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(54) ULTRASONIC IMAGE GUIDANCE OF RADIATION THERAPY PROCEDURES

ULTRASCHALLBILDFÜHRUNG VON STRAHLENTHERAPIEVERFAHREN

GUIDAGE PAR IMAGERIE ULTRASONIQUE DES PROCÉDURES DE THÉRAPIE DE RAYONNEMENT

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EP-A1- 2 358 276
US-A- 6 019 724
US-A1- 2011 009 742

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Description

FIELD OF THE INVENTION

[0001] This invention relates to an ultrasonic diagnostic imaging system for imaging a patient undergoing radiotherapy treatment.

BACKGROUND OF THE INVENTION

[0002] In preparation for radiation therapy or radiotherapy, medical diagnostic images are taken of the treatment target (tumor) to plan the procedure. Both the location (depth) of the tumor and the presence of surrounding healthy tissue structures are taken into consideration in planning the procedure. These considerations lead to a choice of the intensity and focus of the radiation dose, the locations in the tumor where treatment fractions are to be delivered, and the path of the radiation beam through surrounding healthy tissue. Typically the planning images are CT images of the target region, called a simulation CT scan. Based on the CT images, the outcome of the planning is a set of instructions that are sent to the treatment d delivery device, usually a linear accelerator. The instructions define the path of radiation delivery and the planned dose distribution inside the patient. Since the planning images are acquired prior to commencement of the treatment, it is of paramount importance that the treatment target (the tumor) and the surrounding structures (healthy tissues) are positioned exactly as they appear in the simulation CT scan before each treatment fraction; otherwise the dose will not be safely and correctly delivered. Patient positioning is therefore becoming increasingly of interest in order to obtain the desired results of treatment.

[0003] One of the modalities which can be used in image guidance of radiotherapy is ultrasound imaging, which has some unique characteristics. Ultrasound has been widely used for diagnosis of cancer. It is relatively inexpensive and easy to use and, with ever-increasing improvements in image quality, it can have a diagnostic value comparable to MRI or CT imaging. Two dimensional (2D) ultrasound images of the target are compared to the corresponding CT projections conventionally used for radiotherapy planning. Similar to MRI, ultrasound imaging is benign and does not add extra undesirable radiation dose to the patient, and it is generally a non-invasive imaging modality. Ultrasound imaging is therefore a good candidate for organ motion monitoring between treatment fractions, which is a prerequisite for adaptive applications.

[0004] The initial use of ultrasound in radiotherapy followed the typical use of ultrasonic multiplanar reconstruction to visualize two perpendicular planes of the target. This first application of ultrasound was available only for prostate cancer treatment and showed many limitations, which have been documented in the literature. See Langen et al., "Evaluation of ultrasound-based prostate localization for image-guided radiotherapy," Int. J. Radiat. Oncol. Biol. Physics, vol. 57 (2003) at pp 635-44; and Van den Heuvel et al., "Independent verification of ultrasound based image-guided radiation treatment, using electronic portal imaging and implanted gold markers," Med. Phys., vol. 30 (2003) at pp 2878-87. At the present time, only prostate cancer treatment has been clinically implemented using a mechanically swept transducer which continuously scans the target trans-perineally during irradiation. The position of the prostate is compared to the position of the prostate in a trans-perineal ultrasound image acquired prior to commencement of the procedure which is used for the therapy planning. During setup of the patient for each treatment fraction, ultrasound guidance determines the position of the targets and nearby organs at risk. The current position of the target can be used to recalculate dose and, if necessary, re-plan the patient treatment in adaptive applications. See Abramowitz et. al., "Noninvasive Real-time Prostate Tracking Using a Transperineal Ultrasound Approach", In'l J. Rad., Oncol., Biol. & Physics, vol.84 (2012) at pp S133, and Court et al., "Automatic online adaptive radiation therapy techniques for targets with significant shape change: a feasibility study," Phys. Med. Biol., vol. 51 (2006) at pp 2493-50.

[0005] One of the problems inherent in the application of ultrasound for radiation therapy guidance is the need to maintain good acoustic coupling of the ultrasound probe to the body of the patient. Typical ultrasound probes have handles which are grasped by the clinician and used both to hold the probe and to press it into good acoustic contact with the skin of the patient. The problem this causes in radiotherapy is displacement of the tumor and adjacent and intervening tissues and organs by reason of the firm pressure needed to press the probe against the patient. Thus, the use of ultrasound itself becomes a source of repositioning of the anatomy of the patient from that which is shown in the planning images, requiring treatment re-planning and reprogramming of the therapy delivery system as a result. Accordingly it is desirable to be able to use ultrasound for radiotherapy image guidance, but in a way which does not disrupt the constant positioning of organs and tissues necessary for a safe and effective radiotherapy procedure.

[0006] EP 2 358 276 A1 relates to an ultrasound unit with a multiplicity of ultrasound transducers to monitor physiologic parameters, especially motion and deformation, of an object of interest encapsulated by a body in real-time in three dimensions of space and to generate numerical control or trigger information for other medical devices.

[0007] US 6,019,724 A discloses a method for generating quasi-realtime feedback for the purpose of guiding surgical, therapeutic or diagnostic procedures by means of ultrasound imaging, wherein the location of a surgical tool, therapeutic radiation field or a diagnostic energy field is related to the coordinate system of an intraoperative 2D and/or 3D ultrasound imaging system and, optionally, to pre-operative MR/CT/X-ray data, thus allowing synchronized relations between data acquisition, tool movement and image visualizations.

SUMMARY OF THE INVENTION

[0008] The invention is an ultrasonic diagnostic imaging system for imaging a patient undergoing radiotherapy treatment as defined in claim 1. In accordance with the principles of the present invention, an ultrasonic diagnostic imaging system with imaging probe are described which are used for image guidance during radiotherapy without displacing the tissue and organ positioning observed during the therapy planning stage. The imaging probe is a thinly constructed matrix (two dimensional) array of piezoelectric transducers and control microbeamformer which are physically decoupled from other components of the conventional ultrasound probe. This thin, minimalistic probe construct enables the probe to be maintained in acoustic contact with the patient by means of medical grade adhesive tape or a belt, minimizing the amount of pressure needed to maintain the probe in acoustic contact with the patient and resultant tissue displacement problems. The use of a matrix array enables the imaging probe to be operated as a three dimensional phased array which can steer imaging beams over a volumetric region of the body including the therapy target region. Three dimensional imaging of the therapy site can thus be performed electronically (with no moving parts) in real time. The use of a belt or adhesive band to maintain the acoustic contact of the imaging probe with the patient obviates the need for an operator to hold the probe in the room with the radiation generating system and eliminates the need for complex or expensive probe retention devices such as robotic arm systems. Finally, the thin construct of the minimalistic probe reduces interference problems with the therapy beams.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] In the drawings:

FIGURE 1 illustrates a patient undergoing a radiotherapy procedure with a linear accelerator while the therapy target is visualized in real time by an ultrasonic imaging probe of the present invention.

FIGURE 2 illustrates an ultrasound imaging system suitable for use with an imaging probe of the present invention.

FIGURE 3 is a bottom plan view of an imaging probe of the present invention.

FIGURE 4 illustrates 3D imaging of a tumor during radiotherapy with an imaging probe of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0010] In radiotherapy, before, after, and possibly also during each treatment fraction, it is necessary to assess the treatment target position in the patient with respect to the position of the target used during preparation of the radiotherapy treatment plan. Presently, the alternatives proposed for holding the transducer in acoustic contact with the patient during scanning include human operators or robotic/mechanical arm systems. The major reason for this is the absence of probes specifically designed for radiotherapy applications. Conventional diagnostic imaging probes for external use are generally operated by a technician or physician, and have a case shaped with a handle which encloses the transducer crystals and the electronic components. But for ultrasound image guidance during a radiotherapy procedure the probe ideally must be operated remotely and work without the need for a human operator in the treatment room. The present invention comprises a probe specially designed for radiotherapy use in which the piezoelectric array elements and their microbeamformer are decoupled from other electronic components generally incorporated in an ultrasound probe, the piezoelectric elements are arrayed in a two dimensional matrix for real time electronic three dimensional imaging, the elements and microbeamformer are assembled in a flat and light case, and any other electronic parts are incorporated in the cable or, preferably, in the connector at the end of the probe cable. The active imaging elements of the probe therefore can be positioned on the patient and held in position using adhesive components or a belt.

[0011] Referring first to FIGURE 1, a patient 8 is shown undergoing radiotherapy treatment. A linear accelerator 12 is positioned above the patient and delivers radiation beams in intervals called treatment fractions to target anatomy in the patient. In this example the therapeutic beams are directed at the liver of the patient for delivery of therapy to a liver tumor. Attached by adhesive tape or a belt to the abdomen of the patient is an ultrasonic imaging probe of the present invention. A probe cable 14 conveys imaging signals acquired by the probe to an ultrasonic imaging system such as that described in FIGURE 2. The probe performs imaging of the tumor during the procedure so that a remote operator can observe any motion of the patient while therapy is being delivered. The probe also images the region of the tumor between treatment fractions so that the position of the tumor can be assessed in relation to the planning images before resuming treatment. It is seen that no operator is needed in the treatment room with the patient for the imaging probe and that the thin design of the probe poses little obstacle to the delivery of the radiation therapy.

[0012] FIGURE 2 illustrates in block diagram form an ultrasound system constructed in accordance with the principles of the present invention. In this implementation the probe 10 includes a two-dimensional array transducer 500 and a microbeamformer 502. The microbeamformer contains circuitry which control the signals applied to groups of elements ("patches") of the array transducer 500 and does some processing of the echo signals received by elements of each group to produce partially beamformed signals. Microbeamforming in the probe advantageously reduces the number of conductors in the cable 503 between the probe and the ultrasound system and is described in U.S. Pat. No. 5,997,479 (Savord et al.) and in U.S. Pat. No. 6,436,048 (Pesque).

[0013] The probe 10 is coupled to the scanner subsystem 310 of the ultrasound system. The scanner includes a beamformer controller 312 which is responsive to a user control 60 and provides control signals to the microbeamformer 502 instructing the probe as to the timing, frequency, direction and focusing of transmit beams. The beamformer controller also controls the beamforming of received echo signals by its coupling to analog-to-digital (A/D) converters 316 and a beamformer 116. Echo signals received by the probe are amplified by preamplifier and TGC (time gain control) circuitry 314 in the scanner, then digitized by the A/D converters 316. The digitized echo signals are then formed into fully coherent beams by a beamformer 116. Optionally, signals from and to the elements of the array may be beamformed with the beamformer only. The echo signals are processed by an image processor 318 which performs digital filtering, B mode detection, and Doppler processing, and can also perform other signal processing such as harmonic separation, speckle reduction through frequency compounding, and other desired image processing.

[0014] The echo signals produced by the scanner subsystem 310 are coupled to the digital display subsystem 320, which processes the echo signals for display in the desired image format. The echo signals are processed by an image line processor 322, which is capable of sampling the echo signals, splicing segments of beams into complete line signals, and averaging line signals for signal-to-noise improvement or flow persistence. The image lines are scan converted into the desired image format by a scan converter 324 which performs R-theta conversion as is known in the art. The scan converter can also fill in image areas between received beams by interpolation. Individual images or image sequences are stored in a cine memory 326 during capture of image loops. The image in memory is also overlayed with graphics to be displayed with the image, which are generated by a graphics generator 330 which is responsive to the user control for the input of patient identifying information or the movement of cursors, for example.

[0015] For real-time volumetric imaging the display subsystem 320 also includes a volume renderer 328 which receives 3D data sets or sets of spatially separated 2D images and renders them into real-time three dimensional image. The 3D images of the scanned anatomy is displayed on a display 150. The user interface 60 includes controls 62-66 for control of the orientation of the volumetric region scanned by the two dimensional array probe. The user can select a function to be controlled by means of a control 66, such as the orientation of the region to be scanned. The user then uses a joystick or trackball 62 to position the scanned region. Once the scanned region has been set, the user depresses a control 64 to lock in the setting. The beamformer controller 312, the beamformer 116, and the microbeamformer 502 respond to these setting changes by transmitting beams in a desired direction by phased transmission with elements of the two dimensional array 500, then steering received beams in the same directions to acquire a series of receive beams throughout the volumetric region being scanned. These receive beams are processed into scan lines in 3D space, then rendered into a 3D image of the scanned volume by volume rendering. The volumetric region is thus repositioned and scanned with no moving elements in the probe. The effect of operation of these controls is illustrated in FIGURE 4.

[0016] FIGURE 3 is a plan view of an imaging probe 10 of the present invention as viewed from the patient-contacting side. The probe includes a two dimensional (matrix) array 16 of piezoelectric transducer elements made, for example, of PZT ceramic. Piezoelectric elements are preferred in comparison to micromachined transducer elements (MUTs) by reason of their better acoustic transmit energy and sensitivity, which improves the performance of the probe in abdominal applications such as that shown in FIGURE 1. The matrix array is backed by the microbeamformer application-specific integrated circuit which controls the operation of the elements of the array and produces partially beamformed signals from patches of elements of the matrix array to the ultrasound system over coaxial conductors of the cable 14. The conductors of the cable are coupled to connection pads of the microbeamformer integrated circuit. A cover seen in the side views of the probe covers the cable connections. The matrix array and microbeamformer assembly are mounted in a flat polymeric frame 18, giving the probe a low, substantially flat appearance. The probe will generally have a thickness or height (seen in FIGURES 1 and 4) which is less than either its width or length (seen in FIGURE 3), enabling it to be securely taped or belted to the patient. There is an additional advantage of this thin probe, A strain relief 20 assists in and protects the attachment of the cable 14 to the main body and frame of the probe. The substantially flat construct of the probe, aided by its restricted number of components, enables the probe to be securely taped or belted to the skin of the patient and remain stationary throughout the radiotherapy procedure.

[0017] Other conventionally used materials, such as matching layers on the face of the transducer elements 16 and a covering layer (lens) are generally used on the face of the matrix array. A heat-dissipating element may be located on the back of the microbeamformer. Other electronic components such as impedance matching elements and preamplifiers for received signal are located in-line along the cable 14 or in the connector at the end of the cable by which the probe is plugged into the ultrasound system.

[0018] FIGURE 4 illustrates how the electronically steered imaging beams of an imaging probe 10 of the present invention enable the probe to be attached and used without impeding the delivery of therapeutic beams to the target region in the patient. This illustration shows a tumor 42 in the liver 40 of the patient. The imaging probe 10 is attached to the skin surface 6 of the patient and scans ultrasound beams in a conical pattern 22 for imaging. In this example it is seen that the imaging probe is not attached immediately above the target region, but adjacently to the side of it. The user controls 60 are manipulated to steer the conical scan region 22 at an angle so it encompasses the target region 42 to the side of the probe 10. This enables the therapeutic beams to be directed straight down into the patient's body, traveling a short or the shortest path through the body to reach the tumor 42. Thus, minimal healthy tissue is impacted by the therapy beam. It is seen that there is flexibility on where to direct the therapy beam; it can be repositioned to other entry points into the body and to the target region without interference from the probe. This enables the therapy beams 30 to be directed most effectively at the tumor, and to be positioned as needed to avoid damaging healthy organs and tissue around the therapy site. From this example additional advantages of the ultrasound probe constructed in accordance to the present invention become more evident. The two dimensional array enables the beam steering within regions adjacent to the probe and thin construct of the minimalistic (compact) probe reduces interference with the therapy beams. This increases flexibility in the therapy planning procedures, such that the therapeutic beams path can be reduced and brought to the close proximity of the probe without causing an interference with electronic components of the probe.

Claims

1. An ultrasonic diagnostic imaging system for imaging a patient undergoing radiotherapy treatment comprising:

   an ultrasound probe comprising a two dimensional array transducer (16,500), the probe having a patient-contacting face with a width and a length dimension, and a thickness normal to the patient-contacting face which is less than both the width and length dimensions, and a probe cable (14,503) coupled to the array transducer, wherein the probe is adapted to electronically steer ultrasound beams in a volumetric region comprising a target region;
   an ultrasound system, remotely located from the ultrasound probe, and connected to the probe by the probe cable, the ultrasound system adapted to process ultrasound signals produced by the probe for the production of three dimensional images of the target region of a patient; and
   a belt or adhesive band which enables attachment of the ultrasound probe to the patient with the patient-contacting face acoustically coupled to the patient,
   wherein the probe is attachable to the patient while the patient undergoes radiotherapy treatment and the ultrasound system is adapted to produce images of the target region either during treatment or between treatment fractions.

2. The ultrasonic diagnostic imaging system of Claim 1, wherein the ultrasound probe further comprises a microbeamformer (502) coupled to the array transducer,
   wherein the probe cable is coupled to the microbeamformer.

3. The ultrasonic diagnostic imaging system of Claim 2, wherein the ultrasound probe further comprises a polymeric frame (18) supporting the array transducer, the microbeamformer, and the probe cable.

4. The ultrasonic diagnostic imaging system of Claim 2, wherein the ultrasound system further comprises a volume renderer (328) adapted to produce three dimensional images of the target region.

5. The ultrasonic diagnostic imaging system of Claim 2, wherein the ultrasound system further comprises a user control (60) which is operated to orient the volumetric region scanned by the ultrasound probe with respect to the ultrasound array.

6. The ultrasonic diagnostic imaging system of Claim 5, wherein the user control is operated to orient the volumetric region to be oriented to scan a target region which is located laterally to the side of the probe.

7. The ultrasonic diagnostic imaging system of Claim 6, wherein the target region contains a target anatomy (42),
   wherein the target anatomy is treated by a therapeutic beam (30) passing through the patient adjacent to the ultrasound probe.

8. The ultrasonic diagnostic imaging system of Claim 2, further comprising a probe connector, located at the end of the probe cable remote from the array transducer, wherein the probe connector further comprises electronic components of the probe.

Patentansprüche

1. Ultraschalldiagnostisches Bildgebungssystem zum Abbilden eines Patienten, der sich einer Radiotherapiebehandlung unterzieht, umfassend:

eine Ultraschallsonde, umfassend einen zweidimensionalen Array-Transducer (16, 500), wobei die Sonde eine Patientenkontaktfläche mit einer Breiten- und einer Längenabmessung und einer für die Patientenkontaktfläche normalen Dicke, die geringer ist als sowohl die Breiten- als auch die Längenabmessung, aufweist, und ein mit dem Array-Transducer verbundenes Sondenkabel (14, 503), wobei die Sonde angepasst ist, um Ultraschallstrahlen in einer eine Zielregion umfassenden volumetrischen Region elektronisch zu lenken,

ein Ultraschallsystem, das entfernt von der Ultraschallsonde angeordnet ist und durch das Sondenkabel an die Sonde angeschlossen ist, wobei das Ultraschallsystem angepasst ist, um von der Sonde erzeugte Ultraschallsignale für die Erzeugung dreidimensionaler Bilder der Zielregion eines Patienten zu verarbeiten; und

einen Gürtel oder ein Klebeband, der/das die Befestigung der Ultraschallsonde an dem Patienten ermöglicht, wobei die Patientenkontaktfläche akustisch mit dem Patienten verbunden ist,

wobei die Sonde an dem Patienten befestigbar ist, während sich der Patient der Radiotherapiebehandlung unterzieht, und das Ultraschallsystem angepasst ist, um Bilder der Zielregion entweder während der Behandlung oder zwischen Behandlungsfraktionen zu erzeugen.

2. Ultraschalldiagnostisches Bildgebungssystem nach Anspruch 1, wobei die Ultraschallsonde weiter einen mit dem Array-Transducer verbundenen Mikrobeamformer (502) umfasst,
wobei das Sondenkabel mit dem Mikrobeamformer verbunden ist.

3. Ultraschalldiagnostisches Bildgebungssystem nach Anspruch 2, wobei die Ultraschallsonde weiter einen den Array-Transducer, den Mikrobeamformer und das Sondenkabel stützenden Polymerrahmen (18) umfasst.

4. Ultraschalldiagnostisches Bildgebungssystem nach Anspruch 2, wobei das Ultraschallsystem weiter eine Volume-Rendering-Vorrichtung (328) umfasst, die angepasst ist, um dreidimensionale Bilder der Zielregion zu erzeugen.

5. Ultraschalldiagnostisches Bildgebungssystem nach Anspruch 2, wobei das Ultraschallsystem weiter eine Benutzersteuerung (60) umfasst, die betätigt wird, um die von der Ultraschallsonde gescannte volumetrische Region in Bezug auf das Ultraschall-Array auszurichten.

6. Ultraschalldiagnostisches Bildgebungssystem nach Anspruch 5, wobei die Benutzersteuerung betätigt wird, um die auszurichtende volumetrische Region auszurichten, um eine Zielregion zu scannen, die seitlich der Seite der Sonde angeordnet ist.

7. Ultraschalldiagnostisches Bildgebungssystem nach Anspruch 6, wobei die Zielregion eine Zielanatomie (42) enthält, wobei die Zielanatomie durch einen therapeutischen Strahl (30) behandelt wird, der durch den Patienten angrenzend an die Ultraschallsonde verläuft.

8. Ultraschalldiagnostisches Bildgebungssystem nach Anspruch 2, weiter umfassend einen Sondenanschluss, der am Ende des Sondenkabels von dem Array-Transducer entfernt angeordnet ist, wobei der Sondenanschluss weiter elektronische Bauteile der Sonde umfasst.

Revendications

1. Système d'imagerie de diagnostic par ultrasons pour imager un patient subissant un traitement de radiothérapie comprenant :

- une sonde à ultrasons qui comporte un transducteur de réseau bidimensionnel (16, 500), la sonde ayant une face en contact avec le patient avec une dimension de largeur et de longueur, et une épaisseur perpendiculaire à la face en contact avec le patient qui est inférieure aux deux dimensions de largeur et de longueur, et un câble de sonde (14, 503) couplé au transducteur de réseau, dans lequel la sonde est adaptée à électroniquement piloter un faisceau d'ultrasons dans une région volumétrique comprenant une région cible ;
- un système à ultrasons, situé à distance de la sonde à ultrasons, et raccordé à la sonde par le câble de sonde, le système à ultrasons adapté à traiter les signaux ultrasonores produits par la sonde pour la production d'images en trois dimensions de la région cible d'un patient ; et
- une ceinture ou bande adhésive qui permet la fixation de la sonde à ultrasons au patient avec la face en contact avec le patient acoustiquement couplée au patient,
- dans lequel la sonde peut être fixée au patient alors que le patient subit un traitement de radiothérapie et le système à ultrasons est adapté à produire des images de la région cible durant le traitement ou entre les fractions de traitement.

2. Système d'imagerie de diagnostic par ultrasons selon la revendication 1, dans lequel la sonde à ultrasons comprend en outre un microformeur de faisceau (502) couplé au transducteur de réseau,

- dans lequel le câble de sonde est couplé au microformeur de faisceau.

3. Système d'imagerie de diagnostic par ultrasons selon la revendication 2, dans lequel la sonde à ultrasons comprend en outre un châssis polymère (18) supportant le transducteur de réseau, le microformeur de réseau, et le câble de sonde.

4. Système d'imagerie de diagnostic par ultrasons selon la revendication 2, dans lequel le système à ultrasons comprend en outre un dispositif de rendu de volume (328) adapté à produire des images en trois dimensions de la région cible.

5. Système d'imagerie de diagnostic par ultrasons selon la revendication 2, dans lequel le système à ultrasons comprend en outre une commande utilisateur (60) qui est actionnée pour orienter la région volumétrique scannée par la sonde à ultrasons relativement au réseau à ultrasons.

6. Système d'imagerie de diagnostic par ultrasons selon la revendication 5, dans lequel la commande utilisateur est actionnée pour orienter la région volumétrique à orienter pour scanner une région cible qui est située latéralement au côté de la sonde.

7. Système d'imagerie de diagnostic par ultrasons selon la revendication 6, dans lequel la région cible contient une anatomie cible (42),

- dans lequel l'anatomie cible est traitée par un faisceau thérapeutique (30) traversant le patient adjacent à la sonde à ultrasons.

8. Système d'imagerie de diagnostic par ultrasons selon la revendication 2, comprenant en outre un raccord de sonde, situé au niveau de l'extrémité du câble de sonde à distance du transducteur de réseau, dans lequel le raccord de sonde comprend en outre des composants électroniques de la sonde.

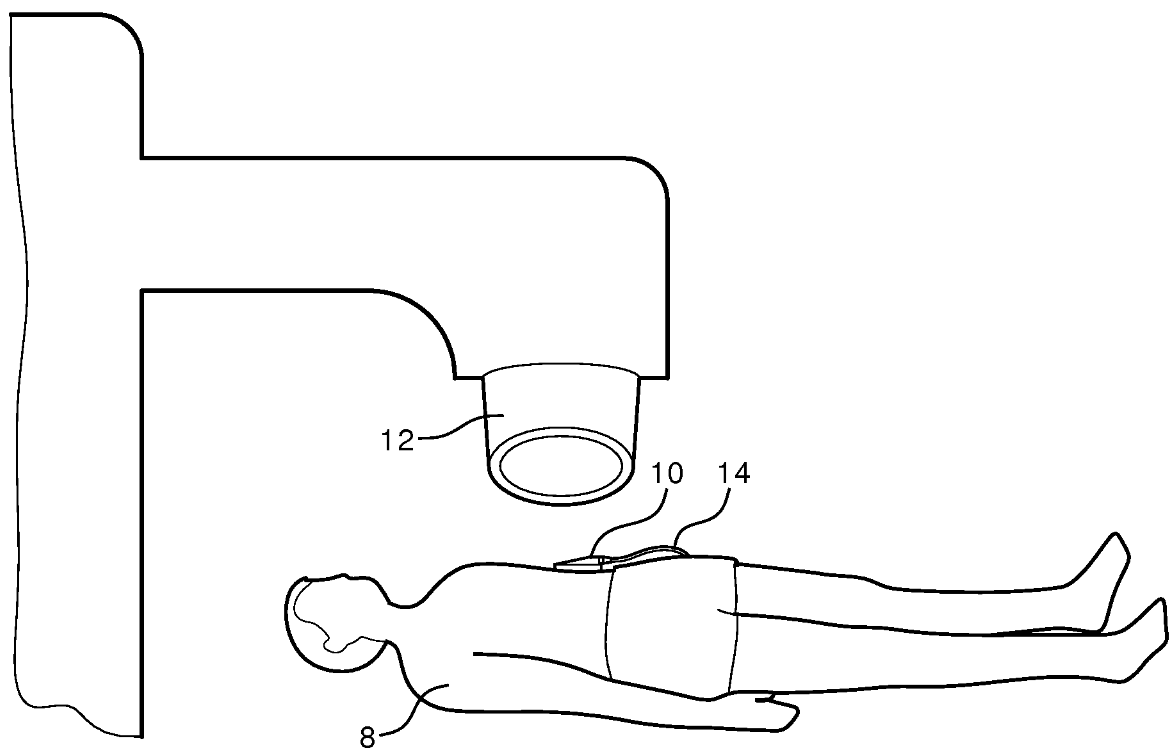

FIG. 1

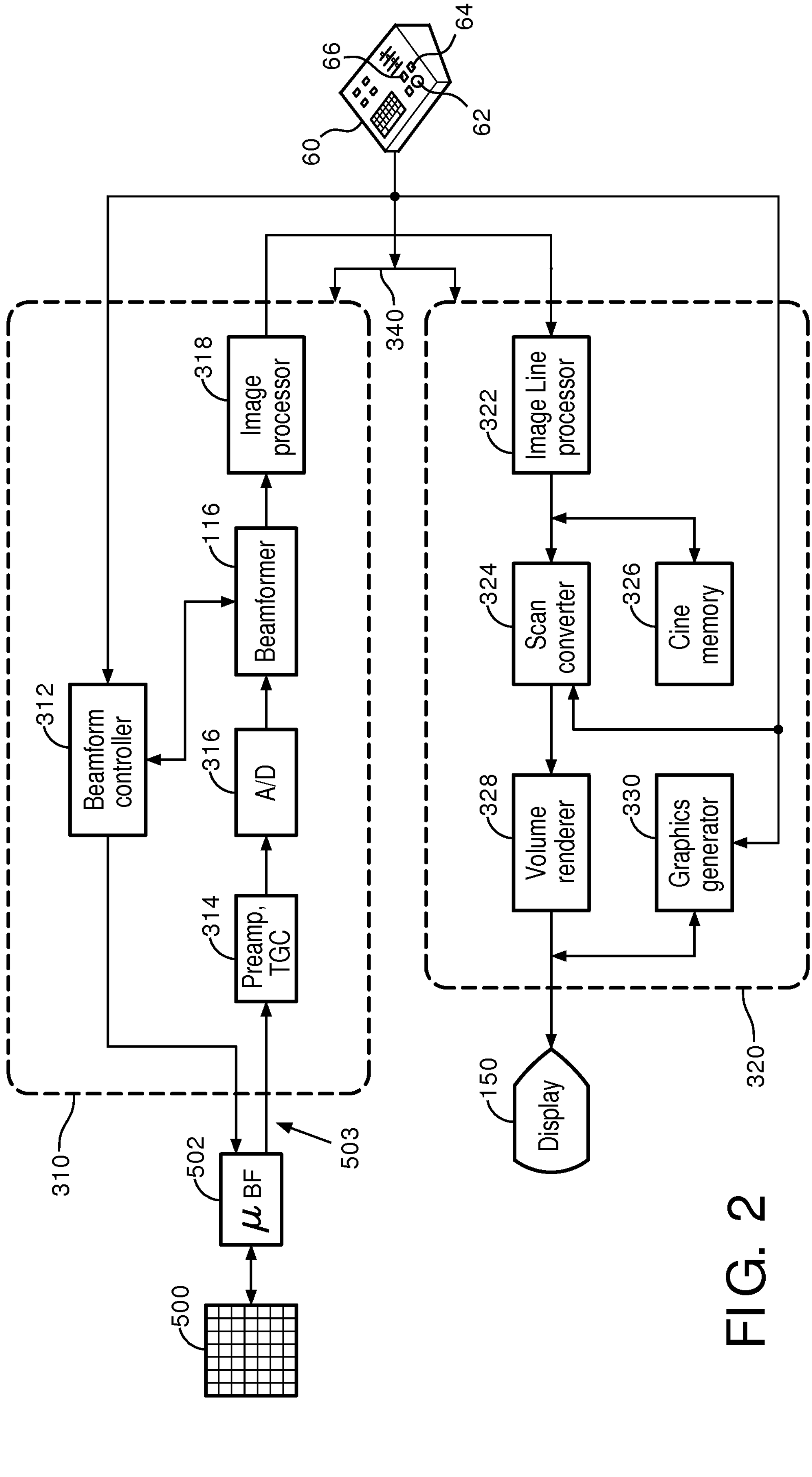
60
66
64
62
340
310
312
Beamform controller
314
Preamp, TGC
316
A/D
116
Beamformer
318
Image processor
500
502
μ BF
503
320
322
Image Line processor
324
Scan converter
326
Cine memory
328
Volume renderer
330
Graphics generator
150
Display

FIG. 2

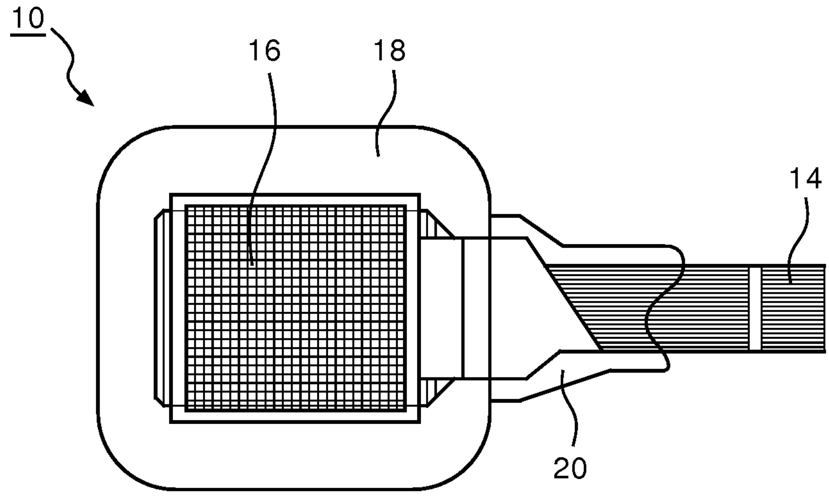

FIG. 3

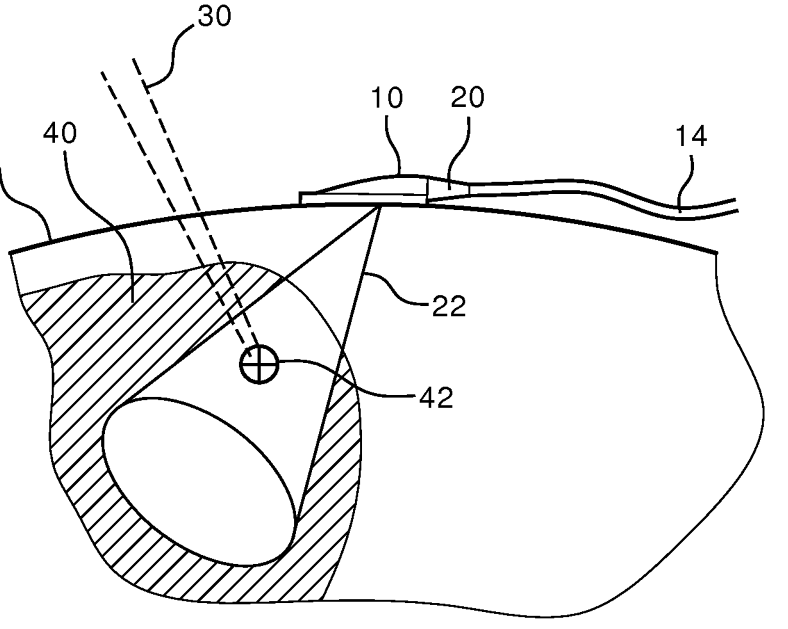

FIG. 4

REFERENCES CITED IN THE DESCRIPTION

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- **COURT et al.** Automatic online adaptive radiation therapy techniques for targets with significant shape change: a feasibility study. *Phys. Med. Biol.,* 2006, vol. 51, 2493-50 **[0004]**

专利名称(译)	放射治疗程序的超声波图像引导

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摘要(译)

超声诊断成像系统具有薄的二维阵列换能器探头，其被胶带或系带给患者以在放射治疗期间对目标区域成像。基于基于在手术之前获取的目标区域的图像进行的计划来进行放射疗法过程。阵列换能器由超声系统操作，以在治疗过程的分数期间或之间通过电子束控制产生目标区域的三维图像。超声图像用于响应于治疗过程期间目标解剖结构的任何移动或移位来调整治疗计划。

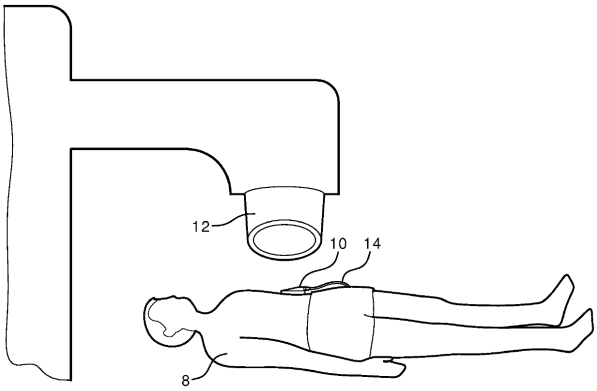

FIG. 1