Title: MRI IN GUIDED RADIOTHERAPY AND POSITION VERIFICATION

Abstract: A Magnetic Resonance Imaging (MRI) system is integrated with a linear accelerator to provide on-line position verification. This integration of an MRI system with a linear accelerator provides for improved radiotherapy treatments with reduced harmful radiation exposure for the patient, better 3-D imaging of tumors and faster acquisition of data for daily radiotherapy position verification.
MRI IN GUIDED RADIOTHERAPY AND POSITION VERIFICATION

This invention relates to improvements in radiotherapy techniques and position verification in radiotherapy. In particular, the invention relates to the use of Magnetic Resonance Imaging (MRI) in radiotherapy and position verification.

Existing radiotherapy treatments are commonly carried out be means of a linear accelerator which bombards cancerous tissues with high energy X-rays or electron beams to inhibit growth and spreading of the malignant tissues. An essential parameter monitored in existing radiotherapy treatments is the exact daily position and extension of the target volume of tissue, including variations in position and size both during the treatment session and throughout the whole treatment course. Tumour control probability analyses indicate that dose escalation, which can be performed in case of an exactly known tumour position, may greatly enhance tumour control.

Present treatment position verification systems are based on external markers made on the body surface and/or on megavoltage imaging which produces low quality images particularly of bony structures. As a result, the daily position of soft tissues (tumours) cannot easily or accurately be verified. For instance, the internal position uncertainty of lung, prostate, cervical, and oesophageal tumours currently results in too large treatment fields.

In a limited number of special cases the positioning problems can be solved with invasive radio opaque markers inside the tumour, which are visible on amorphous silicon flat panel megavoltage imaging. One example of such markers is gold seeds of 1.0 mm diameter and 5 mm length used for prostate position verification as reported by Nederveen et al in Phys. Med. Biol. 46(4), 2001, 1219-30.

Another known approach to position verification is CT. Major disadvantages of the use of integrated CT for daily radiotherapy position verification are the inherent slow data acquisition (gantry rotation), the inferior soft-tissue visibility and the 2D,
transversal slide, imaging.

MRI is commonly used in the 3 dimensional imaging of soft tissues such as the brain and spinal cord to detect abnormalities without the need to expose the subject to harmful radiation such as X-rays.

The present invention aims to alleviate at least some of the problems identified for the prior art radiotherapy apparatus and methods in this technical field.

In accordance with the present invention there is provided a radiation therapy apparatus comprising a magnetic resonance imaging device integrated with a linear accelerator.

Preferably the apparatus is configured such that magnetic imaging device and linear accelerator may be operated both independently and simultaneously.

Desirably the magnetic imaging device and linear accelerator are so integrated such that they share an isocentre. In one embodiment, the linear accelerator as a 6-10mV accelerator, though other accelerator systems may be used and may be preferable depending on the application.

The inventors have found that MRI is ideal for on-line position verification during radiotherapy. MRI is able to make fast 2D images of soft tissues with orientation along and perpendicular to the field axis, allowing imaging at critical locations which are predefined during the treatment planning procedure. However, to use an MRI system for on-line position verification, it is desirable to fully integrate the MRI with the linear accelerator system. Both systems must function independently but simultaneously. One solution includes MRI system integrated with a 6-10MV accelerator, both using the same isocentre.

A variety of potential configurations for an integrated system in accordance with the invention are possible. For example, the MRI could be of an open ring configuration or a drum configuration. Open system may require more sophisticated engineering but may provide
benefits to the subject in providing for less intimidating, more comfortable treatment. In such a design, an open ring MRI system is integrated with a rotating linear accelerator mounted on an additional ring. The additional ring may also support a beam stopper and a megavoltage imaging system.

A preferred and probably more economical design solution may use a closed drum design based on the conventional drum MRI design. In case of such a closed drum MRI system the beam must pass through the wall of the cryostat. This will produce beam attenuation and some scatter radiation, however, the inventors calculations indicate that such attenuation and scatter are within acceptable limits for a total wall thickness of up to about 6 cm aluminium. The cryostat wall is suitably designed such that the total radiation thickness of the wall is uniform.

Active magnetic shielding in the integrated system may provide a minimal field strength at the midplane around the MRI magnet. This active shielding can prevent magnetic distortion of the accelerator tube and will also assist in minimising disturbance of the other accelerator systems in the close proximity of the MRI system. Inclusion of the active shielding results in a system necessarily of wider diameter than a conventional system and thus in a larger distance between isocentre and focus.

The accelerator tube is positioned in the midplane of the magnet touching the magnet surface. By adaption of known head, multi-leaf collimator and magnet designs, overall diameter of the apparatus can be minimised.

Successful accurate operation of novel integrated system is dependent on the absolute positioning of the MR-image in relation to the accelerator isocentre. Normal low field MRI systems may be constructed with minimal geometrical distortion, however the absolute world coordinate calibration is always uncertain. Hence, it is desirable to incorporate independent world coordinate isocentre calibration. These are preferably provided by fiducial table MR-markers and an independent table position verification system which, according to the inventor's calculations, will provide absolute world coordinate position accuracy to about 1
Some embodiments of the invention will now be further described with reference to the following Figures in which:

Figure 1 illustrates an open ring type embodiment of the invention. Figure 2 illustrates a closed drum type embodiment of the invention. Figure 3 shows a sketch of an embodiment similar to that of Figure 2.

As can be seen from Figure 1, an open ring arrangement comprises 3 rings 1, 2 and 3 arranged linearly along a common centre and slightly spaced apart. A table 4 is arranged slightly below the centre line of the rings and in parallel therewith. A subject 5 lies on the table 4, encircled by the rings 1, 2 and 3 for treatment. Rings 1 and 3 represent to MRI system, whilst ring 2 incorporates the linear accelerator. The table 4 is moveable linearly through the rings 1, 2 and 3 so that the subject tissue may be located, imaged and treated. The MRI rings 1 and 3 create an imaging volume which encompasses the accelerator isocentre of ring 2.

Figure 2 illustrates a closed drum arrangement of the invention. The drum comprises two main portions, an outer portion 22 which incorporates the linear accelerator and an inner portion 21 incorporating the MR imaging system. A common bore 20 extends concentrically through the centre of the two cylindrical portions 23, 21. A table 24 is positioned within the bore, slightly below the centre, and is slideable into and out of the bore 20.

Figure 3 shows a more detailed outline sketch of an embodiment of the form shown in Figure 2. The arrangement comprises outer portion 32 which incorporates the linear accelerator having a head including an X-ray gun 39, tube 38 magnet 36 and focus 37. The inner portion 31 of the drum consists of the MR imaging system and surrounds a central bore 30, common to both the MRI and accelerator which share a common isocentre 41. Within bore 30, there is again provided a table 34 above which a subject may be positioned in an area 35 for treatment or analysis. The line 40 indicates the typical floor level relative to the apparatus.
Other embodiments and simple design variations of the embodiments disclosed herein will no doubt occur to the skilled addressee without departing from the true scope of the invention as defined in the appended claims.
CLAIMS

1. A radiation therapy apparatus comprising a magnetic resonance imaging device integrated with a linear accelerator.

2. A radiation therapy apparatus as claimed in claim 1 wherein the apparatus is configured such that magnetic imaging device and linear accelerator may be operated both independently and simultaneously.

3. A radiation therapy apparatus as claimed in claim 1 or claim 2 wherein the magnetic imaging device and linear accelerator are so integrated such that the MRI system creates an imaging volume which encompasses the linear accelerator isocentre.

4. A radiation therapy apparatus as claimed in any preceding claim wherein the apparatus has an open ring configuration.

5. A radiation therapy apparatus as claimed in any of claims 1 to 3 wherein the apparatus has a closed drum configuration.

6. A radiation therapy apparatus as claimed in any preceding claim wherein the apparatus incorporates an active magnetic shielding system.

7. A radiation therapy apparatus as claimed in any preceding claim incorporating an independent world coordinate isocentre calibration system consisting of fiducial table MR-markers and an independent table position verification system.

8. A radiation therapy apparatus substantially as described herein and with reference to the Figures.