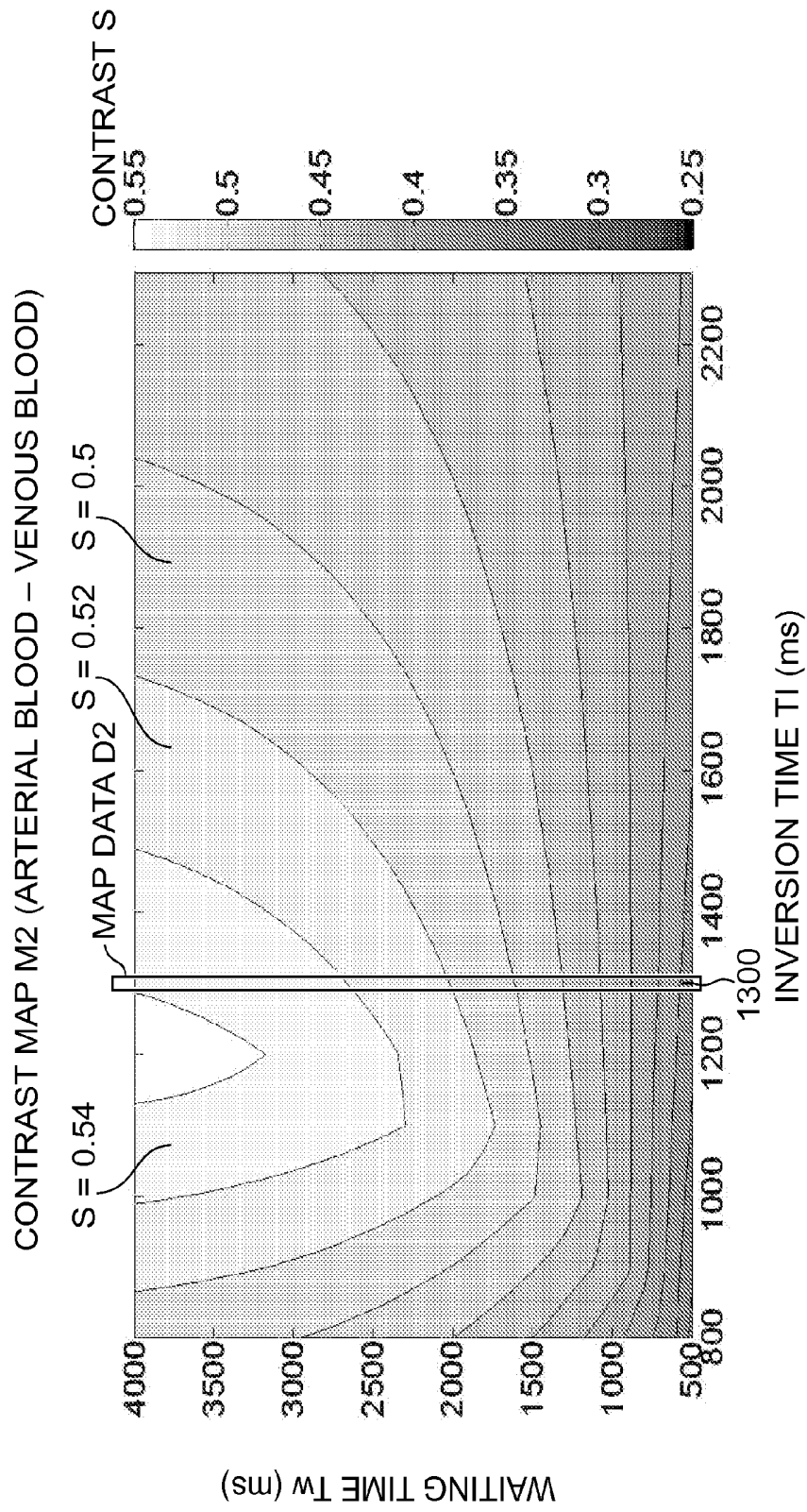


FIG. 28

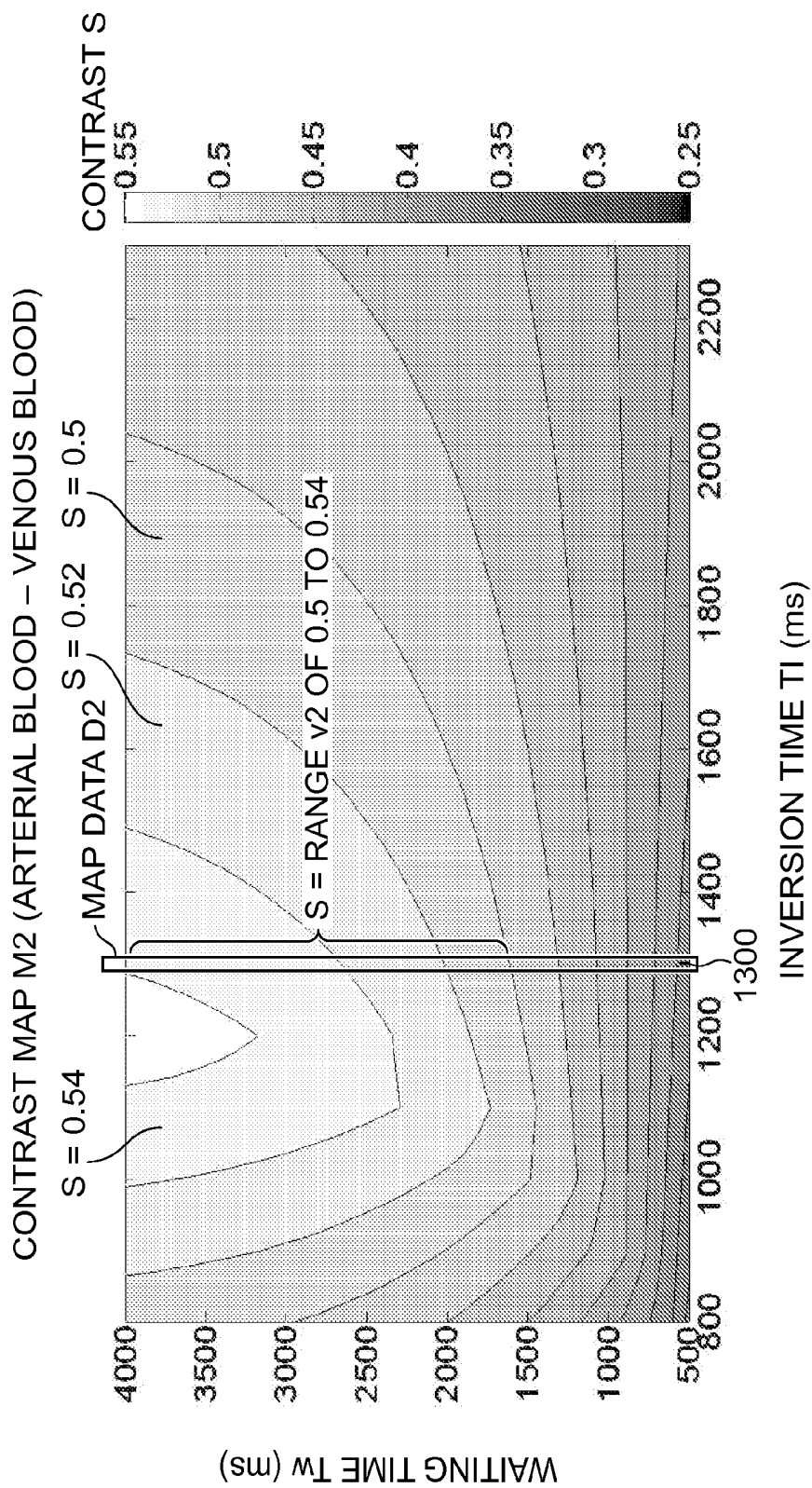


FIG. 29

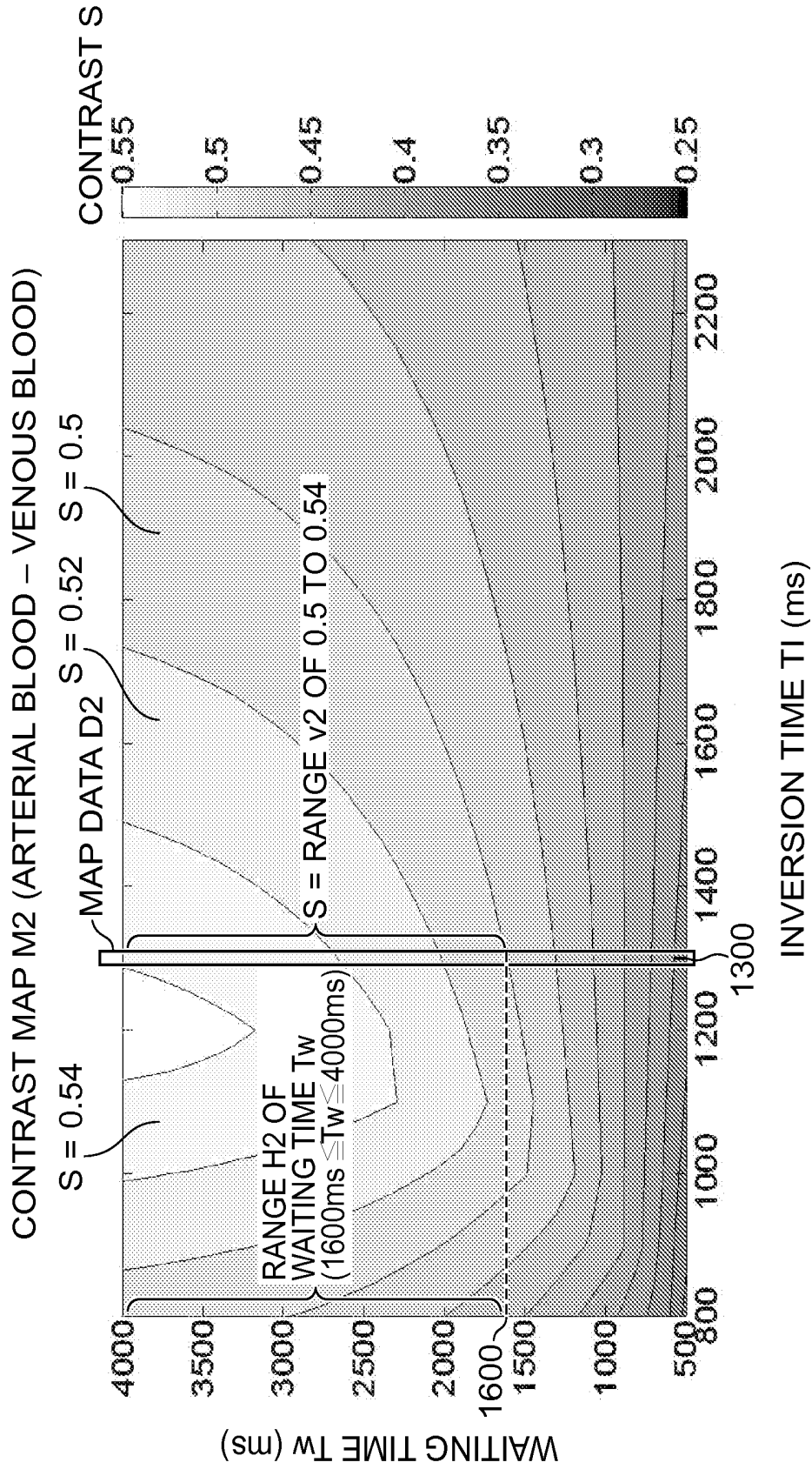


FIG. 30

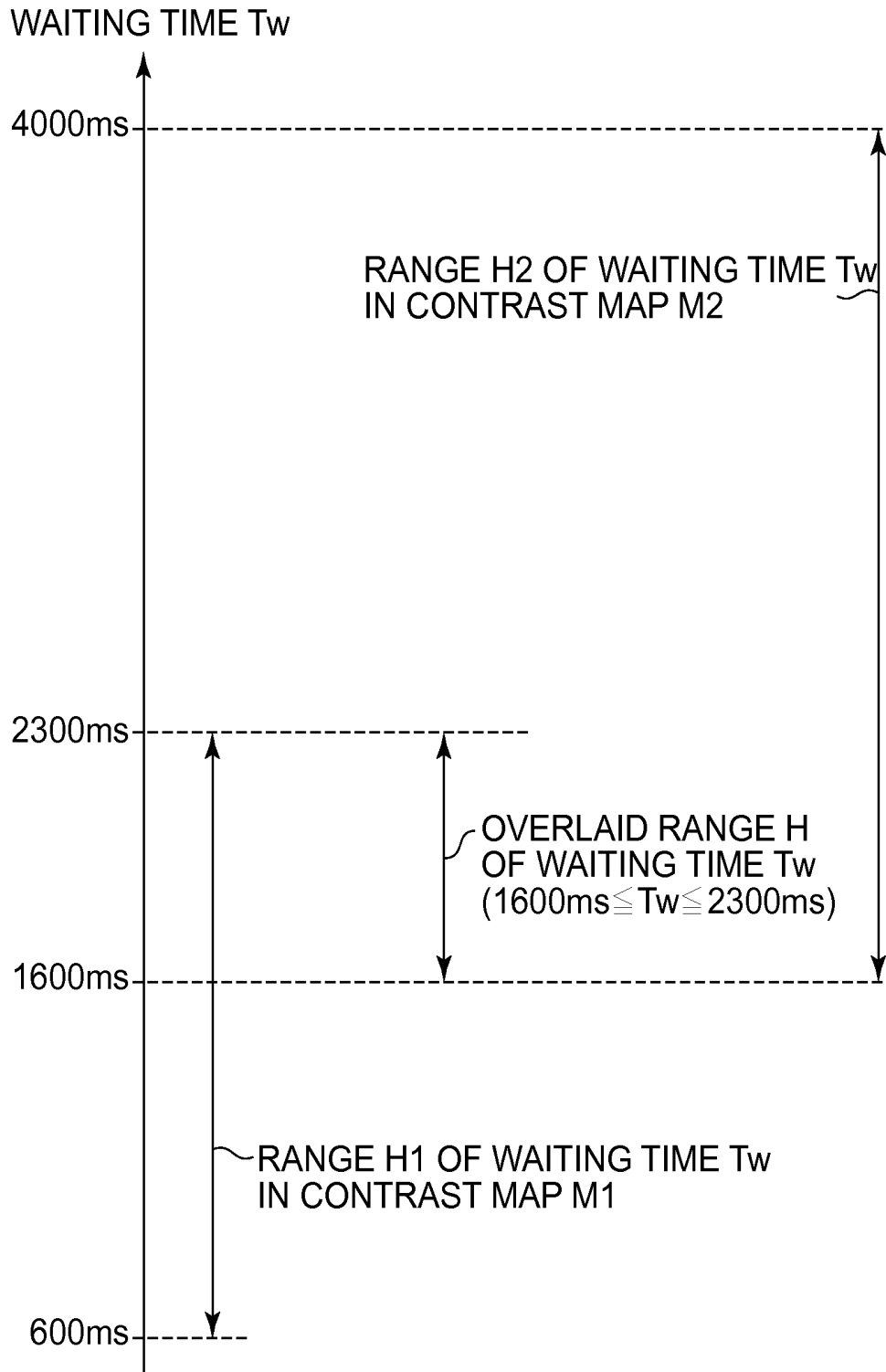


FIG. 31

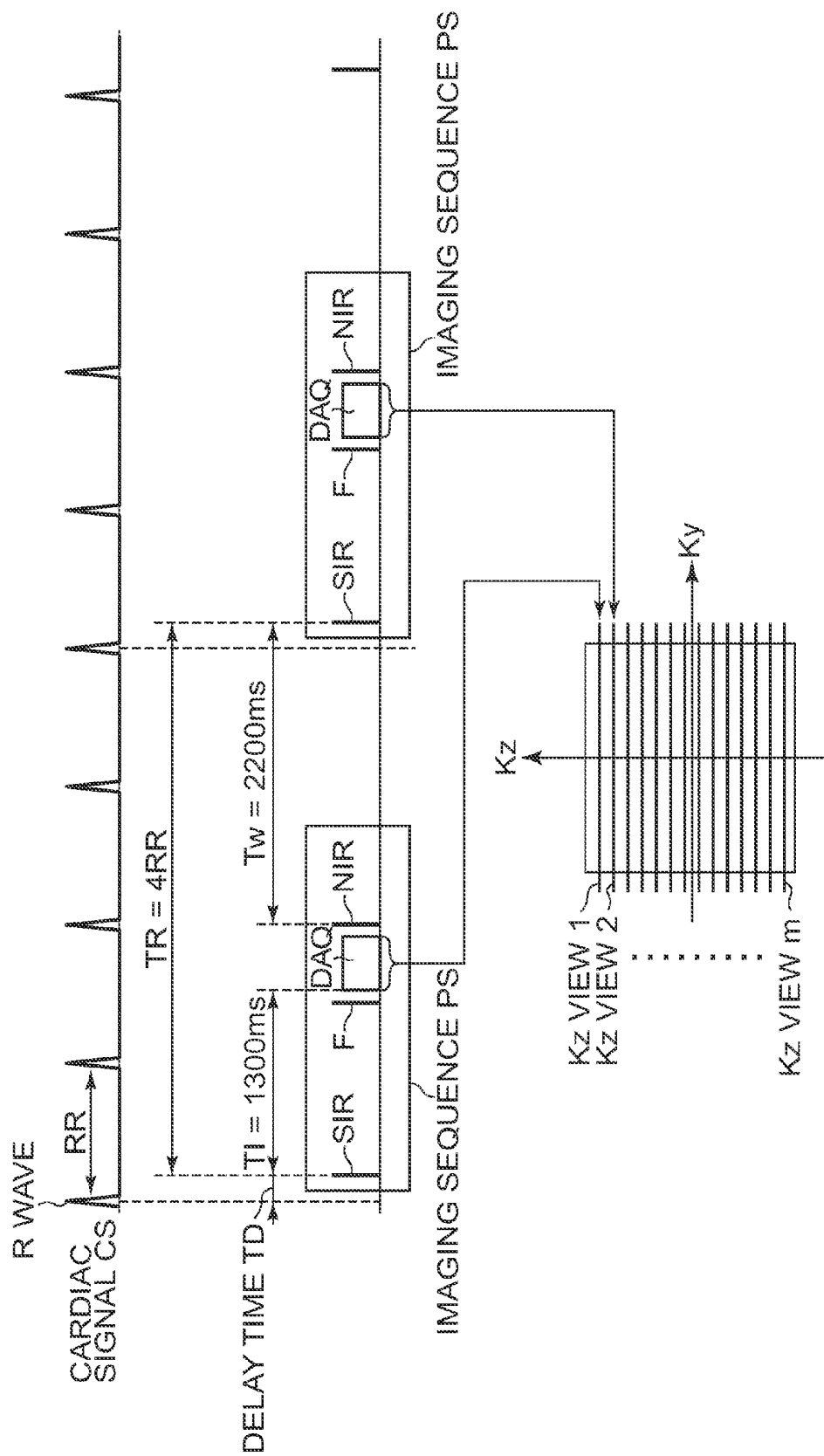


FIG. 32

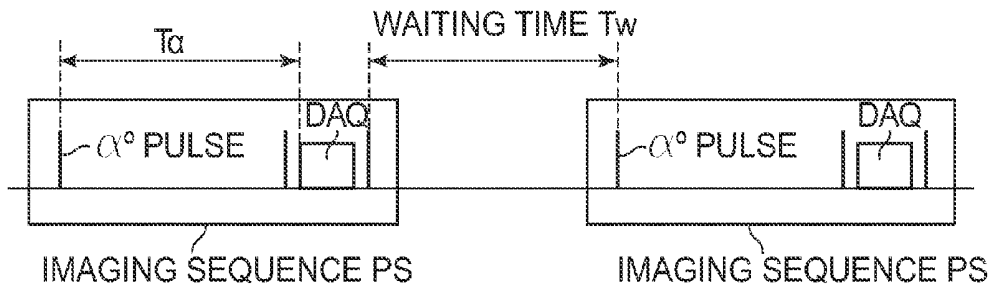


FIG. 33

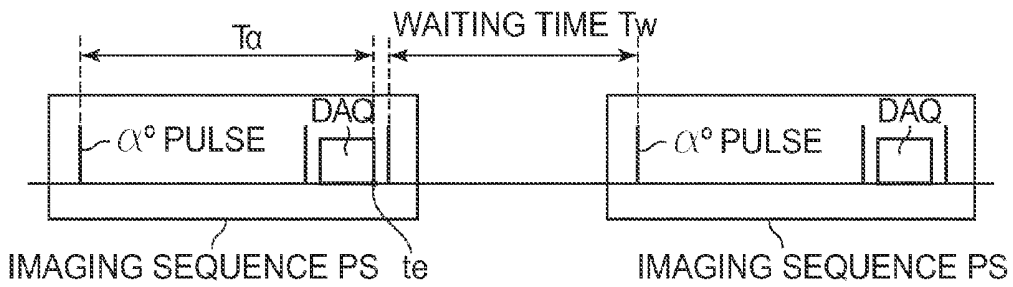
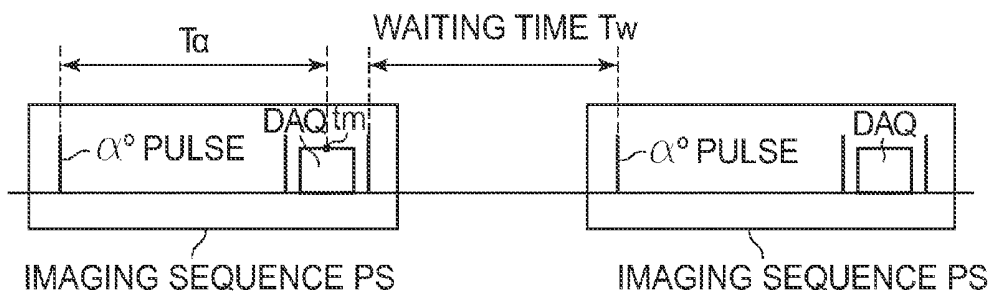


FIG. 34



MAGNETIC RESONANCE SYSTEM AND PROGRAM

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of Japanese Patent Application No. 2013-204940 filed Sep. 30, 2013, which is hereby incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] The present invention relates to a magnetic resonance system that acquires data of blood, and a program applicable to the magnetic resonance system.

[0003] As a method of imaging a blood flow, there has been known a method using an inflow effect (refer to Japanese Unexamined Patent Publication No. 2008-086748).

[0004] Further, as a method for acquiring a blood vessel image using an inflow effect, there has been known a method using an IFIR (Enhance Inflow IR) sequence. In the IFIR sequence, an inversion pulse is applied to invert magnetization of a region where imaging of blood vessel is desired. Then, data acquisition is executed in wait for the elapse of an inversion time since the application of the inversion pulse. In this method, since the blood having sufficiently large vertical magnetization flows into the region where imaging of blood vessel is desired during a period from the application of the inversion pulse to the acquisition of data, it is possible to obtain an image in which the blood vessel is drawn.

[0005] In this method, since the blood vessel is imaged using the blood inflow effect, the blood having sufficiently large vertical magnetization is required to flow into the entire region where imaging of the blood vessel is desired, during the period from the application of the inversion pulse to the acquisition of the data. However, depending on the set value of the inversion time, the blood having sufficiently large vertical magnetization cannot be sufficiently made flow into the entire region where imaging of the blood vessel is desired. Therefore, there can be a case where a desired blood vessel image cannot be obtained. Also, a problem arises in that when the inversion time is made too long, a background tissue is recovered before the data acquisition, so that the contrast of an image is deteriorated.

[0006] There has thus been a demand for an imaging method capable of making the blood with sufficiently large vertical magnetization flow into the entire region where imaging of the blood vessel is desired, and further capable of enhancing the contrast of the image sufficiently.

BRIEF DESCRIPTION

[0007] In a first aspect, a magnetic resonance system which repeatedly executes imaging sequences each having a first RF pulse for flipping each spin in a region containing blood, and a data acquisition sequence acquiring data of the blood from the region is provided. The magnetic resonance system includes a storage unit that stores therein a correspondence relation between a contrast between the blood and a background tissue, a first time taken from the first RF pulse to the data acquisition sequence, and a second time taken from the completion of an imaging sequence to the start of the next imaging sequence, first determining means that determines the first time used when the imaging sequence is repeatedly executed, based on a flow velocity of the blood, and second determining means that determines the second time used

when the imaging sequence is repeatedly executed, based on the first time determined by the first determining means and the correspondence relation.

[0008] In a second aspect, a program applied to a magnetic resonance system which repeatedly executes imaging sequences each having a first RF pulse for flipping each spin in a region containing blood, and a data acquisition sequence acquiring data of the blood from the region, and which stores therein a correspondence relation between a contrast between the blood and a background tissue, a first time taken from the first RF pulse to the data acquisition sequence, and a second time taken from the completion of an imaging sequence to the start of the next imaging sequence is provided. The program causes a computer to execute a first determining process to determine the first time used when the imaging sequence is repeatedly executed, based on a flow velocity of the blood, and a second determining process to determine the second time used when the imaging sequence is repeatedly executed, based on the first time determined by the first determining means and the correspondence relation.

[0009] Since the first time is determined based on the flow velocity of the blood, the blood vessel can be drawn over the entire region to be image. Further, the second time is determined based on the correspondence relation, it is possible to acquire a blood vessel image high in contrast.

[0010] Further advantages will be apparent from the following description of an exemplary embodiment as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 is a schematic diagram of a magnetic resonance system according to an exemplary embodiment;

[0012] FIG. 2 is an explanatory diagram used when a subject 12 is scanned;

[0013] FIG. 3 is a diagram showing a flowchart for executing the scan;

[0014] FIG. 4 is a diagram for describing a method of determining an inversion time T_I ;

[0015] FIG. 5 is a diagram illustrating a contrast map M1 used when determining an allowable range of a waiting time T_w ;

[0016] FIG. 6 is a diagram illustrating a contrast map M2 used when determining an allowable range of a waiting time T_w ;

[0017] FIG. 7 is a diagram showing a flow executed in Step ST4;

[0018] FIG. 8 is a diagram showing a concrete flowchart of Step ST40;

[0019] FIG. 9 is a diagram showing extracted map data D1;

[0020] FIG. 10 is a diagram illustrating a range v_1 of $r=0.5$ contained in the map data D1;

[0021] FIG. 11 is a diagram illustrating a range H1 of a waiting time T_w corresponding to the range v_1 of $r=0.5$;

[0022] FIG. 12 is a diagram showing extracted map data D2;

[0023] FIG. 13 is a diagram illustrating a range v_2 of $s=0.5$ to 0.52 contained in the map data D2;

[0024] FIG. 14 is a diagram illustrating a range H2 of a waiting time T_w corresponding to the range v_2 of $s=0.5$ to 0.52;

[0025] FIG. 15 is a diagram showing by comparison, the range H1 of the waiting time T_w of the contrast map M1 and the range H2 of the waiting time T_w of the contrast map M2;

[0026] FIG. 16 is a diagram illustrating a sequence PS where $TI=1500$ ms and $T_w=2000$ ms;

[0027] FIG. 17 is a diagram showing extracted map data D1;

[0028] FIG. 18 is a diagram illustrating a range v1 of $r=0.5$ contained in the map data D1;

[0029] FIG. 19 is a diagram illustrating a range H1 of a waiting time T_w corresponding to the range v1 of $r=0.5$;

[0030] FIG. 20 is a diagram showing extracted map data D2;

[0031] FIG. 21 is a diagram illustrating a range v2 of $s=0.5$ to 0.54 contained in the map data D2;

[0032] FIG. 22 is a diagram illustrating a range H2 of a waiting time T_w corresponding to the range v2 of $s=0.5$ to 0.54;

[0033] FIG. 23 is a diagram showing by comparison, the range H1 of the waiting time T_w of the contrast map M1 and the range H2 of the waiting time T_w of the contrast map M2;

[0034] FIG. 24 is a diagram illustrating a sequence PS where $TI=1400$ ms and $T_w=2100$ ms;

[0035] FIG. 25 is a diagram showing extracted map data D1;

[0036] FIG. 26 is a diagram illustrating a range H1 of a waiting time T_w corresponding to $r=0.45$;

[0037] FIG. 27 is a diagram showing extracted map data D2;

[0038] FIG. 28 is a diagram illustrating a range v2 of $s=0.5$ to 0.54 contained in the map data D2;

[0039] FIG. 29 is a diagram illustrating a range H2 of a waiting time T_w corresponding to the range v2 of $s=0.5$ to 0.54;

[0040] FIG. 30 is a diagram showing by comparison, the range H1 of the waiting time T_w of the contrast map M1 and the range H2 of the waiting time T_w of the contrast map M2;

[0041] FIG. 31 is a diagram illustrating a sequence PS where $TI=1300$ ms and $T_w=2200$ ms;

[0042] FIG. 32 is a diagram showing an example of an imaging sequence PS where an α° pulse is used;

[0043] FIG. 33 is a diagram showing an example in which a time $T\alpha$ is set to a time between an α° pulse and a completion time point of a data acquisition sequence DAQ; and

[0044] FIG. 34 is a diagram showing an example in which a time $T\alpha$ is set to a time between an α° pulse and a time point tm halfway of execution of a data acquisition sequence DAQ.

DETAILED DESCRIPTION

[0045] An exemplary embodiment will be described hereinafter. The disclosure is however not limited to or by the following exemplary embodiments.

[0046] FIG. 1 is a schematic diagram of a magnetic resonance system according to an exemplary embodiment.

[0047] The magnetic resonance system (hereinafter called "MR system" where MR: Magnetic Resonance) 100 has a magnet 2, a table 3, a receiver coil 4, etc.

[0048] The magnet 2 has a bore 21 in which a subject 12 is accommodated. Further, the magnet 2 incorporates a super-conductive coil, an RF coil, a gradient coil, etc. therein.

[0049] The table 3 has a cradle 3a that supports the subject 12. The cradle 3a is configured so as to be movable into the bore 21. The subject 12 is carried in the bore 21 by the cradle 3a.

[0050] The receiver coil 4 is attached to the subject 12. The receiver coil 4 receives magnetic resonance signals from the subject 12 therein.

[0051] The MR system 100 further has a biological signal processing unit 5, a transmitter 6, a gradient power supply 7, a receiver 8, a storage unit 80, a controller 9, an operation unit 10 and a display unit 11, etc.

[0052] The cardiac signal processing unit 5 receives a signal from a sensor 5a attached to the subject 12 to determine a heart or cardiac rate of the subject and an RR interval.

[0053] The transmitter 6 supplies current to the RF coil. The gradient power supply 7 supplies current to the gradient coil. The receiver 8 performs signal processing such as detection on a signal received from the receiver coil 4.

[0054] The storage unit 80 stores contrast maps M1 and M2 therein (refer to FIGS. 5 and 6). The contrast maps M1 and M2 will be described later.

[0055] The controller 9 controls the operations of respective parts of the MR system 100 so as to realize various operations of the MR system 100 such as transmission of information necessary for the display unit 11, reconstruction of an image on the basis of data received from the receiver 8, etc. The controller 9 has flow velocity calculating means 91, inversion time determining means 92 and waiting time determining means 93, etc.

[0056] The flow velocity calculating means 91 determines a flow velocity v of arterial blood, based on flow velocity information acquired by a scan.

[0057] The inversion time determining means 92 determines an inversion time TI at execution of an imaging sequence, based on the flow velocity v of the arterial blood.

[0058] The waiting time determining means 93 determines a waiting time T_w at the execution of the imaging sequence PS, on the basis of the inversion time TI determined by the inversion time determining means 92 and the contrast maps M1 and M2 (refer to FIGS. 5 and 6).

[0059] Incidentally, the controller 9 is an example that configures the flow velocity calculating means 91, the inversion time determining means 92 and the waiting time determining means 93. The controller 9 functions as these means by executing a prescribed program.

[0060] The operation unit 10 is operated by an operator and inputs various information to the controller 9. The display unit 11 displays the various information thereon.

[0061] The MR system 100 is configured in the above-described manner.

[0062] The subject 12 is imaged by using the MR system 100 configured in the above-described manner.

[0063] FIG. 2 is an explanatory diagram used when the subject 12 is scanned.

[0064] The upper side of FIG. 2A shows cardiac signal CS of the subject and an imaging sequence PS used when scanning the subject. The lower side of FIG. 2 shows an imaging region R of the subject and a k-space (ky-kz plane).

[0065] In the exemplary embodiment, the imaging sequence PS for depicting the arterial blood flowing through the head and neck is repeatedly executed.

[0066] Each imaging sequence PS has a selective inversion pulse SIR (Selective Inversion Recovery), a fat suppression pulse F, a data acquisition sequence DAQ, and a nonselective inversion pulse NIR.

[0067] The selective inversion pulse SIR is an RF pulse for inverting vertical magnetization of a tissue (arterial blood, venous blood, fat, muscle or the like) in a region Rinv containing the head and neck of the subject 12. The selective inversion pulse SIR is applied when a delay time TD has elapsed from an R wave of the cardiac signal CS.

[0068] When the inversion time TI has elapsed from the selective inversion pulse SIR, the data acquisition sequence DAQ for acquiring data in the imaging region R is executed. The data acquisition sequence DAQ is for example, a 3D FSE (Fast Spin Echo) or FIESTA (Fat Imaging Employing Steady state Acquisition). Since the vertical magnetization of each tissue in the region R_{inv} is inverted by the selective inversion pulse SIR, the vertical magnetization of each tissue in the region R_{inv} approaches a null point during the inversion time TI. On the other hand, since the heart is located outside the region R_{inv}, the vertical magnetization M of the arterial blood in the heart keeps M=1 even if the selective inversion pulse SIR is applied. Accordingly, the arterial blood of the vertical magnetization M=1 flows into the neck and head from the heart during the inversion time TI. Thus, since the data acquisition sequence DAQ is executed after the arterial blood of the vertical magnetization M=1 has flown into the neck and head during the inversion time TI, an MR image can be obtained in which the arterial blood is emphasized and depicted and the background tissue (venous blood or the like) is suppressed.

[0069] Also, the fat suppression pulse F is applied immediately before the data acquisition sequence DAQ. It is thus possible to effectively suppress a fat signal in the imaging region R. Incidentally, the fat suppression pulse F is for example, SPECIR (Spectrally Selected IR) or STIR (Short-TI IR).

[0070] Further, the nonselective inversion pulse NIR is applied immediately after the data acquisition sequence DAQ. The nonselective inversion pulse NIR is a pulse applied to invert the magnetization of each tissue in the subject.

[0071] When the waiting time Tw has elapsed after the application of the nonselective inversion pulse NIR, the next imaging sequence PS is executed.

[0072] Even in the case of the next imaging sequence PS, after a selective inversion pulse SIR and a fat suppression signal F are applied, a data acquisition sequence DAQ is executed and a nonselective inversion pulse NIR is applied. Subsequently, in the same manner as above, each imaging sequence PS is repeatedly executed. In the exemplary embodiment, data of one kz view in the ky-kz plane is acquired in one imaging sequence PS. Thus, data of all kz views 1 to m in the ky-kz plane can be acquired by executing m imaging sequences PS.

[0073] The repetition time TR will next be described.

[0074] The repetition time TR can be expressed in the following equation:

$$TR=TI+Ta+Tw \quad \text{Equation 1}$$

[0075] where TI is inversion time,

[0076] Ta is time taken from the start of a data acquisition period DAQ to the application of a nonselective inversion pulse NIR, and

[0077] Tw is waiting time.

[0078] Further, TR is set to satisfy the following condition.

$$TR=RR \times n \quad \text{Equation 2}$$

[0079] where RR is a RR interval, and

[0080] n is an integer

[0081] In the exemplary embodiment, the value of n is a value determined depending on the inversion time TI and the waiting time Tw. A method of determining n will be described later. FIG. 2 shows n=4 as an example of n.

[0082] The above imaging sequences PS is executed to acquire the k-space data, and then the Fourier transform of the data is performed. In this way, the image of the arterial blood

can be obtained. A problem however arises in that if the inversion time TI is too short, it is not possible to sufficiently obtain a blood inflow effect and depict the arterial blood with a high signal. On the other hand, a problem arises in that if the inversion time TI is too long, the background tissue is recovered and the contrast of an image is deteriorated. Further, the optimum value of the inversion time TI varies depending on a blood flow velocity and an imaging region. Accordingly, there is a need to set the inversion time TI suitable for each scan to obtain a high quality blood flow image. Since the contrast between the background tissue and the arterial blood depends even on the waiting time Tw, the waiting time Tw is also required to be set such that a satisfactory contrast is obtained. Thus, in the exemplary embodiment, the values of the inversion time TI and the waiting time Tw are determined and the imaging sequence PS is executed in such a manner that the contrast between the background tissue and the arterial blood can be increased. A description will be made below about a flowchart for determining the values of the inversion time TI and the waiting time Tw and executing the imaging sequence PS.

[0083] FIG. 3 is a diagram showing the flowchart for determining the values of the inversion time TI and the waiting time Tw and executing the imaging sequence PS.

[0084] The flowchart in the exemplary embodiment is roughly divided into two Steps ST10 and ST20. Step ST10 is Step for determining the values of the inversion time TI and the waiting time Tw. Step ST20 is Step for executing the imaging sequence on the basis of the inversion time TI and the waiting time Tw determined in Step ST10.

[0085] Step ST10 includes Steps ST1 to ST4. Thus, upon description of Step ST10, Steps ST1 to ST4 will be described in order.

[0086] In Step ST1, a scan for acquiring information about the flow velocity of the arterial blood of the subject is executed. The flow velocity information on the arterial blood is used for determining the inversion time TI. A concrete procedure for determining the inversion time TI using the flow velocity information on the arterial blood will be described in detail in Steps ST2 and ST3. As the scan for acquiring the flow velocity information on the arterial blood, there can be used a phase contrast MRA or the like. After this scan is executed, the flow proceeds to Step ST2.

[0087] In Step ST2, the flow velocity calculating means 91 (refer to FIG. 1) obtains the flow velocity v of the arterial blood, based on the flow velocity information acquired by the scan in Step ST1. After the flow velocity v is obtained, the flow proceeds to Step ST3.

[0088] In Step ST3, the inversion time determining means 92 (refer to FIG. 1) determines the inversion time TI, based on the flow velocity v of the arterial blood.

[0089] FIG. 4 is a diagram for describing a method of determining the inversion time TI.

[0090] In FIG. 4, arterial blood B that flows from the heart to the head through each blood vessel V is represented by arrows.

[0091] First consider a region RQ of blood to be imaged in high quality in particular within the imaging region R. In the exemplary embodiment, the region RQ is taken to be a region including carotid arteries.

[0092] Next, consider a time Tm required for the arterial blood B to move from a position Pe to a position Pc. The position Pe corresponds to the position of an edge e on the

heart side of the region R_{inv}. The position P_c corresponds to the right edge position of the region RQ.

[0093] The shape of the blood vessel V between the positions P_e and P_c can be taken to approximate to a linear shape extending in an SI direction. In this case, the time T_m necessary for the arterial blood B to move from the position P_e to the position P_c can be represented by the following equation:

$$T_m = L/v \quad \text{Equation 3}$$

[0094] where L is distance from the position P_e to P_c and [0095] v is flow velocity of arterial blood.

[0096] It is desirable that in order to image the blood in the region RQ in high quality, the arterial blood B reaches from the position P_e to the position P_c during the time T_m. Thus, in the exemplary embodiment, the time T_m (=L/v) is taken to be the inversion time T_I. Accordingly, the inversion time T_I can be represented by the following equation:

$$T_I = L/v \quad \text{Equation 4}$$

[0097] Since the flow velocity v of the arterial blood in Equation 4 is obtained in Step ST2, the inversion time T_I can be obtained if the value of the distance L is determined. The distance L may be determined according to, for example, the length in the SI direction of the imaging region R or may be set as a fixed value. In the present embodiment, the distance L is taken to be a value determined according to the length in the SI direction of the imaging region R. Thus, since the flow velocity v and the distance L are already known, the inversion time T_I can be determined from Equation 4. Incidentally, since T_I is determined by the flow velocity v and the distance L as described above (refer to Equation 4), T_I can take various values according to the values of v and L. In the exemplary embodiment, consider the following three values as the value of T_I for convenience of description:

[0098] T_I=1500 ms

[0099] T_I=1400 ms

[0100] T_I=1300 ms

[0101] Then, the description of the flowchart will be continued with T_I being into three cases of T_I=1500 ms, T_I=1400 ms and T_I=1300 ms.

[0102] (1) When T_I is determined to be T_I=1500 ms in Step ST3:

[0103] When T_I is determined to be T_I=1500 ms in Step ST3, the flow proceeds to Step ST4.

[0104] In Step ST4, the waiting time determining means 93 (refer to FIG. 1) determines a waiting time T_w, based on the inversion time T_I determined in Step ST3 and each contrast map. A description will be made below about each contrast map used when determining the waiting time T_w (refer to FIGS. 5 and 6).

[0105] FIGS. 5 and 6 are diagrams showing the contrast maps M1 and M2 each used when determining the waiting time T_w.

[0106] The contrast map M1 (refer to FIG. 5) represents a contrast r between the arterial blood and CSF (cerebrospinal fluid). This map is prepared before scanning the subject. The horizontal axis of the contrast map M1 indicates the inversion time T_I, and the vertical axis thereof indicates the waiting time T_w. The value of the contrast r is associated with the combination of the value of the inversion time T_I and the value of the waiting time T_w. The value of the contrast r can be determined by, for example, calculating a signal value of the arterial blood and a signal value of CSF using the Bloch equation and taking the ratio between these signal values.

[0107] The contrast r has a value in a range of $0.25 \leq r \leq 0.55$. In the contrast map M1, the differences in the value between the contrasts r are represented with brightness/darkness of gray. r=0.25 corresponds to black, and r=0.55 corresponds to white. As the contrast r becomes larger from 0.25, the color of the contrast map M1 gradually approaches from black to white.

[0108] On the other hand, the contrast map M2 (refer to FIG. 6) represents a contrast s between the arterial blood and the venous blood. This map is prepared before scanning the subject. The horizontal axis of the contrast map M2 indicates the inversion time T_I, and the vertical axis thereof indicates the waiting time T_w. The value of the contrast s is associated with the combination of the value of the inversion time T_I and the value of the waiting time T_w. The value of the contrast s can be determined by, for example, calculating a signal value of the arterial blood and a signal value of the venous blood using the Bloch equation and taking the ratio between these signal values.

[0109] The contrast s has a value in a range of $0.25 \leq s \leq 0.55$. In the contrast map M2, the differences in the value between the contrasts s are represented with brightness/darkness of gray. s=0.25 corresponds to black, and s=0.55 corresponds to white. As the contrast s becomes larger from 0.25, the color of the contrast map M2 gradually approaches from black to white.

[0110] In Step ST4, the waiting time T_w is determined using the contrast maps M1 and M2 shown in FIGS. 5 and 6. A description will be made below about the operation of Step ST4.

[0111] FIG. 7 is a diagram showing a flow executed in Step ST4.

[0112] Step ST4 is divided in to two Steps ST40 and ST41.

[0113] In Step ST40, a process for determining a time range usable as the waiting time T_w is executed. A concrete flowchart of Step ST40 is shown in FIG. 8. FIG. 8 will be described later.

[0114] In Step ST41, a process is executed for determining a waiting time T_w at the execution of the sequence from the time range determined in Step ST40.

[0115] A description will be made below about Steps ST40 and ST41 of Step ST4.

[0116] In Step ST4, Step ST40 is first executed (refer to FIG. 8).

[0117] FIG. 8 is a diagram showing a detailed flowchart of Step ST40.

[0118] In Step 40a, the waiting time determining means 93 extracts map data at the inversion time T_I=1500 (ms) determined in Step ST3 from the contrast map M1 (refer to FIG. 5). The extracted map data D1 is shown in FIG. 9. After the extraction of the map data D1, the flow proceeds to Step 40b.

[0119] In Step 40b, the waiting time determining means 93 determines whether or not the contrast r that satisfies the following condition is contained in the map data D1:

$$r \geq r_0 \quad \text{Equation 5}$$

[0120] where r₀ is the lower limit value allowable as the value of the contrast r between the arterial blood and CSF.

[0121] In the exemplary embodiment, r₀ is taken to be set r₀=0.5. In this case, Equation 5 is represented by the following equation:

$$r \geq 0.5 \quad \text{Equation 6}$$

[0122] Thus, the waiting time determining means 93 judges whether or not the contrast r that satisfies the Equation 6 is

contained in the map data D1 at the waiting time $TI=1500$ (ms). When the contrast r that satisfies the Equation 6 is contained in the map data D1, the flow proceeds to Step 40d. On the other hand, when the contrast r that satisfies the Equation 6 is not contained in the map data D1, the flow proceeds to Step 40c. Referring to FIG. 9, it is understood that the map data D1 crosses a region of $r=0.5$. Thus, the contrast r that satisfies the Equation 6 is contained in the map data D1. FIG. 10 shows a range $v1$ of $r=0.5$ contained in the map data D1. Since the contrast r that satisfies the Equation 6 is contained in the map data D1, the flow proceeds to Step 40d.

[0123] In Step 40d, the waiting time determining means 93 specifies the range of a waiting time Tw corresponding to the range $v1$ of $r=0.5$. FIG. 11 shows the range H1 of the waiting time Tw corresponding to the range $v1$ of $r=0.5$. The range H1 of the waiting time Tw is taken to be the following range herein:

$$1100 \text{ (ms)} \leq Tw \leq 2200 \text{ (ms)} \quad \text{Equation 7}$$

[0124] After the range H1 of the waiting time Tw in the contrast map M1 is obtained, the flow proceeds to Step 40e.

[0125] In Step 40e, the waiting time determining means 93 extracts map data at the inversion time $TI=1500$ (ms) determined in Step ST3 from the contrast map M2 (refer to FIG. 6). The extracted map data D2 is shown in FIG. 12. After the extraction of the map data D2, the flow proceeds to Step 40f.

[0126] In Step 40f, the waiting time determining means 93 determines whether or not the contrast s that satisfies the following condition is contained in the map data D2:

$$s \geq s_0 \quad \text{Equation 8}$$

[0127] where s_0 is the lower limit value allowable as the value of the contrast s between the arterial blood and the venous blood.

[0128] In the exemplary embodiment, s_0 is taken to be set to $s_0=0.5$. In this case, Equation 8 is represented by the following equation:

$$s \geq 0.5 \quad \text{Equation 9}$$

[0129] Thus, the waiting time determining means 93 judges whether or not the contrast s that satisfies Equation 9 is contained in the map data D2 at the inversion time $TI=1500$ (ms). When the contrast s that satisfies Equation 9 is contained in the map data D2, the flow proceeds to Step 40h. On the other hand, when the contrast s that satisfies Equation 9 is not contained in the map data D2, the flow proceeds to Step 40g. Referring to FIG. 12, it is understood that the map data D2 crosses regions of contrasts 0.5 to 0.52. Thus, the contrast s that satisfies Equation 9 is contained in the map data D2. FIG. 13 shows a range $v2$ of $s=0.5$ to 0.52 contained in the map data D2. Since the contrast s that satisfies the Equation 9 is contained in the map data D2, the flow proceeds to Step 40h.

[0130] In Step 40h, the waiting time determining means 93 specifies a range H2 of a waiting time Tw corresponding to the range $v2$ of $s=0.5$ to 0.52. FIG. 14 shows the range H2 of the waiting time Tw corresponding to the range $v2$ of $s=0.5$ to 0.52. The range H2 of the waiting time Tw is taken to be the following range herein:

$$1800 \text{ (ms)} \leq Tw \leq 4000 \text{ (ms)} \quad \text{Equation 10}$$

[0131] After the range H2 of the waiting time Tw in the contrast map M2 is obtained, the flow proceeds to Step 40i.

[0132] In Step 40i, the waiting time determining means 93 judges whether or not an overlaid part exists between the

range H1 (refer to FIG. 11) of the waiting time Tw in the contrast map M1 and the range H2 (refer to FIG. 14) of the waiting time Tw in the contrast map M2. The range H1 of the waiting time Tw in the contrast map M1 and the range H2 of the waiting time Tw in the contrast map M2 are shown in FIG. 15 by comparison.

[0133] When the overlaid range H of the waiting time Tw exists between the ranges H1 and H2, the flow proceeds to Step 40k. On the other hand, when the overlaid range H does not exist therebetween, the flow proceeds to Step 40j. In FIG. 15, the waiting time Tw is overlaid therebetween within the range of $1800 \text{ ms} \leq Tw \leq 2200 \text{ ms}$. Therefore, the flow proceeds to Step 40k.

[0134] In Step 40k, the waiting time determining means 93 determines the overlaid range H of the waiting time Tw to be a time range usable as the waiting time Tw . Here, the waiting time Tw is overlaid within the range of $1800 \text{ ms} \leq Tw \leq 2200 \text{ ms}$. Thus, the time range H usable as the waiting time Tw is represented as the following range:

$$1800 \text{ ms} \leq Tw \leq 2200 \text{ ms} \quad \text{Equation 11}$$

[0135] After the time range usable as the waiting time Tw is determined, the flow of Step ST40 is completed. After the completion of Step ST40, the flow proceeds to Step ST41 (refer to FIG. 7).

[0136] In Step ST41, the waiting time determining means 93 determines a waiting time Tw at the execution of the imaging sequence PS from the time range H usable as the waiting time Tw . A method of determining the waiting time Tw will be described below.

[0137] From Equation 1, the waiting time Tw can be represented by the following equation:

$$Tw = TR - (TI + Ta) \quad \text{Equation 12}$$

[0138] Substituting Equation 2 into Equation 12 yields the following equation:

$$Tw = RR \times n - (TI + Ta) \quad \text{Equation 13}$$

[0139] In the Equation 13, RR is a value that can be calculated from a cardiac signal. RR is taken to be $RR=1000$ ms herein. Further, the time Ta is a time taken from the starting point of time of the data acquisition sequence DAQ to the time of application of the nonselective inversion pulse NIR. Since the time Ta is a fixed value determined by the imaging sequence PS, the time Ta is a known value. Here, Ta is taken to be $Ta=500$ ms. Thus, Equation 13 is represented by the following equation:

$$Tw = 1000n - (TI + 500) \quad \text{Equation 14}$$

[0140] Further, the inversion time TI is calculated as $TI=1500$ ms in Step ST3. Thus, substituting $TI=1500$ ms into Equation 14 yields the following equation:

$$\begin{aligned} Tw &= 1000n - (TI + 500) \\ &= 1000n - (1500 + 500) \\ &= 1000n - 2000 \end{aligned} \quad \text{Equation 15}$$

[0141] In Step ST40, the time range H usable as the waiting time Tw is obtained as $1800 \text{ ms} \leq Tw \leq 2200 \text{ ms}$ (refer to Equation 11). Thus, the waiting time Tw represented by the equation (15) is needed to satisfy the following equation:

$$1800 \text{ ms} \leq Tw = 1000n - 2000 \leq 2200 \text{ ms} \quad \text{Equation 16}$$

[0142] The waiting time determining means **93** determines n that satisfies Equation 16. n that satisfies Equation 16 is $n=4$. After $n=4$ is obtained, $n=4$ is substituted into Equation 15. By substituting $n=4$ into Equation 15, the waiting time T_w can be obtained as follows:

$$\begin{aligned} T_w &= 1000n - 2000 \\ &= 1000 \times 4 - 2000 \\ &= 2000 \text{ ms} \end{aligned}$$

[0143] Accordingly, the waiting time can be determined as $T_w=2000$ ms.

[0144] As described above, $TI=1500$ ms and $T_w=2000$ ms are obtained by executing the processes of Steps **ST3** and **ST4**. FIG. 16 shows an imaging sequence **PS** where $TI=1500$ ms and $T_w=2000$ ms. Incidentally, since $n=4$, substituting $n=4$ into Equation 2 yields $TR=4RR$.

[0145] After the waiting time T_w is determined, the flow proceeds to Step **ST20** (refer to FIG. 3).

[0146] In Step **ST20**, the k -space data is acquired in accordance with the imaging sequence **PS** shown in FIG. 16, and the flowchart is terminated.

[0147] In the exemplary embodiment, the time T_m required for the arterial blood **B** to move from the position P_e to the position P_c is determined (refer to FIG. 4 and Equation 3), and the time T_m is set as the inversion time TI . Thus, since the data acquisition sequence **DAQ** is executed when the arterial blood **B** having sufficiently large vertical magnetization flows into the entire region **RQ** (refer to FIG. 4), it is possible to obtain a sufficiently large arterial blood signal from the region **RQ**.

[0148] Further, in the exemplary embodiment, the range H_1 (refer to FIG. 11) of the waiting time T_w when the contrast r between the arterial blood and CSF becomes $r \geq 0.5$, and the range H_2 (refer to FIG. 14) of the waiting time T_w when the contrast s between the arterial blood and the venous blood becomes $s \geq 0.5$ are determined based on the contrast maps **M1** and **M2**. Then, the range H of the waiting time T_w , which is overlaid on both ranges H_1 and H_2 , is identified. The waiting time T_w at the execution of the imaging sequence **PS** is determined from within the range H . Thus, since it is possible for the contrast r between the arterial blood and CSF to have a sufficiently large value and is possible for the contrast s between the arterial blood and the venous blood to have a sufficiently large value, a blood vessel image having a satisfactory contrast can be obtained.

[0149] Incidentally, although the waiting time T_w is defined using the **RR** interval in Equation 13, the waiting time T_w may be defined using the cardiac rate instead of the **RR** interval. If the cardiac rate is represented by **BPM**, the relation of $RR=(60/\text{BPM}) \times 103$ (ms) is established between the **RR** interval and the cardiac rate. Therefore, the waiting time T_w can be determined even if the cardiac rate **BPM** is calculated instead of the **RR** interval.

[0150] The above description has shown the example in which the inversion time TI is determined as $TI=1500$ ms in Step **ST3**. A description will next be made about the case where $TI=1400$ ms.

[0151] (2) When TI is determined as $TI=1400$ ms in Step **ST3**:

[0152] When TI is determined to be $TI=1400$ ms in Step **ST3**, the flow proceeds to Step **40a** (refer to FIG. 8) as with the case where $TI=1500$ ms.

[0153] In Step **40a**, the waiting time determining means **93** extracts map data at the inversion time $TI=1400$ (ms) determined in Step **ST3** from the contrast map **M1** (refer to FIG. 5). The extracted map data **D1** is shown in FIG. 17. After the extraction of the map data **D1**, the flow proceeds to Step **40b**.

[0154] In Step **40b**, the waiting time determining means **93** judges whether or not the contrast r that satisfies $r \geq 0.5$ (refer to Equation 6) is contained within the map data **D1**. Referring to FIG. 17, it is understood that the map data **D1** slightly crosses a region of a contrast 0.5. Thus, the contrast r that satisfies $r \geq 0.5$ is contained in the map data **D1**. FIG. 18 shows a range v_1 of $r=0.5$ contained in the map data **D1**. Since the contrast r that satisfies $r \geq 0.5$ is contained in the map data **D1**, the flow proceeds to Step **40d**.

[0155] In Step **40d**, the waiting time determining means **93** specifies a range of a waiting time T_w corresponding to the range v_1 of $r=0.5$. FIG. 19 shows the range H_1 of the waiting time T_w corresponding to the range v_1 of $r=0.5$. The range H_1 of the waiting time T_w is taken to be the following range herein:

$$1000 \text{ (ms)} \leq T_w \leq 1500 \text{ (ms)} \quad \text{Equation 17}$$

[0156] After the range H_1 of the waiting time T_w in the contrast map **M1** is obtained, the flow proceeds to Step **40e**.

[0157] In Step **40e**, the waiting time determining means **93** extracts map data at the inversion time $TI=1400$ (ms) determined in Step **ST3** from the contrast map **M2** (refer to FIG. 6). The extracted map data **D2** is shown in FIG. 20. After the extraction of the map data **D2**, the flow proceeds to Step **40f**.

[0158] In Step **40f**, the waiting time determining means **93** judges whether or not the contrast s that satisfies $s \geq 0.5$ (refer to Equation 9) is contained in the map data **D1**. Referring to FIG. 20, it is understood that the map data **D2** crosses regions of contrasts 0.5 to 0.54. Thus, the contrast s that satisfies $s \geq 0.5$ is contained in the map data **D2**. FIG. 21 shows a range v_2 of $s=0.5$ to 0.54 contained in the map data **D2**. Since the contrast s that satisfies $s \geq 0.5$ is contained in the map data **D2**, the flow proceeds to Step **40h**.

[0159] In Step **40h**, the waiting time determining means **93** specifies a range H_2 of a waiting time T_w corresponding to the range v_2 of $s=0.5$ to 0.54. FIG. 22 shows the range H_2 of the waiting time T_w corresponding to the range v_2 of $s=0.5$ to 0.54. The range H_2 of the waiting time T_w is taken to be the following range herein:

$$1700 \text{ (ms)} \leq T_w \leq 4000 \text{ (ms)} \quad \text{Equation 18}$$

[0160] After the range H_2 of the waiting time T_w in the contrast map **M2** is obtained, the flow proceeds to Step **40i**.

[0161] In Step **40i**, the waiting time determining means **93** judges whether or not an overlaid part exists between the range H_1 (refer to FIG. 19) of the waiting time T_w in the contrast map **M1** and the range H_2 (refer to FIG. 22) of the waiting time T_w in the contrast map **M2**. The range H_1 of the waiting time T_w in the contrast map **M1**, and the range H_2 of the waiting time T_w in the contrast map **M2** are shown in FIG. 23 by comparison. The overlaid range of the waiting time T_w does not exist in FIG. 23. Therefore, the flow proceeds to Step **40j**.

[0162] In Step **40j**, the waiting time determining means **93** determines the range H_2 of the waiting time T_w in the contrast

map M2 as a time range H usable as a waiting time T_w . Since the range H2 of the waiting time T_w in the contrast map M2 is $1700 \text{ ms} \leq T_w \leq 4000 \text{ ms}$ herein, the time range H usable as the waiting time T_w becomes the following range:

$$1700 \text{ ms} \leq T_w \leq 4000 \text{ ms} \quad \text{Equation 19}$$

[0163] By setting the time range H usable as the waiting time T_w to the range of Equation 19, the contrast s between the arterial blood and the venous blood can be made greater than or equal to $s \geq 0.5$. Incidentally, when the time range H usable as the waiting time T_w is set to the range of Equation 19, the contrast r between the arterial blood and CSF becomes $r < 0.5$ (refer to FIG. 19). Therefore, it is considered that the contrast r between the arterial blood and CSF becomes small. Since, however, the position of CSF is shifted in an RL direction with respect to the position of the carotid artery important for diagnosis, it is considered not to be interferent much in diagnosing the carotid artery even if the contrast r between the arterial blood and CSF is small.

[0164] When the time range usable as the waiting time T_w is determined, the flow of Step ST40 is completed. After the completion of Step ST40, the flow proceeds to Step ST41 (refer to FIG. 7).

[0165] In Step ST41, the waiting time determining means 93 determines a waiting time T_w at the execution of an imaging sequence PS from the time range usable as the waiting time T_w . A method of determining the waiting time T_w will be described below.

[0166] When RR and Ta are taken to be $RR=1000 \text{ ms}$ and $T_a=500 \text{ ms}$ as previously described, the waiting time T_w can be represented by Equation 14. Equation 14 is shown again below.

$$T_w = 1000n - (TI + 500) \quad \text{Equation 14}$$

[0167] Here, the inversion time TI has been calculated as $TI=1400 \text{ ms}$ in Step ST3. Thus, substituting $TI=1400 \text{ ms}$ into Equation 14 yields the following equation:

$$\begin{aligned} T_w &= 1000n - (TI + 500) && \text{Equation 20} \\ &= 1000n - (1400 + 500) \\ &= 1000n - 1900 \end{aligned}$$

[0168] Further, in Step ST40, the time range H usable as the waiting time T_w has been determined as $1700 \text{ ms} \leq T_w \leq 4000 \text{ ms}$ (refer to Equation 19). Thus, the waiting time T_w expressed in Equation 20 is required to satisfy the following equation:

$$1700 \text{ ms} \leq T_w = 1000n - 1900 \leq 4000 \text{ ms} \quad \text{Equation 21}$$

[0169] The waiting time determining means 93 determines n that satisfies Equation 21. n that satisfies Equation 21 is $n=4$ and 5. Substituting $n=4$ into the Equation 20 yields the following value as the waiting time T_w :

$$\begin{aligned} T_w &= 1000n - 1900 \\ &= 1000 \times 4 - 1900 \\ &= 2100 \text{ ms} \end{aligned}$$

[0170] On the other hand, when $n=5$ is substituted into the equation (20), the waiting time T_w becomes the following value:

$$\begin{aligned} T_w &= 1000n - 1900 \\ &= 1000 \times 5 - 1900 \\ &= 3100 \text{ ms} \end{aligned}$$

[0171] Accordingly, the two waiting times $T_w=2100 \text{ ms}$ and $T_w=3100 \text{ ms}$ are obtained. Thus, when the waiting time T_w that satisfies Equation 21 exists in plural form, the minimum waiting time T_w ($=2100 \text{ ms}$) is determined as the waiting time T_w at the execution of the imaging sequence PS in such a manner that a scan time becomes short.

[0172] Accordingly, $TI=1400 \text{ ms}$ and $T_w=2100 \text{ ms}$ are obtained by executing the processes of Steps ST3 and ST4. FIG. 24 shows an imaging sequence PS where $TI=1400 \text{ ms}$ and $T_w=2100 \text{ ms}$. Incidentally, since $n=4$, substituting $n=4$ into the Equation 2 yields $TR=4RR$.

[0173] After the waiting time T_w is determined, the flow proceeds to Step ST20 (refer to FIG. 3), where k-space data is acquired in accordance with the imaging sequence PS shown in FIG. 24, and the flowchart is ended.

[0174] A description will at last be made about where $TI=1300 \text{ ms}$.

[0175] (3) When TI is determined as $TI=1300 \text{ ms}$ in Step ST3:

[0176] When TI is determined to be $TI=1300 \text{ ms}$ in Step ST3, the flow proceeds to Step 40a (refer to FIG. 8) as with the case where $TI=1500 \text{ ms}$ and 1400 ms .

[0177] In Step 40a, the waiting time determining means 93 extracts map data at the inversion time $TI=1300 \text{ (ms)}$ determined in Step ST3 from the contrast map M1 (refer to FIG. 5). The extracted map data D1 is shown in FIG. 25. After the extraction of the map data D1, the flow proceeds to Step 40b.

[0178] In Step 40b, the waiting time determining means 93 judges whether or not the contrast r that satisfies $r \geq 0.5$ (refer to the Equation 6) is contained within the map data D1. Referring to FIG. 25, the map data D1 crosses a region of a contrast 0.45, but does not cross a region of a contrast 0.5. Thus, the contrast r that satisfies $r \geq 0.5$ is not contained in the map data D1. In this case, the flow proceeds to Step 40c.

[0179] In Step 40c, the waiting time determining means 93 first determines the maximum value of the contrast r from the map data D1. Referring to FIG. 25, the maximum value of the contrast r in the map data D1 is 0.45. After the maximum value 0.45 of the contrast r is determined, the waiting time determining means 93 specifies a range H1 of a waiting time T_w corresponding to the maximum value 0.45 of the contrast r . FIG. 26 shows the range H1 of the waiting time T_w corresponding to $r=0.45$. The range H1 of the waiting time T_w is taken to be the following range herein:

$$600 \text{ (ms)} \leq T_w \leq 2300 \text{ (ms)} \quad \text{Equation 22}$$

[0180] After the range H1 of the waiting time T_w in the contrast map M1 is obtained, the flow proceeds to Step 40e.

[0181] In Step 40e, the waiting time determining means 93 extracts map data at the inversion time $TI=1300 \text{ (ms)}$ determined in Step ST3 from the contrast map M2 (refer to FIG. 6). The extracted map data D2 is shown in FIG. 27. After the extraction of the map data D2, the flow proceeds to Step 40f.

[0182] In Step 40f, the waiting time determining means 93 judges whether or not the contrast s that satisfies $s \geq 0.5$ (refer to Equation 9) is contained in the map data D2. Referring to FIG. 27, it is understood that the map data D2 crosses regions of contrasts 0.5 to 0.54. Thus, the contrast s that satisfies $s \geq 0.5$ is contained in the map data D2. FIG. 28 shows a range $v2$ of $s=0.5$ to 0.54 contained in the map data D2. Since the contrast s that satisfies $s \geq 0.5$ is contained in the map data D2, the flow proceeds to Step 40h.

[0183] In Step 40h, the waiting time determining means 93 specifies a range H2 of a waiting time T_w corresponding to the range $v2$ of $s=0.5$ to 0.54. FIG. 29 shows the range H2 of the waiting time T_w corresponding to the $v2$ of $s=0.5$ to 0.54. The range H2 of the waiting time T_w is taken to be the following range herein:

$$1600 \text{ (ms)} \leq T_w \leq 4000 \text{ (ms)} \quad \text{Equation 23}$$

[0184] After the range H2 of the waiting time T_w in the contrast map M2 is obtained, the flow proceeds to Step 40i.

[0185] In Step 40i, the waiting time determining means 93 judges whether or not an overlaid part exists between the range H1 (refer to FIG. 26) of the waiting time T_w in the contrast map M1 and the range H2 (refer to FIG. 29) of the waiting time T_w in the contrast map M2. The range H1 of the waiting time T_w in the contrast map M1, and the range H2 of the waiting time T_w in the contrast map M2 are shown in FIG. 30 by comparison. In FIG. 30, the waiting time T_w overlaps within the range of $1600 \text{ ms} \leq T_w \leq 2300 \text{ ms}$. Therefore, the flow proceeds to Step 40k.

[0186] In Step 40k, the waiting time determining means 93 determines the overlapped range H of the waiting time T_w as a time range usable as a waiting time T_w . The waiting time T_w overlaps within the range of $1600 \text{ ms} \leq T_w \leq 2300 \text{ ms}$ herein. Thus, the time range H usable as the waiting time T_w becomes the following range:

$$1600 \text{ ms} \leq T_w \leq 2300 \text{ ms} \quad \text{Equation 24}$$

[0187] When the time range usable as the waiting time T_w is determined, the flow of Step ST40 is ended. When Step ST40 is terminated, the flow proceeds to Step ST41 (refer to FIG. 7).

[0188] In Step ST41, the waiting time determining means 93 determines a waiting time T_w at the execution of an imaging sequence PS from the time range usable as the waiting time T_w . A method of determining the waiting time T_w will be described below.

[0189] When RR and Ta are taken to be RR=1000 ms and Ta=500 ms as previously described, the waiting time T_w can be represented by Equation 14. Equation 14 is shown again below.

$$T_w = 1000n - (TI + 500) \quad \text{Equation 14}$$

[0190] Here, the inversion time TI has been calculated as TI=1300 ms in Step ST3. Thus, substituting TI=1300 ms into Equation 14 yields the following equation:

$$\begin{aligned} T_w &= 1000n - (TI + 500) && \text{Equation 25} \\ &= 1000n - (1300 + 500) \\ &= 1000n - 1800 \end{aligned}$$

[0191] Further, in Step ST40, the time range H usable as the waiting time T_w has been determined as $1600 \text{ ms} \leq T_w \leq 2300$

ms (refer to Equation 24). Thus, the waiting time T_w expressed in Equation 25 is required to satisfy the following equation:

$$1600 \text{ ms} \leq T_w = 1000n - 1800 \leq 2300 \text{ ms} \quad \text{Equation 26}$$

[0192] The waiting time determining means 93 determines n that satisfies Equation 26. n that satisfies Equation 26 is $n=4$ and 5. Substituting $n=4$ into Equation 25 yields the following value as the waiting time T_w :

$$\begin{aligned} T_w &= 1000n - 1800 \\ &= 1000 \times 4 - 1800 \\ &= 2200 \text{ ms} \end{aligned}$$

[0193] On the other hand, when $n=5$ is substituted into Equation 25, the waiting time T_w becomes the following value:

$$\begin{aligned} T_w &= 1000n - 1800 \\ &= 1000 \times 5 - 1800 \\ &= 3200 \text{ ms} \end{aligned}$$

[0194] Accordingly, the two waiting times $T_w=2200 \text{ ms}$ and $T_w=3200 \text{ ms}$ are obtained. Thus, when the waiting time T_w that satisfies Equation 26 exists in plural form, the minimum waiting time T_w ($=2200 \text{ ms}$) is determined as the waiting time T_w at the execution of the imaging sequence PS in such a manner that a scan time becomes short.

[0195] Accordingly, TI=1300 ms and $T_w=2200 \text{ ms}$ are obtained by executing the processes of Steps ST3 and ST4. FIG. 31 shows an imaging sequence PS where TI=1300 ms and $T_w=2200 \text{ ms}$. Incidentally, since $n=4$, substituting $n=4$ into Equation 2 yields $TR=4RR$.

[0196] After the waiting time T_w is determined, the flow proceeds to Step ST20 (refer to FIG. 3), where k-space data is acquired in accordance with the imaging sequence PS shown in FIG. 31, and the flowchart is ended.

[0197] When TI=1300 ms, the contrast of $r \geq 0.5$ is not contained in the map data D1 extracted from the contrast map M1. Therefore, the maximum value 0.45 of the contrast r is determined from the map data D1 to specify a range H1 ($600 \text{ ms} \leq T_w \leq 2300 \text{ ms}$) of a waiting time T_w corresponding to the maximum value 0.45 of the contrast (refer to FIG. 26). Thereafter, an overlaid range H of the waiting time T_w is obtained (refer to FIG. 30). The waiting time T_w is determined from this range H. Accordingly, the value of the contrast r can be set to the maximum value allowable when TI=1300 ms.

[0198] Incidentally, in the exemplary embodiment, the imaging sequence PS has the inversion pulse SIR (i.e., RF pulse of which the flip angle is 180°). The disclosure is however not limited to the inversion pulse SIR, but can use an α° pulse (where α : arbitrary angle). FIG. 32 shows an example of an imaging sequence PS where the α° pulse is used. In FIG. 32, the time between the α° pulse and the data acquisition sequence DAQ is expressed in " $T\alpha$ ". In this case, the time $T\alpha$ may be calculated based on the flow velocity v of the arterial blood as with the inversion time TI. Further, the waiting time T_w can be determined using the contrast map

that defines the correspondence relation between the time $T\alpha$, the waiting time T_w and the contrast r (or contrast s).

[0199] Further, the time $T\alpha$ may be set as the time between an α° pulse and a completion time point t_e of a data acquisition sequence DAQ as shown in FIG. 33. Alternatively, the time $T\alpha$ may be set as the time between an α° pulse and a time point t_m halfway of execution of a data acquisition sequence DAQ as shown in FIG. 34.

[0200] Incidentally, in the exemplary embodiment, the waiting time T_w is determined using the two contrast maps M1 and M2, but may be determined using only either one of the contrast maps. For example, when it is important to increase the contrast between the arterial blood and the venous blood, the waiting time T_w may be determined using only the contrast map M2. On the other hand, when it is important to increase the contrast between the arterial blood and CSF, the waiting time T_w may be determined using only the contrast map M1.

[0201] Further, in the exemplary embodiment, the imaging sequence PS is provided with the selective inversion pulse SIR, the fat suppression pulse F, the data acquisition sequence DAQ, and the nonselective inversion pulse NIR. The imaging sequence PS may however have pulses other than the selective inversion pulse SIR, the fat suppression pulse F and the nonselective inversion pulse NIR, or have a sequence different from the data acquisition sequence DAQ. Further, the imaging sequence PS is provided with the fat suppression pulse F and the nonselective inversion pulse NIR, but may not include these pulses F and NIR.

[0202] Although the exemplary embodiment has described the example in which the arterial blood is imaged, the systems and methods described herein can be applied even to the case where the venous blood is imaged.

[0203] While the disclosure has been described specifically on the basis of the exemplary embodiment, the present invention is not limited to the exemplary embodiments referred to above. It is needless to say that various changes can be made thereto within the scope not departing from the gist thereof.

1. A magnetic resonance system configured to repeatedly execute imaging sequences each having a first RF pulse for flipping each spin in a region containing blood, and a data acquisition sequence acquiring data of the blood from the region, the magnetic resonance system comprising:

a storage unit configured to store a correspondence relation between a contrast between the blood and a background tissue, a first time taken from the first RF pulse to the data acquisition sequence, and a second time taken from a completion of an imaging sequence to a start of a next imaging sequence;

first determining means configured to determine the first time used when the imaging sequence is repeatedly executed, based on a flow velocity of the blood; and

second determining means configured to determine the second time used when the imaging sequence is repeatedly executed, based on the first time determined by the first determining means and the correspondence relation.

2. The magnetic resonance system according to claim 1, wherein the storage unit is configured to store a first map that defines a correspondence relation between a contrast between the blood and a first background tissue, a first time taken from the first RF pulse to the data acquisition sequence, and a second time taken from a completion of an imaging sequence to a start of a next imaging sequence, and

wherein the second determining means is configured to determine a time range usable as the second time, based on the first time determined by the first determining means and the first map, and is configured to determine the second time used when the imaging sequence is repeatedly executed, from the time range.

3. The magnetic resonance system according to claim 2, wherein the blood is arterial blood, and

wherein the first background tissue is venous blood.

4. The magnetic resonance system according to claim 2, wherein the second determining means is configured to specify first data at the first time determined by the first determining means from the first map, and is configured to determine a time range usable as the second time, based on the first data.

5. The magnetic resonance system according to claim 4, wherein the storage unit is configured to store a second map that defines a second correspondence relation between a contrast between the blood and a second background tissue, a first time taken from the first RF pulse to the data acquisition sequence, and a second time taken from a completion of an imaging sequence to a start of a next imaging sequence, and

wherein the second determining means is configured to specify second data at the first time determined by the first determining means from the second map, and is configured to determine a time range usable as the second time, based on the first data and the second data.

6. The magnetic resonance system according to claim 5, wherein the second determining means is configured to specify a first range of the second time corresponding to a contrast greater than or equal to a first predetermined value, based on the first data,

wherein the second determining means is configured to specify a second range of the second time corresponding to a contrast greater than or equal to a second predetermined value, based on the second data, and

wherein the second determining means is configured to determine a time range usable as the second time, based on the first range of the second time and the second range of the second time.

7. The magnetic resonance system according to claim 6, wherein when an overlaid range of the second time exists between the first range of the second time and the second range of the second time, the second determining means is configured to determine the overlaid range of the second time as a time range usable as the second time.

8. The magnetic resonance system according to claim 6, wherein when the overlaid range of the second time does not exist between the first range of the second time and the second range of the second time, the second determining means is configured to determine the first range as a time range usable as the second time.

9. The magnetic resonance system according to claim 5, wherein the second background tissue is cerebrospinal fluid.

10. The magnetic resonance system according to claim 2, wherein the second determining means is configured to determine the second time used when the imaging sequence is repeatedly executed, from the time range usable as the second time on the basis of a cardiac rate or an RR interval and the first time determined by the first determining means.

11. The magnetic resonance system according to claim 1, wherein the first time is a time taken from the first RF pulse to a starting point of time of the data acquisition sequence.

12. The magnetic resonance system according to claim **11**, wherein the first RF pulse is an inversion pulse, and the first time is an inversion time.

13. The magnetic resonance system according to claim **1**, wherein the imaging sequence has a second RF pulse between the first RF pulse and the data acquisition sequence.

14. The magnetic resonance system according to claim **13**, wherein the second RF pulse is a fat suppression pulse.

15. The magnetic resonance system according to claim **1**, wherein a sequence for determining the flow velocity of the blood is executed.

16. A program applied to a magnetic resonance system which is configured to repeatedly execute imaging sequences each having a first RF pulse for flipping each spin in a region containing blood, and a data acquisition sequence acquiring data of the blood from the region, and which is configured to store a correspondence relation between a contrast between the blood and a background tissue, a first time taken from the first RF pulse to the data acquisition sequence, and a second

time taken from a completion of an imaging sequence to a start of a next imaging sequence, the program configured to cause a computer to execute:

- a first determining process to determine the first time used when the imaging sequence is repeatedly executed, based on a flow velocity of the blood; and
- a second determining process to determine the second time used when the imaging sequence is repeatedly executed, based on the first time determined by the first determining means and the correspondence relation.

17. The program according to claim **16**, wherein the blood is arterial blood.

18. The program according to claim **16**, wherein the imaging sequence has a second RF pulse between the first RF pulse and the data acquisition sequence.

19. The program according to claim **18**, wherein the second RF pulse is a fat suppression pulse.

20. The program according to claim **16**, wherein the first RF pulse is an inversion pulse, and the first time is an inversion time.

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专利名称(译)	磁共振系统和程序		
公开(公告)号	US20150094563A1	公开(公告)日	2015-04-02
申请号	US14/501119	申请日	2014-09-30
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		
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		
[标]发明人	SUWA YUKO TAKEI NAOYUKI		
发明人	SUWA, YUKO TAKEI, NAOYUKI		
IPC分类号	A61B5/026 G01R33/38 G01R33/50 G01R33/30 A61B5/00 A61B5/0205		
CPC分类号	A61B5/0263 A61B5/7285 A61B5/0205 A61B5/743 A61B5/0816 G01R33/307 G01R33/38 A61B5/024 G01R33/50 G01R33/4822 G01R33/5602 G01R33/5607 G01R33/56308 G01R33/5673		
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摘要(译)

一种磁共振系统，被配置为重复执行成像序列，每个成像序列具有用于在包含血液的区域中翻转每个自旋的第一RF脉冲，以及从该区域获取血液数据的数据获取序列。磁共振系统包括存储单元，其被配置为存储血液和背景组织之间的对比度之间的对应关系，第一时间从第一RF脉冲到数据采集序列，以及第二时间从完成成像序列到下一成像序列的开始，第一确定装置配置成确定使用的第一时间，第二确定装置配置成确定使用的第二时间。

