(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 2 958 488 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
02.08.2017 Bulletin 2017/31

(21) Application number: **14705762.4**

(22) Date of filing: **19.02.2014**

(51) Int Cl.:
A61N 1/40 *(2006.01)* ***A61N 7/02*** *(2006.01)*
A61B 18/14 *(2006.01)* ***G06T 7/00*** *(2017.01)*
A61B 5/00 *(2006.01)* ***G01R 33/48*** *(2006.01)*
A61B 5/01 *(2006.01)* ***A61B 5/055*** *(2006.01)*
A61B 18/00 *(2006.01)* ***A61N 5/10*** *(2006.01)*
A61N 7/00 *(2006.01)* ***A61B 90/00*** *(2016.01)*

(86) International application number:
PCT/EP2014/053198

(87) International publication number:
WO 2014/128147 (28.08.2014 Gazette 2014/35)

(54) HYPERTHERMIA FOR DIAGNOSTIC IMAGING

HYPERTHERMIE FÜR DIE DIAGNOSTISCHE BILDGEBUNG

IMAGERIE DE DIAGNOSTIC PAR HYPERTHERMIE

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **22.02.2013 EP 13156374**

(43) Date of publication of application:
30.12.2015 Bulletin 2015/53

(73) Proprietor: **Koninklijke Philips N.V.**
5656 AE Eindhoven (NL)

(72) Inventor: **VAHALA, Erkki, Tapani**
NL-5656 AE Eindhoven (NL)

(74) Representative: **Cohen, Julius Simon**
Philips Intellectual Property & Standards
High Tech Campus 5
5656 AE Eindhoven (NL)

(56) References cited:
EP-A1- 2 500 740
US-A- 5 284 144
US-A- 5 722 411
US-A1- 2002 151 786

- **Vaupel ET AL: "Metabolic Status and Reaction to Heat of Normal and Tumor Tissue" In: "Thermoradiotherapy and Thermochemotherapy Medical Radiology", 1995, Springer-Verlag Berlin Heidelberg, XP055063891, ISBN: 978-3-64-263382-9 pages 157-176, DOI: 10.1007/978-3-642-57858-8_8, the whole document**

EP 2 958 488 B1

Description

FIELD OF THE INVENTION

[0001] The invention relates to the field of diagnostic imaging, in particular magnetic resonance imaging, and treatments for destroying cells within a subject of interest.

BACKGROUND OF THE INVENTION

[0002] Diagnostic imaging like magnetic resonance imaging (MRI) is becoming a more important issue in the area of therapy. In particular, diagnostic imaging is used in the area of cancer treatments to plan an efficient treatment of cancerous tissues in an area of interest of the subject of interest, as described e.g. in WO 02/082995 A1. As described therein, a magnetic resonance (MR) apparatus is used to plan a treatment regimen using a linear accelerator (linac). The features of slice width selection and depth selection are used to better ascertain where a medial malignancy is within a subject of interest, which is an animate being, e.g. a human being or an animal. A conversion algorithm translates the linac input into an imaging region for a magnetic resonance sequence that images the malignancy. Along each planned treatment trajectory radiation and MR projection images are superimposed to delineate the malignancy clearly for beam aiming and collimation adjustments. This enables a reliable planning of the treatment.

[0003] Nevertheless, the effectiveness of the treatment is not known during the irradiation treatment. This also applies to all kinds of treatments, in particular cancer treatments, where cells within the subject of interest are destroyed. Similarly, the cell death due to chemotherapy or tissue necrosis due to heating is difficult to measure. Current MR imaging and MR spectroscopy, which rely on blood oxygen level, are sensitive to patient movement and errors from signal changes due to the therapy.

[0004] US 5284 144 describes a hyperthermia/MRI probe which is utilized to monitor temperatures within a heating zone.

[0005] US 5722411 describes an ultrasound apparatus, which can be used for thermal treatment. US 5722411 mentions a method in which imaging for a treatment effect check is performed.

SUMMARY OF THE INVENTION

[0006] It is an object of the invention to provide means for improved diagnostic imaging and for improved treatment for destroying cells within the target zone of a subject of interest. In order to understand the invention, the application discloses a diagnostic imaging system, comprising a magnetic resonance imaging system for providing an image representation of at least a portion of a subject of interest positioned in an examination space, a hyperthermia device for locally heating a target zone within the portion of the subject of interest, and a control unit for controlling the MR imaging system and the hyperthermia device, wherein the diagnostic imaging system is adapted to provide a diagnostic image representation of the portion of the subject of interest by correlating image representations obtained at different temperatures of the target zone, wherein the diagnostic image representation comprises information on temperature dependent changes of the metabolism of the subject of interest. The present invention is achieved by a treatment system, in particular an oncological treatment system, comprising a diagnostic imaging system as described above, a treatment module for applying a treatment to the subject of interest for destroying cells within the target zone, and a control module for controlling the treatment module for applying the treatment based on diagnostic image representations obtained by the diagnostic imaging system. In order to understand the invention, the application discloses a method for providing a diagnostic image representation of a portion of a subject of interest, comprising the steps of providing an image representation of at least a portion of a subject of interest positioned in an examination space, whereby a target zone of the portion of subject of interest has a first temperature, locally heating the target zone, providing a further image representation of the portion of the subject of interest positioned in an examination space, whereby the target zone has a second temperature, correlating the obtained image representations with the target zone having the first and the second temperature, and providing a diagnostic image representation of the portion of the subject of interest with the correlated image representations, wherein the diagnostic image representation comprises information on temperature dependent changes of the metabolism of the subject of interest. In order to understand the invention, the application discloses a method for treatment, in particular for oncological treatment, of a subject of interest, comprising the steps of applying a treatment dose for destroying cells within the target zone of the subject of interest, providing a diagnostic image representation of a portion of a subject of interest covering the target zone according to the above method, and applying a further treatment dose for destroying cells within the target zone of the subject of interest based on the diagnostic image representation.

[0007] In a still further aspect of the present invention, the object is achieved by a software package for upgrading a magnetic resonance (MR) imaging system, whereby the software package contains instructions for controlling the MR imaging system according to the above method.

[0008] Accordingly, changes of the metabolism of the subject of interest, which is an animate being, e.g. a human being or an animal, can be evaluated using the MR imaging system. This information can be used to direct a treatment to such areas, where the cells have not yet been destroyed as desired. Such metabolism changes can be identified based on oxygenation, e.g., by a blood oxygen level dependent (BOLD) image representations,

which can be evaluated by magnetic resonance (MR) scans. Another possibility of identifying metabolism changes is MR spectroscopy, which enables the detection of the amount of metabolic activity. Also, Perfusion and/or diffusion imaging can be used to detect an altered flow within tissues in the subject of interest. By comparing the difference of the above measurements between the first and the second temperature, the efficiency of the treatment can be evaluated and the further treatment can be adapted based on the metabolism changes. Areas, where the cells have already been destroyed, can be excluded from further treatments to speed up the treatment and reduce the stress and exposure for a subject of interest. In general, the temperature of the subject of interest is not part of the diagnostic image representation.

[0009] Accordingly, treatment doses can be adapted in respect to intensity and/or location. In particular, the control module can control the treatment module for applying the treatment to apply a treatment dose with an adapted intensity at an adapted location.

[0010] The first and second image representation are usually provided in a near temporal context, e.g. during a treatment with the treatment system. The image representations are preferably provided when a desired temperature is reached or the heating has been performed for a pre-defined time.

[0011] The hyperthermia device can be any kind of device for locally heating the target zone. Preferably, the hyperthermia device is adapted to direct heat to the target zone to avoid the heating of areas out of the target zone. The hyperthermia device can be provided integrally within the MRI system. Preferably, the hyperthermia device is arranged to heat the target zone of the subject of interest when positioned within the examination space. Further preferred, the hyperthermia device is positioned in or at the examination space. Nevertheless, it is also possible to provide the hyperthermia device separately, and the subject of interest is moved into the examination space of the MRI system for providing the image representations thereof and to a different location for applying heat with the hyperthermia device. Preferably, a contact gel pad is provided to facilitate transmission of heat from the ultrasound-based hyperthermia device to the target zone. In a further embodiment, the hyperthermia device is a device movable within the examination space.

[0012] The image representations, including the diagnostic image representation, can be provided in any suitable form, e.g. as visible images. Nevertheless, it is not required to provide the image representations as images, they can be provided as any kind of data achieved from an imaging system prior to generating the image. E.g. the diagnostic image representation can be generated based on data received when performing MR scans of the portion of the subject of interest. Also the diagnostic image representation can be provided in any form. E.g. the diagnostic image representation can be provided in any form suitable for the control module to automatically control the treatment module. The diagnostic image representation is preferably provided as visible image indicating the metabolism changes. The image representation can also comprise two or more kinds of representations, e.g. a visible image that enables an operator of the diagnostic imaging system and/or the treatment system to verify the metabolism activity and/or the metabolism changes, and a representation which is e.g. passed directly to the control module.

[0013] The control unit for controlling the MRI system and the hyperthermia device can be a separate control unit, or a control unit of the MRI system, which is adapted to additionally control the hyperthermia device.

[0014] In the treatment system, the treatment module can be any kind of device suitable to achieve the destruction of cells. The treatment module can be provided integrally within the MRI system. Preferably, the treatment module is arranged to destroy cells within the target zone of the subject of interest when positioned within the examination space. Further preferred, the treatment module is positioned in or at the examination space. Nevertheless, it is also possible to provide the treatment module separately, and the subject of interest is moved into the examination space of the MRI system for providing the image representations thereof and to a different location for applying treatment with the treatment module. In a further embodiment, the treatment module is a device movable within the examination space.

[0015] The control module for controlling the treatment module and the diagnostic imaging system can be a separate control module, or a control unit of the diagnostic imaging system, which is adapted to additionally control the treatment module. Furthermore, the control module can be a control unit of the MRI system, which is adapted to additionally control the treatment module and the hyperthermia device.

[0016] The first temperature generally refers to a temperature without heating the target zone, and the second temperature refers to a temperature after the target area has been heated. One temperature, usually the first temperature, refers to normal body temperature. The lower temperature, typically the body temperature, can be obtained after heating the target zone with the hyperthermia device through normal thermal conduction and perfusion. Nevertheless, the method can also be performed by first heating the target zone to the second temperature and then cooling the target zone to the first temperature for providing the further image representation. The cooling can comprise active cooling or normal thermal conduction and perfusion only.

[0017] The step of applying a treatment dose for destroying cells within the target zone refers to any kind of suitable treatment. The treatment module can directly or indirectly achieve the destruction of the cells.

[0018] The method steps of the above methods can be performed in any suitable order and are not limited to the order listed above. In the method for treatment, the steps of providing a diagnostic image representation and applying a further treatment dose can be performed re-

peatedly to provide a treatment with a continuous verification of the success of the treatment and a continuous adaptation to the diagnostic image representation.

[0019] The target zone refers to a 3-dimensional zone within the subject of interest, where the cells to be destroyed are located. Typically, the target zone is a zone containing cancerous cells.

[0020] According to a preferred embodiment of the diagnostic imaging system the control unit is adapted to perform a pulsed operation of the hyperthermia device and the MR imaging system to provide an image representation of the portion of the subject of interest when the hyperthermia device is inactive. Correlation errors can be reduced by an efficient modulation of the hyperthermia device and the MR imaging system. Accordingly, the operation of the MR imaging system is not limited by the operation of the hyperthermia device.

[0021] According to a preferred embodiment of the diagnostic imaging system the hyperthermia device is an ultrasonic and/or a radio-frequency (RF) irradiation device. The irradiation can be used to efficiently heat the target zone within the subject of interest directly. Heating of the subject of interest outside the target zone can be reduced.

[0022] According to a preferred embodiment the hyperthermia device is a heat source, which can be brought into contact with the subject of interest.

[0023] According to a preferred embodiment the diagnostic imaging system comprises an application module for applying a contrast agent to the subject of interest. The contrast agent can be used to improve the diagnostic image representation in respect to changes of the metabolism of the subject of interest. Contrast agents can be sensitive to heat shock proteins, oxygen concentration, radiation damage or others.

[0024] According to a preferred embodiment the diagnostic imaging system is adapted to provide a diagnostic image representation of the portion of the subject of interest including hypoxia information of the portion of the subject of interest. Cancerous cells frequently show a reduced local hypoxia. By comparing the difference between the first and second temperature signals of the target zone, the amount of hypoxia can be estimated, and the amount of treatment damage to the cells can be estimated from the temporally altered response due to the thermal stress. The hypoxia information can be fed back to dose calculations even before the treatment starts, to boost the dose on hypoxic volumes. The damage estimation can be used to optimize the amount of dose to minimize damage to healthy tissue while ensuring the effectiveness of treatment on the target zone during the irradiation or a single fraction. For example, with blood oxygen level dependent (BOLD) image representations, hypoxic tissue does not show a similar change due to different temperatures as normal tissue.

[0025] According to a preferred embodiment of the treatment system the control module is further adapted to control the hyperthermia device for locally heating the target zone within the portion of the subject of interest together with the treatment module for applying the treatment. In addition to improving location and doses of the treatment, the hyperthermia can be used to enhance the outcome of the treatment, i.e. the treatment effectiveness can be improved by hyperthermia. This is partly due to increased metabolism, altered blood-flow, and reduced local hypoxia often present in cancerous tissue. Due to the locally applied heat, cells outside the target zone are not subject to an increased destruction.

[0026] According to a preferred embodiment of the treatment system the treatment module comprises a high power linear accelerator for applying irradiation to the target zone of the subject of interest. The linear accelerator (linac) can be used to irradiate the target zone with high accuracy in respect to location and intensity, i.e. dose.

[0027] According to a preferred embodiment of the treatment system the treatment module comprises a high intensity focused ultrasound device for applying ultrasound to the target zone of the subject of interest. The high intensity focused ultrasound (HIFU) device can be used to irradiate the target zone with high accuracy in respect to location and intensity, i.e. dose. Preferably, the HIFU device can be used as hyperthermia device when controlled to heat the target area with low intensity, so that a separate hyperthermia device can be omitted.

[0028] According to a preferred embodiment of the treatment system the treatment module comprises a chemotherapy/drug release module for releasing drugs into the subject of interest. The drugs can destroy the cells, or improve the destruction of the cells when using a further treatment system as from the above treatment systems. The release module is preferably provided to release the drugs in or close to the target zone.

[0029] According to a preferred embodiment the method for providing a diagnostic image representation comprises applying a contrast agent to the subject of interest. The contrast agent can be used to improve the diagnostic image representation in respect to changes of the metabolism of the subject of interest. Contrast agents can be sensitive to heat shock proteins, oxygen concentration, radiation damage or others.

[0030] According to a preferred embodiment of the method for providing a diagnostic image representation the step of providing a diagnostic image representation of the portion of the subject of interest with the correlated image representations comprises identifying hypoxic areas within the portion of the subject of interest. Cancerous cells frequently show a reduced local hypoxia. By comparing the difference between the first and second temperature signals of the target zone, the amount of hypoxia can be estimated, and the amount of treatment damage to the cells can be estimated from the temporally altered response due to the thermal stress. The hypoxia information can be fed back to dose calculations even before the treatment starts, to boost the dose on hypoxic volumes. The damage estimation can be used to opti-

mize the amount of dose to minimize damage to healthy tissue while ensuring the effectiveness of treatment on the target zone during the irradiation or a single fraction. For example, with blood oxygen level dependent (BOLD) image representations, hypoxic tissue does not show a similar change due to different temperatures as normal tissue.

[0031] According to a preferred embodiment of the method for treatment of a subject of interest the step of applying a treatment dose for destroying cells within the target zone of the subject of interest comprises locally heating the target zone. In addition to improving location and doses of the treatment, the hyperthermia can be used to enhance the outcome of the treatment, i.e., the treatment effectiveness can be improved by hyperthermia. This is partly due to increased metabolism, altered blood-flow, and reduced local hypoxia often present in cancerous tissue. Due to the locally applied heat, cells outside the target zone are not subject to an increased destruction.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter. Such an embodiment does not necessarily represent the full scope of the invention, however, and reference is made therefore to the claims and herein for interpreting the scope of the invention.

[0033] In the drawings:

Fig. 1 is a schematic illustration of a first embodiment of a diagnostic imaging system in accordance with the invention,

Fig. 2 is a schematic illustration of a second embodiment of a diagnostic imaging system in accordance with the invention, and

Fig. 3 is a timing diagram indicating the activation f different components of a treatment system.

DETAILED DESCRIPTION OF EMBODIMENTS

[0034] Fig. 1 shows a schematic illustration of an embodiment of a diagnostic imaging system 100 comprising a magnetic resonance (MR) imaging system 110 and a hyperthermia device 111.

[0035] The MR imaging system 110 comprises an MR scanner 112 and includes a main magnet 114 provided for generating a static magnetic field. The main magnet 114 has a central bore that provides an examination space 116 around a center axis 118 for a subject of interest 120, usually a patient, to be positioned within. In this embodiment, the central bore and therefore the static magnetic field of the main magnet 114 has a horizontal orientation in accordance with the center axis 118. In an alternative embodiment, the orientation of the main magnet 114 can be different. Further, the MR imaging system 110 comprises a magnetic gradient coil system 122 provided for generating gradient magnetic fields superimposed to the static magnetic field. The magnetic gradient coil system 122 is concentrically arranged within the bore of the main magnet 114, as known in the art.

[0036] Further, the MR imaging system 110 includes a radio frequency (RF) antenna device 140 designed as a whole-body coil having a tubular body. The RF antenna device 140 is provided for applying an RF magnetic field to the examination space 116 during RF transmit phases to excite nuclei of the subject of interest 120. The RF antenna device 140 is also provided to receive MR signal from the excited nuclei during RF receive phases. In a state of operation of the MR imaging system 110, RF transmit phases and RF receive phases are taking place in a consecutive manner. The RF antenna device 140 is arranged concentrically within the bore of the main magnet 114. As is known in the art, a cylindrical metal RF screen 124 is arranged concentrically between the magnetic gradient coil system 122 and the RF antenna device 140.

[0037] Moreover, the MR imaging system 110 comprises an MR image reconstruction unit 130 provided for reconstructing MR images from the acquired MR signals and an MR imaging system control unit 126 with a monitor unit 128 provided to control functions of the MR scanner 112, as is commonly known in the art. Control lines 132 are installed between the MR imaging system control unit 126 and an RF transmitter unit 134 that is provided to feed RF power of an MR radio frequency to the RF antenna device 140 via an RF switching unit 136 during the RF transmit phases. The RF switching unit 136 in turn is also controlled by the MR imaging system control unit 126, and another control line 138 is installed between the MR imaging system control unit 126 and the RF switching unit 136 to serve that purpose. During RF receive phase, the RF switching unit 136 directs the MR signals from the RF antenna device 140 to the MR image reconstruction unit 130 after pre-amplification.

[0038] The hyperthermia device 111 is an ultrasonic irradiation device which is a high intensity focused ultrasound (HIFU) device for applying ultrasound to the target zone of the subject of interest, which is controlled to heat the target area with low intensity. The hyperthermia device 111 comprises a transducer box 142 including a transducer head, which is located integrally with the MR imaging system 110 to heat a subject of interest 120 located in the examination space 116, as shown in Fig. 1. The transducer head is movable to apply ultrasonic irradiation to a desired target zone of the subject of interest 120. A contact pad 144 is provided to improve the transmission of the ultrasonic irradiation from the transducer box 142 into the target zone.

[0039] A medical treatment system comprises the above diagnostic imaging system 100 and a treatment module 146 for applying a treatment to the subject of interest for destroying cells within the target zone. The treatment module 146, which is indicated in fig. 3, is a

high power linear accelerator (linac) for applying irradiation to the target zone of the subject of interest.

[0040] The control unit 126 for controlling the MRI system 110 performs a combined control of the MRI system 110, the hyperthermia device 111, and the treatment module 146.

[0041] The operation of the medical treatment system will now be described with reference to Fig. 3

[0042] In an initial step S0 at time t1, an image representation of a portion of a subject of interest 120 covering the target zone is provided by the MRI system 110. The subject of interest 120 has normal body temperature, also referred to as first temperature. The image representation is a blood oxygen level dependent (BOLD) image representation.

[0043] In a subsequent step at a time t2, the hyperthermia device 111 is activated by the control unit 126 to locally heat the target zone to a second temperature above the body temperature. When the second temperature is reached, the hyperthermia device 111 is deactivated and a further image representation of the portion of the subject of interest is provided by the MRI system 110. Also the further image representation is a BOLD image representation.

[0044] In step S2, the image representations obtained at the first and second temperatures are correlated by the control unit 126 to provide a diagnostic image representation of the portion of the subject of interest. The diagnostic image representation comprises information on temperature dependent changes of the metabolism of the subject of interest 120. In this embodiment, the diagnostic imaging system 100 is adapted to provide the diagnostic image representation including hypoxia information. The amount of hypoxia is estimated, and the amount of treatment damage to the cells is estimated.

[0045] Furthermore, the control unit 126 calculates a dose correction of an initial dose, which was applied prior to S0 to direct a treatment to such areas, where the cells have not yet been destroyed as desired. The dose correction is calculated based on the diagnostic image representation, i.e. based on the representations provided at t1 and t2. Accordingly, the hypoxia information is fed back to dose calculations to boost the dose on hypoxic volumes. Based on the damage estimation, the amount and location of dose is optimized to minimize damage to healthy tissue while ensuring the effectiveness of the treatment on the target zone during the irradiation. The dose refers to a location and intensity of the treatment applied by the treatment module. In this embodiment, the dose refers to a target area of the linac 146 and the intensity of the linac 146.

[0046] In step S3, the treatment is applied to the target zone by the linac 146 according to the dose calculated above. Furthermore, the MRI system 110 is operated to provide therapy images.

[0047] Subsequent steps S4 and S5 are essentially identical to steps S0 and S1, respectively, and provide image representations at times t3 and t4. Accordingly, at t3 an image representation at the first temperature is provided. Accordingly, the target area cools down to the first temperature, which is lower than the second temperature, by normal thermal conduction and perfusion. In an alternative embodiment, active cooling is applied to support cool down of the target area.

[0048] In step S6, the image representations obtained at the first and second temperatures at times t1, t2, t3 and t4 are correlated by the control unit 126 to provide a diagnostic image representation of the portion of the subject of interest 120 as described with respect to S2. With the correlation of multiple image representations for the first and second temperature, the process of the treatment is monitored. Again, based on the diagnostic image representation, the control unit 126 calculates a dose correction of the prior dose of S3.

[0049] In an alternative embodiment, the control module is further adapted to control the hyperthermia device 111 for locally heating the target zone within the portion of the subject of interest 120 together with the treatment module 146 for applying the treatment. Accordingly, the treatment is applied under hyperthermia conditions.

[0050] Fig. 2 shows a schematic illustration of an embodiment of a diagnostic imaging system 100 according to a second embodiment. The diagnostic imaging system 100 according to the second embodiment is mostly identical to the diagnostic imaging system 100 according to the first embodiment, so that only differences will be described. Also the methods for providing a diagnostic image representation and for treatment are applied as described above.

[0051] The diagnostic imaging system 100 according to the second embodiment differs from the first embodiment merely in the positioning of the transducer box 142, which is positioned outside the examination space 116. Accordingly, to apply heating to the target zone, the subject of interest 120 is moved out of the examination space 116 on a movable tabletop 148. After heating the target zone, the subject of interest 120 is returned into the examination space 116.

[0052] 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. 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. 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. Any reference signs in the claims should not be construed as limiting the scope.

REFERENCE SYMBOL LIST

[0053]

100	diagnostic imaging system
110	magnetic resonance (MR) imaging system
111	hyperthermia device
112	magnetic resonance (MR) scanner
114	main magnet
116	RF examination space
118	center axis
120	subject of interest
122	magnetic gradient coil system
124	RF screen
126	MR imaging system control unit
128	monitor unit
130	MR image reconstruction unit
132	control line
134	RF transmitter unit
136	RF switching unit
138	control line
140	radio frequency (RF) antenna device
142	transducer box
144	contact pad
146	treatment module, linac
148	tabletop

Claims

1. A treatment system comprising

- a diagnostic imaging system (100), wherein the diagnostic imaging system comprises:
- a magnetic resonance (MR) imaging system (110) for providing an image representation of at least a portion of a subject of interest (120) positioned in an examination space (116),
- a hyperthermia device (111) for locally heating a target zone within the portion of the subject of interest (120), and
- a control unit (126) for controlling the MR imaging system (110) and the hyperthermia device (111),

wherein the diagnostic imaging system is adapted to provide a diagnostic image representation of the portion of the subject of interest (120) by correlating image representations obtained at different temperatures of the target zone, wherein the diagnostic image representation comprises information on temperature dependent changes of the metabolism of the subject of interest (120) wherein the treatment system is **characterized by**

- a treatment module (146) for applying a treatment to the subject of interest (120) for destroying cells within the target zone, wherein the treatment module is a high power linear accelerator or a chemotherapy/drug release module, and
- a control module (126) for controlling the treatment module (146) for applying the treatment based on diagnostic image representations obtained by the diagnostic imaging system (100).

2. The treatment system (100) according to claim 1, wherein
the control unit (126) is adapted to perform a pulsed operation of the hyperthermia device (111) and the MR imaging system (110) to provide an image representation of the portion of the subject of interest (120) when the hyperthermia device (111) is inactive.

3. The treatment system (100) according to claim 1, wherein
the hyperthermia device (111) is an ultrasonic and/or an radio-frequency irradiation device.

4. The treatment system (100) according to claim 1, comprising an application module for applying a contrast agent to the subject of interest (120).

5. The treatment system (100) according to claim 1, wherein
the diagnostic imaging system (100) is adapted to provide a diagnostic image representation of the portion of the subject of interest (120) including hypoxia information of the portion of the subject of interest (120).

6. The treatment system according to claim 1, wherein the control module (126) is further adapted to control the hyperthermia device (111) for locally heating the target zone within the portion of the subject of interest (120) together with the treatment module (146) for applying the treatment.

7. A software package for upgrading a treatment system, comprising a magnetic resonance imaging system (110), a hyperthermia device (111) for locally heating a target zone and a treatment module (146) for applying a treatment to the subject of interest (120) for destroying cells within the target zone, wherein the treatment module is a high power linear accelerator or a chemotherapy/drug release module, whereby the software package contains instructions for controlling the system (110) according to a method comprising the steps of applying a treatment dose by means of the high power linear accelerator or the chemotherapy/drug release module for destroying cells within the target zone of the subject of interest (120), providing an image representation of at least a portion of a subject of interest (120) positioned in an examination space (116), whereby a target zone of the portion of subject of interest (120) has a first temperature,

locally heating the target zone,
providing a further image representation of the portion of the subject of interest (120) positioned in an examination space (116), whereby the target zone has a second temperature,
correlating the obtained image representations with the target zone having the first and the second temperature, and
providing the diagnostic image representation of the portion of the subject of interest (120) with the correlated image representations, wherein the diagnostic image representation comprises information on temperature dependent changes of the metabolism of the subject of interest (120)
applying a further treatment dose by means of the high power linear accelerator or the chemotherapy/drug release module for destroying cells within the target zone of the subject of interest (120) based on the diagnostic image representation.

8. A software package according to claim 7, wherein the step of providing a diagnostic image representation of the portion of the subject of interest (120) with the correlated image representations comprises identifying hypoxic areas within the portion of the subject of interest (120).

Patentansprüche

1. Behandlungssystem umfassend:

- ein diagnostisches Bildgebungssystem (100), wobei das diagnostische Bildgebungssystem Folgendes umfasst:
- ein Magnetresonanz- (MR) Bildgebungssystem (110) zum Bereitstellen einer Bilddarstellung von mindestens einem Teil eines interessierenden Subjekts (120), das in einem Untersuchungsraum (116) positioniert ist,
- eine Hyperthermie-Vorrichtung (111) zum lokalen Erwärmen einer Zielzone innerhalb des Teils des interessierenden Subjekts (120), und
- eine Steuereinheit (126) zum Steuern des MR-Bildgebungssystems (110) und der Hyperthermie-Vorrichtung (111),

wobei das diagnostische Bildgebungssystem dafür ausgelegt ist, eine diagnostische Bilddarstellung des Teils des interessierenden Subjekts (120) bereitzustellen, indem bei verschiedenen Temperaturen der Zielzone erlangte Bilddarstellungen korreliert werden, wobei die diagnostische Bilddarstellung Informationen über temperaturabhängige Änderungen des Stoffwechsels des interessierenden Subjekts (120) umfasst, wobei das Behandlungssystem **gekennzeichnet ist durch**

- ein Behandlungsmodul (146) zum Anwenden einer Behandlung auf das interessierende Subjekt (120), um Zellen in der Zielzone zu zerstören, wobei das Behandlungsmodul ein Hochleistungs-Linearbeschleuniger oder ein Modul zur Freisetzung von Chemotherapie/Arzneimittel umfasst, und
- ein Steuermodul (126) zum Steuern des Behandlungsmoduls (146) zur Anwendung der Behandlung basierend auf diagnostischen Bilddarstellungen, die durch das diagnostische Bildgebungssystem (100) erlangt wurden.

2. Behandlungssystem (100) nach Anspruch 1, wobei die Steuereinheit (126) dafür ausgelegt ist, einen gepulsten Betrieb der Hyperthermie-Vorrichtung (111) und des MR-Bildgebungssystems (110) durchzuführen, um eine Bilddarstellung des Teils des interessierenden Subjekts (120) bereitzustellen, wenn die Hyperthermie-Vorrichtung (111) inaktiv ist.

3. Behandlungssystem (100) nach Anspruch 1, wobei die Hyperthermie-Vorrichtung (111) eine Ultraschall- und/oder eine Hochfrequenz-Bestrahlungsvorrichtung ist.

4. Behandlungssystem (100) nach Anspruch 1, umfassend
ein Anwendungsmodul zum Anwenden eines Kontrastmittels auf das interessierende Subjekt (120).

5. Behandlungssystem (100) nach Anspruch 1, wobei das diagnostische Bildgebungssystem (100) dafür ausgelegt ist, eine diagnostische Bilddarstellung des Teils des interessierenden Subjekts (120) einschließlich Hypoxie-Informationen des Teils des interessierenden Subjekts (120) bereitzustellen.

6. Behandlungssystem nach Anspruch 1, wobei
das Steuermodul (126) weiterhin dafür ausgelegt ist, die Hyperthermie-Vorrichtung (111) zum lokalen Erwärmen der Zielzone in dem Teil des interessierenden Subjekts (120) zusammen mit dem Behandlungsmodul (146) zum Anwenden der Behandlung zu steuern.

7. Softwarepaket zur Aufrüstung eines Behandlungssystems, umfassend ein Magnetresonanz-Bildgebungssystem (110), eine Hyperthermie-Vorrichtung (111) zum lokalen Erwärmen einer Zielzone und ein Behandlungsmodul (146) zum Anwenden der Behandlung auf das interessierende Subjekt (120), um Zellen in der Zielzone zu zerstören, wobei das Behandlungsmodul ein Hochleistungs-Linearbeschleuniger oder ein Modul zur Freisetzung von Chemotherapie/Arzneimittel ist,
wobei das Softwarepaket Anweisungen zum Steuern des Systems (110) gemäß einem Verfahren um-

fasst, das die folgenden Schritte umfasst:

Anwenden einer Behandlungsdosis mittels des Hochleistungs-Linearbeschleunigers oder des Moduls zur Freisetzung von Chemotherapie/Arzneimittel, um Zellen in der Zielzone des interessierenden Subjekts (120) zu zerstören,
Bereitstellen einer Bilddarstellung von mindestens einem Teil eines interessierenden Subjekts (120), das in einem Untersuchungsraum (116) positioniert ist, wobei eine Zielzone des Teils des interessierenden Subjekts (120) eine erste Temperatur hat,
lokales Erwärmen der Zielzone,
Bereitstellen einer weiteren Bilddarstellung des Teils des interessierenden Subjekts (120), das in einem Untersuchungsraum (116) positioniert ist, wobei die Zielzone eine zweite Temperatur hat,
Korrelieren der erlangten Bilddarstellungen mit der Zielzone mit der ersten und der zweiten Temperatur, und
Bereitstellen der diagnostischen Bilddarstellung des Teils des interessierenden Subjekts (120) mit den korrelierten Bilddarstellungen, wobei die diagnostische Bilddarstellung Informationen über temperaturabhängige Änderungen des Stoffwechsels des interessierenden Subjekts (120) umfasst,
Anwenden einer weiteren Behandlungsdosis mittels des Hochleistungs-Linearbeschleunigers oder des Moduls zur Freisetzung von Chemotherapie/Arzneimittel für die Zerstörung von Zellen in der Zielzone des interessierenden Subjekts (120) basierend auf der diagnostischen Bilddarstellung.

8. Softwarepaket nach Anspruch 7, wobei
der Schritt des Bereitstellens einer diagnostischen Bilddarstellung des Teils des interessierenden Subjekts (120) mit den korrelierten Bilddarstellungen das Identifizieren von hypoxischen Bereichen in dem Teil des interessierenden Subjekts (120) umfasst.

Revendications

1. Système de traitement comprenant

- un système de diagnostic par imagerie (100), dans lequel le système de diagnostic par imagerie comprend :
- un système d'imagerie par résonance magnétique (RM) (110) pour fournir une représentation en image d'au moins une partie d'un sujet d'intérêt (120) positionné dans un espace d'examen (116),
- un dispositif d'hyperthermie (111) pour chauffer localement une zone cible dans la partie du sujet d'intérêt (120), et
- une unité de commande (126) pour commander le système d'imagerie par RM (110) et le dispositif d'hyperthermie (111),

dans lequel le système de diagnostic par imagerie est adapté pour fournir une représentation d'image de diagnostic de la partie du sujet d'intérêt (120) en corrélant des représentations en image obtenues à différentes températures de la zone cible, dans lequel la représentation d'image de diagnostic comprend des informations sur des changements du métabolisme du sujet d'intérêt (120), en fonction de la température,
dans lequel le système de traitement est **caractérisé par**

- un module de traitement (146) pour appliquer un traitement au sujet d'intérêt (120) pour détruire des cellules dans la zone cible, dans lequel le module de traitement est un accélérateur linéaire à haute puissance ou un module de chimiothérapie/ libération de médicament, et
- un module de commande (126) pour commander le module de traitement (146) pour appliquer le traitement sur la base des représentations d'image de diagnostic obtenues par le système de diagnostic par imagerie (100).

2. Système de traitement (100) selon la revendication 1, dans lequel
l'unité de commande (126) est adaptée pour réaliser un fonctionnement pulsé du dispositif d'hyperthermie (111) et du système d'imagerie par RM (110) pour fournir une représentation en image de la partie du sujet d'intérêt (120) lorsque le dispositif d'hyperthermie (111) est inactif.

3. Système de traitement (100) selon la revendication 1, dans lequel
le dispositif d'hyperthermie (111) est un dispositif d'irradiation par ultrasons et/ou radiofréquences.

4. Système de traitement (100) selon la revendication 1, comprenant
un module d'application pour appliquer un agent de contraste au sujet d'intérêt (120).

5. Système de traitement (100) selon la revendication 1, dans lequel
le système de diagnostic par imagerie (100) est adapté pour fournir une représentation d'image de diagnostic de la partie du sujet d'intérêt (120) comprenant des informations sur l'hypoxie de la partie du sujet d'intérêt (120).

6. Système de traitement selon la revendication 1, dans

lequel
le module de commande (126) est adapté en outre pour commander le dispositif d'hyperthermie (111) pour chauffer localement la zone cible dans la partie du sujet d'intérêt (120) conjointement avec le module de traitement (146) pour appliquer le traitement.

7. Ensemble de logiciel pour améliorer un système de traitement comprenant un système d'imagerie par résonance magnétique (110), un dispositif d'hyperthermie (111) pour chauffer localement une zone cible et un module de traitement (146) pour appliquer un traitement au sujet d'intérêt (120) pour détruire des cellules dans la zone cible, dans lequel le module de traitement est un accélérateur linéaire à haute puissance ou un module de chimiothérapie/ libération de médicament,
l'ensemble de logiciel contenant des instructions pour commander le système (100) selon un procédé comprenant les étapes consistant à
appliquer une dose de traitement au moyen de l'accélérateur linéaire à haute puissance ou du module de chimiothérapie/ libération de médicament pour détruire des cellules dans la zone cible du sujet d'intérêt (120)
fournir une représentation en image d'au moins une partie d'un sujet d'intérêt (120) positionné dans un espace d'examen (116), une zone cible de la partie du sujet d'intérêt (120) ayant une première température,
chauffer localement la zone cible,
fournir une autre représentation en image de la partie du sujet d'intérêt (120) positionné dans un espace d'examen (116), la zone cible ayant une deuxième température,
corréler les représentations en image obtenues avec la zone cible ayant les première et deuxième températures, et
fournir la représentation d'image de diagnostic de la partie du sujet d'intérêt (120) avec les représentations en image corrélées, dans lequel la représentation d'image de diagnostic comprend des informations sur les changements du métabolisme du sujet d'intérêt (120), en fonction de la température,
appliquer une autre dose de traitement au moyen de l'accélérateur linéaire à haute puissance ou du module de chimiothérapie/ libération de médicament pour détruire des cellules dans la zone cible du sujet d'intérêt (120) sur la base de la représentation d'image de diagnostic.

8. Ensemble de logiciel selon la revendication 7, dans lequel
l'étape de fourniture d'une représentation d'image de diagnostic de la partie du sujet d'intérêt (120) avec les représentations en image corrélées comprend l'identification de zones hypoxiques dans la partie du sujet d'intérêt (120).

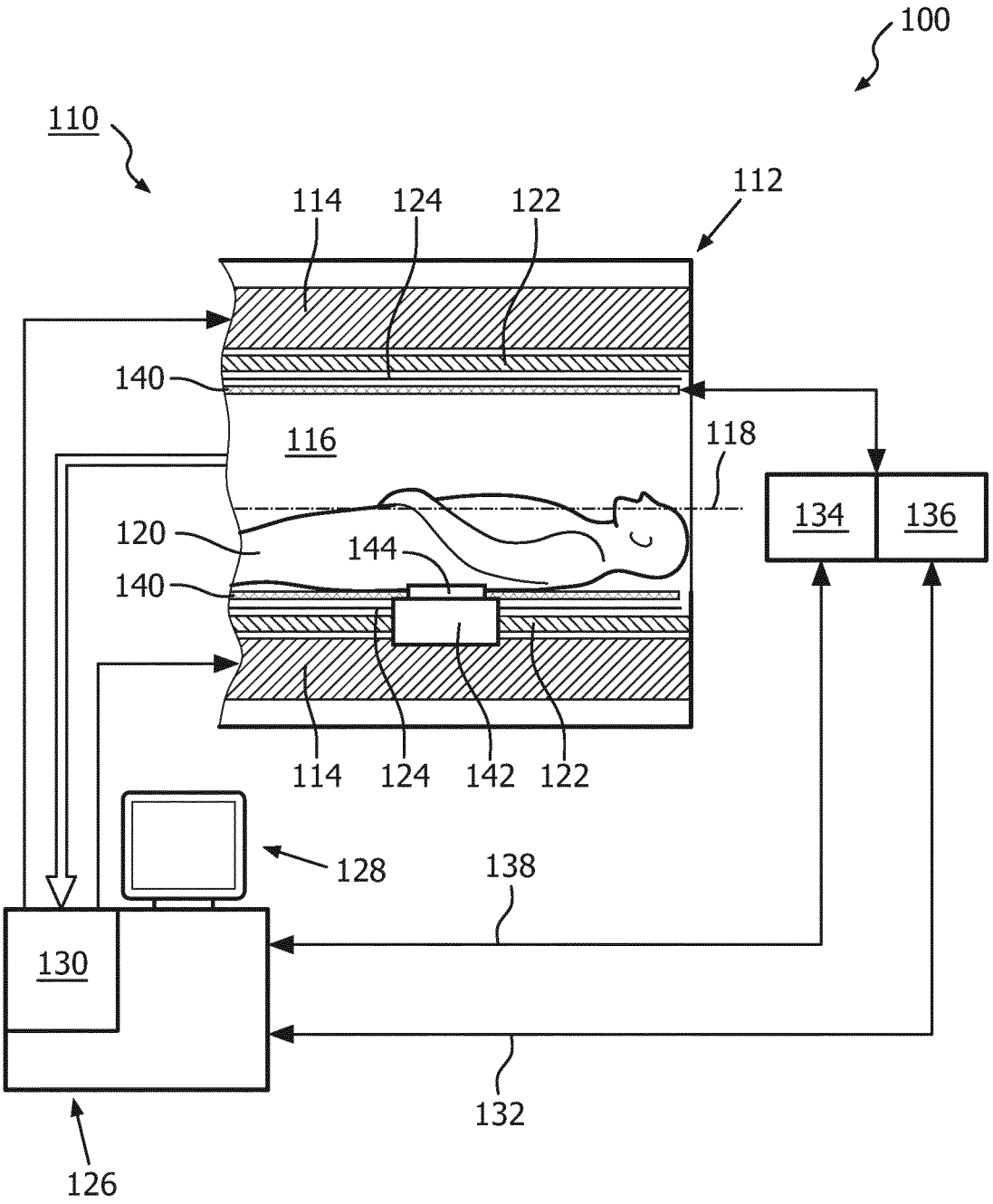
100
110
112
114
124
122
140
116
118
134
136
120
144
140
114
124
142
122
128
138
130
132
126

FIG. 1

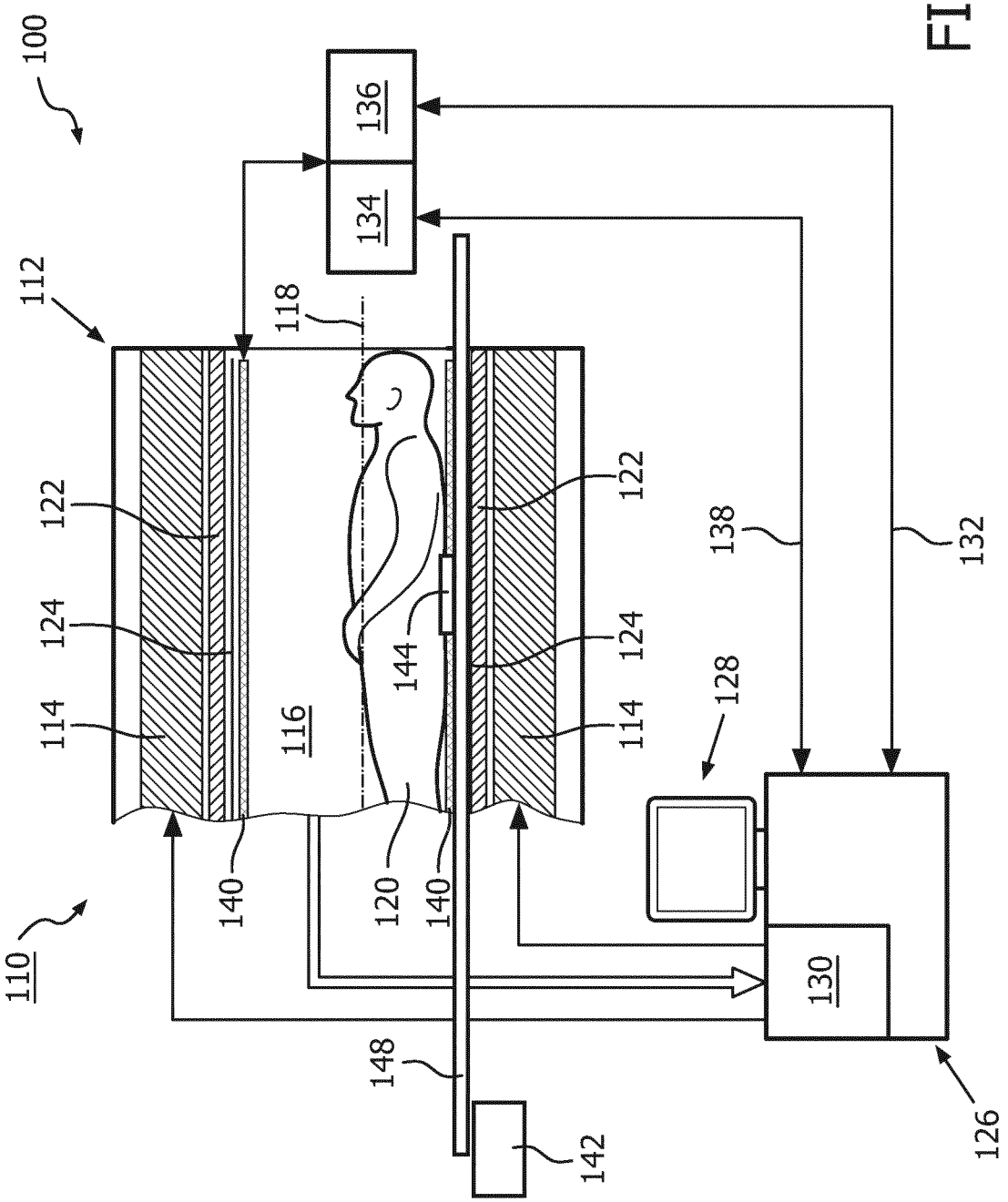
100
136
134
112
118
122
124
114
116
140
120
140
144
122
124
114
138
132
128
130
110
148
142
126

FIG. 2

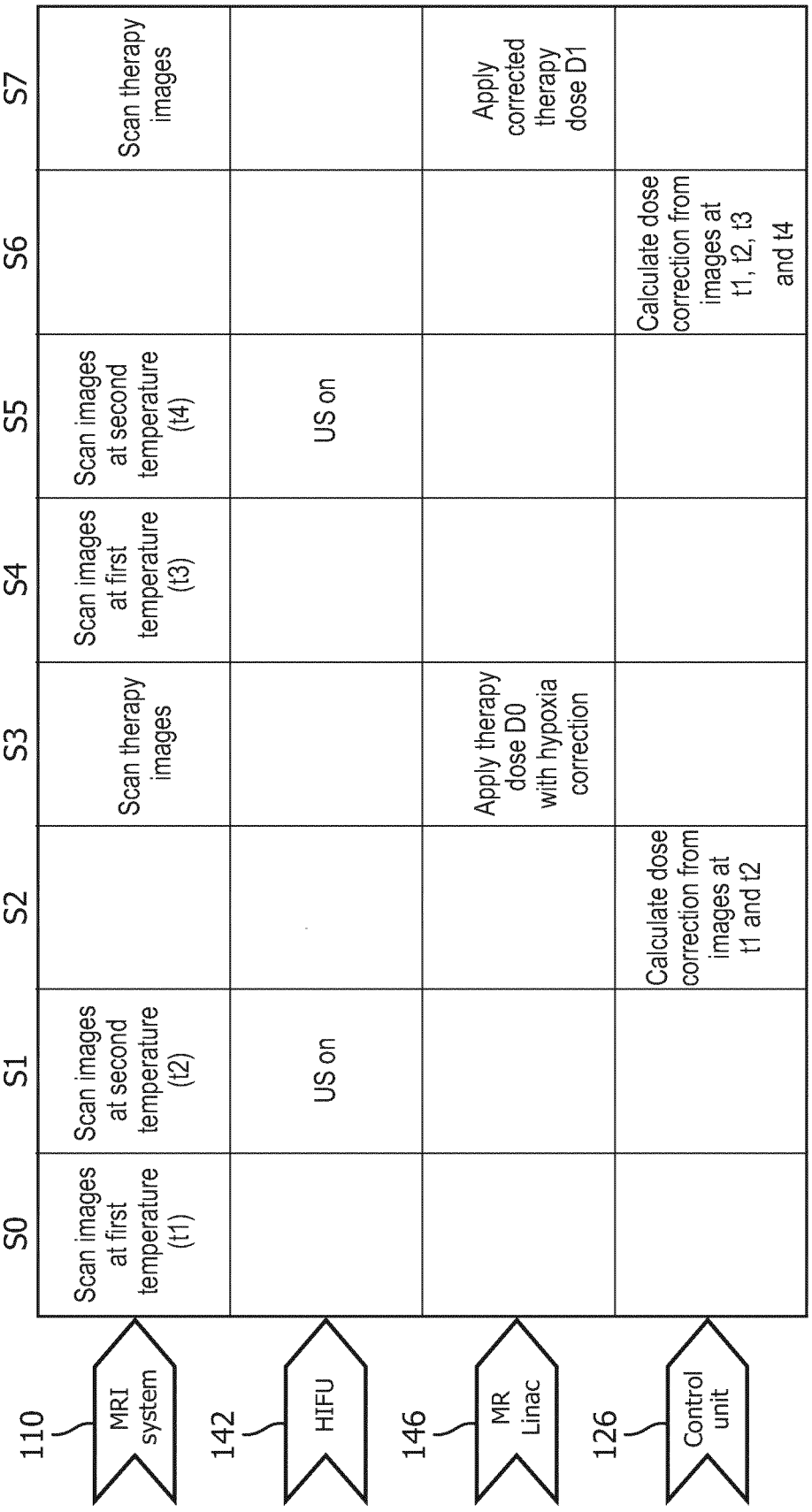
S0
S1
S2
S3
S4
S5
S6
S7
110
MRI system
Scan images at first temperature (t1)
Scan images at second temperature (t2)
Scan therapy images
Scan images at first temperature (t3)
Scan images at second temperature (t4)
Scan therapy images
142
HIFU
US on
US on
146
MR Linac
Apply therapy dose D0 with hypoxia correction
Apply corrected therapy dose D1
126
Control unit
Calculate dose correction from images at t1 and t2
Calculate dose correction from images at t1, t2, t3 and t4

FIG. 3

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- WO 02082995 A1 **[0002]**
- US 5284144 A **[0004]**
- US 5722411 A **[0005]**

专利名称(译)	用于诊断成像的热疗		
公开(公告)号	EP2958488B1	公开(公告)日	2017-08-02
申请号	EP2014705762	申请日	2014-02-19
[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.		
当前申请(专利权)人(译)	皇家飞利浦N.V.		
[标]发明人	VAHALA ERKKI TAPANI		
发明人	VAHALA, ERKKI, TAPANI		
IPC分类号	A61N1/40 A61N7/02 A61B18/14 G06T7/00 A61B5/00 G01R33/48 A61B5/01 A61B5/055 A61B18/00 A61N5/10 A61N7/00 A61B90/00		
CPC分类号	A61B5/015 A61B5/055 A61B5/4836 A61B18/14 A61B2018/00738 A61B2018/00791 A61B2090/374 A61N1/403 A61N5/1039 A61N7/02 A61N2005/1055 A61N2007/0082 G01R33/4814 A61B5/0036 A61B5/743 G06T7/0012 G06T2207/10096 G06T2207/30004 G06T2207/30196		
代理机构(译)	COHEN，朱利叶斯SIMON		
优先权	2013156374 2013-02-22 EP		
其他公开文献	EP2958488A1		
外部链接	Espacenet		

摘要(译)

诊断成像系统（100）包括：磁共振（MR）成像系统（110），用于提供感兴趣的对象（120）的至少一部分的图像表示；热疗设备（111），用于局部加热目标区域。 在感兴趣的对象的部分（120）中，以及一个或多个处理器，用于控制MR成像系统（110）和热疗设备（111）。 在目标区域的不同温度下获得的相关图像表示提供了有关目标受试者新陈代谢的温度依赖性变化的信息（120）。 治疗模块（146）对感兴趣的受试者（120）进行治疗以破坏靶区内的细胞。 一个或多个处理器基于由诊断成像系统（100）获得的诊断图像表示来控制治疗模块（146）以进行治疗。 评估感兴趣对象的代谢变化以将治疗引导至尚未破坏细胞的区域。

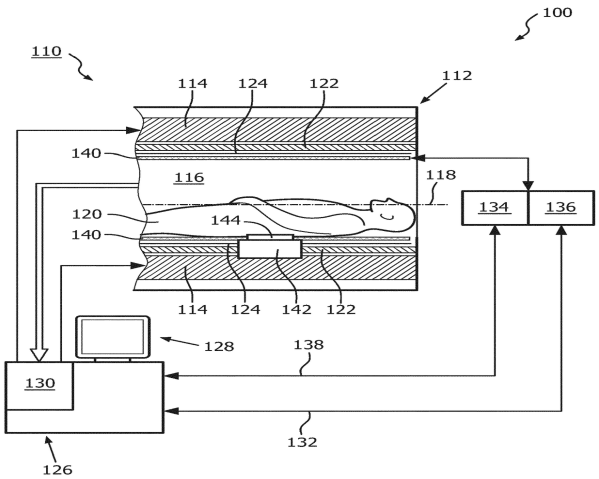

FIG. 1