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(54) **RADIATION THERAPY PLANNING AND FOLLOW-UP SYSTEM WITH LARGE BORE NUCLEAR AND MAGNETIC RESONANCE IMAGING OR LARGE BORE CT AND MAGNETIC RESONANCE IMAGING**

STRAHLENTHERAPIEPLANUNG UND NACHSORGESYSTEM MIT LARGE-BORE-KERN- UND MAGNETRESONANZBILDGEBUNG ODER LARGE-BORE-CT- UND MAGNETRESONANZBILDGEBUNG

PLANIFICATION DE THÉRAPIE PAR RAYONNEMENT ET SYSTÈME DE SUIVI PAR IMAGERIE À RÉSONANCE NUCLÉAIRE ET MAGNÉTIQUE À GRANDE OUVERTURE OU CT À GRANDE OUVERTURE ET IMAGERIE À RÉSONANCE MAGNÉTIQUE

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Description

[0001] The present application relates to image guided radiation therapy planning. It finds particular application in conjunction with multi-modality radiation therapy planning.

[0002] Radiation therapy is a common therapeutic technique in oncology in which a dose or series of doses of high energy gamma (γ) radiation, particle beam, or other radiation is delivered to a patient's body or targeted region of a patient's body to achieve a therapeutic effect, e.g. eradicate cancerous tissue. The radiation therapy session(s) are planned prior to radiation treatment based on one or more planning volumetric images which aim to define the anatomical boundaries of the tumor and surrounding tissues in order to determine radiation beam parameters and dose distribution. Computed tomography (CT) scanners are typically employed in radiation therapy planning (RTP) because the imaging bore has sufficient size to accommodate the equivalent of larger/flat radiation therapy couches and average size or larger than average size patients with immobilization devices. Also, the CT data so acquired provides directly the attenuation properties of the tissue which is useful for RTP. RTP couches are carefully designed flat supports that ensure the patient is treated in the same position as imaged. One problem with CT imaging for RTP is that the patient is subjected to additional ionizing radiation which causes concern for additional long term adverse side effects such as cancer (which is in many cases the very thing being treated). In addition, CT fails to provide the requisite image quality for all soft-tissue regions of the body.

[0003] Positron emission tomography (PET) has been recently introduced as a viable imaging modality for cancer detection, including metastatic spread. When fused with other data, such as CT, PET provides additional tumor functional information for radiation therapy planning and monitoring. In PET scans, a patient is administered a radiopharmaceutical, in which the radioactive decay events of the radiopharmaceutical produce positrons. Each positron interacts with an electron over a short range to produce a positron-electron annihilation event that emits two oppositely directed gamma rays. Using coincidence detection circuitry, a ring array of radiation detectors surrounding the patient detects the coincident oppositely directed gamma ray events which correspond to the annihilation event. A line of response (LOR) connecting the two coincident detections contains the position of the annihilation event. The lines of response are analogous to projection data and are reconstructed to produce a two- or three-dimensional image. PET focuses on regions of high metabolic activity, such as neoplastic cancerous tissue and therefore helps to differentiate malignant tumors from benign tumors, hypoxic regions, characterize tumor recurrence, and radiation necrosis.

[0004] PET has shown potential to improve staging, prognosis, planning, and follow-up monitoring. However, a few limitations of PET include limited spatial resolution and a lack of additional anatomic detail beyond tissue where high tracer accumulation occurs. PET is generally poor at delineating anatomical detail and therefore has difficulty locating a tumor relative to other patient anatomy. Multi-modality PET-CT systems exists for radiation therapy planning but, as mentioned above, this arrangement will still subject the patient to additional harmful ionizing radiation from the CT scanning employed. Magnetic resonance imaging (MRI) and spectroscopy (MRS) offer potential as a replacement for anatomical imaging in RTP. In MR scans, the nuclear spins of the body tissue to be examined are aligned by a static main magnetic field B_0 and are excited by transverse magnetic fields B_1 oscillating in the radiofrequency (RF) band. The resulting relaxation signals are exposed to gradient magnetic fields to localize the resultant resonance. The relaxation signals are received and reconstructed in a known manner into a single or multiple dimension image. MRI has superior soft tissue imaging while MRS is capable of characterizing tissue metabolism which can provide information regarding angiogenesis, cell proliferation, and apoptosis in the region of interest. However, magnetic resonance systems are limited by their bore size which cannot comfortably accommodate the larger than average size patients and larger RTP couch/flat tabletop. Furthermore, in certain immobilization/fixation situations additional bore space (>70cm) is beneficial and currently does not exist for MR systems.

[0005] Accuracy of image registration between imaging modalities is an important feature for RTP and therefore both scans must preferably be performed in the same session to avoid patient movement and misregistration errors. Discrepancies between combined image representations can have a significant impact on treatment evaluation tools such as dose volume histogram, tumor control probability, normal tissue complication probability, and conformality index. Therefore, a need exists for a PET-MRI multi-modality radiation therapy planning system with a bore large enough to comfortably accommodate the RTP couch/flat tabletop, larger than average size patient, and immobilization devices to perform scans in a single imaging session with improved workflow.

[0006] The present application provides a new and improved method and system which overcomes the above-referenced problems and others.

[0007] In accordance with one aspect, a radiation therapy planning (RTP) system is presented. The RTP system includes a magnetic resonance (MR) system with a first bore which defines an MR imaging region which receives a subject along an MR longitudinal axis. The first bore has a diameter of at least 70cm, and in a preferred embodiment is 85 cm. The RTP system includes a nuclear imaging scanner with a second bore which defines a nuclear imaging region which receives the subject along a nuclear longitudinal axis which is aligned with the MR longitudinal axis. The second has a diameter of at least 70cm, and in a preferred embodiment is 85cm.

The system includes a radiation therapy couch with flat tabletop which moves linearly along a patient support track through the MR and nuclear imaging regions which positions the subject sequentially in the MR and nuclear imaging region, wherein the radiation therapy type couch is detachable from the patient support track for use in a radiation therapy system. The flat tabletop material is compatible with both MR and PET imaging procedures.

[0008] In accordance with another aspect, a method for generating a radiation therapy plan is presented. The method includes positioning a subject supported by a radiation therapy couch in one of an MR imaging region of an MR scanner and a nuclear imaging region of a nuclear scanner. An MR or nuclear image representation of a target volume is acquired and the target volume is localized relative to the corresponding imaging region. The localized target volume is registered to the radiation therapy couch and an expected coordinate position of the patient is determined relative to the radiation therapy couch. The subject is re-positioned linearly along a patient support track from one of the MR imaging region and nuclear imaging region to the other imaging region of one of the nuclear scanner and MR scanner which shares a common longitudinal axis therewith. An image representation of the target volume is acquired with the other one of the nuclear and MR scanners. The acquired MR and nuclear image representations are combined into a combined image representation. A radiation therapy plan is generated, according to the one of the combined, MR, and nuclear image representations. A first bore which defines the MR imaging region and a second bore which defines the nuclear imaging region each have a diameter of at least 70cm. The radiation therapy type couch is detached from the patient support track for use in a radiation therapy system.

[0009] One advantage resides in an improved workflow.

[0010] Another advantage is that ionizing radiation exposure during radiation therapy planning is reduced.

[0011] Another advantage is that the radiation therapy plan will be improved by the addition of soft-tissue contrast from the MR images.

[0012] Still further advantages of the present invention will be appreciated by those of ordinary skill in the art upon reading and understand the following detailed description.

[0013] The invention may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for purposes of illustrating the preferred embodiments and are not to be construed as limiting the invention.

FIGURE 1 is a diagrammatic illustration of a multiple modality radiation therapy planning system;

FIGURE 2 is a flow chart of a method of planning radiation therapy with the system of FIGURE 1;

FIGURE 3 is a flow chart of another method of planning radiation therapy with the system of FIGURE 1; and

FIGURE 4 is a flow chart of a method of monitoring and updating radiation therapy with the system of FIGURE 1.

[0014] With reference to FIGURE 1, a radiation therapy planning (RTP) system **10** is capable of magnetic resonance imaging and/or spectroscopy and a second imaging modality being one of PET, SPECT, or computed tomography (CT) imaging. The RTP system **10** includes an anatomical imaging system, in the illustrated embodiment a large bore anatomical scanner **12**, such as a magnetic resonance scanner, housed within a first gantry **14**. A first patient receiving bore **16** defines a first or MR examination region **18** of the MR scanner **12**. The patient receiving bore **16** has a diameter of at least 70cm. However, larger bore diameters, such as 85 cm, are also contemplated. Larger bore MR scanners can be realized by increasing the clear bore of the superconducting magnet, and increasing the diameter of RF body coil and gradient coil components within the bore. The reduced efficiency of RF body coil (for transmit function) and gradient coil components can be offset somewhat by use of increased RF amplifier power and gradient amplifier power. The MR scanner includes a main magnet **20** which generates a temporally stable and spatially uniform B_0 field through the first examination region **18**. Gradient magnetic field coils **22** disposed adjacent the main magnet serve to generate magnetic field gradients along selected axes relative to the B_0 magnetic field for spatially encoding magnetic resonance signals, for producing magnetization-spoiling field gradients, or the like. The magnetic field gradient coil **22** may include coil segments configured to produce magnetic field gradients in three orthogonal directions, typically longitudinal or z, transverse or x, and vertical or y-directions. The gradient coils maybe recessed into the main magnet to accommodate the increased bore diameter.

[0015] A radio-frequency (RF) coil assembly **24**, such as a whole-body radio frequency coil, is disposed adjacent the examination region. The RF coil assembly generates radio frequency B_1 pulses for exciting magnetic resonance in the aligned dipoles of the subject. The radio frequency coil assembly **24** also serves to detect magnetic resonance signals emanating from the imaging region within a field-of-view (FOV) having a cross-sectional diameter of at least 55cm. Receive-only RF coils may also be used for detection of the magnetic resonance signals. A larger FOV of approximately 60-65cm can be achieved with the larger 85cm bore. Optional localized iron boosters are incorporated into the RF coil assembly **24** to achieve the larger cross-sectional FOV without truncating the axial FOV. In this arrangement, the axial FOV is increased proportionally to the increase of the cross-sectional FOV, by magnet design, or optionally the axial FOV is maintained to be similar to smaller bore (e.g., 60 cm bore) MR systems to create an oblate spherical or ellipsoidal imaging volume. In large bore MR systems,

typically there are no provisions for extending the axial FOV beyond that of a conventional 60cm bore system.

[0016] The second imaging system, in the illustrated embodiment a functional scanner **26**, such as a PET scanner, is housed within a second gantry **28** which defines a second patient receiving bore **30**. The patient receiving bore **30** has a diameter of at least 70cm. However, larger bore diameters, such as 85 cm, are also contemplated. It should be appreciated that a CT scanner, SPECT scanner, or the like, is also contemplated. A stationary ring of radiation detectors, such as a layer of optical detectors **32** optically coupled to a scintillator layer **34**, is arranged around the bore **30** to define a second or PET examination region **36**. An RF shield **38** is optionally disposed on the face of the optical detector **32** and scintillator **34** assembly and, in some embodiments, extends down the front and rear ends of the detector assembly. The RF shield **38** shields RF noise emanating from the PET scanner that may interfere with MR scanning. Where the PET (or SPECT) scanner utilizes conventional photo multiplier tubes (PMTs) as optical detectors, they would incorporate magnetic shielding material to reduce effects of the fringe magnetic field of the MR system on the PMTs. Where solid state detectors are used magnetic shielding can be eliminated (but RF shielding would still be utilized). The RF shielding is also beneficial in the event the leakage RF field from RF pulses of the MR scanner **12** could excite or interfere with scintillators associated electronics. Therefore, the RF shield **38** also acts to reduce the RF interference originating from the optical detectors **32** and associated circuitry. The scintillator layer **34** is constantly emitting optical radiation which triggers an electrical response from the optical detectors. This electrical response generates RF interference which can adversely affect the MR signal to noise ratio. In a SPECT scanner, the detectors **32** are incorporated into individual heads, which are mounted for rotation about the second bore **30** and radial movement relative to the subject.

[0017] To acquire magnetic resonance data of a subject, the subject is positioned inside the MR examination region **18**, preferably at or near an isocenter of the main magnetic field. A scan controller **40** controls a gradient controller **42** which causes the gradient coils **22** to apply the selected magnetic field gradient pulses across the imaging region, as may be appropriate to a selected magnetic resonance imaging or spectroscopy sequence. The scan controller **40** controls an RF transmitter **44** which causes the RF coil assembly **24** to generate magnetic resonance excitation and manipulation B_1 pulses. The scan controller also controls one or more RF receivers **46** which are connected to the RF coil assembly **24** to receive the generated magnetic resonance signals therefrom. The received data from the receivers **46** is temporarily stored in a data buffer **48** and processed by a MR data processor **50**. The MR data processor **50** can perform various functions as are known in the art, including image reconstruction (MRI), magnetic resonance spectroscopy (MRS), and the like. Reconstructed magnetic resonance images, spectroscopy readouts, and other processed MR data are stored in an MR image memory **52.**

[0018] To acquire nuclear imaging data, the patient is positioned in the PET examination region **36.** The PET scanner **26** is operated by a PET scan controller **60** to perform selected imaging sequences of the selected target area. Typically, an object or patient to be imaged is injected with one or more radiopharmaceutical or radioisotope tracers then placed in the PET examination region **36.** Examples of such tracers for PET are 18F-FDG, C-11, and for SPECT are Tc-99m, Ga67, and In-111. For SPECT tracers, gamma radiation is produced directly by the tracer. For PET, the presence of the tracer within the object produces emission radiation from the object. Radiation events are detected by the scintillator detectors **34** around the examination region **36.** A time stamp is associated with each detected radiation event by a time stamp unit **62.** A coincidence detector **64** determines coincident pairs of γ rays and the line of responses (LOR) defined by each coincident pair of γ rays based on differences in detection time of the coincidence pairs and the known diameter of the field of view. A reconstruction processor **66** reconstructs all the LORs into an image representation which is stored in a functional image memory **68.** Optionally, a time-of-flight processor **70** localizes each radiation event by deriving time-of-flight information from the timestamps for each LOR.

[0019] In one embodiment, the patient is positioned first in the nuclear scanner **26** and imaged. After the nuclear image data is acquired, selected components of the nuclear scanner **26** are powered down, and in the case of PMTs the applied bias voltage is temporarily lowered to reduce/stop the emission of RF signals that could interfere with the MR scanner **12** during image acquisition. The patient support is translated into the MR examination region **18** and the MR scanner **12** acquires MR imaging data, including data for attenuation correction of the PET data, for reconstruction. Once the MR data acquisition is complete, the selected components of the nuclear scanner **26** are powered up. By the time the current patient leaves the examination room and the next patient arrives and is prepared for imaging, the nuclear scanner **26** is fully operational and ready for nuclear image data acquisition of the patient. If the nuclear detectors have not reached their nominal operating temperature, heating elements **72** can accommodate the process. In another embodiment, the optical detectors **32** and associated circuitry of the nuclear scanner **26** are selectively powered down during an MR procedure. To recommence normal operation of the PET scanner **26,** a heating element **72** rapidly increases the optical detectors **32** temperature to a nominal operating temperature after a prolonged quiescent period or maintains a minimum operating temperature during the quiescent period. The nuclear scanner **26** can be placed in a quiescent mode which includes powering down or by reducing power supplied to the op-

tical detectors **32** to reduce RF interference. After a quiescent period, the scanner is activated or placed in an active mode with the optional aid of the heating element **72** to acquire nuclear imaging data. The heating element **72** can be a resistive heating element, a warm air conduit, a fluid radiator, or the like. In another embodiment, the PET circuitry **60**, **62**, **64**, **66**, **68**, **70** are disposed outside of the examination room to reduce RF interference. Alternatively or additionally, the MR scanner **12** can be placed in a quiescent (reduced RF noise) mode during the nuclear imaging procedure.

[0020] The diagnostic imaging system **10** includes a workstation or graphic user interface (GUI) **80** which includes a display device **82** and a user input device **84** which a clinician can use to select scanning sequences and protocols, display image data, and the like.

[0021] The two gantries **14**, **28** are adjacent to one another in a linear arrangement and in close proximity to one another. The gantries **14**, **28** share a common radiation therapy planning (RTP) couch **90** that translates along a longitudinal axis between the two examination regions **18**, **36** along a patient support track or path **92**. Optionally the couch is of a rotating design to accommodate rotation of the patient between PET and MR scanners, along with linear travel through each. A motor or other drive mechanism (not shown) provides the longitudinal movement and vertical adjustments of the support in the examination regions **18**, **34**. Optionally, the RTP couch **90** includes retractable rails **93**, shown in the retracted position, to keep the patient on the couch during transit. In the illustrated embodiment, the second gantry **28** translates along a gantry track **94** to reduce the patient's transit time between the two imaging systems **12**, **26**. A closed arrangement between gantries reduces the likelihood of patient movement and misregistration errors. The gantries can be separated to reduce interference between the imaging modalities. For example, the optical detectors **32** of the PET scanner **26** emit RF signals which may interfere with resonance detection of the MR scanner **12.** Also, the magnetic fringe field of the MR scanner reduces with distance from the scanner. In one embodiment, the gantries **14**, **28** can be brought together to reduce the possibility of patient misalignment or they can be move apart to reduce the interference between the nuclear and MR scanners **12**, **26** by moving one or both of the scanner **12**, **26** along the tracks **94**.

[0022] In radiation therapy planning, the patient must be in the same fixated position during the pre-treatments, between-treatments, and post-treatments image acquisitions as for during the radiation treatments procedure. Radiation treatment procedures in many cases include a series of planned (fractionated) dose deliveries. The RTP couch **90** is detachable from the patient support track **92** for use in the radiation therapy system. By using the same couch for therapy planning and therapy delivery, image registration errors, positioning errors stemming from geometrical inaccuracies between the two couches are reduced or avoided.

[0023] A radiation treatment system tabletop is optionally larger than a conventional MR or nuclear imaging system patient support to accommodate various patient positions which aims to achieve an optimal treatment path to the target region. In either imaging system, the patient support and in some cases positioning/fixation of the patient with extremities elevated, is limited by the size of the bore, generally 60cm for conventional MR systems and 70cm for conventional PET systems, which in turn limits the available patient positions. This is one reason that radiation therapy planning is typically performed using computer tomography (CT) systems with larger bores (~80-85 cm) that can accept the larger radiation therapy couches. However, planning with CT systems is done at the cost of exposing already vulnerable patients to even more ionizing radiation which can have additional long term adverse side effects. Also, with additional ionizing radiation dose from CT there is a reluctance to perform intra-treatment imaging to assess treatment response or organ shift/changes for re-planning purposes. With MR this concern diminishes. However, CT is established for RTP since the attenuation properties of the tissue are directly obtained, hard tissue is imaged well and good geometric accuracy is achieved. With this in mind, an alternate embodiment includes large bore CT-MR combination for RTP. CT is presently the gold standard for RTP, but it is of medical benefit to have MR data to fuse with the CT data to improve the RT planning, to account for soft tissue structures or vessels near the tumor for example, as part of the treatment plan. Also, as mentioned, it is of benefit to use MR for tumor response monitoring/follow up due to the lack of additional ionizing radiation. Similar to the described large bore Nuclear Medicine (NM), e.g., PET, scanner and MR scanner, with RTP couch/flat tabletop, the NM scanner may instead be a large bore CT scanner. In this embodiment, a CT contrast agent replaces the PET contrast agent. In this way, a single workflow session for a given patient may be realized efficiently for RTP, where patient movement is minimized between the CT and MR image acquisitions with improved co-registration. Preferably the CT and MR scanners are in the same room. In an additional alternate embodiment, they are close spatially and the shared couch for RTP additionally includes a trolley that allows for easy transport of the fixated patient on flat tabletop, from one system to the other. In the described cases of CT+MR, CT may be used for RTP with MR data acquired and fused for improved planning, MR may be used for RTP, and either or both CT and MR may be used for treatment response/effectiveness monitoring (preferably MR). In another embodiment, a nuclear medicine scanner and a combined MR/CT scanner are provided. The NM and CT scanners can be used for planning and the NM and MR scanners can be used periodically for follow-up examinations to monitor progress.

[0024] The RTP system **10** includes the larger bores **16**, **36**, with a diameter of 70cm or greater, and preferably 80-85 cm, which is large enough to accommodate the

RTP couch **90** having dimensions replicating that of the corresponding radiation treatment system. In this arrangement, accurate patient positioning is reproduced between the RTP system **10** and the radiation treatment system to monitor treatment progress between fractions, or after several fractions, without introducing harmful additional ionizing radiation to the patient.

[0025] The RTP couch **90**, and analogous treatment system couch, are flat rather than concave or curved such as in conventional imaging systems. Conventional imaging systems typically have a concave shape to conform to the circular opening of the bore and to limit the patient's movement. The vertical and longitudinal motion of the couch **90** is accurate and reproducible. The RTP couch **90** includes a plurality of the mounting structures **96**, such as mounting holes, fixtures, or the like for accommodating various specialized attachments and restraints for precisely and repeatedly immobilizing the patient in a common, fixed position during the multiple fractions of a treatment cycle. The couch **90** and restraints are compatible for both MR imaging and nuclear and CT imaging and should not include any substantial artifact producing objects or materials. For example, the couch **90** is nonferromagnetic, has low RF loss, and does not generate a proton signal to meet MR compatibility criteria. For nuclear and CT imaging compatibility, the couch 90 has low gamma ray and X-ray attenuation and scatter in the energy ranges used for imaging. These criteria for MR can generally be achieved with mechanical design, glass and/or kevlar reinforced plastics, with some degree of gamma ray and X-ray attenuation, which for nuclear and CT imaging compatibility can be modeled and quantified for the RTP couch **90** and MR coil or patient fixation accessories, and accounted for by the respective reconstruction processors **50**, **66**.

[0026] Registration marks, fiducial markers, **98** in FIGURE 1, or a combination of the two are incorporated into or on the surface of the couch **90** which registers the couch relative to the image scanners **12, 26** and the subject. In one embodiment, a patient registration system **100** detects the registration marks, e.g. grids, lines, points, or the like, or the fiducial markers **98.** The patient registration system **100** includes at least one of a gantry laser **102,** a wall mounted laser (not shown), an overhead (not shown), or any combination thereof which have precise spatial relationships to the isocenter of the two examination regions **18, 36.** The lasers generate a signal representative of the three dimensional (3D) spatial position of the registration marks according to the laser angle and measured distance relative to the examination regions **18, 36.** A registration processor **104** determines the three dimensional spatial coordinates of the registration marks according to these signals and compares the actual coordinate position of the registration marks to the expected coordinate position. The patient can be tattooed with registration marks which are then detectable by the patient registration system **100** for localization. The registration processor **104** determines the comparison between the actual coordinate position, received from the registration system **100**, and the expected coordinate position of the registration marks and generates a feedback signal which is displayed on the GUI **80** for advising a clinician. A similar feedback signal is generated by the registration processor **104** for registering the RTP couch **90** to the corresponding examination region **18, 36.** The generated signal instructs the controller **40, 60** of each respective imaging scanner **12, 26** to adjust the vertical and/or horizontal position of the RTP couch **90** accordingly.

[0027] In another embodiment, fiducial markers, which are imageable by the both scanners **12, 26,** are affixed to the mounting structures **96** of the RTP couch **90** and/or the patient, or to fixation devices attached to the patient. Localization scans are performed to determine the 3D coordinate positions of the fiducial markers relative to the imaging region **18, 36.** The registration processor **104** determines the actual coordinate positions of the fiducials from the localization scans and compares them to the expected coordinate positions. The registration processor **104** instructs the clinician via the GUI **80** to reposition the patient or instructs the respective scanner controllers to reposition the RTP couch **90.** It should be appreciated that the fiducial markers can be detectable by the patient registration system **100** such that the patient and the couch **90** can be registered using either the imaging scanners **12, 26** or the patient registration system **100** with the fiducial markers. The fiducial markers may be visible in the individual modality image data sets to ease the registration of multiple modality image data sets for a fused image display for RTP and treatment monitoring. In a preferred workflow for monitoring, the patient returns for scanning, their fixation and fiducial marker arrangement is applied, and the newly acquired image data are optionally (and automatically) fused with the image data pre-treatment.

[0028] With reference to FIGURE 2, in pre-treatment radiation therapy planning, the target volume, which is to receive therapeutic radiation doses, is imaged then localized **S102** relative to the MR imaging region **18** using the MR scanner **12** after the nuclear scanner **26** is place in a quiescent mode **S100**. The quiescent mode refers to an operating mode in which the scanner does not emit any noise, e.g. electrical or RF, that can potentially cause interference with the functioning of the other scanner. MR imaging of the target region generates anatomical data regarding the shape, size and position for the target region. MR imaging is superior to CT imaging for delineating tumor soft tissue versus healthy tissue as well as surrounding soft tissue or vessel structures. CT is superior to MR imaging for imaging of harder tissues, including bone, and also remains preferred in some conditions for very fast scanning in certain body applications where motion artifacts due to breathing affect image quality. Once the target region is localized, the patient position and the target volume are registered to the RTP couch **S104** using the patient registration system **100.** The registration

process determines the expected coordinate position of the registration marks on the patient and the RTP couch **90.** The nuclear scanner **26** is placed in an active mode **S106** with the optional aid of the heating element **72.** To prepare for nuclear image data acquisition, the patient is injected, or was previously injected prior to the start of the MR study, with a radio-isotope **S108**. The MR scanner **12** is placed in a quiescent mode **S110** and the nuclear scanner **26** is optionally moved adjacent to the MR scanner **S112** to reduce the longitudinal distance the patient travels between the MR and the nuclear imaging regions **18, 36.** The MR scanner is placed in a quiescent mode during the acquisition of a pre-treatment nuclear image representation of the target region **S114**. Nuclear imaging, such as PET, offers functional data rather than anatomical data of the target region, such as characterizing cell proliferation to show presence of tumors, blood flow, cell necrosis, hypoxia, or the like of the target region. The functional data can be useful for updating a generated treatment plan during the treatment cycle to account for increases or decreases in tumor malignancy, cell death, or other clinically significant findings. The registered pre-treatment image representations from the MR and PET scanners **12, 26** are combined **S116** into a composite image by a fusion processor **110.** The fused image is analyzed by a planning processor **112** which generates or updates a treatment plan **S118** according to the anatomical and functional characteristics of the target region. The generated or updated radiation treatment plan from **S118** is carried out by a separate radiation treatment system according to the generated or updated treatment plan **S120** such that the patient is positioned on a treatment couch, of the radiation treatment system, according to the determined expected coordinate position. In another embodiment, the fixated patient is transported from the RTP system **10** to the radiation treatment system on a trolley such that the patient is imaged and treated on the same RTP couch **90.** The treatment plan is of course overseen, adjusted and approved by a treatment specialist, such as a radiation oncologist. Visualization of the treatment plan may be on the graphical user interface (GUI) **80** or on a separate Treatment Planning GUI (not shown) interfaced to the planning processor **112**.

[0029] With reference to FIGURE 3, to prepare for nuclear image data acquisition, the patient is injected, or was previously injected prior to the start of the MR study, with a radio-isotope **S200** and the MR scanner **12** is place in a quiescent mode **S202**. The target volume, which is to receive therapeutic radiation doses, is then imaged and localized **S204** relative to the nuclear imaging region **36** using the nuclear scanner **26**. Nuclear imaging of the target region generates functional data regarding the characterization of cell proliferation to show presence of tumors, blood flow, cell necrosis, hypoxia, or the like of the target region. The functional data can be useful for updating a generated treatment plan during the treatment cycle to account for increases or decreases in malignancy or cell death. Once the target region is localized, the patient position and the target volume are registered to the RTP couch **S206** using the patient registration system **100**. The registration process determines the expected coordinate position of the registration marks on the patient and the RTP couch **90**. The MR scanner **12** is placed in an active mode **S208** while to nuclear scanner **26** is placed in a quiescent mode **S210** and optionally moved adjacent **S212** to the MR scanner **12** to reduce the longitudinal distance the patient travels between the MR and the nuclear imaging regions **18**, **36**. MR imaging of the target region generates anatomical data regarding the shape, size and position for the target region rather than functional data. MR imaging is superior to CT imaging for delineating tumor soft tissue versus healthy tissue. as well as surrounding soft tissue or vessel structures. CT is superior to MR imaging for imaging of harder tissues, including bone, and also remains preferred in some conditions for very fast scanning in certain body applications where motion artifacts due to breathing affect image quality. After MR image data acquisition **S214**, the registered pre-treatment image representations from the MR and nuclear scanners **12**, **26** are combined **S216** into a composite image by a fusion processor **110**. The fused image is analyzed by a planning processor **112** which generates or updates a treatment plan **S218** according to the anatomical and functional characteristics of the target region. The radiation treatment is carried out by a radiation treatment system according to generated or updated treatment plan **S120** such that the patient is positioned on a treatment couch, of the radiation treatment system, according to the determined expected coordinate position. The treatment plan is of course overseen, adjusted and approved by a treatment specialist, such as a radiation oncologist. Visualization of the treatment plan may be on the graphical user interface (GUI) **80** or on a separate Treatment Planning GUI (not shown) interfaced to the planning processor **112**.

[0030] Although described above with the anatomical images being taken prior to the functional images, it is to be appreciated that the order can be reversed.

[0031] With reference to FIGURE 4, since the patient is not subjected to the harmful additional ionizing radiation of CT imaging, intra-treatment MR, or MR and NM, imaging and monitoring can be performed more often, such as before and after each treatment session. After the patient and the RTP couch **90** are registered **S200** according to the expected coordinate position of the patient during the planning process, MR and nuclear images of the target region are acquired **S202** and combined **S204** with the fusion processor **112.** The planning processor **112** analyzes the fused image representation **S206** and determines whether to update the current treatment plan **S208** and administer the updated treatment plan **S210**, continue with the current treatment plan and administer the treatment fraction again **S212**, or to end the treatment cycle **S214** because the target volume has been eradicated or is no long malignant. In some cases only MR data may be acquired for the treatment moni-

toring phase.

[0032] The invention has been described with reference to the preferred embodiments. Modifications and alterations may occur to others upon reading and understanding the preceding detailed description. It is intended that the invention be constructed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.

Claims

1. A radiation therapy planning and follow-up system (10), comprising:

a magnetic resonance (MR) scanner (12) with a first bore (16) which defines an MR imaging region (18) that is configured to receive a subject along an MR longitudinal axis;
a second imaging scanner (26) with a second bore (30) which defines a second imaging region (36) that is configured to receive the subject along a second longitudinal axis, the second longitudinal axis being aligned with the MR longitudinal axis ; and wherein the second imaging scanner (26) is selected from the group: a PET imaging scanner, a SPECT imaging scanner, a computed tomography imaging scanner; and
a radiation therapy couch (90) that is configured to move linearly along a patient support track (92) through the MR and second imaging regions (18, 36) for positioning the subject sequentially in the MR and second imaging regions (18, 36), **characterised in that**:

the radiation therapy couch (90) is detachable from the patient support track (92) for use in a radiation therapy system; and
the first bore (16) and the second bore (30) having a diameter of at least 70 cm.

2. The radiation therapy planning and follow-up system (10) according to claim 1, further including:

a fusion processor configured to combine an image representation generated from data collection in the MR imaging region (18) and an image representation generated from data collection in the second imaging region (36) into a composite image representation; and
a planning processor (112) configured to generate a radiation therapy treatment plan according to the composite image representation.

3. The radiation therapy planning and follow-up system (10) according to either one of claims 1 and 2, wherein the radiation therapy couch (90) includes:

at least one mounting structure (96) configured to accept a variety of restraint devices which are configured for immobilizing the subject in a selected, fixed position; and
a plurality registration marks (98) disposed on a surface of the radiation therapy couch (90) or incorporated therein.

4. The radiation therapy planning and follow-up system (10) according to any one of claim 1-3, further including:

a patient registration system (100) configured to register a position of the radiation therapy couch (90) relative to the subject and to the MR and second scanners (12, 26) which includes:

at least one laser (102) having a precise relationship to an isocenter of the MR and second imaging regions (18, 36) wherein the laser is configured to generate a signal representative of a location of each of a plurality registration marks (96) disposed on the subject, on fixation devices attached to the patient, and/or on the radiation therapy couch (90); and
a registration processor (104) configured to determine the three-dimensional coordinate position of each registration mark according to the generated signal.

5. The radiation therapy planning and follow-up system (10) according to any one of claims 1-4, further including:

registration marks which are detectable by both the MR and second scanner (12, 26) and a registration processor (104), configured to determine a coordinate position of the registration marks from scans of the MR and second imaging regions (18, 36).

6. The radiation therapy planning and follow-up system (10) according to either one of claims 4 and 5, wherein the second imaging scanner is a PET imaging scanner and wherein the registration processor (104) is configured to generate a feedback signal based on an actual coordinate position and an expected coordinate position of each registration mark and at least one of:

displays the generated feedback signal on a graphical user interface (80);
instructs at least one of a MR scan controller (40) and a PET scan controller (60) to adjust the position of the radiation therapy couch (90) and/or the slice or slab positions for image acquisition; and

provides the feedback signal to a fusion processor (110) which combines the PET and MR image representations.

7. The radiation therapy planning and follow-up system (10) according to any one of claims 1-6, wherein the second imaging scanner (26) is a PET imaging scanner (26) with a PET bore (30) which defines a PET imaging region (36), the PET imaging scanner (26) including:

a ring of optical detectors (32) disposed adjacent to the PET imaging region (36) and optically coupled to a scintillator layer (34), the ring of optical detectors (32) being configured to generate PET imaging data in response to emitted radiation in the PET imaging region; and
a radio-frequency shield (38) disposed between the scintillator layer (34) and the PET imaging region (38), wherein said radio-frequency shield optionally surrounds the PET imaging scanner in entirety.

8. The radiation therapy planning and follow-up system (10) according to claim 7, wherein the PET imaging scanner (26) further includes:

a heating element (72), such as a resistive heating element, a warm air conduit, or a fluid reservoir, that is disposed adjacent to the optical detectors (32) wherein the heating element (72) is configured to increase a temperature of the optical detectors and associated circuitry to a nominal operating temperature or is configured to maintain a minimum operating temperature,; and
wherein the optical detectors (32) are photomultiplier tube optical detectors;
wherein the PET imaging scanner (26) further includes:

a circuit that is configured to temporarily lower an operating voltage in the photo-multiplier tube optical detectors.

9. The radiation therapy planning and follow-up system (10) according to any one of claims 1-8, wherein the radiation therapy planning and follow-up system (10) is disposed on a mobile platform which can be transported from one location to another.

10. A method for generating or updating a radiation therapy plan, comprising the steps of:

positioning a subject supported by a radiation therapy couch (90) in one of an MR imaging region (18) of an MR scanner (12) and a second imaging region (36) of a second imaging scanner (26) wherein the second imaging scanner (26) is a PET imaging scanner or a SPECT imaging scanner;
acquiring an MR or a PET or a SPECT image representation of a target volume and localizing the target volume relative to the corresponding imaging region (18, 36);
registering the localized target volume to the radiation therapy couch (90) and determining an expected coordinate position of the patient relative to the radiation therapy couch (90);
re-positioning the subject linearly along a patient support track (92) from one of the MR imaging region (18) and the second imaging region (36) to the other imaging region (18, 36) of the second imaging scanner (26) and the MR scanner (12) which shares a common longitudinal axis therewith;
acquiring an image representation of the target volume with the other one of the second and the MR scanner (12, 26);
combining the MR and second image representations in a combined image representation; and
generating or updating a radiation therapy plan according to the acquired MR and second image representations; and
detaching the radiation therapy couch (90) from the patient support track (92) for use in a radiation therapy system;
wherein a first bore (16) which defines the MR imaging region (18) and a second bore (30) which defines the second imaging region (36) each have a diameter of at least 70 cm.

11. The method according to claim 10, further including the steps of:

prior to acquiring the MR image representation, placing the second imaging scanner (26) in a quiescent mode and optionally translating the second imaging scanner (26) away from the MR scanner (12) along a gantry track (94) such that the scanners (12, 26) are non-adjacent to one another; and
after acquiring the MR image representation, placing the second imaging scanner (26) in an active mode and optionally translating the second imaging scanner (26) towards the MR scanner (12) along a gantry track (94) such that the scanners (12, 26) are adjacent to one another.

12. The method according to any one of claims 10 and 11, further including the steps of:

prior to acquiring the second image representation, placing the MR scanner (12) in a quiescent mode and optionally translating the second imaging scanner (26) towards the MR scanner (12)

along a gantry track (94) such that the scanners (12, 26) are adjacent to one another; and
after acquiring the second image representation, placing the MR scanner (12) in an active mode and optionally translating the second imaging scanner (26) away from the MR scanner (12) along a gantry track (94) such that the scanners (12, 26) are non-adjacent to one another.

13. The method according to either one of claims 11 and 12 further including the steps of:

while the second imaging scanner (26) is in the quiescent mode, maintaining a minimum operating temperature of optical detectors (32) of the second imaging scanner (26).

14. The method according to claim 13, further including the step of:

while placing the second imaging scanner (26) in the active mode, heating optical detectors (32) of the second imaging scanner (26) to a nominal operating temperature.

15. The method according to any one of claims 12 and 13, further including the step of:

shielding optical detectors and electronics (32) of the second imaging scanner (26) from RF and static magnetic field interference of the MR scanner (12).

Patentansprüche

1. Strahlentherapieplanungs- und Nachsorgesystem (10), das Folgendes umfasst:

einen Magnetresonanz (MR)-Scanner (12) mit einem ersten Tunnel (16), der eine MR-Bildgebungsregion (18) definiert, die dafür eingerichtet ist, einen Patienten entlang einer MR-Längsachse aufzunehmen;
einen zweiten Bildgebungsscanner (26) mit einem zweiten Tunnel (30), der eine zweite Bildgebungsregion (36) definiert, die dafür eingerichtet ist, den Patienten entlang einer zweiten Längsachse aufzunehmen, wobei die zweite Längsachse mit der MR-Längsachse ausgerichtet ist;
und wobei der zweite Bildgebungsscanner (26) ausgewählt wird aus der Gruppe bestehend aus: einem PET-Bildgebungsscanner, einem SPECT-Bildgebungsscanner und einem Computertomographie-Bildgebungsscanner; und
eine Strahlentherapieliege (90), die dafür eingerichtet ist, sich linear entlang einer Patientenauflageschiene (92) durch die MR- und die zweite Bildgebungsregion (18, 36) zu bewegen, um den Patienten sequentiell in der MR-Bildgebungsregion und der zweiten Bildgebungsregion (18, 36) zu positionieren, **dadurch gekennzeichnet, dass**:

die Strahlentherapieliege (90) von der Patientenaufnahmeschiene (92) abnehmbar ist, um in einem Strahlentherapiesystem verwendet zu werden; und
der erste Tunnel (16) und der zweite Tunnel (30) einen Durchmesser von mindestens 70 cm haben.

2. Strahlentherapieplanungs- und Nachfolgesystem (10) nach Anspruch 1, das weiterhin Folgendes umfasst:

einen Fusionsprozessor, der dafür eingerichtet ist, eine anhand der Datensammlung in der MR-Bildgebungsregion (18) erzeugte Bilddarstellung und eine anhand der Datensammlung in der zweiten Bildgebungsregion (36) erzeugte Bilddarstellung zu einer zusammengesetzten Bilddarstellung zu kombinieren; und
einen Planungsprozessor (112), der dafür eingerichtet ist, einen Strahlentherapie-Behandlungsplan gemäß der zusammengesetzten Bilddarstellung zu generieren.

3. Strahlentherapieplanungs- und Nachsorgesystem (10) nach einem der Ansprüche 1 und 2, wobei die Strahlentherapieliege (90) Folgendes umfasst:

wenigstens eine Montagestruktur (96), die dafür eingerichtet ist, eine Vielzahl von Rückhaltevorrichtungen aufzunehmen, die dafür eingerichtet sind, den Patienten in einer ausgewählten, festen Position zu immobilisieren; und
eine Vielzahl von Registrierungsmarken (98), die auf einer Oberfläche der Strahlentherapieliege (90) angeordnet oder darin integriert sind.

4. Strahlentherapieplanungs- und Nachfolgesystem (10) nach einem der Ansprüche 1 bis 3, das weiterhin Folgendes umfasst:

ein Patientenregistrierungssystem (100), das dafür eingerichtet ist, eine Position der Strahlentherapieliege (90) in Bezug auf den Patienten und den MR-Scanner sowie den zweiten Scanner (12, 26) zu registrieren, wobei das Patientenregistrierungssystem Folgendes umfasst:
wenigstens einen Laser (102) mit einer präzisen Beziehung zu einem Isozentrum der MR-Bildgebungsregion und der zweiten Bildgebungsregion (18, 36), wobei der Laser dafür eingerichtet

ist, ein Signal zu erzeugen, das die Lage von jeder der Vielzahl von auf dem Patienten angeordneten Registrierungsmarken (96) auf an dem Patienten angebrachten Fixierungsvorrichtungen und/oder der Strahlentherapieliege (90) angibt; und

einen Registrierungsprozessor (104), der dafür eingerichtet ist, die dreidimensionale Koordinatenposition von jeder der Registrierungsmarken entsprechend dem erzeugten Signal zu ermitteln.

5. Strahlentherapieplanungs- und Nachfolgesystem (10) nach einem der Ansprüche 1 bis 4, das weiterhin Folgendes umfasst:

Registrierungsmarken, die durch sowohl den MR-Scanner und den zweiten Scanner (12, 26) als auch durch einen Registrierungsprozessor (104) detektierbar sind und dafür eingerichtet sind, eine Koordinatenposition der Registrierungsmarken anhand von Scans der MR-Bildgebungsregion und der zweiten Bildgebungsregion (18, 36) zu ermitteln.

6. Strahlentherapieplanungs- und Nachfolgesystem (10) nach einem der Ansprüche 4 und 5, wobei der zweite Bildgebungsscanner ein PET-Bildgebungsscanner ist und wobei der Registrierungsprozessor (104) dafür eingerichtet ist, ein Rückmeldesignal basierend auf einer tatsächlichen Koordinatenposition und einer erwarteten Koordinatenposition jeder Registrierungsmarke zu erzeugen und wenigstens entweder:

das erzeuge Rückmeldesignal auf einer graphischen Benutzeroberfläche (80) anzuzeigen;

wenigstens entweder eine MR-Scan-Steuereinheit (40) oder eine PET-Scan-Steuereinheit (60) anzuweisen, die Position der Strahlentherapieliege (90) und/oder die Schicht- oder Slab-Positionen für die Bilderfassung einzustellen; oder

das Rückmeldesignal einem Fusionsprozessor (110) zuzuführen, der die PET-Bilddarstellung und die MR-Bilddarstellung miteinander kombiniert.

7. Strahlentherapieplanungs- und Nachfolgesystem (10) nach einem der Ansprüche 1 bis 6, wobei der zweite Bildgebungsscanner (26) ein PET-Bildgebungsscanner (26) mit einem PET-Tunnel (30) ist, der eine PET-Bildgebungsregion (36) definiert, wobei der PET-Bildgebungsscanner (26) Folgendes umfasst:

einen Ring aus optischen Detektoren (32), die angrenzend an die PET-Bildgebungsregion (36) angeordnet sind und optisch mit einer Szintillatorschicht (34) gekoppelt sind, wobei der Ring aus optischen Detektoren (32) dafür eingerichtet ist, in Reaktion auf in der PET-Bildgebungsregion emittierte Strahlung PET-Bildgebungsdaten zu erzeugen; und

eine Hochfrequenzabschirmung (38), die zwischen der Szintillatorschicht (34) und der PET-Bildgebungsregion (38) angeordnet ist, wobei die genannte Hochfrequenzabschirmung wahlweise den gesamten PET-Bildgebungsscanner umgibt.

8. Strahlentherapieplanungs- und Nachfolgesystem (10) nach Anspruch 7, wobei der PET-Bildgebungsscanner (26) weiterhin Folgendes umfasst:

ein Heizelement (72), zum Beispiel ein ohmsches Heizelement, einen Warmluftkanal oder einen Fluidbehälter, das angrenzend an die optischen Detektoren (32) angeordnet ist, wobei das Heizelement (72) dafür eingerichtet ist, eine Temperatur der optischen Detektoren und der zugehörigen Schaltung auf eine nominale Betriebstemperatur zu erhöhen, oder dafür eingerichtet ist, eine minimale Betriebstemperatur aufrechtzuerhalten; und

wobei die optischen Detektoren (32) optische Detektoren von Fotovervielfacherröhren sind;

wobei der PET-Bildgebungsscanner (26) weiterhin Folgendes umfasst:

eine Schaltung, die dafür eingerichtet ist, eine Betriebstemperatur in den optischen Detektoren der Fotovervielfacherröhre zeitweilig zu senken.

9. Strahlentherapieplanungs- und Nachfolgesystem (10) nach einem der Ansprüche 1 bis 8, wobei das Strahlentherapieplanungs- und Nachfolgesystem (10) auf einer mobilen Plattform angeordnet ist, die von einem Ort zu einem anderen transportiert werden kann.

10. Verfahren zum Erzeugen oder Aktualisieren eines Strahlentherapieplans, das die folgenden Schritte umfasst:

Positionieren eines auf einer Strahlentherapieliege (90) liegenden Patienten in entweder einer MR-Bildgebungsregion (18) eines MR-Scanners (12) oder einer zweiten Bildgebungsregion (36) eines zweiten Bildgebungsscanners (26), wobei der zweite Bildgebungsscanner (26) ein PET-Bildgebungsscanner oder ein SPECT-Bildgebungsscanner ist;

Erfassen einer MR- oder einer PET- oder einer SPECT-Bilddarstellung eines Zielvolumens und Lokalisieren des Zielvolumens relativ zu der ent-

sprechenden Bildgebungsregion (18, 36);
Registrieren des lokalisierten Zielvolumens mit der Strahlentherapieliege (90) und Ermitteln einer erwarteten Koordinatenposition des Patienten in Bezug auf die Strahlentherapieliege (90);
Umpositionieren des Patienten auf lineare Weise entlang einer Patientenauflageschiene (92) aus entweder der MR-Bildgebungsregion (18) oder der zweiten Bildgebungsregion (36) in die andere Bildgebungsregion (18, 36) des zweiten Bildgebungsscanners (26) bzw. des MR-Scanners (12), der eine gemeinsame Längsachse hiermit teilt;
Erfassen einer Bilddarstellung des Zielvolumens mit dem anderen Scanner, also dem zweiten Scanner oder dem MR-Scanner (12, 26);
Kombinieren der MR-Bilddarstellung und der zweiten Bilddarstellung zu einer kombinierten Bilddarstellung; und
Erzeugen oder Aktualisieren eines Strahlentherapieplans entsprechend der erfassten MR-Bilddarstellung und der zweiten Bilddarstellung; und
Abnehmen der Strahlentherapieliege (90) von der Patientenauflageschiene (92) zur Verwendung in einem Strahlentherapiesystem;
wobei ein erster Tunnel (16), der die MR-Bildgebungsregion (18) definiert, und ein zweiter Tunnel (30), der die zweite Bildgebungsregion (36) definiert, jeweils einen Durchmesser von wenigstens 70 cm haben.

11. Verfahren nach Anspruch 10, das weiterhin die folgenden Schritte umfasst:

vor dem Erfassen der MR-Bilddarstellung Platzieren des zweiten Bildgebungsscanners (26) in einen Ruhemodus und wahlweise Verschieben des zweiten Bildgebungsscanners (26) entlang einer Gantry-Schiene (94) von dem MR-Scanner (12) weg, so dass die Scanner (12, 26) nicht aneinander angrenzen; und
nach dem Erfassen der MR-Bilddarstellung Platzieren des zweiten Bildgebungsscanners (26) in einen aktiven Modus und wahlweise Verschieben des zweiten Bildgebungsscanners (26) entlang einer Gantry-Schiene (94) auf den MR-Scanner (12) zu, so dass die Scanner (12, 26) aneinander angrenzen.

12. Verfahren nach einem der Ansprüche 10 und 11, das weiterhin die folgenden Schritte umfasst:

vor dem Erfassen der zweiten Bilddarstellung Platzieren des MR-Bildgebungsscanners (12) in einen Ruhemodus und wahlweise Verschieben des zweiten Bildgebungsscanners (26) entlang einer Gantry-Schiene (94) auf den MR-Scanner (12) zu, so dass die Scanner (12, 26) aneinander angrenzen; und
nach dem Erfassen der zweiten Bilddarstellung Platzieren des MR-Bildgebungsscanners (12) in einen aktiven Modus und wahlweise Verschieben des zweiten Bildgebungsscanners (26) entlang einer Gantry-Schiene (94) von dem MR-Scanner (12) weg, so dass die Scanner (12, 26) nicht aneinander angrenzen.

13. Verfahren nach einem der Ansprüche 11 und 12, das weiterhin die folgenden Schritte umfasst:

Aufrechterhalten einer minimalen Betriebstemperatur der optischen Detektoren (32) des zweiten Bildgebungsscanners (26), während sich der zweite Bildgebungsscanner (26) im Ruhemodus befindet.

14. Verfahren nach Anspruch 13, das weiterhin den folgenden Schritt umfasst:

Aufheizen der optischen Detektoren (32) des zweiten Bildgebungsscanners (26) auf eine nominale Betriebtemperatur, während der zweite Bildgebungsscanner (26) in den aktiven Modus gebracht wird.

15. Verfahren nach einem der Ansprüche 12 und 13, das weiterhin den folgenden Schritt umfasst:

Abschirmen der optischen Detektoren und der Elektronik (32) des zweiten Bildgebungsscanners (26) gegen HF- und statische Magnetfeld-Interferenzen des MR-Scanners (12).

Revendications

1. Système de planification et de suivi de thérapie par rayonnement (10), comprenant :

un scanneur à résonance magnétique (MR) (12) avec un premier alésage (16) qui définit une région d'imagerie MR (18) qui est configurée pour recevoir un sujet le long d'un axe longitudinal MR ;
un second scanneur d'imagerie (26) avec un second alésage (30) qui définit une seconde région d'image (36) qui est configurée pour recevoir le sujet le long d'un second axe longitudinal, le second axe longitudinal étant aligné avec l'axe longitudinal MR ; et
dans lequel le second scanneur d'imagerie (26) est choisi dans le groupe formé d'un scanneur d'imagerie PET, d'un scanneur d'imagerie SPECT et d'un scanneur d'imagerie par tomographie assistée par ordinateur ; et

une couche de thérapie par rayonnement (90) qui est configurée pour se déplacer de manière linéaire le long d'une voie de support de patient (92) à travers la région d'imagerie MR et la seconde région d'imagerie (18, 36) pour positionner le sujet en séquence dans la région d'imagerie MR et la seconde région d'imagerie (18, 36), **caractérisé en ce que** :

la couche de thérapie par rayonnement (90) peut être détachée de la voie de support de patient (92) pour utilisation dans un système de thérapie par rayonnement ; et
le premier alésage (16) et le second alésage (30) ont un diamètre d'au moins 70 cm.

2. Système de planification et de suivi de thérapie par rayonnement (10) selon la revendication 1, comprenant en outre :

un processeur de fusion configuré pour combiner une représentation d'image générée par collecte de données dans la région d'imagerie MR (18) et une représentation d'image générée par collecte de données dans la seconde région d'imagerie (36) afin d'obtenir une représentation d'image composite ; et
un processeur de planification (112) configuré pour générer un plan de traitement en thérapie par rayonnement selon la représentation d'image composite.

3. Système de planification et de suivi de thérapie par rayonnement (10) selon l'une quelconque des revendications 1 et 2, dans lequel la couche de thérapie par rayonnement (90) comprend :

au moins une structure de montage (96) configurée pour accepter une variété de dispositifs de retenue qui sont configurés pour immobiliser le sujet dans une position fixe choisie ; et
une pluralité de marques de repérage (98) disposées sur une surface de la couche de thérapie par rayonnement (90) ou incorporées à celle-ci.

4. Système de planification et de suivi de thérapie par rayonnement (10) selon l'une quelconque des revendications 1 à 3, comprenant en outre :

un système de repérage du patient (100) configuré pour repérer une position de la couche de thérapie par rayonnement (90) par rapport au sujet et au scanneur MR et au second scanneur (12, 26), qui comprend :

au moins un laser (102) ayant une relation précise avec un isocentre de la région d'imagerie MR et de la seconde région d'imagerie (18, 36), dans lequel le laser est configuré pour générer un signal représentatif d'un emplacement de chacune d'une pluralité de marques de repérage (96) disposées sur le sujet, sur des dispositifs de fixation fixés au patient et/ou sur la couche de thérapie par rayonnement (90) ; et
un processeur de repérage (104) configuré pour déterminer la position en coordonnées tridimensionnelles de chaque marque de repérage selon le signal généré.

5. Système de planification et de suivi de thérapie par rayonnement (10) selon l'une quelconque des revendications 1 à 4, comprenant en outre :

des marques de repérage qui peuvent être détectées à la fois par le scanneur MR et le second scanneur (12, 26) et un processeur de repérage (104) configuré pour déterminer une position de coordonnées des marques de repérage à partie de balayages de la région d'imagerie MR et de la seconde région d'imagerie (18,36).

6. Système de planification et de suivi de thérapie par rayonnement (10) selon l'une quelconque des revendications 4 et 5, dans lequel le second scanneur d'imagerie est un scanneur d'imagerie PET et dans lequel le processeur de repérage (104) est configuré pour générer un signal de rétroaction sur la base d'une position de coordonnées courantes et d'une position des coordonnées attendues de chaque marque de repérage et d'au moins une des situations suivantes :

on affiche le signal de rétroaction généré sur une interface utilisateur graphique (80) ;
on instruit au moins l'un d'un contrôleur de balayage MR (40) et d'un contrôleur de balayage PET (60) pour ajuster la position de la couche de thérapie par rayonnement (90) et/ou les positions en tranches ou en plaques pour l'acquisition d'images, et
on fournit le signal de rétroaction à un processeur de fusion (110) qui combine les représentations d'image PET et MR.

7. Système de planification et de suivi de thérapie par rayonnement (10) selon l'une quelconque des revendications 1 à 6, dans lequel le second scanneur d'imagerie (26) est un scanneur d'imagerie PET (26) avec un orifice PET (30) qui définit une région d'imagerie PET (36), le scanneur d'imagerie PET (26) comprenant :

une couronne de détecteurs optiques (32) disposés adjacents à la région d'imagerie PET (36) et optiquement couplés à une couche de scin-

tillateur (34), la couronne de détecteurs optiques (32) étant configurée pour générer des données d'imagerie PET en réponse à un rayonnement émis dans la région d'imagerie PET ; et
un écran de fréquence radio (38) disposé entre la couche de scintillateur (34) et la région d'imagerie PET (38), dans lequel ledit écran de fréquence radio entoure éventuellement le scanneur d'imagerie PET dans sa totalité.

8. Système de planification et de suivi de thérapie par rayonnement (10) selon la revendication 7, dans lequel le scanneur d'imagerie PET (26) comprend en outre :

un élément chauffant (72), tel qu'un élément chauffant à résistance, un conduit d'air chaud ou un réservoir de fluide qui est disposé adjacent aux détecteurs optiques (32), dans lequel l'élément chauffant (72) est configuré pour augmenter la température des détecteurs optiques et des circuits associés à une température de fonctionnement théorique ou est configuré pour maintenir une température de fonctionnement minimale ; et
dans lequel les détecteurs optiques (32) sont des détecteurs optiques à tube photomultiplicateur ;
dans lequel le scanneur d'imagerie PET (26) comprend en outre :

un circuit qui est configuré pour abaisser temporairement une tension de fonctionnement dans les détecteurs optiques à tube photomultiplicateur.

9. Système de planification et de suivi de thérapie par rayonnement (10) selon l'une quelconque des revendications 1 à 8, dans lequel le système de planification et de suivi de thérapie par rayonnement (10) est disposé sur une plateforme mobile qui peut être transportée d'un emplacement à un autre.

10. Procédé de génération ou de mise à jour d'un plan de thérapie par rayonnement, comprenant les étapes consistant à :

positionner un sujet supporté par une couche de thérapie par rayonnement (90) dans l'une d'une région d'imagerie MR (18) d'un scanner MR (12) et d'une seconde région d'imagerie (36) d'un second scanneur d'imagerie (26), dans lequel le second scanneur d'imagerie (26) est un scanneur d'imagerie PET ou un scanneur d'image SPECT ;
acquérir une représentation d'image MR ou PET ou SPECT d'un volume cible et localiser le volume cible par rapport à la région d'imagerie correspondante (18, 36) ;
repérer le volume cible localisé sur la couche de thérapie par rayonnement (90) et déterminer une position de coordonnées attendue du patient par rapport à la couche de thérapie par rayonnement (90) ;
repositionner le sujet de manière linéaire le long d'une voie de support de patient (92) de l'une de la région d'imagerie MR (18) et de la seconde région d'imagerie (36) à l'autre région d'imagerie (18, 36) du second scanneur d'imagerie (26) et du scanneur MR (12) qui partage un axe longitudinal commun avec celui-ci ;
acquérir une représentation d'image du volume cible avec l'autre du second scanneur et du scanneur MR (12, 26) ;
combiner la représentation d'image MR et la seconde représentation d'image dans une représentation d'image combinée ; et
générer ou mettre à jour un plan de thérapie par rayonnement selon la représentation d'image MR et la seconde représentation d'image acquises ; et
détacher la couche de thérapie par rayonnement (90) de la voie de support de patient (92) pour utilisation dans un système de thérapie par rayonnement ;
dans lequel un premier alésage (16) qui définit la région d'imagerie MR (18) et un second alésage (30) qui définit la seconde région d'imagerie (36) ont chacun un diamètre d'au moins 70 cm.

11. Procédé selon la revendication 10, comprenant en outre les étapes consistant à,
avant l'acquisition de la représentation d'image MR, placer le second scanneur d'imagerie (26) en mode de repos et écarter éventuellement par translation le second scanneur d'imagerie (26) du scanneur MR (12) le long d'une piste de roulement (94) de sorte que les scanneurs (12, 26) ne soient pas adjacents l'un avec l'autre ; et,
après l'acquisition de la représentation d'image MR, placer le second scanneur d'imagerie (26) en mode actif et rapprocher éventuellement par translation le second scanneur d'imagerie (26) du scanneur MR (12) le long d'une voie de roulement (94) de sorte que les scanneurs (12, 26) soient adjacents l'un avec l'autre.

12. Procédé selon l'une quelconque des revendications 10 et 11, comprenant en outre les étapes consistant à,
avant l'acquisition de la seconde représentation d'image, placer le scanneur d'imagerie MR (12) en mode de repos et rapprocher éventuellement par translation le second scanneur d'imagerie (26) du scanneur MR (12) le long d'une piste de roulement

(94) de sorte que les scanneurs (12, 26) soient adjacents l'un avec l'autre ; et,
après l'acquisition de la seconde représentation d'image, placer le scanneur d'imagerie MR (12) en mode actif et écarter éventuellement par translation le second scanneur d'imagerie (26) du scanneur MR (12) le long d'une voie de roulement (94) de sorte que les scanneurs (12, 26) ne soient pas adjacents l'un avec l'autre.

13. Procédé selon l'une quelconque des revendications 11 et 12, comprenant en outre l'étape consistant à, tandis que le second scanneur d'imagerie (26) est en mode de repos, maintenir une température de fonctionnement minimale des détecteurs optiques (32) du second scanneur d'imagerie (26).

14. Procédé selon la revendication 13, comprenant en outre l'étape consistant à,
tandis que l'on place le second scanneur d'imagerie (26) en mode actif, chauffer les détecteurs optiques (32) du second scanneur d'imagerie (26) à une température de fonctionnement théorique.

15. Procédé selon l'une quelconque des revendications 12 et 13, comprenant en outre l'étape consistant à :

protéger les détecteurs optiques et l'électronique (32) du second scanneur d'imagerie (26) des interférences du scanner MR (12) dues au champ magnétique RF et au champ magnétique statique.

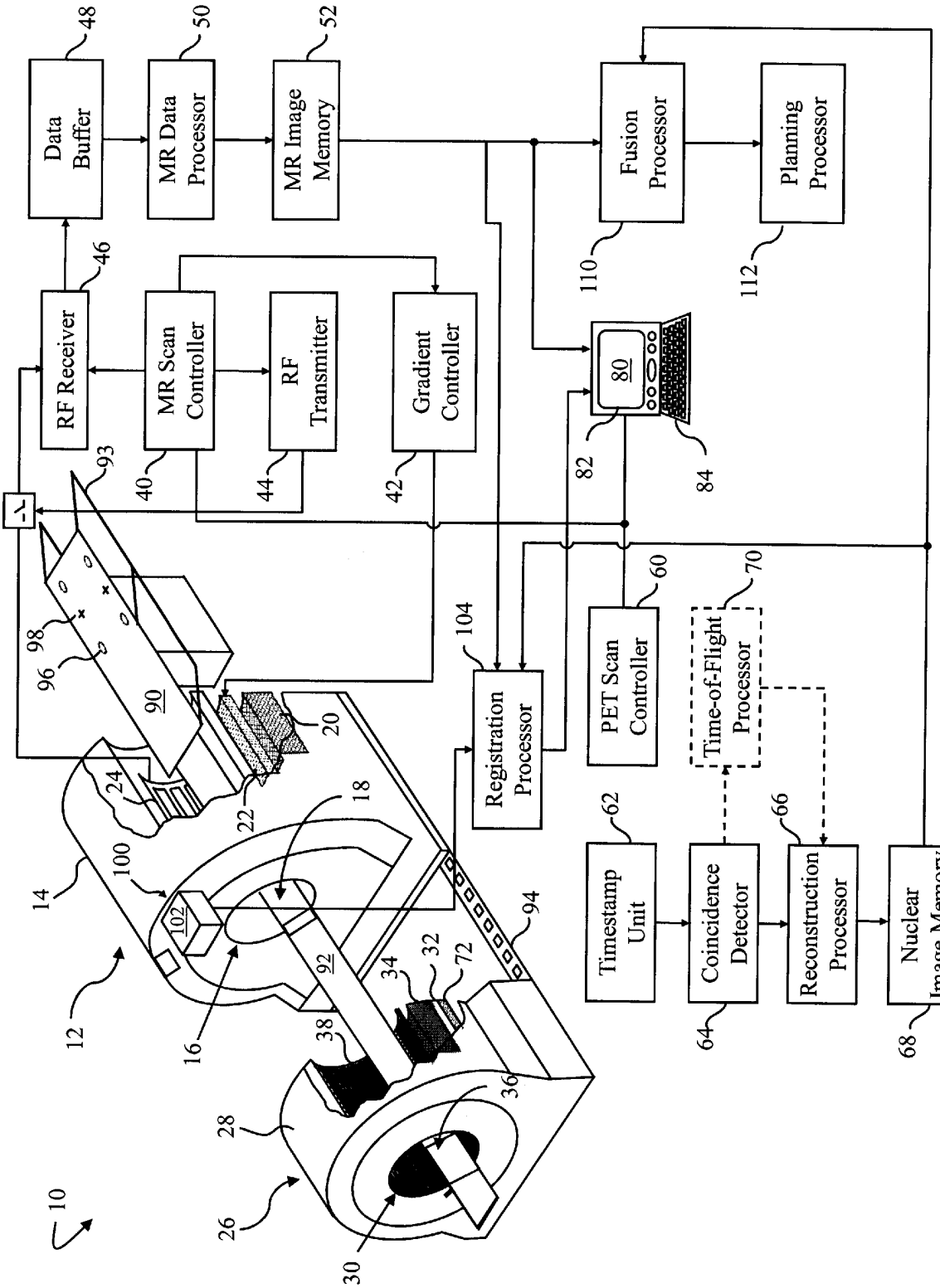
Data Buffer
MR Data Processor
MR Image Memory
Fusion Processor
Planning Processor
RF Receiver
MR Scan Controller
RF Transmitter
Gradient Controller
Registration Processor
PET Scan Controller
Time-of-Flight Processor
Timestamp Unit
Coincidence Detector
Reconstruction Processor
Nuclear Image Memory
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Figure 1

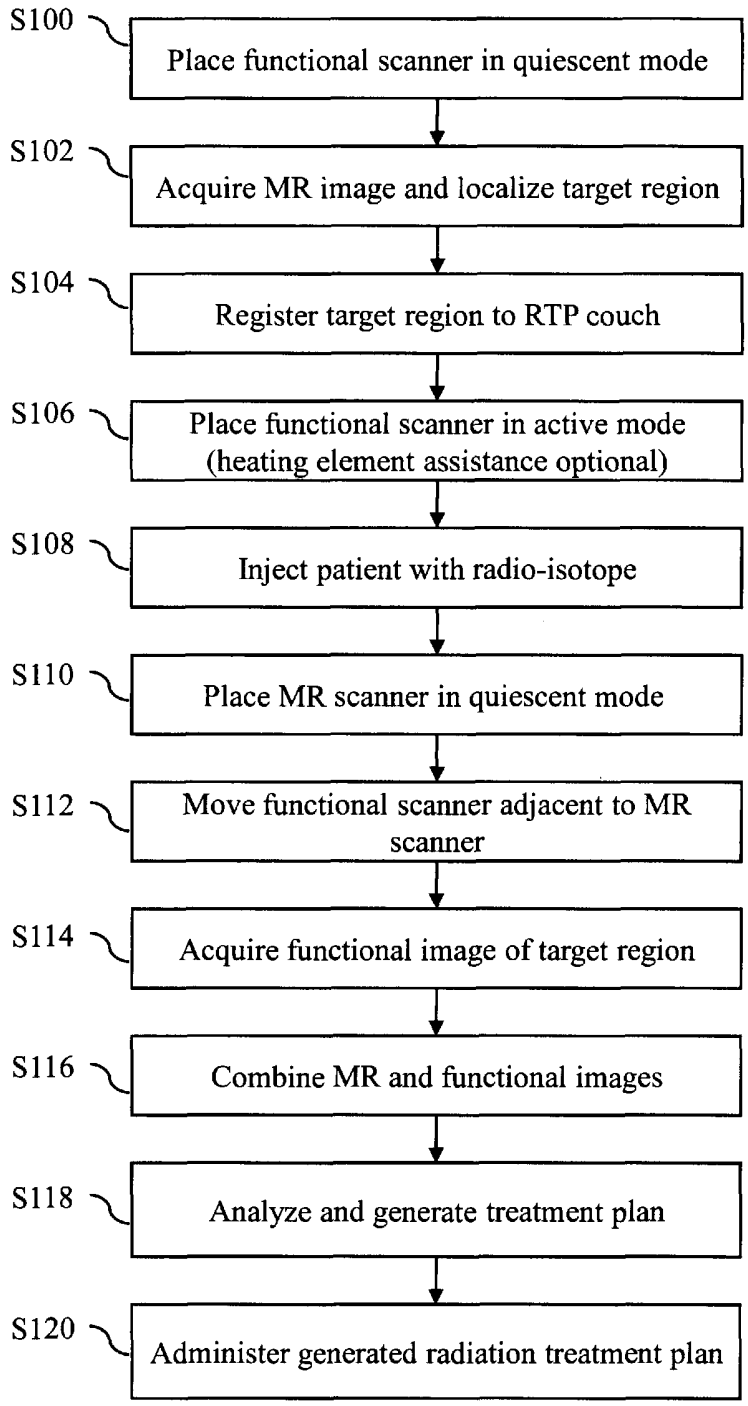
S100
Place functional scanner in quiescent mode
S102
Acquire MR image and localize target region
S104
Register target region to RTP couch
S106
Place functional scanner in active mode (heating element assistance optional)
S108
Inject patient with radio-isotope
S110
Place MR scanner in quiescent mode
S112
Move functional scanner adjacent to MR scanner
S114
Acquire functional image of target region
S116
Combine MR and functional images
S118
Analyze and generate treatment plan
S120
Administer generated radiation treatment plan

Figure 2

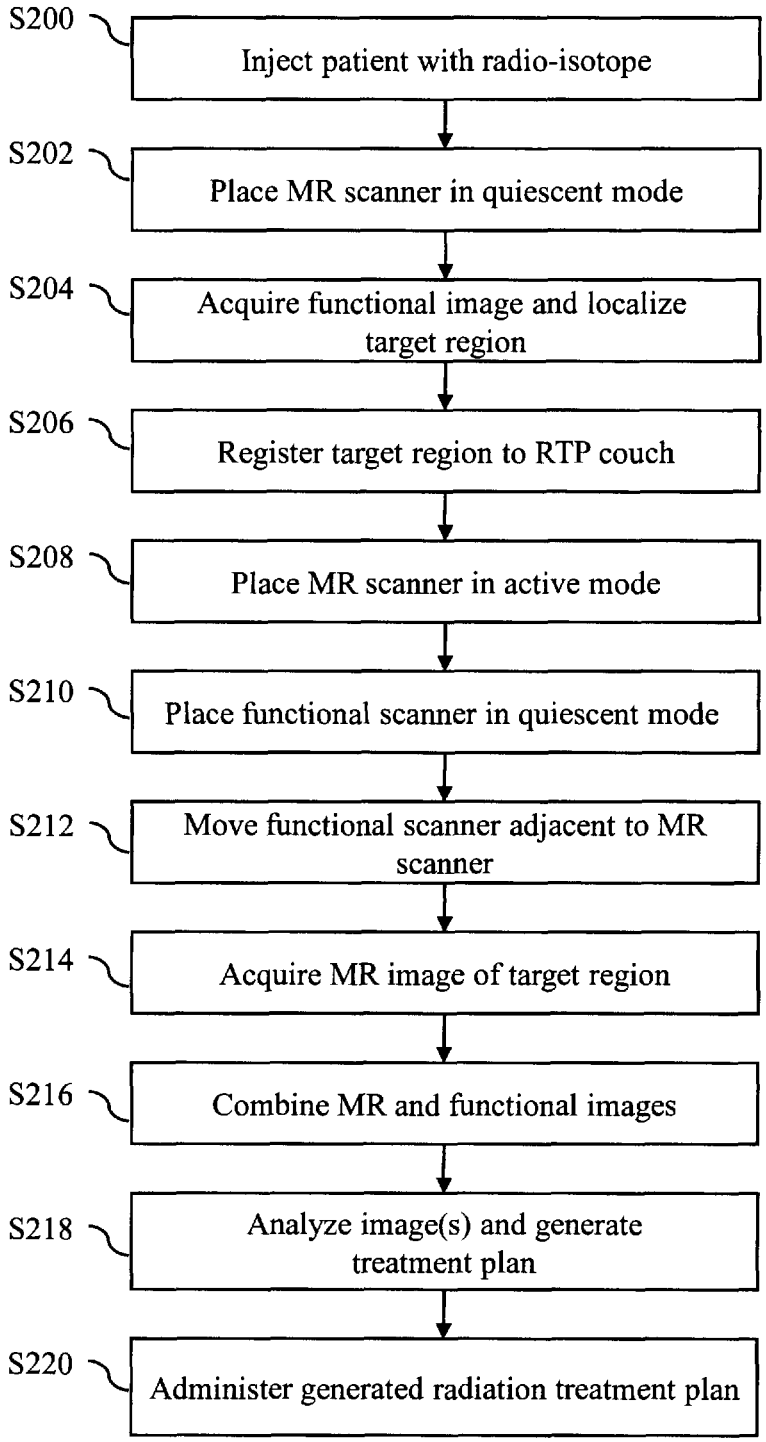
S200
Inject patient with radio-isotope
S202
Place MR scanner in quiescent mode
S204
Acquire functional image and localize target region
S206
Register target region to RTP couch
S208
Place MR scanner in active mode
S210
Place functional scanner in quiescent mode
S212
Move functional scanner adjacent to MR scanner
S214
Acquire MR image of target region
S216
Combine MR and functional images
S218
Analyze image(s) and generate treatment plan
S220
Administer generated radiation treatment plan

Figure 3

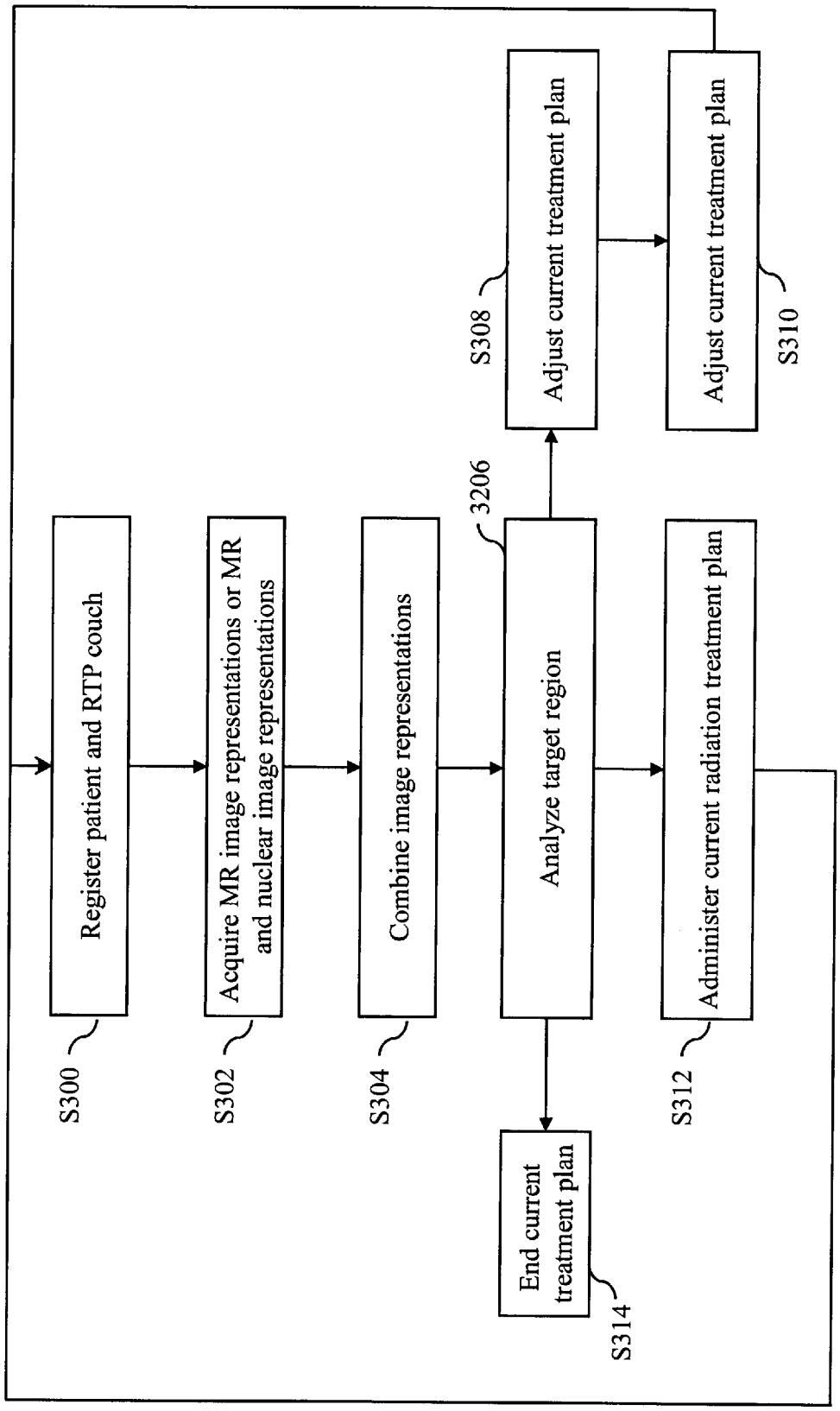
Register patient and RTP couch
S300
Acquire MR image representations or MR and nuclear image representations
S302
Combine image representations
S304
3206
Analyze target region
S308
Adjust current treatment plan
S310
Adjust current treatment plan
Administer current radiation treatment plan
S312
End current treatment plan
S314

Figure 4

专利名称(译)	放射治疗计划和随访系统，大口径核磁共振成像或大口径CT和磁共振成像		
公开(公告)号	EP2651513B1	公开(公告)日	2015-10-14
申请号	EP2011811381	申请日	2011-12-13
[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	OJHA NAVDEEP MORICH MICHAEL ANDREW		
发明人	OJHA, NAVDEEP MORICH, MICHAEL ANDREW		
IPC分类号	A61N5/10 G01R33/48 A61B5/055 A61B6/03 A61B6/00 A61B5/00		
CPC分类号	A61N5/1039 A61B5/0035 A61B5/055 A61B5/0555 A61B6/032 A61B6/037 A61B6/4417 A61B6/5247 A61N5/1071 A61N2005/1052 A61N2005/1055 A61N2005/1061 G01R33/4808 G01R33/481 G01R33/4812		
代理机构(译)	STEFFEN，THOMAS		
优先权	61/423621 2010-12-16 US		
其他公开文献	EP2651513A1		
外部链接	Espacenet		

摘要(译)

放射治疗计划和跟踪系统（10）包括MR扫描仪（12），其具有限定MR成像区域（18）的第一孔（16）和功能扫描仪（26），例如核成像扫描仪，或具有第二孔（30）的CT扫描仪，其限定核或CT成像区域（36）。第一和第二孔（16,30）的直径至少为70厘米，优选为80-85厘米。放射治疗型床（90）沿着MR纵轴线线性地穿过MR成像区域（18），并且沿着MR或纵向轴线对齐的核或CT纵轴线移动核或CT成像区域（36）。该床在MR和核或CT成像区域（18,36）中顺序地定位对象。融合处理器将从MR成像区域（18）中的数据收集生成的图像表示和从核或CT成像区域（36）中的数据收集生成的图像表示组合成合成图像表示，并且计划处理器（112）生成根据合成图像的放射疗法治疗计划。

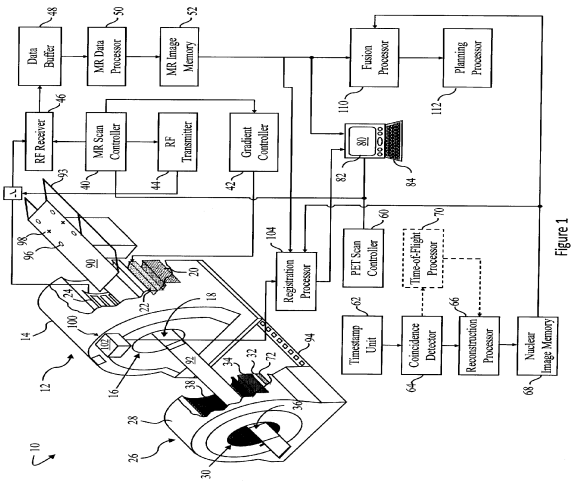

Figure 1