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(71) Applicant (for all designated States except US): **HO-LOGIC, INC.** [US/US]; 35 Crosby Drive, Bedford, MA 01730-1401 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **SMITH, Andrew** [US/US]; 8 Glen Road, Lexington, MA 02420 (US). **STEIN, Jay, A.** [US/US]; 314 Dartmouth Street, Boston, MA 02116 (US).

(74) Agents: **KAVRUKOV, Ivan, S.** et al.; Cooper & Dunham LLP, 1185 Avenue of the Americas, New York, NY 10036 (US).

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(54) Title: ORTHOVOLTAGE BREAST RADIATION THERAPY

(57) Abstract: X-ray breast imaging and therapy can be carried out in a single compression of the breast using the same x-ray source, can be repeated at different orientation of the x-ray beam relative to the breast, and can be based on the geometry of a known mammography system, or a known breast tomosynthesis system, or a known prone table breast biopsy system.



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5 Inventors:

Andrew Smith

Jay A. Stein

Title:**10 Orthovoltage Breast Radiation Therapy****Field:**

[0000] This patent specification is in the field of x-ray breast imaging and therapy, and specifically pertains to using the same instrument to image a breast with x-rays and
15 to carry out x-ray therapy of the breast.

Background:

[0001] X-ray mammography has long been used for breast imaging in screening and
20 in diagnostics, for example by using equipment such as the systems commercially available currently from Lorad of Danbury, Connecticut under the trade name Selenia. More recently, Lorad has introduced x-ray breast tomosynthesis systems to add three-dimensional information and places such systems in investigational clinical use in this country.

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[0002] When breast cancer is found, the treatment can involve surgical removal of the tumor and surrounding tissue, possibly chemotherapy, and irradiation of the lumpectomy cavity and neighborhood with ionizing radiation. If the surgical cavity is sufficiently small, the radiation therapy treatment plan can be limited to partial breast
30 irradiation, where the radiation is directed to the location of the tumor, in an attempt to spare healthy tissue far from the pathology site from radiation exposure. Several methods have been used or proposed for partial breast irradiation, as discussed below.

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5 1. External high energy radiation source

[0003] A traditional method uses an external source of high energy radiation, typically a linear accelerator (Linac) such as manufactured by Varian, as illustrated in Fig.

1. Typically, a pre-treatment CT or MRI image of the patient's breast provides
10 information that treatment planning software uses to determine irradiation parameters such as clinical target volume (CTV) and the number of independent irradiating beams (typically 4-5) and their cross sections. The energies of the beams are also decided, which typically are in the 6-20 MV range. The patient then undergoes radiation treatment that involves administering the radiation by sending the beams along the
15 appropriate directions for the appropriate times and at the appropriate energies. The patient usually is supine, although prone and other positions are possible. The treatment is often repeated in fractional doses that in totality equal the required total dose to the target site, often 30-40 Gy. For breast irradiation, a common treatment plan is daily radiation for 5-6 weeks, 5 fractional doses per week. A new treatment plan that is being
20 investigated is accelerated breast irradiation, which uses two fractional doses daily over 5 days for 10 treatments total.

2. Internal breast brachytherapy

25 [0004] In this method, multiple catheters (5-30) are implanted in the breast in the vicinity of the lumpectomy cavity, as illustrated in Fig. 2. The treatment involves delivering a radioactive source into each catheter. For accelerated breast irradiation protocols, this typically is done twice a day for 5 days. The catheters are removed at the end of the treatment. The radioactive source for each catheter is controlled using an
30 afterloader. This is a mechanical system that has a shielded housing containing the radioactive source. There are mechanical ports that allow the connection to catheters. Under computer control, the source is delivered through the catheter by use of a metal wire to which the source is attached. The source can be precisely delivered to desired locations in the catheter at controllable velocities.

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5 3. Internal balloons

[0005] An example of a device of this type is manufactured by Cytac Proxima and is called Mammosite. (www.mammosite.com) and is illustrated in Fig. 3. It includes a balloon attached to a catheter. The balloon is surgically implanted inside the lumpectomy cavity. During treatment, a radioactive source is delivered to the balloon through the catheter, using an afterloader. The treatment is twice per day for 5 days. Other companies (Xoft) are investigating using similar methods that use a miniature x-ray tube rather than a radioactive source to deliver the radiation.

15 4. Intraoperative radiation therapy

[0006] An example of an intraoperative radiation therapy device is manufactured by Zeiss. A similar device was marketed by Photoelectron Corp. The device and its use are illustrated in Figs. 4 and 5. This method uses a miniature x-ray source that can be positioned inside the breast intraoperatively. The device is placed at the lumpectomy site and the radiation therapy treatment is administered. Unlike the methods summarized above, which spread the irradiation over several days, this intraoperative device is used immediately or at least soon after lumpectomy and delivers the radiation in the surgical setting.

25 5. Stereotactic peripheral brachytherapy (SPB)

[0007] This approach has been proposed but it is believed that it is not yet available on the market. It is expected to be presented at the American Association of Physicists in Medicine (AAPM) meeting on July 30, 2006, and an abstract is available in the AAPM journal. The concept was previously presented, at a regional AAPM meeting in New England in February 2006:

[0008] chapter.aapm.org/NE/meet021506/presentations/2006_02_15_NEAAPM_Sio
shansi.pdf

5 [0009] As illustrated in Figs. 6-9, the method involves administering radioisotope radiation externally, in close proximity to the lumpectomy cavity. The system uses two curved applicators, with the breast compressed between them. Inside each of the applicators are catheter channels, which allow the administration of radiation by the introduction of radioactive materials inside the catheters. The breast is compressed
10 between the applicators, and the radionuclide is traversed amongst the catheters, using an afterloader. The dwell time and velocity are adjusted to deliver the desired radiation dose at a given location along the catheter. In a subsequent session, the breast is compressed from an orthogonal direction, and again irradiated. The total radiation to the target lumpectomy cavity is designed to deliver the proper therapeutic dose. Because the
15 irradiation comes from both sides of the breast, and from the orthogonal views, the dose to the skin is lower than would be the case if the irradiation was from only one or two directions. An important part is the lesion targeting (not shown). Before irradiation, the compressed breast (with the applicators) is imaged and the location of the cavity is identified, relative to the applicators. This is used to define the locations of the
20 radioisotopes for the eventual therapy. For example, the imaging could determine that the target area is underneath catheters # 2-4, at specific distances along each of these catheters. The imaging device can be a standard mammographic imaging system, where x-rays traverse the breast and form an image at a digital detector. Alternatively, the imaging can use a prone biopsy table in a similar fashion. The radionuclide suggested is
25 Ir-192, which has a mean gamma energy averaging 300 KeV.

Summary of new approach:

[00010] In an effort to overcome various disadvantages of the known methods
30 referred to above, a new approach uses breast compression geometry similar to that used in x-ray mammography or tomosynthesis. The same device and the same ionizing radiation source can image the breast to estimate the geometry and/or other parameters site that should be irradiated, and to deliver the therapeutic radiation. The radiation source can be such that there is no radiation when the system is turned off, thereby
35 avoiding the challenges of storing and using radioisotopes.

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[00011] For both pre-therapy imaging and for radiation therapy, the breast is compressed between two surfaces, to immobilize and thin the breast. A radiation source operates in an imaging mode and a detector assembly and image processing equipment form one or more images of the breast. The location and/or other parameters of the irradiation target in the breast are determined from the imaging system. Radiation beam collimators then are adjusted so that the radiation pattern from the same source on the breast matches the target area. The radiation source is then operated in a therapy mode, whereby a therapeutic radiation dose is delivered to the target. The breast is then compressed in a different direction, and the imaging and therapeutic delivery proceed as above. The process can be repeated for different directions. The radiation source and the imaging detector can be on a c-arm or another support system that allows the system to be moved around the breast for imaging and irradiation from different directions, preferably including from the opposing side.

20 [00012] When the radiation source is an x-ray tube, the imaging energies can be in the typical kV range used for mammographic imaging while the therapeutic energies can be higher, such as in the orthovoltage range. As a non-limiting example, the imaging x-ray energy can be in the 20-40 kVp range while the therapy x-ray energies can be in the 120-300 kVp range. The low energies for imaging allow high contrast visibility of the lumpectomy cavity and surrounding tissue, and the high therapeutic energies give good penetration through the breast, sparing the skin from over exposure.

[00013] Imaging and therapy irradiation can use a multitude of directions, e.g., at least two orthogonal directions but perhaps more, or non-orthogonal directions. The treatment can be done, e.g., over 5 days, twice per day. A subset or all of the compression directions and imaging/irradiations can be done at each session.

[00014] Instead of using conventional mammography to image the lesion area in two dimensions only, the new system can use a tomosynthesis system as the pre-planning imaging technology. In this alternative, the breast is immobilized and a tomosynthesis

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5 scan is carried out to image the breast from a number of different directions. The
resulting three-dimensional information is used to better define the lesion's orientation in
three dimensions and to calculate the optimal dose profile. An example of a suitable
tomosynthesis system has been demonstrated at trade shows and in clinical use by Lorad
and Hologic, Inc. of Bedford, Massachusetts. Certain aspects of this tomosynthesis
10 system are described in co-pending U.S. patent applications Ser.
Nos. US2004/0101095A1 Dkt. 68514; US2005/0113681A1 Dkt. 7117; and co-pending
PCT International applications Nos.: PCT/US2005/42613 Dkt. 72952;
PCT/US2005/41941 Dkt. 73441; 11/059,282 Dkt. 73862; and 11/271,050 Dkt. 75969.
The contents of all said patent applications are hereby incorporated by reference in this
15 patent specification.

[00015] The new system using a radiation source such as an x-ray tube has a number
of advantages compared with a Linac-based system. For example, in the therapy mode
the new system can use x-ray tubes operating in the 70-300 kV range, while Linac
20 sources typically operation at 6 MV and up. Linac-based therapy systems typically use a
CT or MRI scan for the treatment planning. With the breast, this may not be optimal, as
the breast shape and orientation change from when the CT or MRI scan is done to when
the patient is repositioned on the Linac's couch. Further, the lumpectomy cavity may be
better visualized using the low energy mammographic imaging of the new x-ray based
25 system compared to the higher energy (and lower contrast) CT images. When a Linac-
based system is used, treatment accuracy may degrade because typically it is more
difficult to accurately target the exact treatment area with a Linac source and, therefore,
the target area may need to be increased to guarantee proper irradiation of the lesion area,
causing potential increase in radiation side effects. Moreover, Linac sources are much
30 more expensive than x-ray tubes, and are large and heavy and typically need to be
installed in basements and shielded areas. In contrast, an x-ray system of the type
disclosed in this patent specification can be relatively inexpensive and can be situated
more conveniently throughout a hospital. Further, irradiation with a Linac source
typically is done with the patient in the supine position, with her arm over her head, a
35 position in which it can be difficult to avoid irradiation of the heart and chest areas, while

5 this is not an issue with an x-ray system that directs the radiation through the compressed breast and generally avoids the chest cavity.

[00016] Compared with radionuclide-based system, the new x-ray system does not have the shielding and storage requirements or radioisotopes, and can use radiation exactly defined to a given area and intensity. While a known stereotactic peripheral brachytherapy (SBP) requires different applicators for different size breasts and different lesion sizes, the new x-ray system can use the same beam collimator system that can be adjusted to give any desired outline of irradiation. In SPB, the source of the imaging radiation and the source of the therapy radiation are different and at substantially different positions and orientations relative to the target tissue, while in the new system that are at the same or substantially the same positions and orientations. Unlike SPB, the new system need not image the breast through objects that are between the breast and the compression paddle or breast platform. Because the new system can use a single radiation source such as an x-ray source for both imaging and therapy, in the same breast compression, it can greatly improve image and therapy registration compared with known systems that use one source for imaging and another for therapy. Because the new system irradiates a continuous area in the therapy mode, rather than areas irradiated from a discrete set of radioisotopes' positions, it can deliver a more uniform dose profile. The new system does not need lead shield behind the applicator. Further, it can use the benefits of tomosynthesis imaging for therapy planning.

Brief description of the drawings:

[00017] Figs. 1-9 illustrate known or previously proposed systems.

[00018] Fig. 10 illustrates a coronal view of a breast positioned for imaging and/or therapy in the new system disclosed in this patent specification.

[00019] Fig. 11 illustrates irradiation of an off-center lesion from 5 directions, shown by arrows, where the colors indicate deposited radiation dose scaled to 100%.

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[00020] Fig. 12 illustrated in block diagram form a breast imaging/therapy system constituting a non-limiting example of the new approach disclosed in this patent specification.

10 [00021] Fig. 13 illustrates a prone table above an x-ray source and imaging detector.

Detailed description of preferred embodiments:

15 [00022] Referring to Fig. 10, a non-limiting example of the new system disclosed in this patent specification has a general configuration similar to said mammography system offered under the trade name Selenia or the tomosynthesis system described in said co-pending patent application. The system compresses a breast 100 between a breast platform 102 and a compression paddle 104 in a manner used in said breast mammography and breast tomosynthesis systems. An x-ray source 106, such as an x-ray tube, can be energized to emit an x-ray beam (not shown) that is collimated into suitable cross-section by collimator system 106, and traverses compression paddle 104 and breast 100.

25 [00023] In imaging mode, x-ray source 100 emits an x-ray beam at energies in the mammography range, e.g., in the 20-40 kVp range, and an imaging detector 110 forms an x-ray image of breast 100. Detector 100 can be a flat panel digital detector of the type used in said Selenia system, and source 106, compression paddle 104. breast platform 100 and imaging detector 110 can be mounted on the same C-arm configured for selective rotation around breast 100. The patient can be standing or sitting. Alternatively, 30 the patient can be on a prone breast table such as the table available from Lorad under the trade name MultiCare, and the x-ray source and imaging detector can be mounted to rotate around a vertical axis relative to the breast. The image is processed by imaging software and information from the detector and/or imaging software is used, together with any input from a health professional, by a therapy planning system similar to those 35 conventionally used in radiation therapy planning but adjusted to the parameters of using

5 x-ray energies appropriate to the system disclosed here, such as in 120-300 kVp range. For example, a radiation therapy planning system available from Philips under the trade name Pinnacle³ can be used, adapted as needed to account for the fact that the new systems uses x-rays in the orthovoltage range for treatment and that the imaging information can come from a conventional mammogram or from tomosynthesis
10 images. Further information on the Pinnacle³ radiation therapy planning system can be found at
new <http://www.medical.philips.com/main/products/ros/products/pinnacle3/index.asp>

[00024] In the therapy mode, breast 100 can remain in the same compressed
15 position. Collimator system 108 and x-ray source 106 are re-set according to results from the therapy planning software such that the x-ray beam from source 106 has a cross-section appropriate to the breast portion that should be irradiated and is in the appropriate x-ray energy range and is ON for the appropriate time period(s) to deliver the appropriate fraction dose of radiation to the selected breast portion. A shield (not shown) can be
20 introduced between breast 100 and imaging detector 110 to protect the detector from the higher energy x-rays used in therapy, or the detector can be withdrawn or otherwise protected when therapy x-rays impinge on breast 100.

[00025] After imaging and irradiation at one direction through the breast, e.g., the
25 direction illustrated in Fig. 10, the breast is released, the equipment is rotated around the breast, and the breast is compressed again for imaging and therapy at a different orientation of the x-ray beam relative to the breast. The imaging, therapy planning, and therapy sequence is then repeated. The therapy planning at the new orientation can be similar to that at the first orientation, or can be speeded up by using information from the
30 first therapy planning results, or could be omitted altogether based on results from the therapy planning at the first orientation and/or inputs from the health care professional. This sequence of imaging, (any) therapy planning, and x-ray therapy can be repeated several times for different orientation of the x-ray beam relative to breast 100. Different orientation can be used in the same session (day) with the patient and/or in different
35 sessions (days). As apparent, the different orientations optimize the radiation dose at the

5 breast volume that should be irradiated while reducing the skin dose as well as the dose at breast tissue that should not be irradiated.

[00026] Fig. 11 illustrates (in color) the x-ray therapy at five different directions. In a first orientation, a therapy x-ray beam 201 irradiates an internal breast volume to deliver a first fractional radiation dose, and also irradiates other breast tissue along its path. In another orientation of the x-rays relative to the breast, a therapy x-ray beam 202 delivers another fractional dose, and beams 203, 204 and 205 deliver additional fractional doses along their respective paths. The beams may be set to deliver the same or different fractional radiation doses. In the illustrated example, x-ray beam 201 delivers a higher dose than the other beams. The color scale at the bottom of Fig. 11 and the colors used for the beam show that beam 201 delivers a higher dose while each of the other beams delivers a lower dose similar to or equal to that of the other beams (other than beam 201). The colors of the beams also show that the dose drops off as the beam penetrates further into the breast, and that the dose at the target of the radiation therapy treatment (the red area) is much higher than at any other portion of the breast.

[00027] Fig. 12 illustrates the new system in block diagram form. In the imaging mode or operation, output information from imaging detector 110 is delivered to image processor 120 that includes computer equipment and software as in said Selenia system to form an x-ray image and may include additional hardware/software for coupling and interfacing with a therapy planning unit 122. Based on information from image processor 120, on input from a health care professional, and on characteristics of x-ray source 108 and possibly other system parameters, therapy planning unit 122 uses otherwise conventional therapy planning software to deliver therapy plan information to source & collimator controls 124. In the therapy mode, source & collimator controls 124 communicate with x-ray source 106 and collimator system 108 to set them for delivery of the appropriate radiation to a patient's breast that is between collimator system 108 and imaging detector 110. Appropriate radiation in this context refers to an x-ray beam that is shaped by collimator 108 to the desired cross-section, and is at the appropriate x-ray energy range and is kept on for the appropriate duration set by the radiation planning

5 software and/or the health professional. If desired, the x-ray energy can be varied during therapy exposure and the energy distribution within a beam cross-section also can be varied, e.g., with suitable x-ray filters and/or by suitable control of x-ray tube driving voltage. Units 106, 108 and 110 are mounted on a C-arm 126 for positioning at different angler relative to the patient's breast to image and irradiate the breast from different
10 directions. Image processor 120 typically includes one or more interfaces such as a keyboard and mouse through which a health professional can enter information and control the system, and one or more image display devices such as computer screens.

[00028] Thus, the system disclosed in this patent specification comprises an x-ray
15 source and collimators at one side of a patient's breast and an imaging x-ray detector at the other side. When operated in an imaging mode, the system images the breast and the imaging information, possibly together with other inputs, is used to generate a therapy plan. Preferably while the breast remains compressed as it was in the imaging mode, the system changes over to a therapy mode, and results from the therapy plan are used to
20 control the x-ray tube and the collimator system to deliver therapy x-ray radiation to a selected volume in the breast. The process typically is repeated at different orientations of the x-ray beam relative to the breast, with the breast being released and then again compressed for each different orientation.

25 [00029] If the new system is based on a tomosynthesis system is used rather than on a mammography system such as the Selenia system, in the imaging mode the new system takes a number of images at different orientation relative to the breast while the breast remains in the same compression, and the resulting two-dimensional image information from each orientation is processed into three-dimensional information, e.g., in the form of
30 slice images that can be at any selected orientation relative to the breast and can show the lumpectomy site in three dimensions. This three-dimensional information is then used by the therapy planning software to set the therapy parameters. In the therapy mode, the tomosynthesis-based system can irradiate the breast from several different directions while the breast remains in the same compression as in the imaging mode. The beam
35 used in this therapy mode can be in the same orientations as in imaging mode or at

5 different orientations, and the number of orientations in the therapy mode can be the same or different compared with the number used in the imaging mode. In this manner, a greater number of orientations can be conveniently used as compared with the number of orientations in a mammography based imaging/therapy system. If desired, the process of tomosynthesis imaging/therapy can be repeated at a different breast compression where
10 the paddle/breast support is oriented differently relative to the breast.

[00030] Another example of the new system is based on a prone table such as the unit that is available from Lorad under the trade name MultiCare and is illustrated in Fig.

13. In the imaging mode of using the new system, the patient is in the prone position on
15 the table, with a breast protruding downward through an opening in the table. The protruding breast is compressed between a compression paddle and breast platform that are similar to those described above but are mounted on a C-Arm that rotates about an upwardly extending axis. The same C-Arm carries a similar x-ray source and a similar x-ray imaging detector, and can be otherwise similar to the configuration and operation
20 described above except for rotation about an upwardly extending axis. After imaging a breast at one orientation of the x-ray beam relative to the breast, developing a therapy plan based on imaging at that orientation, and adjusting the collimator system and using therapy irradiation accordingly, the breast is released, the C-Arm is rotated to a different orientation relative to the breast, and the imaging and irradiation steps are repeated for
25 the new orientation. Of course, the biopsy needle stage that is added to the prone table for use in obtaining a biopsy sample of breast tissue is not mounted on the table for the imaging and x-ray therapy that the new system carries out. The known prone table can be modified to allow for rotating its C-Arm through a greater angle to enable imaging and therapy at a greater range of orientation of the x-ray beam relative to the patient's breast.

30 [00031] While a single x-ray source can be used for both imaging and therapy irradiation, an alternative is to use two x-ray sources, one for imaging and another for therapy, mounted such that each can be moved into position as needed and preferably such that the focal spot of each can be moved to substantially the same position for a
35 given imaging/therapy orientation of the respective x-ray beam. For example, when each

5 source is an x-ray tube, one would emit x-rays in the mammography range and the other in the orthovoltage range. The lower energy range tube would be used first for imaging and, while the breast remains compressed in the same position in space, the higher energy x-ray tube would be moved such that its focal spot is at substantially the same position that the focal spot of the lower energy x-ray tube was for imaging at that orientation. For
10 example, the two x-ray tubes can be mounted on a rotating arm (not shown) or a sliding arm (not shown) that is in turn mounted on the C-arm of a new system based on a mammography unit such as the Selenia system from Lorad or a tomosynthesis unit or a prone table such as MultiCare table from Lorad.

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What is claimed is:

1. A method of treating a patient's breast with therapy radiation comprising:
10 placing the patient in a prone position on a patient table with the breast
extending downwardly through an opening in the table;
imaging the breast with an imaging system using imaging radiation to produce
image information describing at least one image of the breast;
computer-processing the image information to generate radiation target
15 information pertaining to a target volume to be treated with therapy
radiation;^[as1]
delivering therapy radiation to the breast from a source of therapy radiation,
wherein:
(a) at least a therapy radiation emitting portion of the source remains
20 below the patient table while moving around the breast, about an
upwardly extending axis, to deliver therapy radiation to the breast
from several different positions of said radiation therapy emitting
portion;
(b) the therapy radiation that the source delivers to the breast is at an
25 energy selected for breast tissue radiation therapy that is at least as
high as the orthovoltage range but is below an energy range for
whole body therapy radiation; and
(iii) the delivery of said therapy radiation to the breast is controlled by
taking into account said radiation target information generated in
30 said computer-processing.
2. A method as in claim 1 in which said imaging comprises imaging the breast with
a tomosynthesis system.

- 5 3. A method as in claim 2 including using the tomosynthesis system to image the breast from several different directions to generate said imaging information in three dimensions.
- 10 4. A method as in claim 3 in which said computer-processing comprises defining said target volume in three dimensions.
5. A method as in claim 3 in which said computer-processing includes calculating a therapy radiation dose characteristic.
- 15 6. A method as in claim 2 in which said tomosynthesis system is an x-ray system and said imaging radiation in the 20-40 kVp range.
- 20 7. A method as in claim 1 in which said therapy radiation is in the orthovoltage range.
8. A method as in claim 7 in which said therapy radiation is in the 120-300 kVp range.
- 25 9. A method as in claim 1 in which the therapy radiation is x-radiation.
10. A method as in claim 1 in which said imaging radiation is x-radiation at energies in a breast imaging range and said therapy radiation is penetrating radiation [as2] at a higher energy range.
- 30 11. A method as in claim 1 comprising using one source of radiation for said imaging radiation and another source of radiation for said therapy radiation.
12. A method as in claim 1 comprising using a single x-ray tube to generate said imaging radiation at one time and said therapy radiation at a different time.
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- 5 13. A method as in claim 1 including maintaining the breast immobilized in substantially the same position throughout said imaging and said delivery of therapy radiation thereto.
- 10 14. A method as in claim 13 in which said maintaining the breast immobilized comprises compressing the breast.
- 15 15. A method as in claim 1 including immobilizing the breast in different positions for delivering therapy radiation thereto from respective different ones of said several positions of the therapy radiation emitting portion of the source.
16. A method as in claim 15 in which said immobilizing comprises compressing the breast.
- 20 17. A method as in claim 1 in which the imaging system includes an imaging detector and said imaging comprises moving the imaging detector around the breast while maintaining the detector below the patient table.
- 25 18. A method as in claim 17 in which said therapy radiation source provides the imaging radiation and including providing a shield between the detector and the breast to protect the detector from the imaging radiation.
19. A method as in claim 1 in which said computer processing comprises generating a therapy treatment plan.
- 30 20. A method as in claim 1 in which said upwardly extending axis is vertical.
21. A method of treating a patient's breast with therapy radiation comprising:
immobilizing the patient's breast;
imaging the immobilized breast with imaging radiation to produce image
35 information describing at least one image of the breast;

5 computer-processing the image information to generate radiation target
information pertaining a volume to be irradiated with therapy
radiation;[as3]
delivering therapy radiation to the breast from a source of therapy radiation,
wherein:

- 10 (a) at least a therapy radiation emitting portion of the source moves
around the breast, about a laterally extending axis, to deliver
therapy radiation to the breast from several different positions of
said radiation therapy emitting portion;
- (b) the therapy radiation that the source delivers to the breast is at an
15 energy selected for breast tissue radiation therapy that is at least as
high as the orthovoltage range but is below an energy range for
whole body therapy radiation; and
- (iii) the delivery of said therapy radiation to the breast is controlled by
taking into account said target volume [as4] information generated in
20 said computer-processing.

22. A method as in claim 21 in which said imaging comprises imaging the breast
with a tomosynthesis system.

25 23. A method as in claim 22 including using the tomosynthesis system to image the
breast from several different directions to generate said imaging information in
three dimensions.

24. A method as in claim 20 including using the imaging system to image the breast
30 from several different directions to generate said target information in three
dimensions.

25. A method as in claim 24 in which said computer-processing comprises defining
the target volume in three dimensions.

- 5 26. A method as in claim 21 in which said computer-processing includes calculating
a therapy radiation dose characteristic.
27. A method as in claim 21 in which said imaging comprises imaging the breast
with radiation in the 20-40 kVp range.
- 10 28. A method as in claim 21 in which said delivery of therapy radiation comprises
delivery of radiation that is in the orthovoltage range.
- 15 29. A method as in claim 27 in which said therapy radiation is in the 120-300 kVp
range.
30. A method as in claim 21 in which the therapy radiation is x-radiation.
31. A method as in claim 21 in which said imaging radiation is x-radiation at
20 energies in a breast imaging range and said therapy radiation is x-radiation at a
higher energy range.
32. A method as in claim 21 including maintaining the breast immobilized in
substantially the same position throughout said imaging and said delivery of
25 therapy radiation thereto.
33. A method as in claim 31 in which said maintaining the breast immobilized
comprises compressing the breast.
- 30 34. A method as in claim 21 including immobilizing the breast in different positions
for delivering therapy radiation therefore from respective different ones of said
several positions of the therapy radiation emitting portion of the source.
- 35 35. A method as in claim 33 in which said immobilizing comprises compressing the
breast.

5

36. A method as in claim 21 in which the imaging system includes an imaging detector and said imaging comprises moving the imaging detector around the breast.

10

37. A method as in claim 21 in which said computer processing comprises generating a therapy treatment plan.

38. A method as in claim 21 in which said laterally extending axis is horizontal.

15

39. A system for imaging a patient's breast and treating the breast with therapy radiation comprising:

a breast immobilizing device;

an imaging detector producing image information describing at least one image of the breast;

20

an image processor coupled with the imaging detector to receive the image information therefrom and configured to use the image information to generate target volume information pertaining to a volume to be irradiated with therapy radiation and to generate therapy planning information;

25

a source of therapy radiation having a therapy radiation emitting portion and configured to deliver therapy radiation to the breast from a source of therapy radiation, wherein:

30

(a) at least the therapy radiation emitting portion of the source is mounted and driven to move around the breast, about an axis extending from the breast nipple to the patient's chest wall, to deliver therapy radiation to the breast from several different positions of said radiation therapy emitting portion;

(b) the therapy radiation that the source delivers to the breast is at an energy selected for breast tissue radiation therapy that is at least as

5 high as the orthovoltage range but is below an energy range for
whole body therapy radiation; and
a therapy planning unit coupled to said image processor to receive said therapy
planning information therefrom and coupled to said source of therapy
radiation to control the emission of therapy radiation therefrom to take
10 into account said therapy planning information.

40. A system for imaging a patient's breast and treating the breast with therapy
radiation comprising:
- a breast immobilizing device;
 - 15 an imaging detector producing image information describing at least one
image of the breast;
 - an image processor coupled with the imaging detector to receive the image
information therefrom to generate therapy planning information;
 - a source of therapy radiation having a therapy radiation emitting portion and
20 configured to deliver therapy radiation to the breast from a source of
therapy radiation, wherein:
 - (a) at least the therapy radiation emitting portion of the source moves
around the breast, about an axis extending from the breast nipple to
the patient's chest wall, to deliver therapy radiation to the breast
25 from several different positions of said radiation therapy emitting
portion;
 - (b) the therapy radiation that the source delivers to the breast is at an
energy selected for breast tissue radiation therapy that is at least as
high as the orthovoltage range but is below an energy range for
30 whole body therapy radiation; and
 - a therapy planning unit coupled to said image processor to receive said therapy
planning information therefrom and coupled to said source of therapy
radiation to control the emission of therapy radiation therefrom to take
35 into account said therapy planning information.

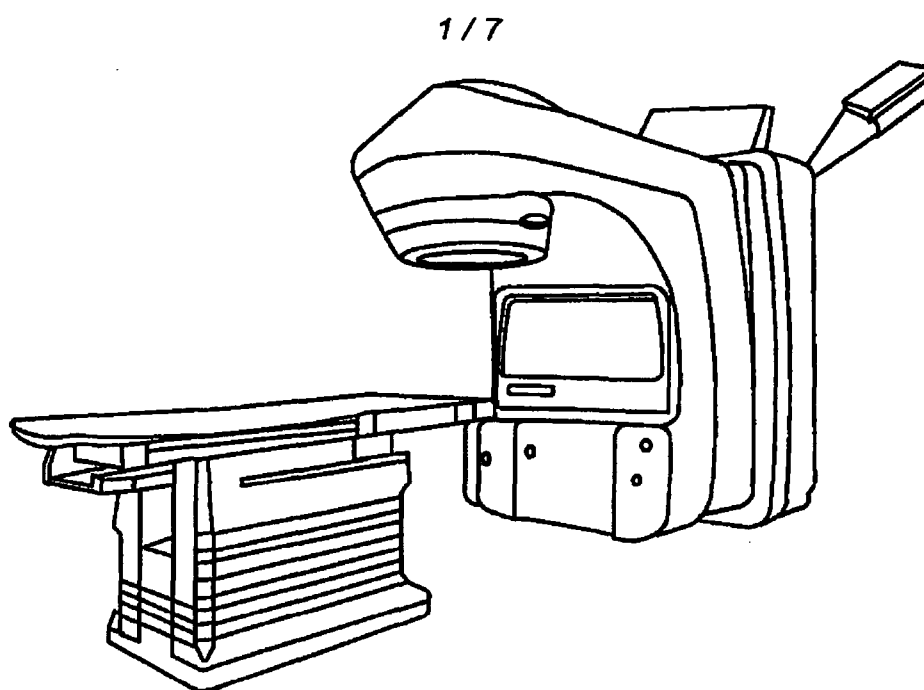


FIG. 1

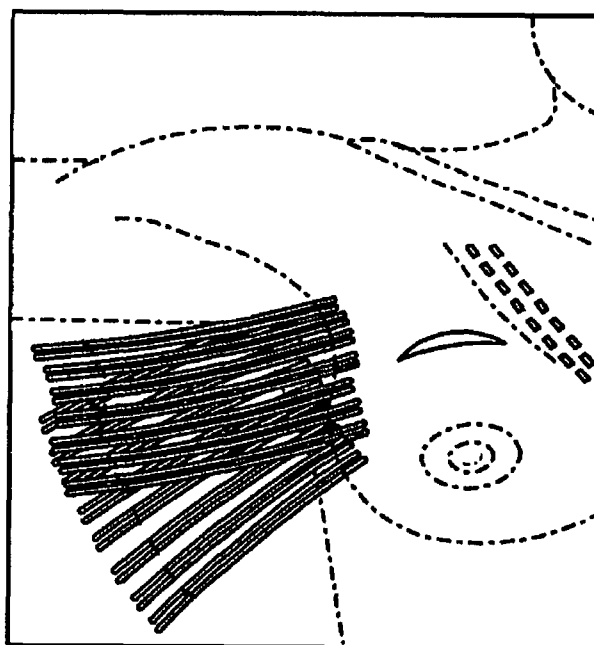


FIG. 2. Interstitial brachytherapy

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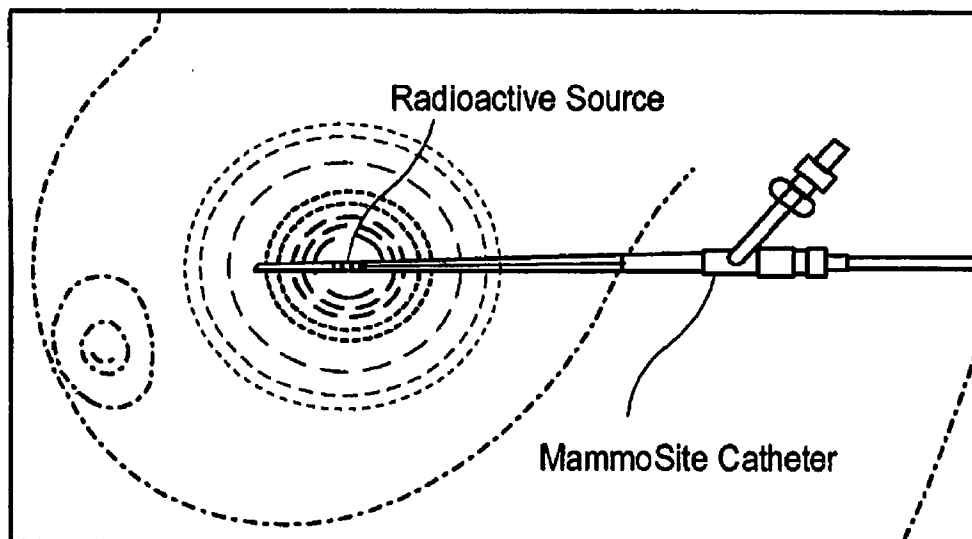


FIG. 3. Internal Balloons

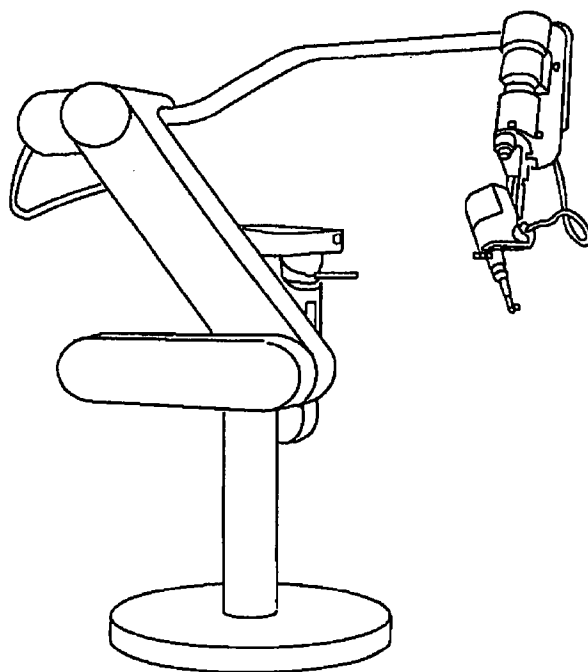


FIG. 4. Intraoperative radiation therapy device

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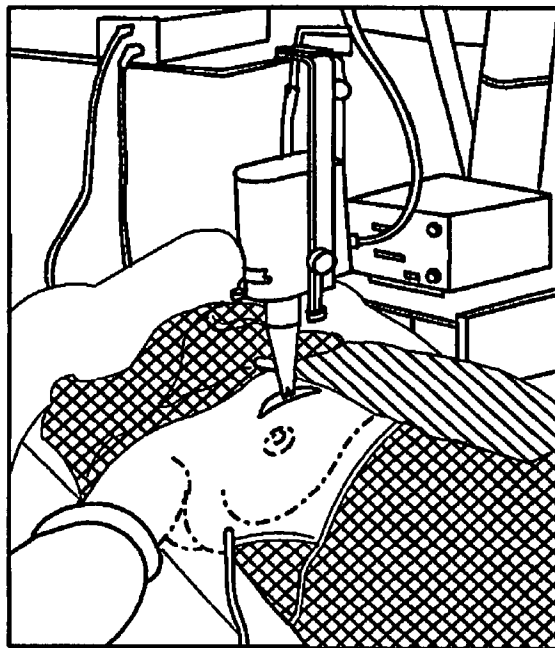


FIG. 5. Intraoperative radiation therapy device in operation

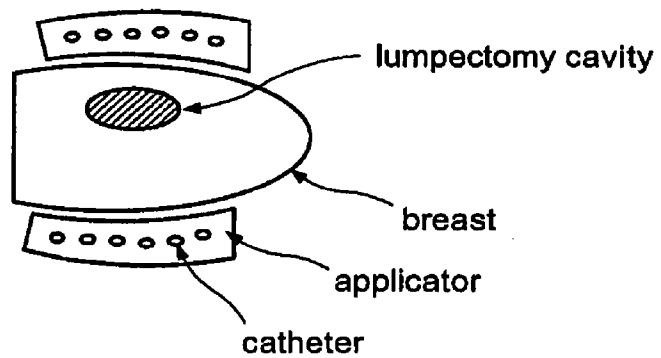


FIG. 6. Sagittal view of peripheral brachytherapy device

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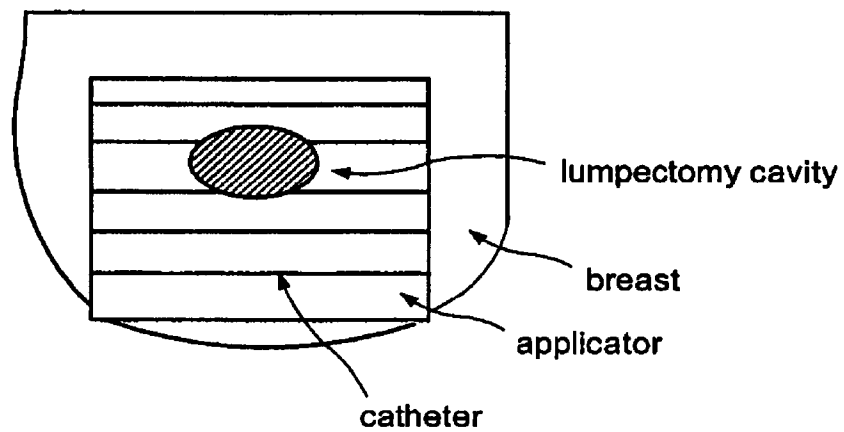


FIG. 7. Transaxial view of peripheral brachytherapy device

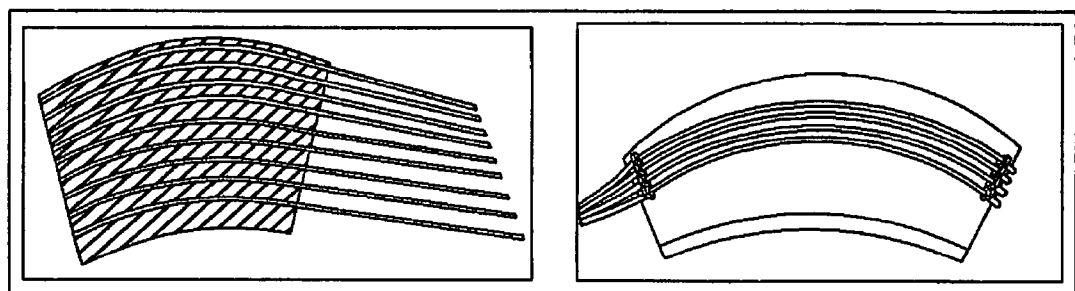


FIG. 8. Examples of applicators

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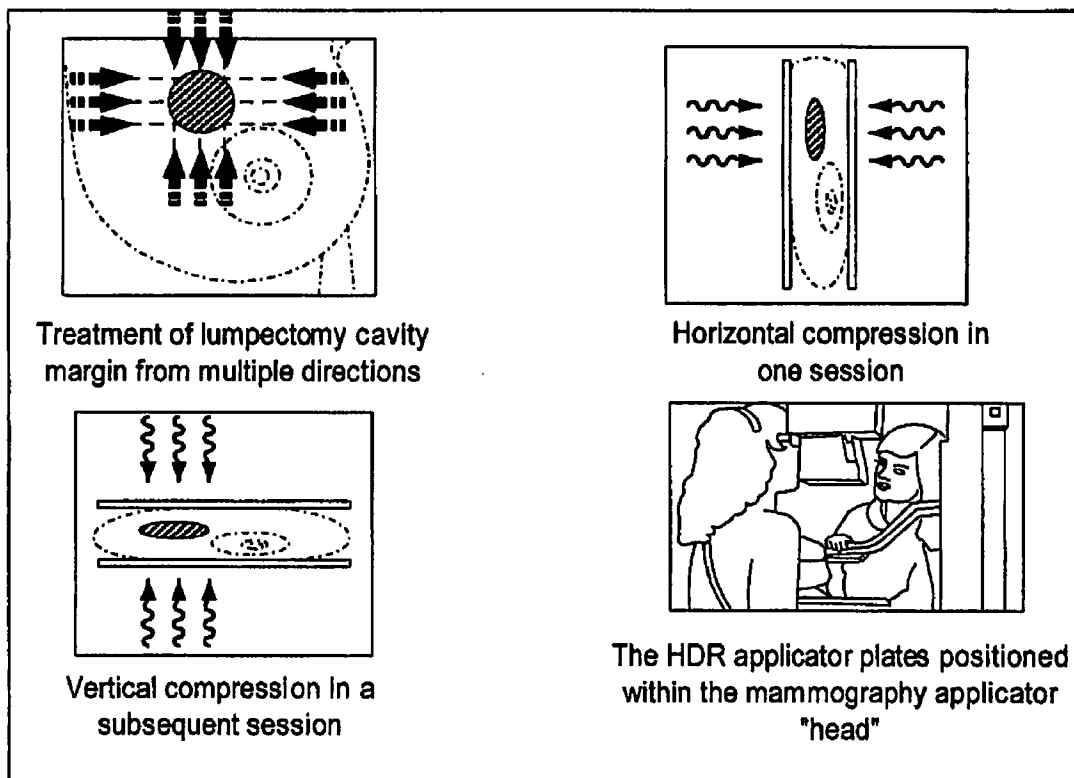


FIG. 9. The breast is exposed in two compressions

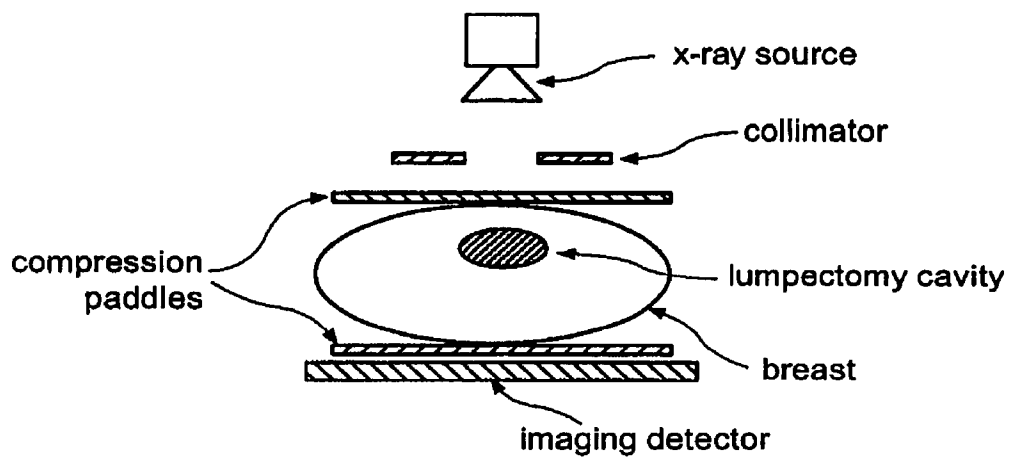


FIG. 10. Coronal view of new x-ray based system for imaging / therapy

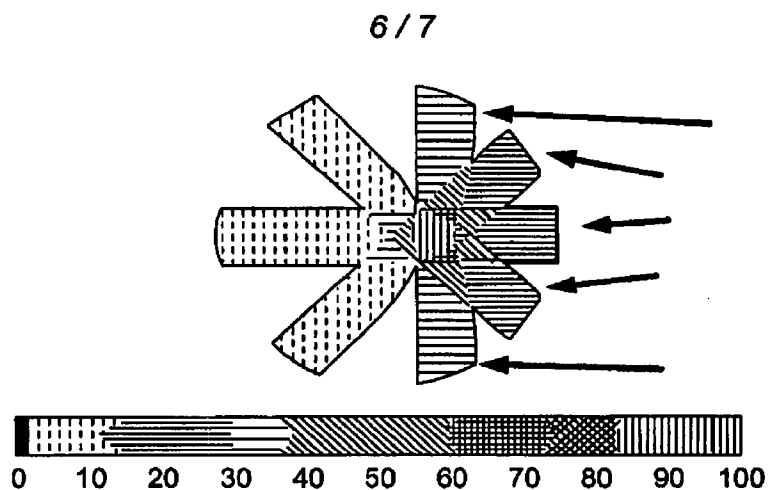


FIG. 11. Example showing irradiation of an off-center lesion from 5 directions, shown by arrows, where the colors indicate deposited radiation dose scaled to 100%

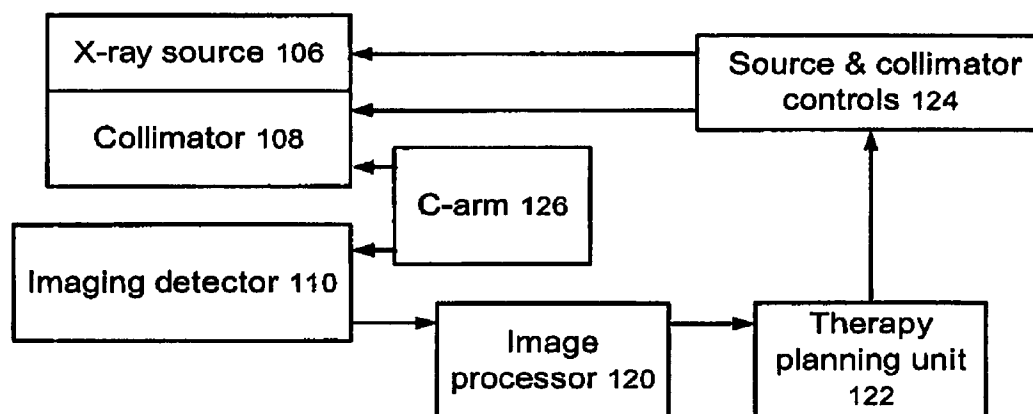


FIG. 12. Block diagram of orthovoltage breast imaging / therapy system

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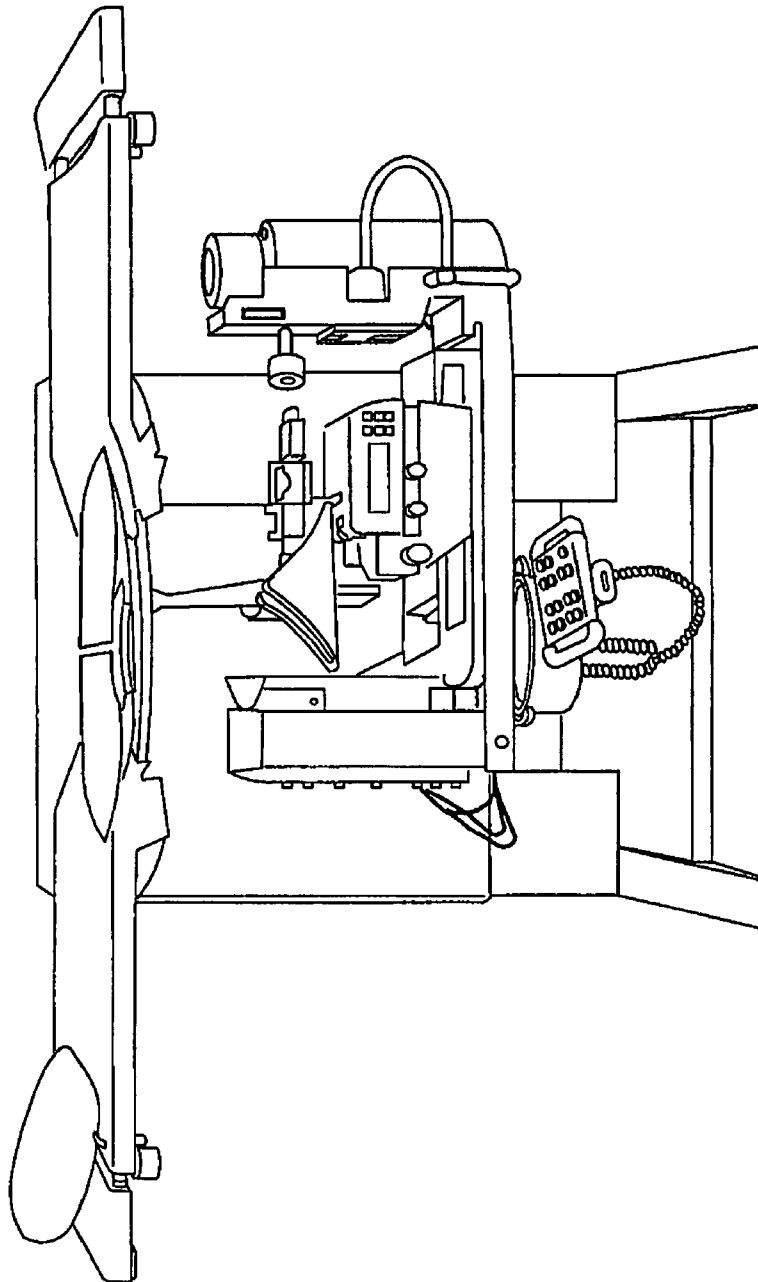


FIG. 13. Prone table above x-ray source and imaging detector