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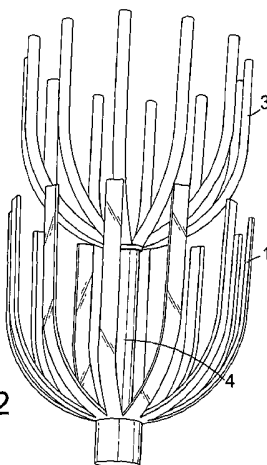


Fig. 2

(57) Abstract: Breast immobilisation apparatus for use in breast imaging to allow medical intervention is disclosed. The apparatus comprises a body support platform for supporting the body of a patient in a prone position, the body support platform having a hole through which the breast of a patient is allowed to pendulantly project in use; and a breast cup arranged below the hole for receiving a breast of the patient and comprising means for uniformly compressing the breast to immobilise it without substantially deforming the breast, and an aperture arrangement to allow access to a substantial portion of the surface of the breast for medical intervention. A breast immobilisation method for use in breast imaging to allow medical intervention is disclosed. The method comprises supporting the body of a patient in a prone position, pendulantly projecting a breast of the patient through a hole in the body support platform; and receiving the breast of the patient in a breast cup, uniformly compressing the breast to immobilise it without substantially deforming the breast, and providing an aperture arrangement to allow access to a substantial portion of the surface of the breast for medical intervention.

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BREAST IMMOBILISATION APPARATUS AND METHOD FOR USE IN BREAST IMAGING TO ALLOW MEDICAL INTERVENTION

The present invention relates to a breast immobilisation apparatus and method for use in breast imaging to allow medical intervention.

In the process of imaging breasts it is usually necessary to gently immobilise the breasts to ensure that the image quality is not interfered with due to movement of the breasts. Movements of the patient during imaging can in turn result in the movement of the breast. If the breast is not immobilised during the performance of interventional procedures under real-time image guidance, interventional probes (e.g. biopsy needle) can also cause movement of the breast during their insertion into the breast. Prior art breast immobilisation techniques include squashing or sandwiching the breast between the two compression-plates or compression-grids whilst the patient is in a standing or prone position. This bi-lateral method of immobilisation is not desirable since it potentially causes flattening and merging of the breast lesions. It is usually also necessary to position the breasts in accordance with the special requirements of the imaging modality (e.g. x-ray, magnetic resonance, ultrasound). It is desirable that the imaging modalities used should – in addition to the breast – also be able to image the chest-wall and axillary-tail anatomies of the patients.

Magnetic Resonance Imaging (MRI) is considered to be a method of imaging which has high sensitivity in terms of detecting smaller lesions in the breast and also high specificity in terms of characterising the nature of the lesions. Typically the patient must be inserted in a cylindrical MRI magnet, although more recently ultra-short magnets also having a large bore have become available (see WO01/70109). Such MRI systems have the advantages that the patient feels less claustrophobic and the patient is more accessible to medical staff during diagnostic imaging and more importantly during the performance of medical interventions which require access to the breasts during imaging. The performance of interventional procedures under real-time MRI guidance is generally only possible in the MRI systems employing ultra-short and large-bore magnets due to the physical constraints of the conventional, axially-long cylindrical magnet based MRI systems.

WO96/08199 discloses a device for guiding a medical intervention tool. A patient lies prone on a body support platform with their breasts pendulantly protruding through holes in the platform. One at a time the breast can be immobilised for imaging using a contractible basket which comprises two basket members which are urged together. The basket members have holes in them to allow medical intervention tools to be inserted there through. This device is for use with axially-long, narrow-bore conventional MRI systems and hence it is designed to enable an image to be taken of the immobilised breast. After initial imaging for the localisation of the lesion(s), the patient is then removed from the bore of the MRI machine to allow medical intervention via the holes in the basket members. Since the targeting of the lesion(s) by the interventional tool such as a probe has to happen when the patient is outside the MRI system, the conventional MRI system do not allow interactive medical intervention under image guidance.

The basket members in WO96/08199 immobilise the breast but also deform it since the two basket members are urged together. This deformation of the breast distorts the true shape of the morphology of the breast and can lead to lesions and the like being merged together by the force of the distorting compression. This distortion can also impact deleteriously on the medical intervention process.

The present invention aims to provide an improved breast immobilisation apparatus for use in breast diagnostic imaging and in the performance of (real time and non-real time) image-guided medical interventional procedures.

One aspect of the invention provides breast immobilisation apparatus for use in breast imaging to allow medical intervention, the apparatus comprising a body support platform for supporting the body of a patient in a prone position, the body support platform having a hole through which the breast of a patient is allowed to pendulantly project in use; and a breast cup arranged below the hole for receiving a breast of the patient and comprising means for uniformly compressing the breast to immobilise it without substantially deforming the breast, and an aperture arrangement to allow access to a substantial portion of the surface of the breast for medical intervention, wherein the means for uniformly compressing the breast comprises a rigid structure and a resilient urging arrangement on an inner side of the rigid structure for urging into engagement with the breast for compression of the breast, and the aperture

arrangement comprises an array of apertures in the rigid structure or gaps between parts of the rigid structure.

Thus, this aspect of the present invention overcomes the deficiencies in the prior art and provides for the immobilisation and support of the breast in its more natural shape in a breast cup which is designed to better match the natural shape of a breast. The cup shape can be ellipsoidal, dome shaped or hemispherical. Different shapes and sizes can be provided for patients. The aperture arrangement ensures that medical staff can access the breast through the breast cup to carry out medical intervention techniques during imaging if possible or after imaging if necessary.

In one embodiment the rigid structure comprises a mesh or a plurality of finger-like projections radiating from a common point.

In one embodiment the resilient urging arrangement comprises a hydraulic or pneumatic arrangement for expansion to urge against the surface of the breast.

In one embodiment the breast cup includes a flange running around an upper edge of the rigid structure, the upper edge defines an opening through which the breast is received, the breast cup is adapted to be inserted through the hole in the body support platform, and the flange is adapted to engage with an upper surface of the body support platform to hold the breast cup extending below the body support platform. This allows for simple exchange of the breast cup to use a breast cup to suit the size and shape of a patient's breast.

In one embodiment the body support platform has a flexible upper surface to mould to the shape of the prone patient. This ensures improved patient comfort and more importantly it ensures that the majority of the breast of the patient fits into the breast cup

In one embodiment the body support platform has a second hole for receiving a second breast of the patient, the apparatus including a second said breast cup arranged below the second hole. Thus the present invention enables single or double breast immobilisation and imaging.

In one embodiment the breast cup is disposable.

In one embodiment the body support platform comprises an upper surface having the hole therethrough and a base for placement on a conventional imaging body support platform, the base being connected to the upper surface to space the upper surface from the base below the hole to provide room for the breast cup received in the hole.

One aspect of the invention provides a breast imaging arrangement comprising the breast immobilisation apparatus, a medical intervention tool for medical intervention of the breast, and a tool support arrangement for supporting the medical intervention tool and enabling movement of the medical intervention tool to contact any required point on the surface of the breast.

This aspect of the present invention makes medical intervention simpler since the medical intervention tool is supported on the apparatus.

In one embodiment the breast cup includes MRI reference markers detectable during imaging, the apparatus including a processing arrangement for receiving a selection of a location within the breast to be targeted by the medical intervention tool and data on the detected reference markers, and a tool support driving mechanism for driving the tool support arrangement, wherein the processing arrangement is adapted to calculate drive signals and to control the tool support driving mechanism to automatically locate the medical intervention tool at the location to be targeted. This embodiment enabled automatic 'robotic' positioning of the medical intervention tool at the correct location for the medical intervention within the breast.

In one embodiment the breast imaging arrangement, includes an MRI magnet arrangement having a large bore and ultra-short axial length therefore allowing the placement of the patient and the apparatus within the bore of the magnet and also providing access to the breast by the medical staff , the breast immobilisation apparatus, the tool support arrangement and the medical intervention tool are arranged in the bore for medical intervention during imaging, and the MRI magnet arrangement includes a detecting antenna arranged around the breast cup for detection of MRI signals from the breast.

Another aspect of the invention provides a breast immobilisation method comprising for use in breast imaging to allow medical intervention, the method comprising supporting the body of a patient in a prone position, pendulantly projecting a breast of the patient through a hole in the body support platform; and receiving the breast of the patient in a breast cup, uniformly compressing the breast to immobilise it without substantially deforming the breast, and providing an aperture arrangement to allow access to a substantial portion of the surface of the breast for medical intervention, wherein uniformly compressing the breast comprises using a rigid structure and a resilient urging arrangement on an inner side of the rigid structure for urging into engagement with the breast for compression of the breast, and the aperture arrangement comprises an array of apertures in the rigid structure or gaps between parts of the rigid structure.

Another aspect of the invention provides a breast imaging method comprising immobilising the breast of a patient using the breast immobilisation method, inserting the patient in an MRI magnet arrangement having a large bore and ultra-short axial length therefore allowing the placement of the patient and the apparatus within the bore of the magnet and also providing access to the breast by medical staff, arranging a detecting antenna around the breast cup for detection of MRI signals from the breast, and using a medical intervention tool to access the breast for medical intervention through the breast cup during imaging.

Embodiments of the present invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a diagram of a rigid part of the breast cup according to one embodiment of the present invention;

Figure 2 is a diagram of the rigid part of the breast cup showing the insertion of the pneumatic compressible member according to the first embodiment of the present invention;

Figure 3 is a diagram of the complete breast cup according to the first embodiment of the present invention;

Figure 4 is a diagram showing different sized breast cups according to the first embodiment of the present invention;

Figure 5 is a diagram showing the patient support platform with a breast cup support arrangement beneath according to the first embodiment of the present invention;

Figure 6 is a diagram showing the detecting antennas on the breast cup support arrangement according to the first embodiment of the present invention;

Figure 7 is a diagram showing the insertion of two breast cups in the holes in the patient support platform according to the first embodiment of the present invention;

Figure 8 is a diagram illustrating the positioning of the breast cups in the breast cup support arrangement according to the first embodiment of the present invention;

Figure 9 is a diagram illustrating the process for inflating the pneumatic compressible members in the breast cups according to the first embodiment of the present invention;

Figure 10 is a diagram illustrating the pneumatic compressible members in an inflated state immobilising the breasts in the breast cups according to the first embodiment of the present invention;

Figure 11 is a schematic cross section through a breast in the breast cup before inflation of the pneumatic compressible members according to the first embodiment of the present invention;

Figure 12 is a schematic cross section through a breast in the breast cup after inflation of the pneumatic compressible members according to the first embodiment of the present invention;

Figures 13 and 14 are diagrams illustrating the medical intervention tool support mechanism for use in imaging a single breast according to a second embodiment of the present invention;

Figure 15 is a diagram illustrating the breast cup support arrangement according to the second embodiment of the present invention;

Figure 16 is a diagram illustrating the inflation of the pneumatic compressible member according to the second embodiment of the present invention;

Figure 17 is a diagram illustrating the breast immobilised in the breast cup and the medical intervention tool in operation in accordance with the second embodiment of the present invention;

Figure 18 is a diagram illustrating the breast cup support arrangement with the medical intervention tool support in accordance with the second embodiment of the present invention;

Figure 19 to 24 are diagrams illustrating a third embodiment of the present invention comprising an apparatus for retro fitment to a conventional patient support platform;

Figure 25 is a diagram illustrating an alternative invention;

Figure 26 is a diagram illustrating an alternative invention;

Figure 27a and 27b is a diagram illustrating a fourth embodiment of the present invention;

Figure 28 is a diagram illustrating a fifth embodiment of the present invention; and Figures 29 to 31 are diagrams illustrating different antenna configurations according to embodiments of the invention.

A first embodiment of the present invention will now be described with reference to figures 1 to 12. This embodiment enables the immobilisation of both breast of a patient at the same time to enable imaging of both breasts simultaneously in for example an MRI scanner.

Figure 1 illustrates a rigid structure 1 forming part of a breast cup. The rigid structure 1 comprises a plurality of finger-like projections radiating from a common point from which the finger-like projections are supported by a support sleeve 2. The finger-like projections radiate to form an outer surface of the breast cup. They form a generally dome shape extending from a cylindrical shape in this embodiment. The support sleeve 2 has an aperture to receive a resilient urging arrangement 3 as illustrated in figure 2. The resilient urging arrangement 3 comprises a plurality of finger-like projections matching the finger-like projections of the rigid structure 1. The finger-like projections of the resilient urging arrangement 3 are hollow and sealed at their top ends. At their bottom ends where they meet at a common point, they intercommunicate with each other and with a hollow tube 4. This provides a pneumatic or hydraulic structure which can be expanded (inflated or pumped up) via the tube 4. The tube 4 passes through the support sleeve 2 so that the resilient urging arrangement 3 is supported by the rigid structure 1. The resilient urging arrangement 3 can be fixed to the rigid structure 1 e.g. by adhesion or any other suitable fixing arrangement.

Figure 3 illustrates the complete structure of a breast cup in which a flange 5 is attached to upper ends of the rigid structure 1. The flange 5 is made of a rigid or slightly / semi flexible material and its purpose is to engage with an upper surface of a patient support platform around the periphery of an aperture in the surface of the patient support platform to enable the rigid structure 1 with attached resilient urging arrangement 3 to hang through aperture. The flange 5 has a breast aperture 6 therein corresponding to the dimensions of the cylindrical open end of the rigid structure 1.

As can be seen in figure 4, different sized breast cups can be provided to accommodate the different breast sizes of the patients. The outer dimensions of the flange 5 remain the same for each of the different sized breast cups to engage with the periphery of the aperture in the patient support platform. Only the breast aperture 6 varies in size for the flanges 5 to match the variation in size of the rigid structure 1. The breast cup can be disposable. This ensures health and hygiene requirements are met. No other parts of the apparatus need be disposable or cleaned after every use since they do not come into contact with the patient.

Figure 5 illustrates a patient support platform 10 having apertures 11 and 12 for allowing the breasts of a patient to pendulantly project there through. Beneath the body support platform 10 and connected to a lower surface thereof is a support arrangement 13. The support arrangement 13 is arranged to support the breast cups, detection antennae, and a tool support arrangement as will be described in more detail herein after. The support arrangement 13 includes three spaced support connectors 13a, 13b and 13c. As can be seen in figure 6, a support rod 14 is supported in the middle support connector 13b and two antennae 15a and 15b are supported on the support rod 14 using a slidable and lockable sleeve 16. This enables the antennae to be raised or lowered relative to the support arrangement 13. The antennae 15a and 15b are supported to be coaxial with the outer two support connectors 13a and 13c.

Figure 7 illustrates the insertion of two breast cups 7 into the apertures 11 and 12 in the patient support platform 10. Each breast cup 7 is inserted so that the tube 4 insert through a respective support connector 13a or 13c and the flange 5 lies flush with the upper surface of the patient support platform 10. The surface of the patient support platform 10 can be made of a flexible, semi-rigid or resilient material so that it conforms to the contours of the patient. It can for example be made of a sheet of resilient material such as rubber or a strong fabric material. This promotes better engagement of the breasts and ensures that the maximum breast material protrudes into the breast cups 7.

Figure 8 illustrates the breast cups 7 in position. Once they are in position the antennae 15a and 15b are raised up the rod 14 to surround the breast cups 7 to enable good detection of MRI signals from the breasts during MRI imaging in an MRI scanner.

Figure 9 is a view under the patient support platform 10 with a patient lying prone with her breasts protruding into the breast cups 7. A pneumatic or hydraulic connection 18 is then made to the tubes 4 for expansion (inflation, pumping up etc) of the resilient urging arrangement 3. Figure 10 illustrates the resilient urging arrangement 3 of each breast cup 7 in an urging (inflated or pumped up) state so that an inner surface of the resilient urging arrangement 3 is in compressible contact with the surface of the patient's breasts.

Figures 11 and 12 illustrate the effect of this embodiment of the invention on the breast of the patient. These figures schematically illustrate a section through a breast 20 of a patient in which lesions 21, 22, 23 and 24 are present. In figure 11 the breast is located in the breast cup 7 but the resilient urging arrangement is not in an urging state. Figure 12 illustrates the resilient urging arrangement 3 in an urging state in which radial compression of the breast takes place. This does not result in significant distortion of the breast and most importantly it does not result in significant distortion of the lesions 21, 22, 23 and 24. This omnidirectional and substantially uniform force applied to the breast 20 ensures that the breast is immobilised but kept in a natural shape, thereby keeping the anatomy of the breast in a natural shape.

In this first embodiment both breasts can be imaged simultaneously. The support arrangement 13 can also be arranged to support a medical intervention support for supporting a medical intervention tool, in a similar arrangement depicted in Figures 19 to 24. However, for simplification, a structure for providing medical intervention tool support will be described in more detail with reference to a configuration for imaging a single breast.

Figures 13 to 18 illustrate a second embodiment of the invention for imaging a single breast and providing for medical intervention. This embodiment uses the same breast cup structure 7 as for the first embodiment and the same support structure 13. Also the same slidable and lockable sleeve 16 with a single antenna 15 is used carried by the same rod 14. However, in this embodiment, the rod 14 carrying the antenna 15 is positioned in one of the outer support connectors 13c.

A medical intervention tool support structure is provided which comprises a slidable and lockable sleeve 30 on the rod 14 carrying a gimbal ring 31 carrying two arms 32

such that the arms 32 can rotate about the axis of the gimbal ring 31. The arms 32 are connected at a first end to the gimbal ring 31 by pivot joints so that the arms can rotate about an axis perpendicular to the axis of the gimbal ring 31. The arms 32 are connected at a second end to a rod 34 which carries a tool support block 33 which is rotatable about the rod 34 and slideable along the rod 34. The tool support block 33 can support any necessary medical intervention tool (not shown in figure 13). The tool support block 33 can be changed or modified to suit any medical intervention tool.

The structure of the medical intervention tool support structure enables a medical intervention tool to be positioned at any angle and in any direction to enable the medical intervention tool to engage any part of the surface of the breast through gaps in the breast cup.

Figure 14 illustrates the arrangement of this embodiment after insertion of the breast cup 7 into the aperture in the patient support platform. The antenna 15 has been raised into its detecting position surrounding the breast cup 7. The medical intervention tool support structure has been raised also.

Figure 15 schematically illustrates the support structure 13 detached from the patient support platform 10 with the breast cup 7 (minus the flange 5) held in the support connector 13b.

Figure 16 is a view under the patient support platform 10 with a patient lying prone with her breast protruding into the breast cup 7. A pneumatic or hydraulic connection 18 is then made to the tubes 4 for expansion (inflation, pumping up etc) of the resilient urging arrangement 3. Figure 17 illustrates the resilient urging arrangement 3 of the breast cup 7 in an urging (inflated or pumped up) state so that an inner surface of the resilient urging arrangement 3 is in compressible contact with the surface of the patient's breast. Also a medical intervention tool 40 is mounted on the medical intervention tool support arrangement. Figure 18 schematically illustrates the support structure 13 detached from the patient support platform 10 with the breast cup 7 (minus the flange 5) held in the support connector 13b.

Although in this embodiment a specific medical intervention tool support arrangement is disclosed, an alternative arrangement can comprise a robotic arm capable of moving in any direction around the breast cup.

Figures 19 to 24 illustrate a third embodiment of the present invention in which the apparatus can be added to a stand-alone, standard patient support platform that does not have one or two apertures to receive the patient's breasts.

This arrangement comprises a base 50 which is placed on the patient support platform 200. Supported by the base 50 and spaced there from is a body support surface 51 having two apertures therein to receive the patient's breasts. Below the body support surface 51 and connected to a lower surface thereof is a support arrangement 53. The support arrangement 53 is arranged to support the breast cups 7 and detection antennae 55a and 55b. The support arrangement 53 includes three spaced support connectors 53a, 53b and 53c. A support rod 54 is supported in the middle support connector 53b and two antennae 55a and 55b are supported on the support rod 54 using a slidable and lockable sleeve 56. This enables the antennae 55a and 55b to be raised or lowered relative to the support arrangement 53. The antennae 55a and 55b are supported to be coaxial with the outer two support connectors 53a and 53c.

Figure 22 illustrates the connection of a pneumatic or hydraulic connection 58 for activation of the urging of the resilient urging arrangement of the breast cups 7 in a manner as described with reference to the first embodiment.

A medical intervention tool support structure is provided which comprises a slidable and lockable sleeve 300 on the rod 54 carrying a gimbal ring 310 carrying two arms 320 such that the arms 320 can rotate about the axis of the gimbal ring 310. The arms 320 are connected at a first end to the gimbal ring 310 by pivot joints so that the arms can rotate about an axis perpendicular to the axis of the gimbal ring 310. The arms 320 are connected at a second end to a rod 340 which carries a tool support block 330 which is rotatable about the rod 340 and slideable along the rod 340. The tool support block 330 can support any necessary medical intervention tool 350 shown approaching the tool support block 330 in figure 23. The tool support block 330 can be changed or modified to suit any medical intervention tool.

The structure of the medical intervention tool support structure enables a medical intervention tool to be positioned at any angle and in any direction to enable the medical intervention tool to engage any part of the surface of the breast through gaps in the breast cup.

Thus this third embodiment enables the retro fitting of the apparatus to a conventional patient support platform for insertion into the bore of an MRI scanner.

In this embodiment the medical intervention tool support arrangement can be incorporated as described with reference to the first embodiment.

Figure 25 illustrates an alternative invention. In this invention a different configuration for the breast cups is used. The diagram is of a view from under the patient support platform. Two breast cups 70 are illustrated hanging from the underside of the patient support platform. The breast cups 70 comprise resilient tubes extending from the patient support platform downwards. The resilient tubes are made of resilient sheet material with vertical ribs 90 to provide enhanced rigidity in the vertical direction. The lower end of the tube may be of narrower diameter than the upper end. At the lower end of the tube an urging arrangement is provided comprising a compressing ring 71 and 72. Each compressing ring 71 and 72 is supported by arms 73 and 74 connected to a locking ring on a support rod 75. The compressing rings can be moved upwards to slide over the outer face of the resilient tubes to compress the ends so as to apply a compressing force on the breasts of the patient. Surplus resilient material 80 and 81 is drawn down through the compression rings 71 and 72 during the compression operation. The resilient tubes can be provided with apertures therein to allow for access to the breasts for medical intervention. Support arms 76 and 77 are provided to support antennae 78 and 79 which are arranged surrounding the breast cups 70.

Figure 26 illustrates an alternative invention in which a support structure 100 is arranged below a patient support platform. A fixed support 101 extends from the support structure and an extendible support rod 102 is inserted in the fixed support 101. At the end of the extendible support rod 102 is arranged a flared portion 102a which carries a breast cup 103 in the form of a plurality of finger-like projections extending radially and upwardly from the flared portion 102a. Each finger-like portion has apertures therein to provide access to the surface of the breast for medical

intervention. An antenna arrangement 104 comprises a number of coils, which in this specific example is three (but it can be any appropriate number) which is arranged around the breast cup 103. The antenna arrangement is mounted on an antenna support 104a which is slideably mounted on the extendible support rod 102 which allows the height of the breast cup 103. The extendible support rod allows the height of the breast cup 103 to be adjusted.

In use, a patient's breast is inserted in the breast cup 103. The antennae 104 are then moved from a lower position to an upper position where they surround the breast cup 103. In doing so the antennae 104 engage with the outer surface of the breast cup and urge the finger-like portions to compress the patient's breast. Alternatively the finger-like portions are sprung in a radial and axial direction such that they are held open during insertion of the breast and allowed to spring back to compress the breast in a direction towards the centre of the breast.

A medical intervention tool support arrangement is provided by an arm 105 pivoted on the fixed support 101. The arm curves in an arcuate manner upwards and away from the fixed support 101. A bracket 106 is slideably attached to the arm 105 to allow it to slide up and down the arm in an arc. A support member 107 is pivotally mounted on the bracket 106 to allow the support member to pivot about an axis perpendicular to the arc of the arm 105. A medical intervention tool 108 is mounted in the support member 107 for engagement with the surface of the breast through the gaps between the finger-like projections of the breast cup 103 or through the apertures 120 in the finger-like projections.

Although not shown in previous embodiments, the apertures 120 provided in the invention of figure 25 may be provided in the finger like projections 1 to enable the medical intervention tool to pass through. Where an inflatable or pneumatic lining is provided for gripping the breast in such a configuration, holes can be provided through this also to allow access to the breast there through.

Figures 27a and 27b illustrate a breast cup of a fourth embodiment of the present invention. The breast cup of this embodiment comprises a rigid mesh 150 forming an outer part of the breast cup and finger-like projections 151 of hollow expandable material arranged on an inner surface extending from a common point at the base on

the breast cup and extending radially and upwardly within the cup. The projections 151 *interconnect at the common point 152 and can be inflated or expanded pneumatically or hydraulically from this point.*

The breast cup of this embodiment is similar to the first embodiment except that the finger-like projections 1 are replaced with a rigid mesh. The breast cup of this embodiment can be used with the arrangement of the first and second embodiments.

Figure 28 illustrates a breast cup of a fifth embodiment of the present invention. In this embodiment resilient finger-like projections are connected at a common point and extend radially and upwardly. A rigid mesh cup 161 is arranged to be moveable vertically upwards over the finger-like projections to urge the projections radially inwardly to compress the breast of the patient.

In the fourth and fifth embodiments of the present invention, the use of the rigid mesh provides apertures through which medical intervention tools can gain access to the breast of the patient.

Where the apparatus of the embodiments is for use in an MRI scanner, the apparatus is formed from material that is MRI compatible.

The medical intervention tool using any of the embodiments can comprise a probe, a biopsy needle for obtaining a tissue sample from a suspicious lesion, or other trans-cannula procedures such as cryoablation, laser ablation, hyperthermia, medication delivery, percutaneous removal, draining. Further, the medical intervention tools can comprise surgical tools for keyhole surgery.

The medical intervention tool support arrangement in any embodiment can be electromechanically driven under the control of a computer. The breast cup can contain imaging markers such as MRI markers that show up in the breast image. The position of these markers in the image relative to an area to which the medical intervention tool is to be guided can be determined by the computer. This information can be used to generate control signals to control the medical intervention tool support arrangement to move the medical intervention tool to an appropriate location in an appropriate

orientation to approach a desired target area of a lesion in the breast to medical intervention.

Although in all of these embodiments a specific detecting antenna arrangement is disclosed, as part of this invention, other alternative antenna designs, such as the ones illustrated in figures 29 to 30 can also be adopted and used.

Although the present invention has been described with reference to specific embodiments, it will be apparent to a skilled person in the arts that modifications lie within the spirit and scope of the appended claims.

Claims

1. Breast immobilisation apparatus for use in breast imaging to allow medical intervention, the apparatus comprising
 - a body support platform for supporting the body of a patient in a prone position, the body support platform having a hole through which the breast of the patient is allowed to pendulantly project in use; and
 - a breast cup arranged below the hole for receiving the breast of the patient and comprising means for uniformly compressing the breast to immobilise it without substantially deforming the breast, and an aperture arrangement to allow access to a substantial portion of the surface of the breast for medical intervention; wherein the means for uniformly compressing the breast comprises a rigid structure and a resilient urging arrangement on an inner side of the rigid structure for urging into engagement with the breast for compression of the breast, and the aperture arrangement comprises an array of apertures in the rigid structure or gaps between parts of the rigid structure.
2. Breast immobilisation apparatus according to claim 1, wherein the rigid structure comprises a mesh or a plurality of finger-like projections radiating from a common point.
3. Breast immobilisation apparatus according to claim 1 or claim 2, wherein the resilient urging arrangement comprises a hydraulic or pneumatic arrangement for expansion to urge against the surface of the breast.
4. Breast immobilisation apparatus according to any preceding claim, wherein the breast cup includes a flange running around an upper edge of the rigid structure, the upper edge defines an opening through which the breast is received, the breast cup is adapted to be inserted through the hole in the body support platform, and the flange is adapted to engage with an upper surface of the body support platform to hold the breast cup extending below the body support platform.
5. Breast immobilisation apparatus according to claim 3, wherein the body support platform has a flexible upper surface to mould to the shape of the prone patient.

6. Breast immobilisation apparatus according to any preceding claim, wherein the breast cup comprises one of a plurality of different sized cups selected for the breast size of the patient.
7. Breast immobilisation apparatus according to any preceding claim, wherein the body support platform has a second hole for receiving a second breast of the patient, the apparatus including a second said breast cup arranged below the second hole.
8. Breast immobilisation apparatus according to any preceding claim, wherein the breast cup is disposable.
9. Breast immobilisation apparatus according to any preceding claim, wherein the body support platform comprises an upper surface having the hole there through and a base for placement on a conventional imaging body support platform, the base being connected to the upper surface to space the upper surface from the base below the hole to provide room for the breast cup received in the hole.
10. A breast imaging arrangement comprising the breast immobilisation apparatus according to any preceding claim, a medical intervention tool for medical intervention of the breast, and a tool support arrangement for supporting the medical intervention tool and enabling movement of the medical intervention tool to contact any required point on the surface of the breast.
11. A breast imaging arrangement according to claim 10, wherein the breast cup includes MRI reference markers detectable during imaging, the apparatus including a processing arrangement for receiving a selection of a location within the breast to be targeted by the medical intervention tool and data on the detected reference markers, and a tool support driving mechanism for driving the tool support arrangement, wherein the processing arrangement is adapted to calculate drive signals and to control the tool support driving mechanism to automatically locate the medical intervention tool at the location to be targeted.
12. A breast imaging arrangement according to claim 10 or claim 11, including a MRI magnet arrangement having a bore, wherein an axial length of the magnet arrangement down the bore is less than a diameter of the bore, the breast

immobilisation apparatus, the tool support arrangement and the medical intervention tool are arranged in the bore for medical intervention during imaging, and the MRI magnet arrangement includes a detecting antenna arranged around the breast cup for detection of MRI signals from the breast.

13. A breast immobilisation method for use in breast imaging to allow medical intervention, the method comprising

supporting the body of a patient in a prone position, pendulantly projecting a breast of the patient through a hole in the body support platform; and

receiving the breast of the patient in a breast cup, uniformly compressing the breast to immobilise it without substantially deforming the breast, and providing an aperture arrangement to allow access to a substantial portion of the surface of the breast for medical intervention wherein uniformly compressing the breast comprises using a rigid structure and a resilient urging arrangement on an inner side of the rigid structure for urging into engagement with the breast for compression of the breast, and the aperture arrangement comprises an array of apertures in the rigid structure or gaps between parts of the rigid structure.

14. A breast imaging method comprising immobilising the breast of a patient using the breast immobilisation method according to claim 13, inserting the patient in an MRI magnet arrangement having a bore, wherein an axial length of the magnet arrangement down the bore is less than a diameter of the bore, arranging a detecting antenna around the breast cup for detection of MRI signals from the breast, and using a medical intervention tool to access the breast for medical intervention through the breast cup during imaging.

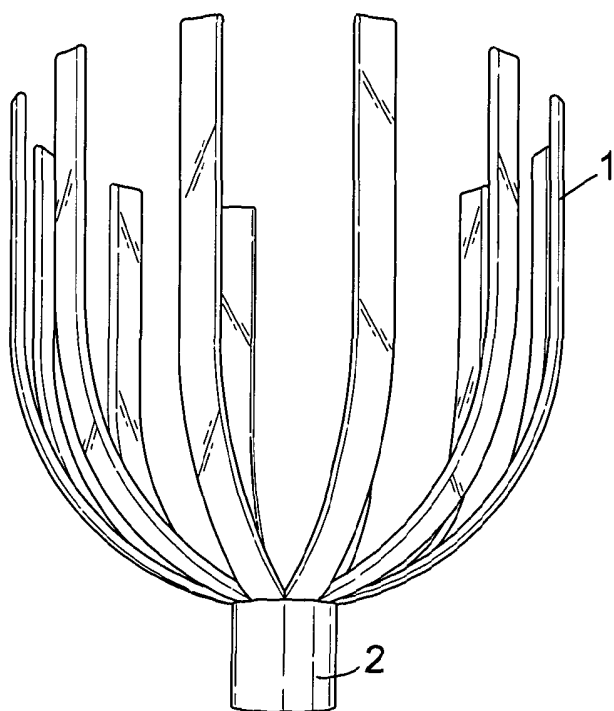


Fig. 1

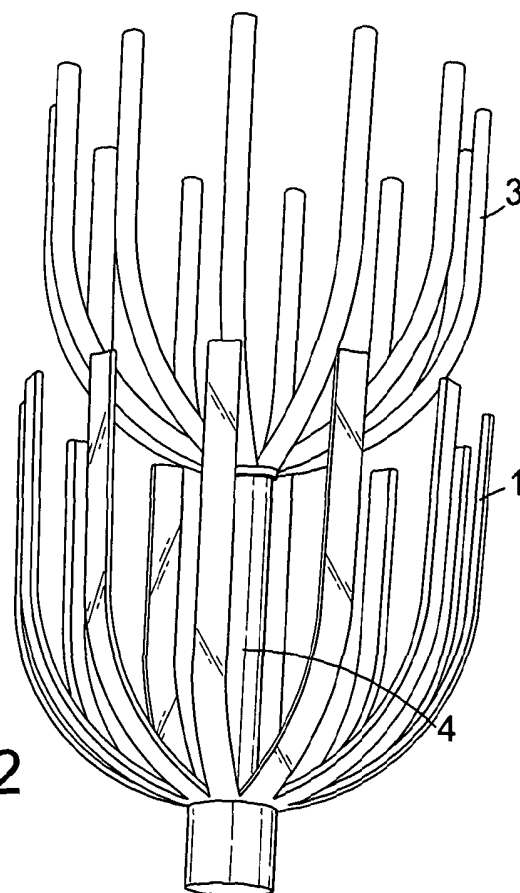


Fig. 2

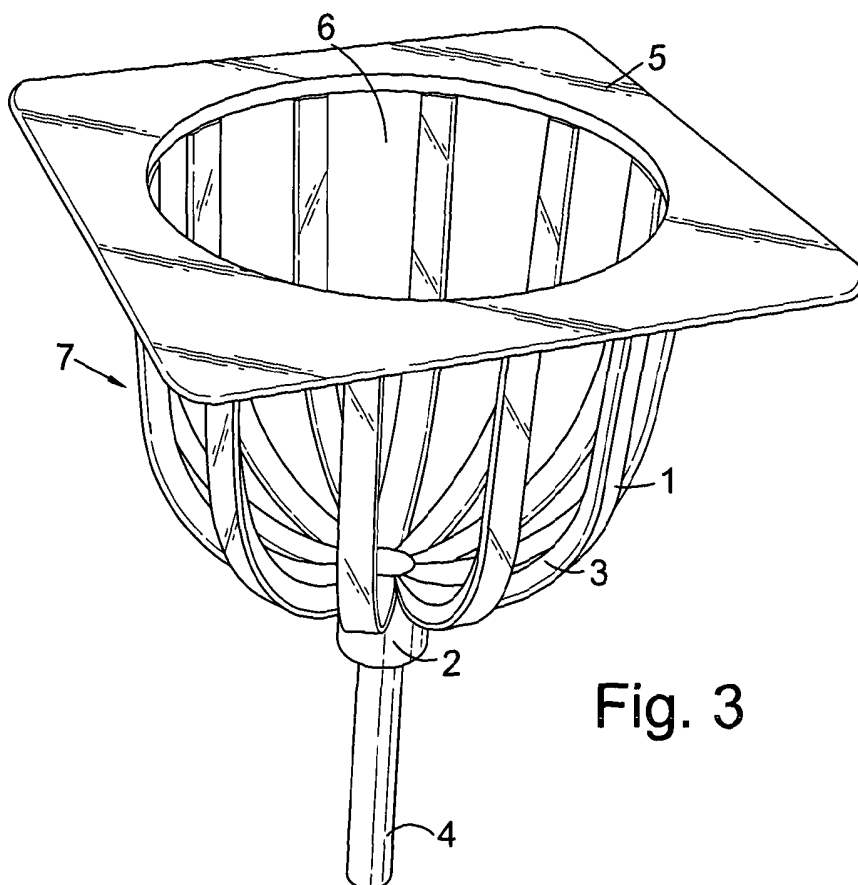


Fig. 3

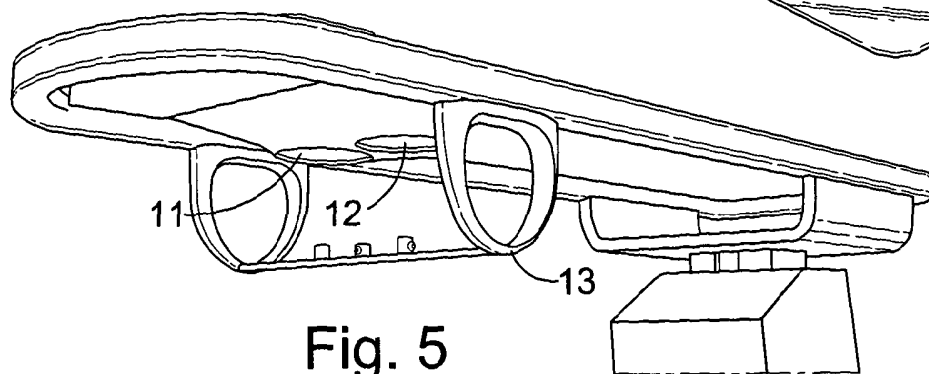
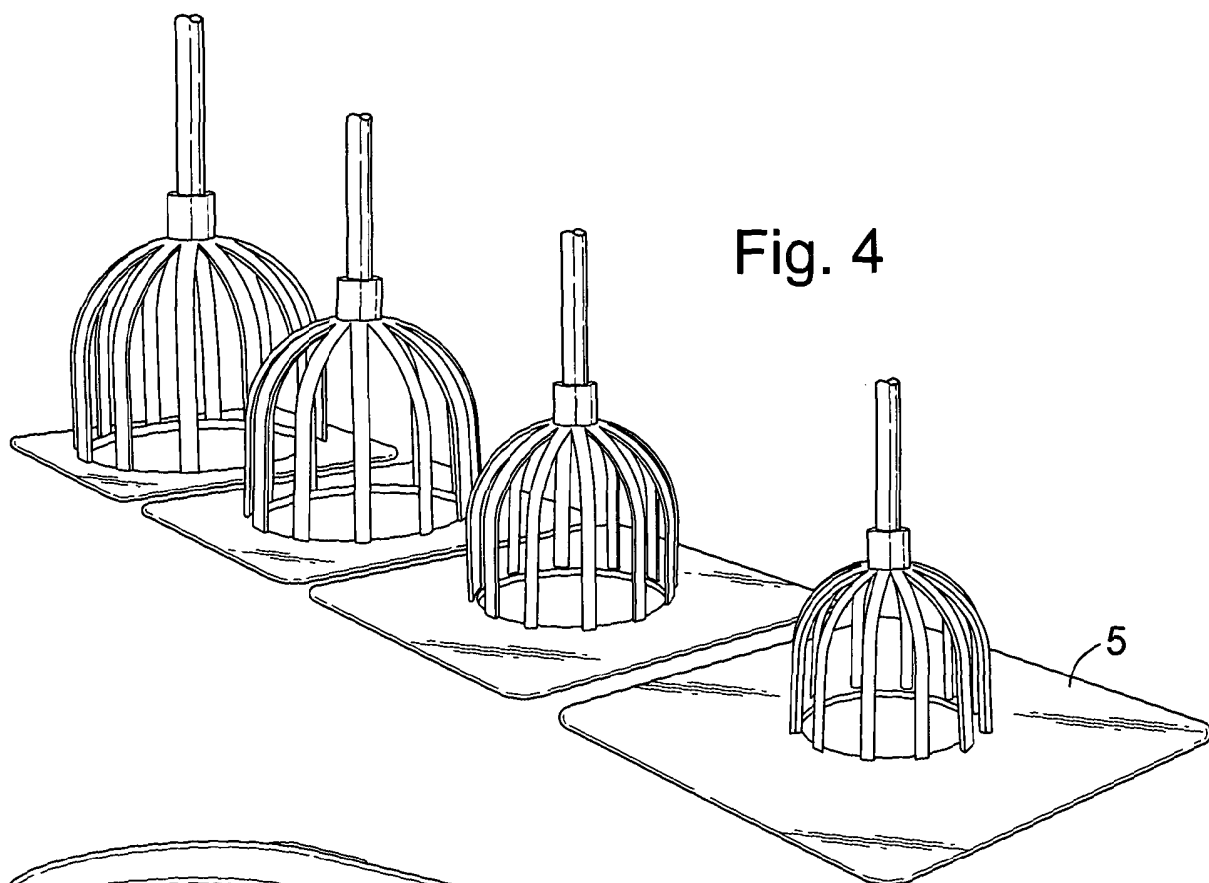


Fig. 5

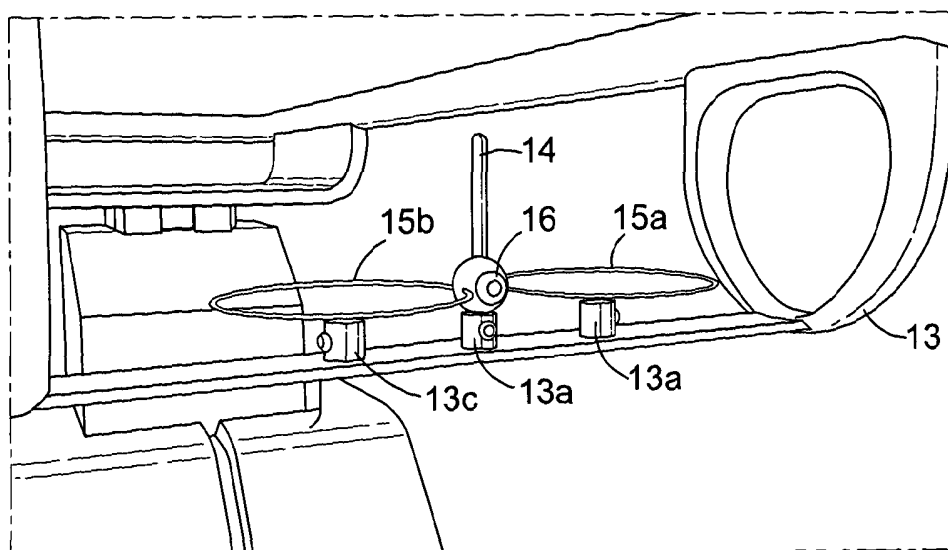


Fig. 6

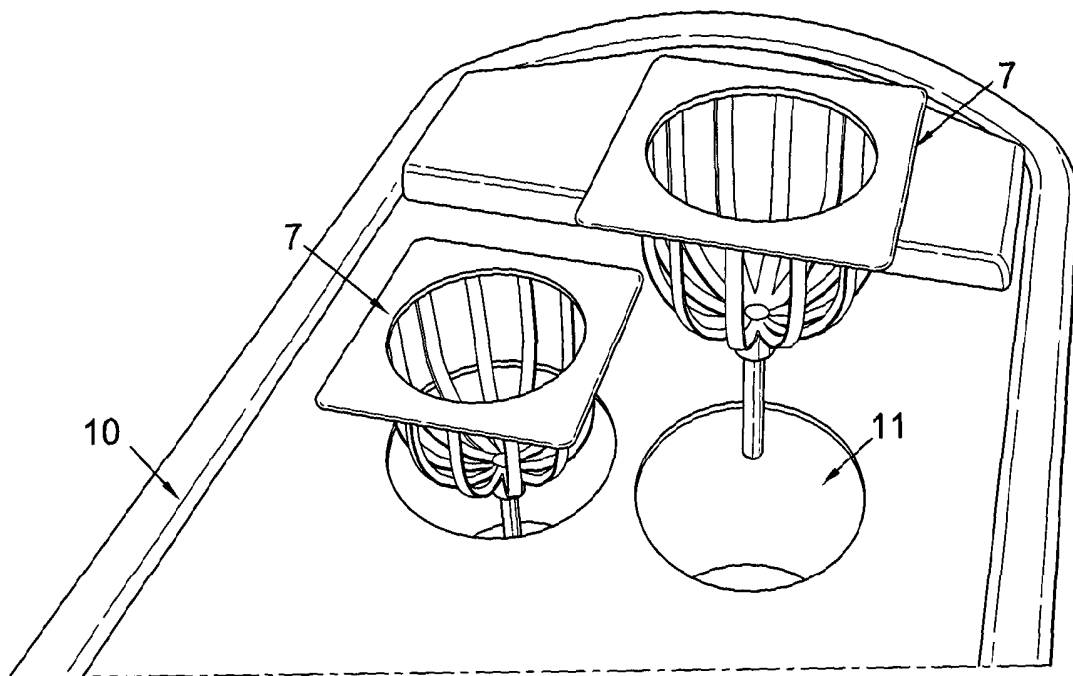


Fig. 7

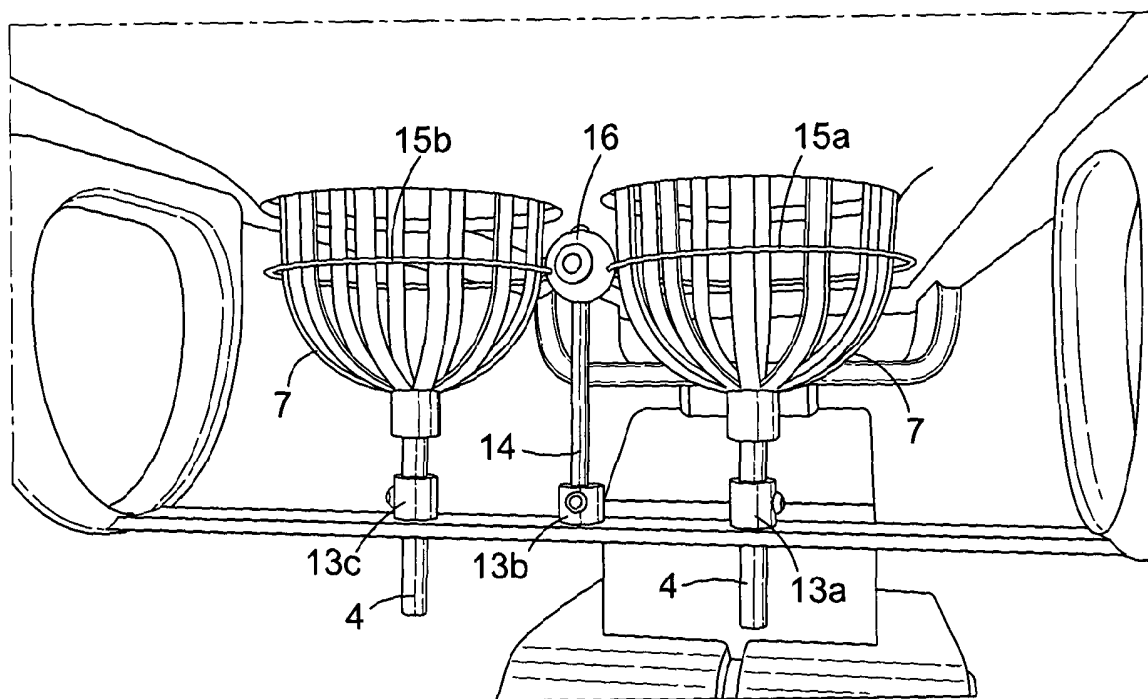


Fig. 8

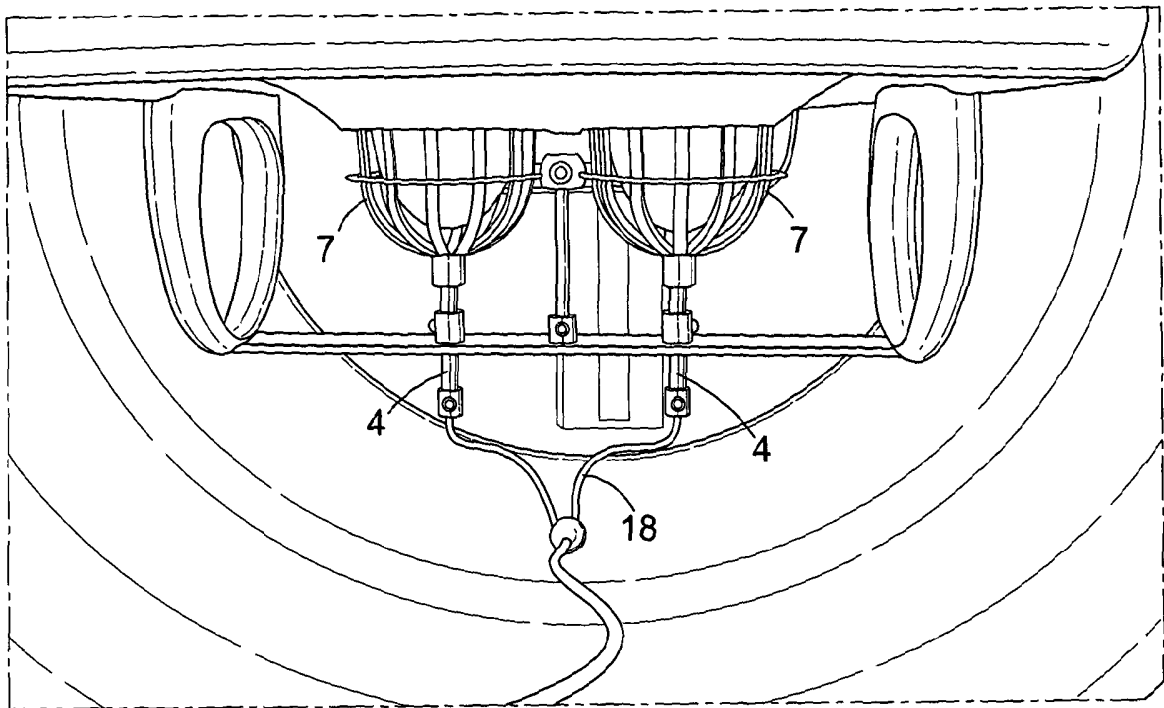


Fig. 9

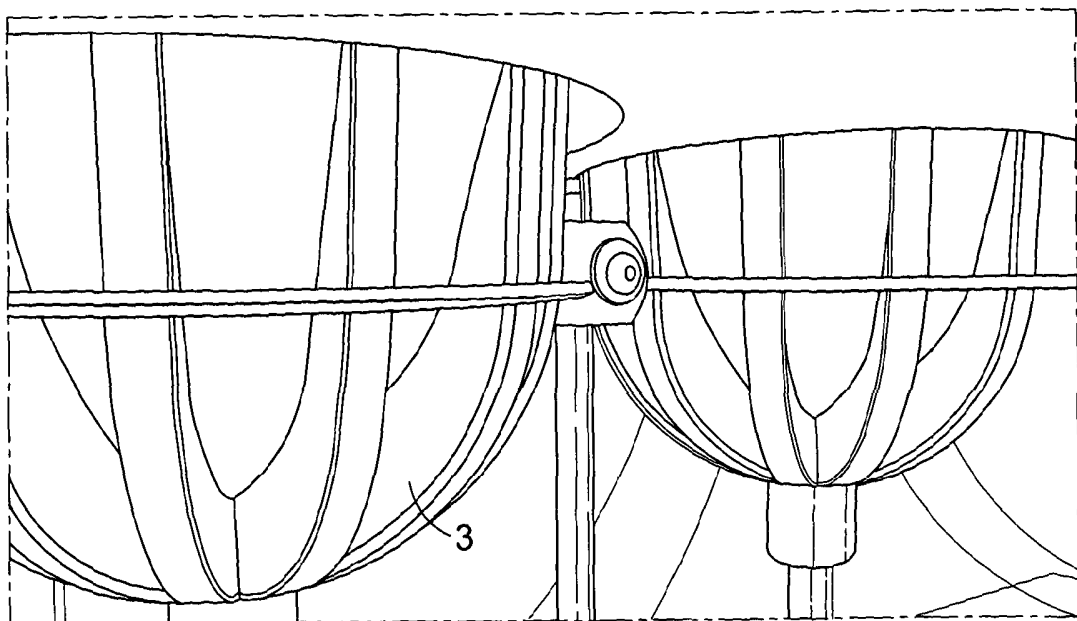


Fig. 10

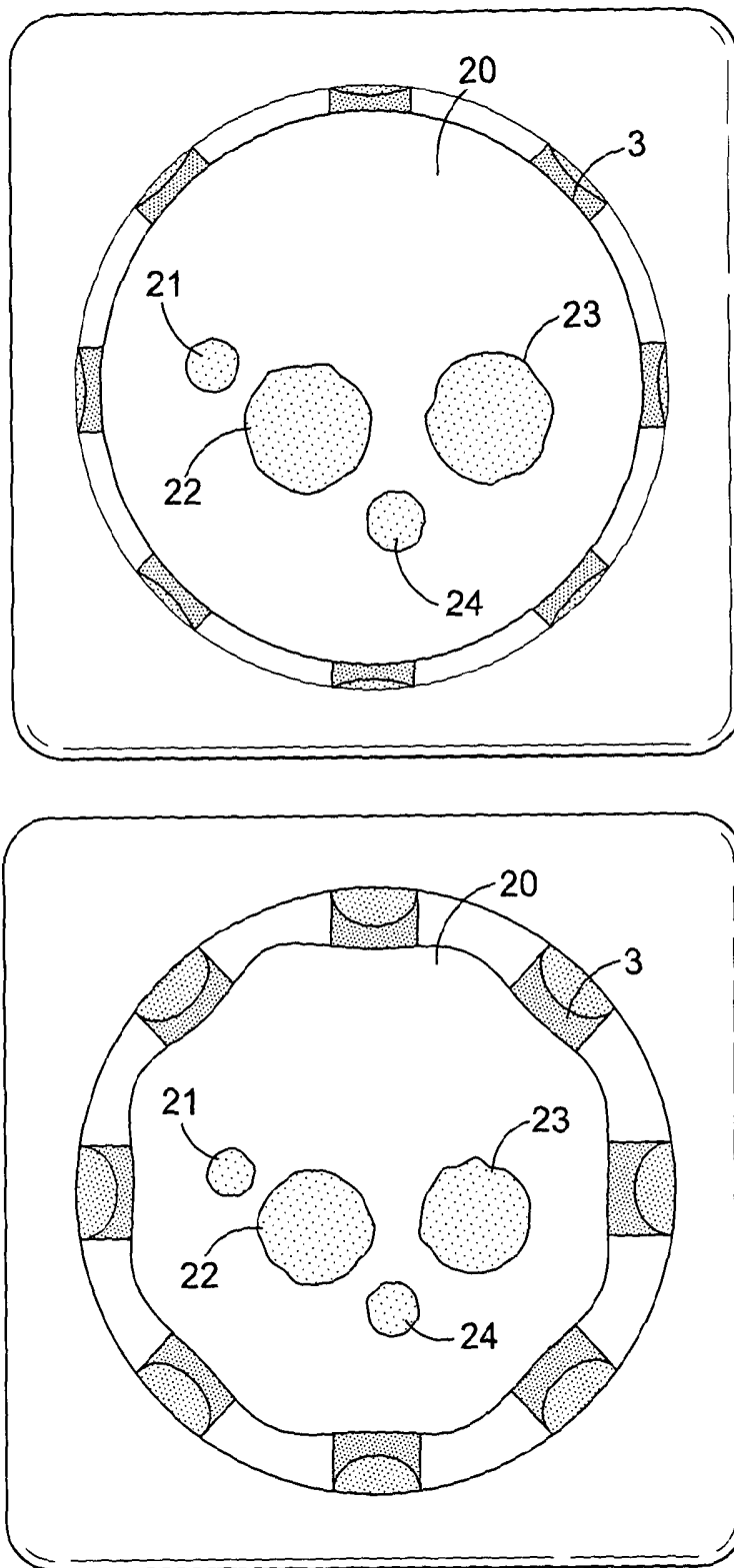


Fig. 12

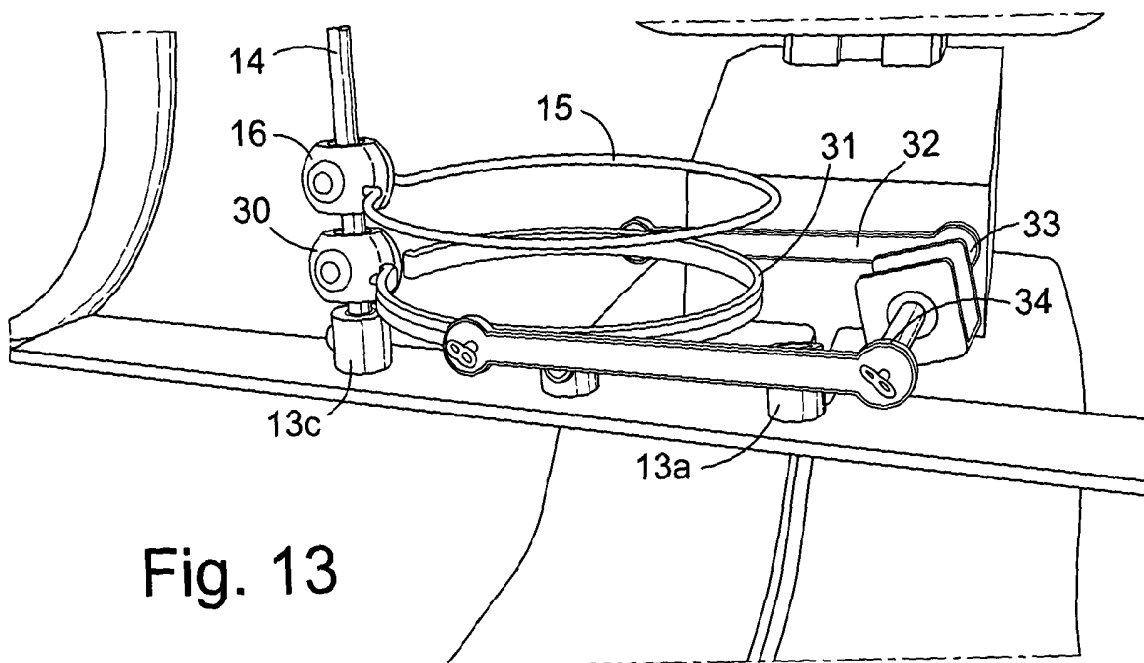


Fig. 13

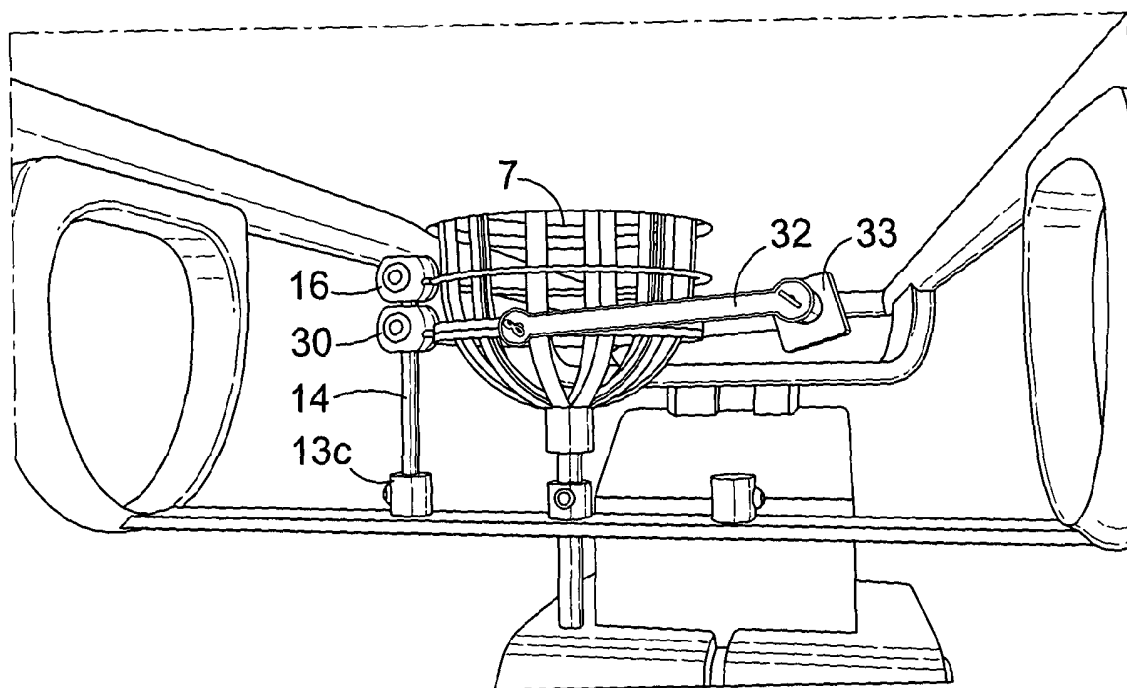
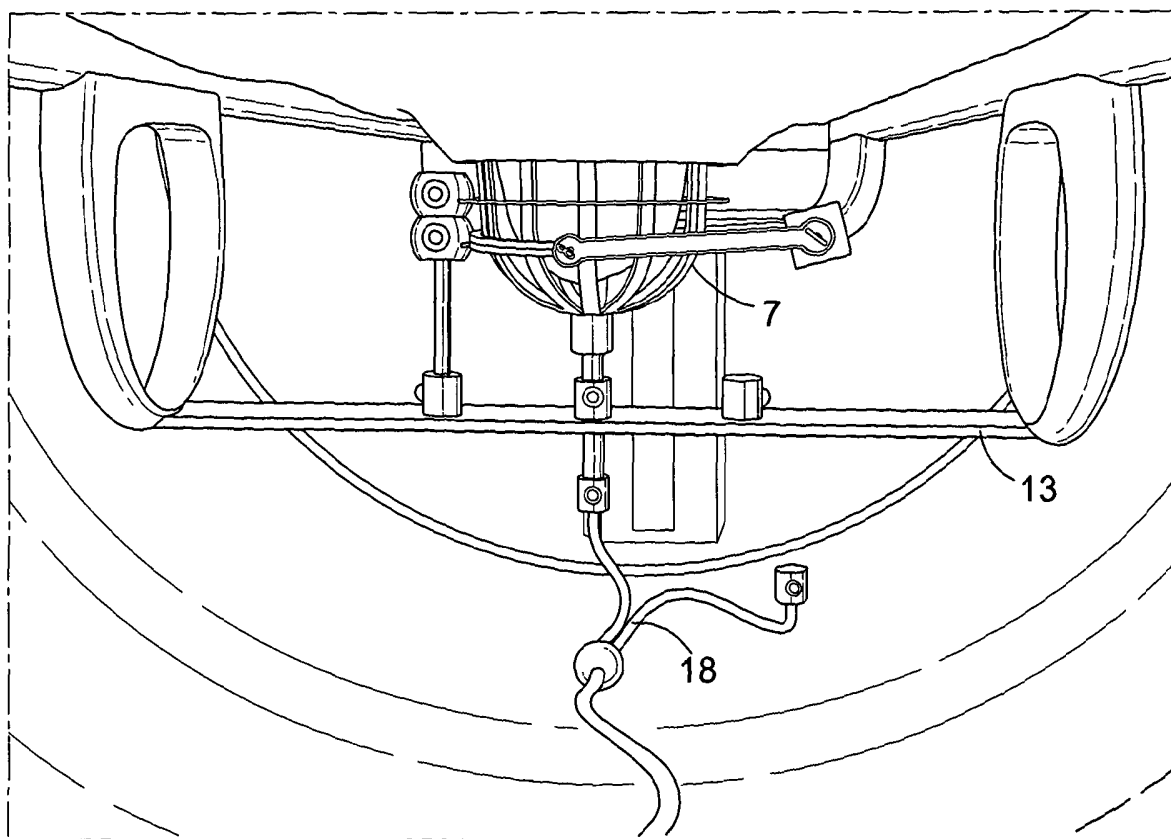
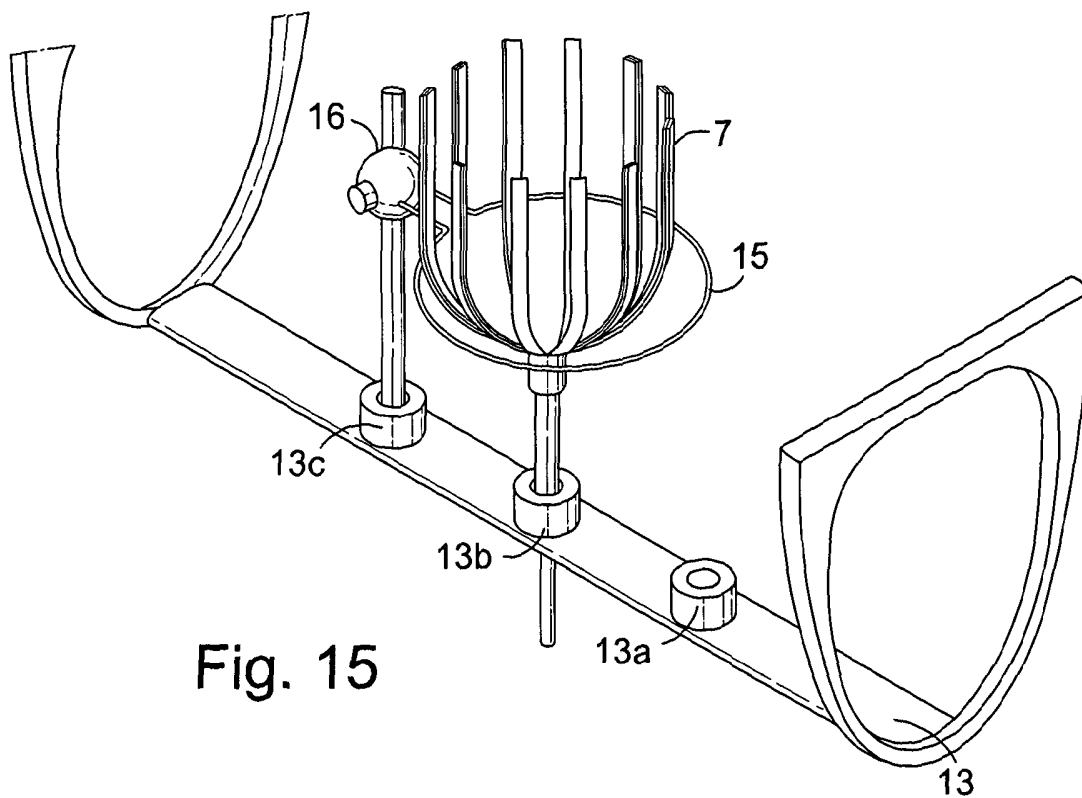


Fig. 14



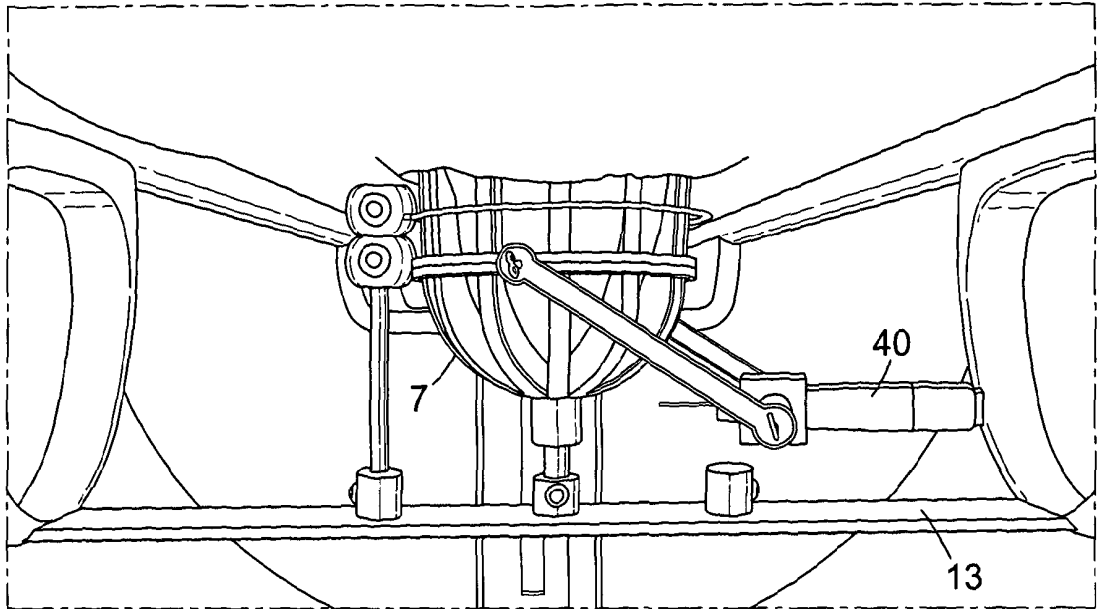


Fig. 17

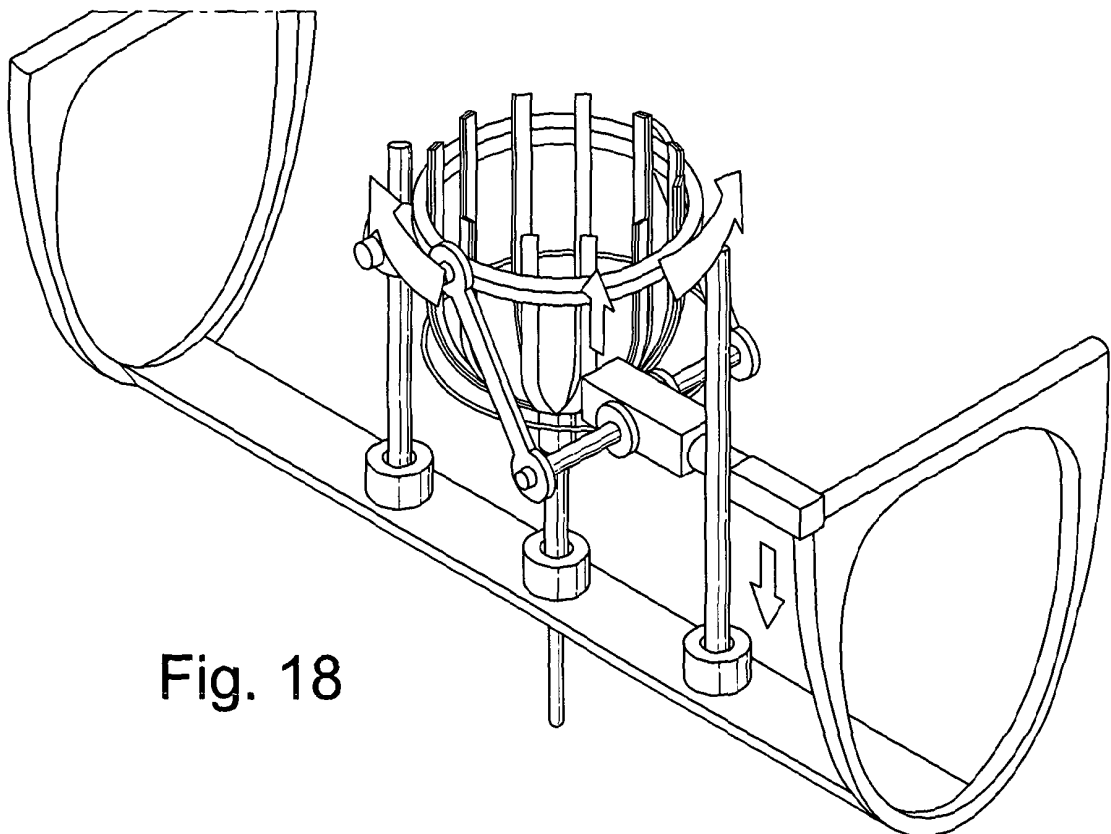


Fig. 18

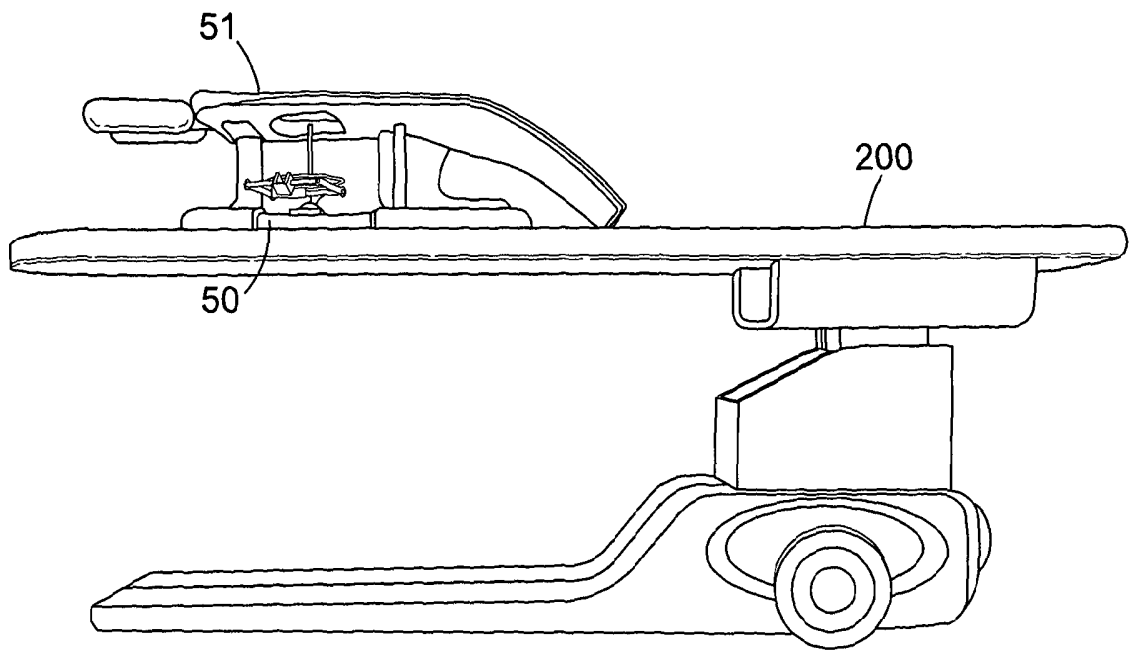


Fig. 19

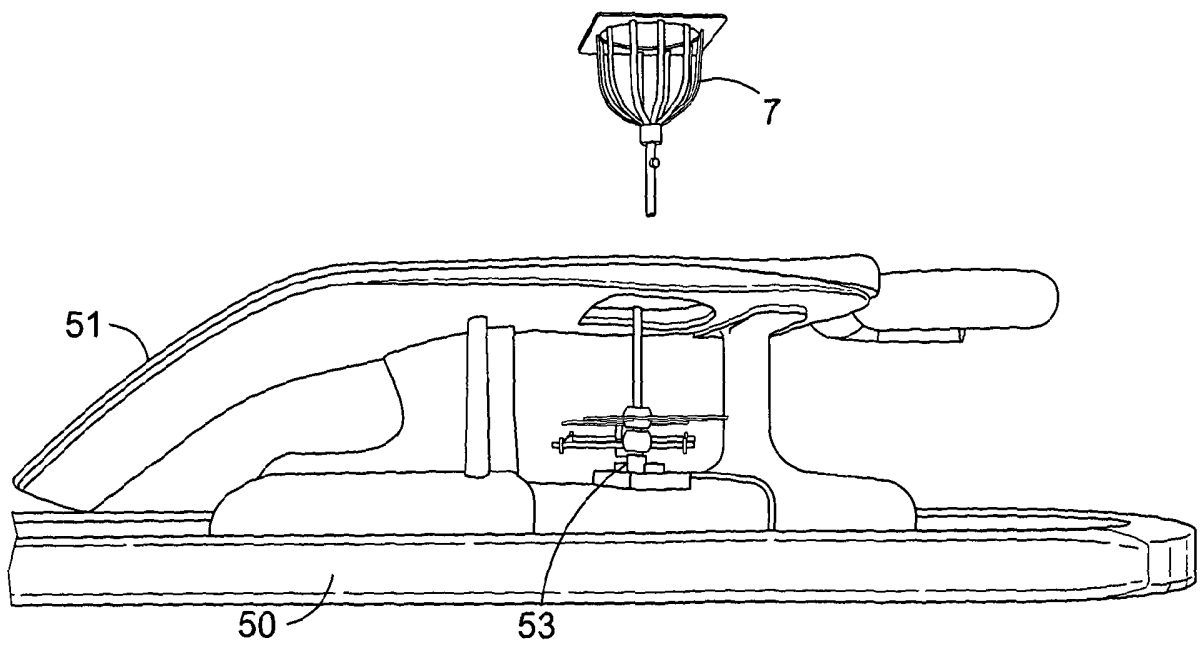


Fig. 20

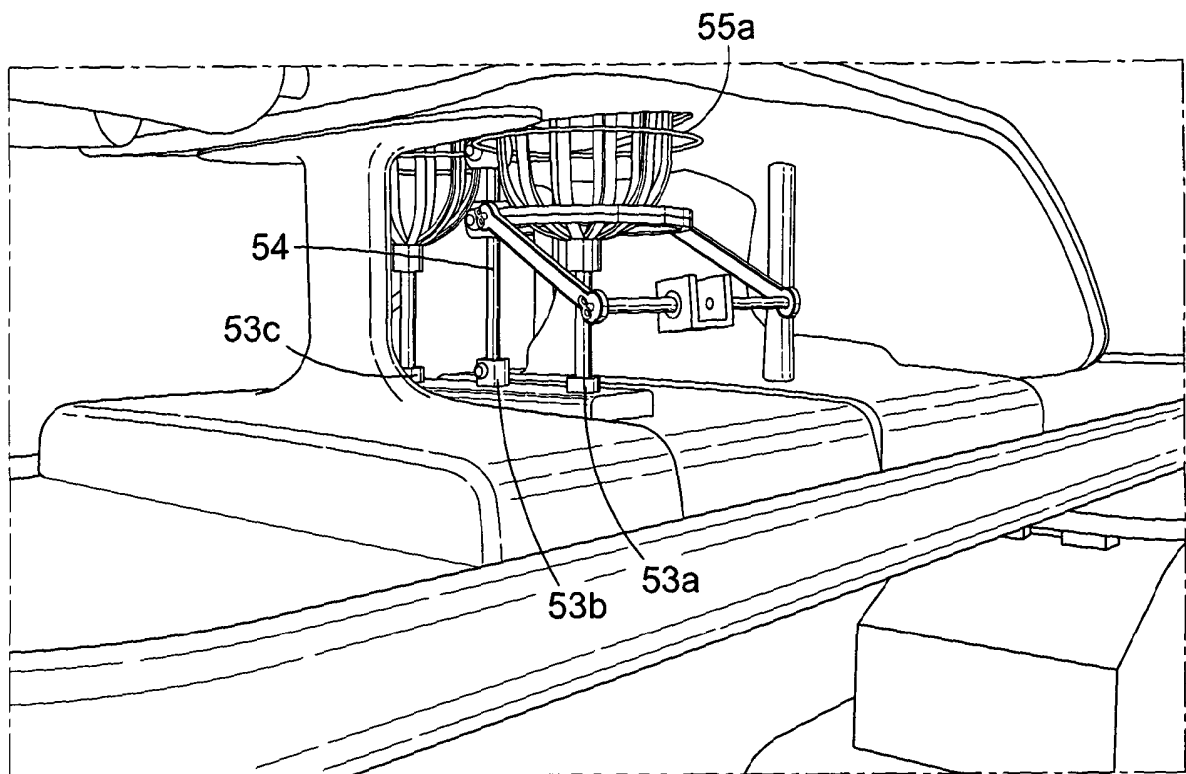


Fig. 21

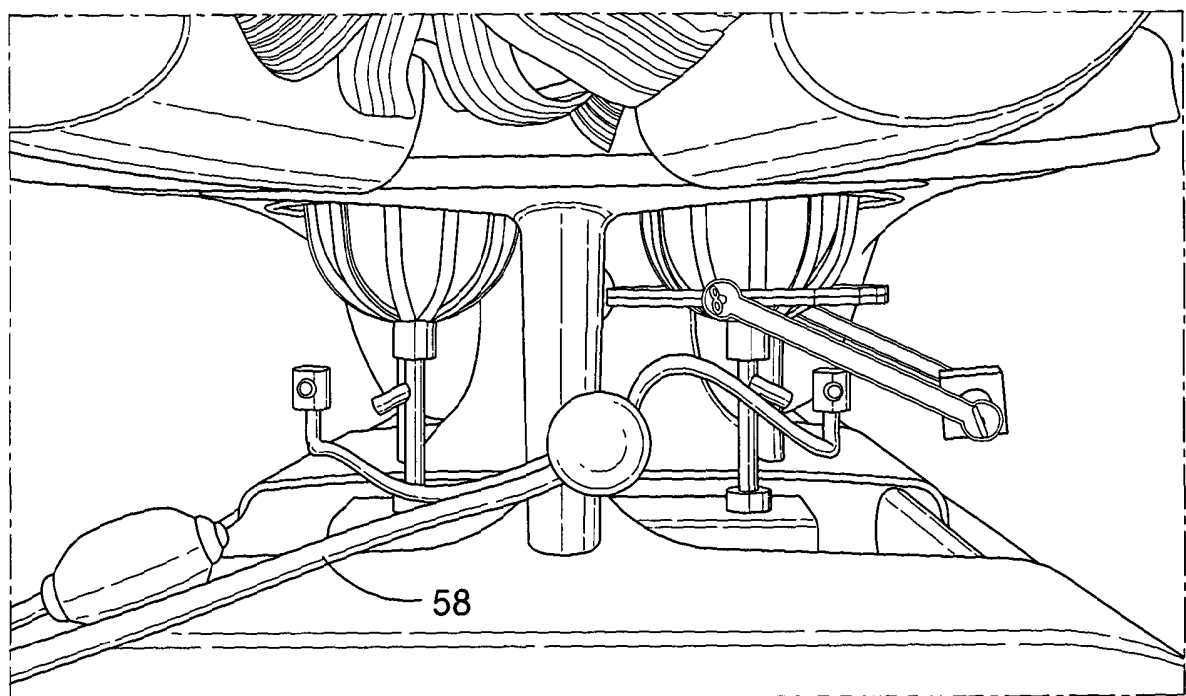


Fig. 22

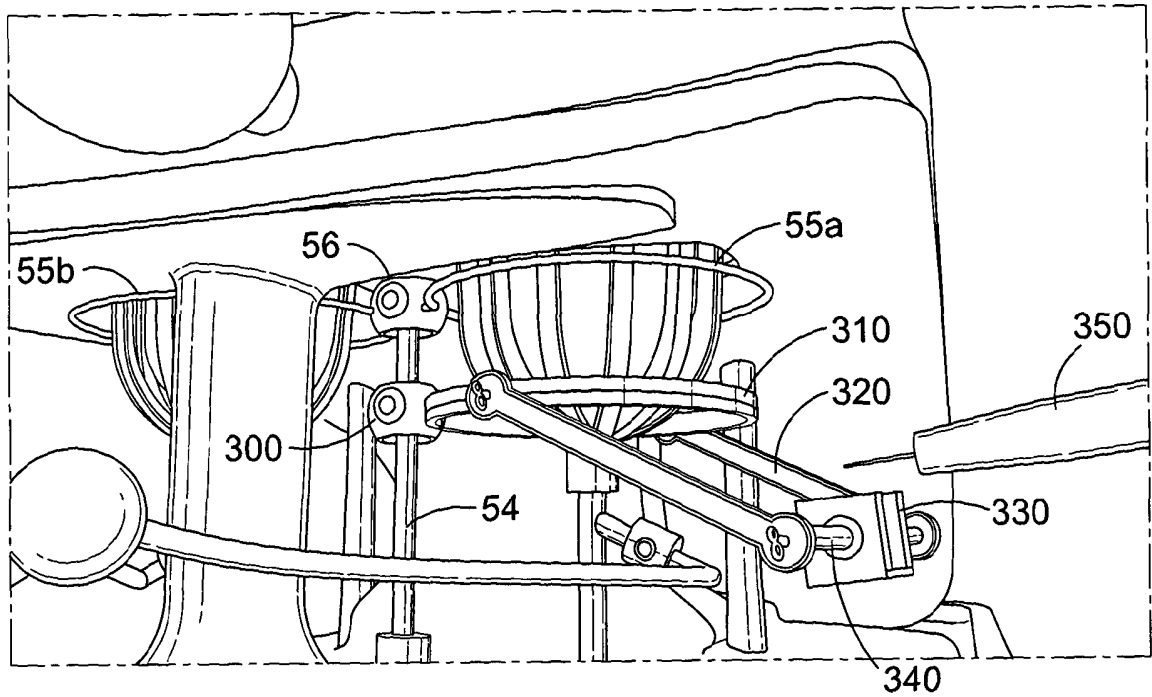


Fig. 23

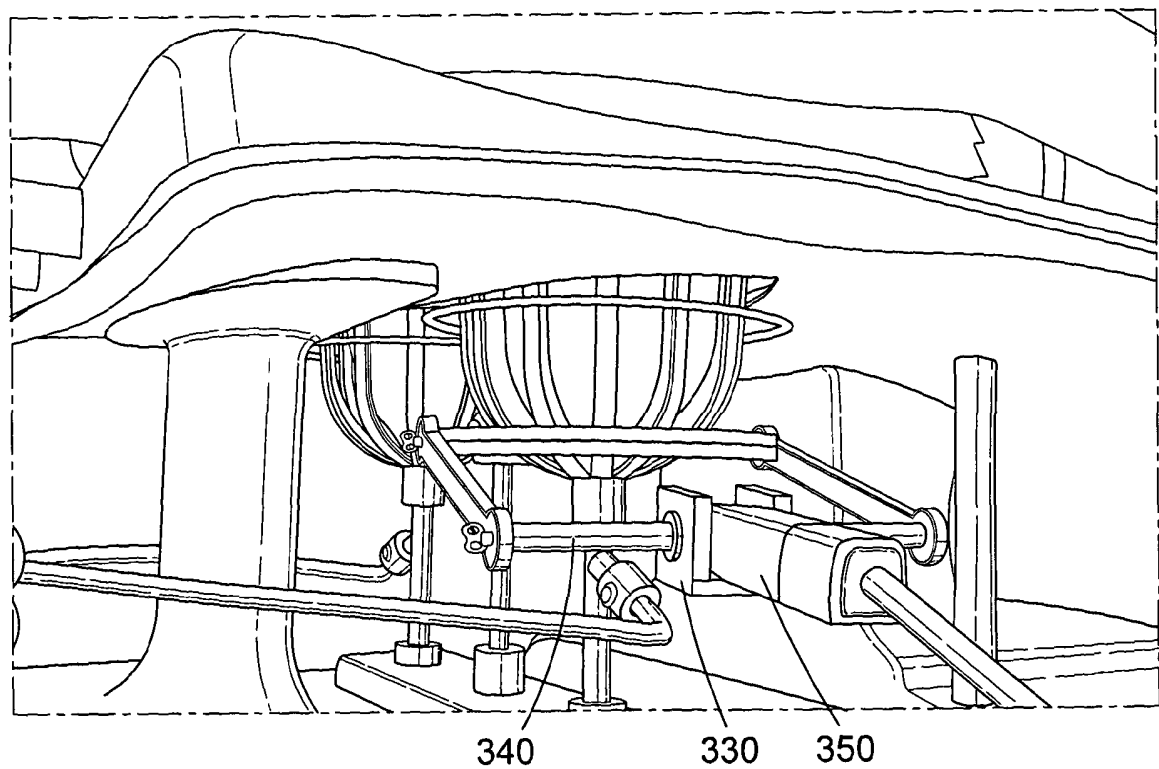


Fig. 24

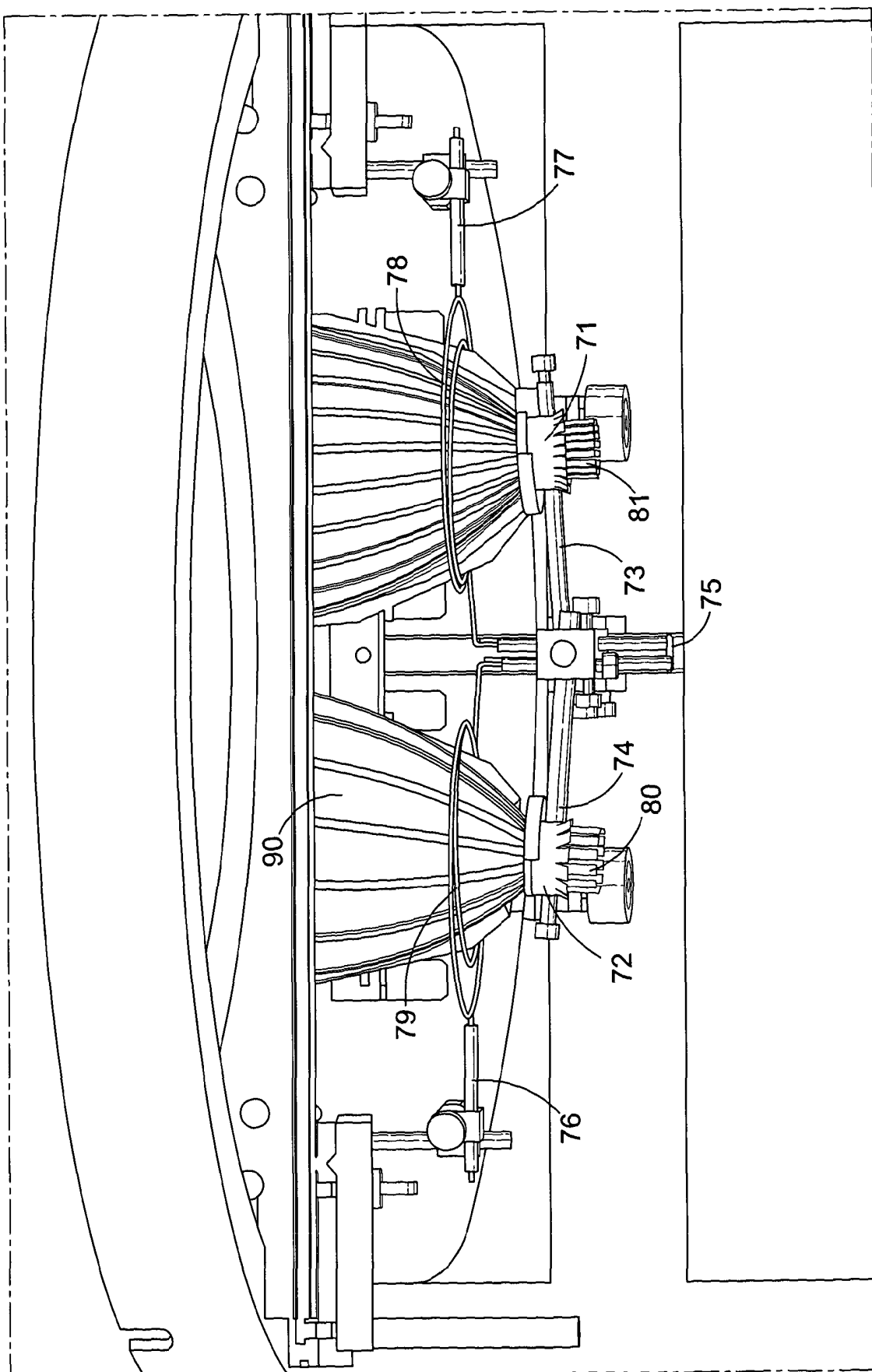


Fig. 25

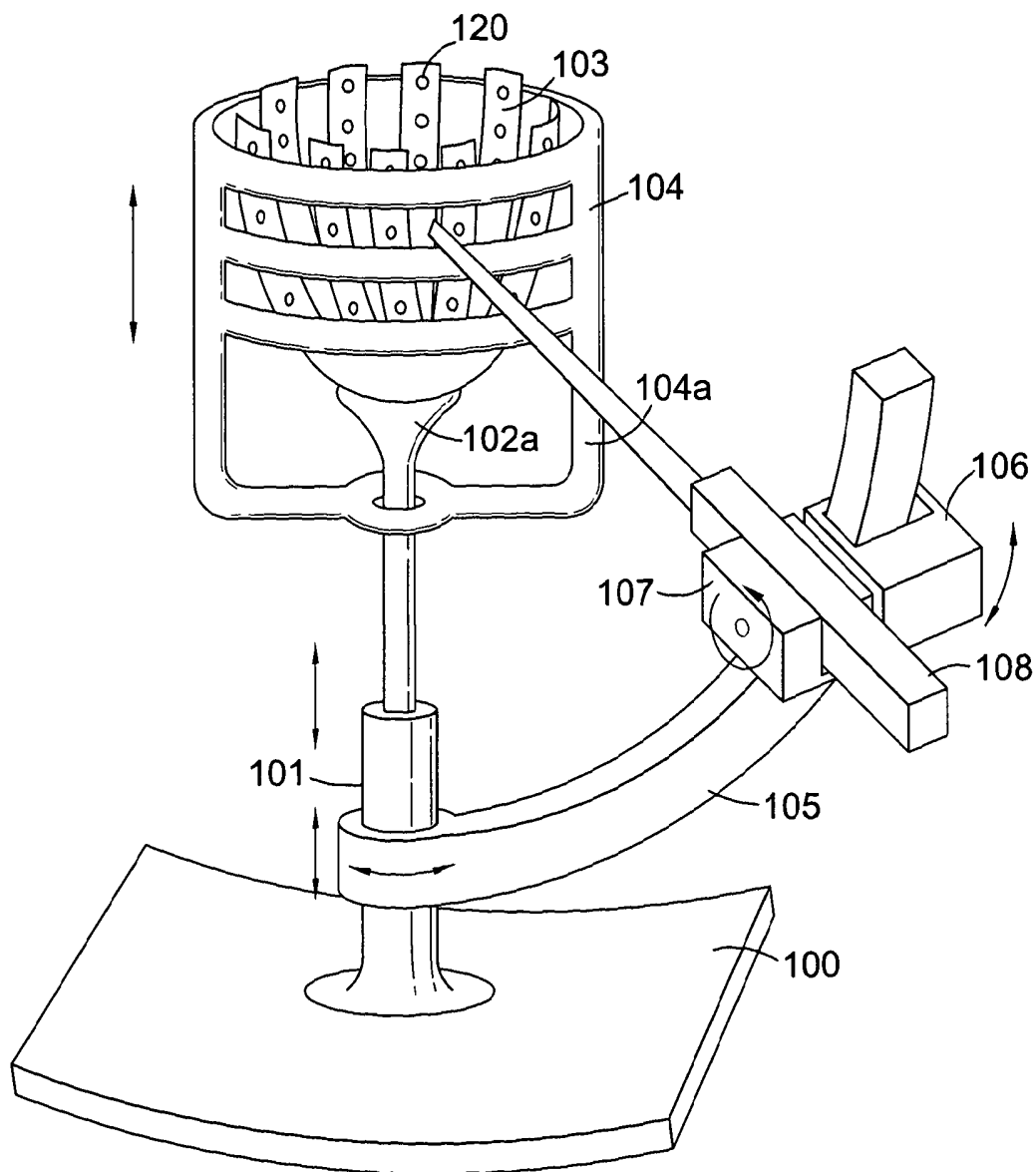


Fig. 26

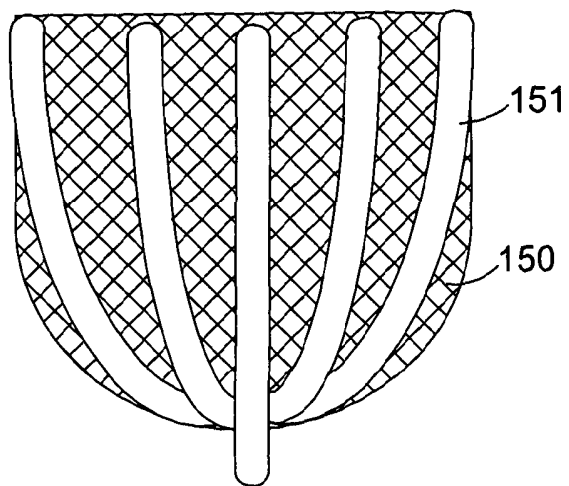


Fig. 27a

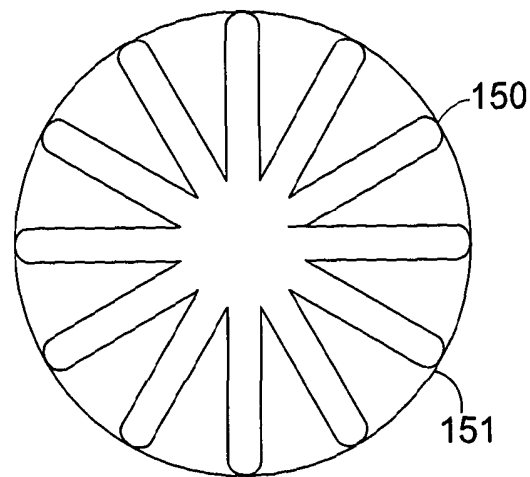


Fig. 27b

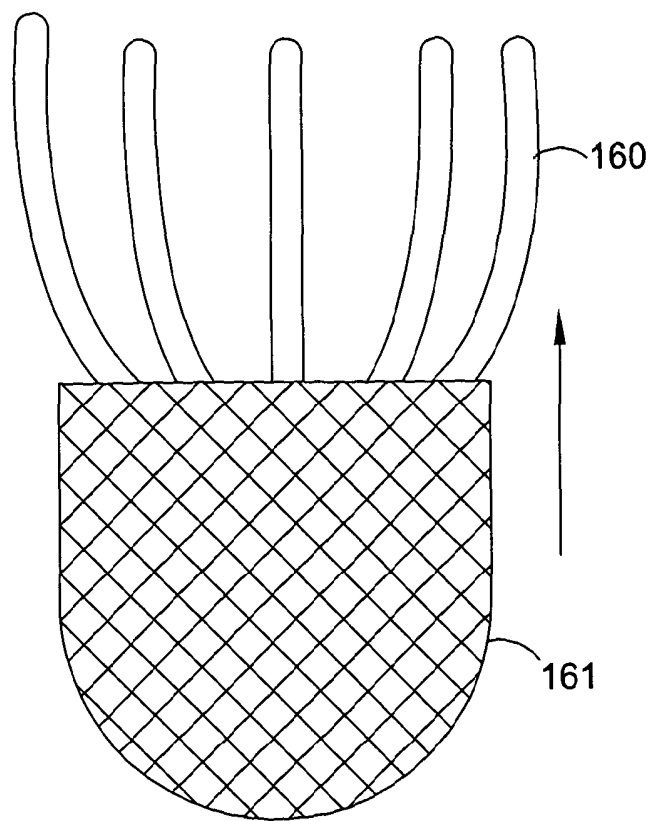


Fig. 28

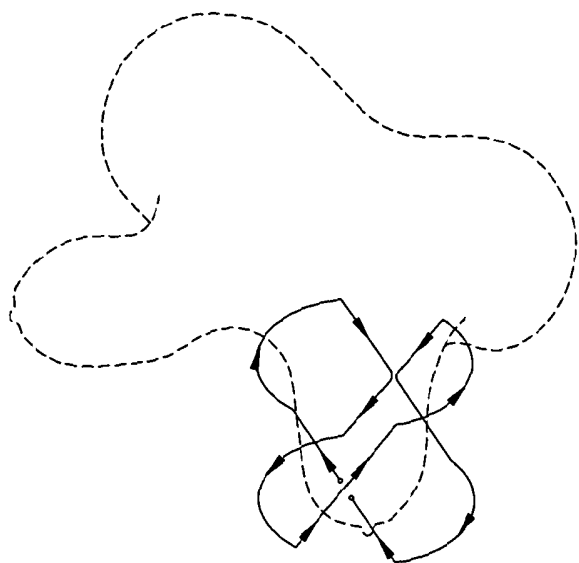


Fig. 29

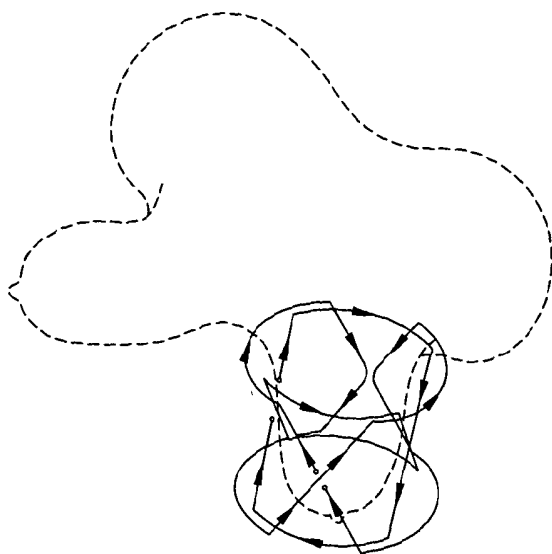


Fig. 30

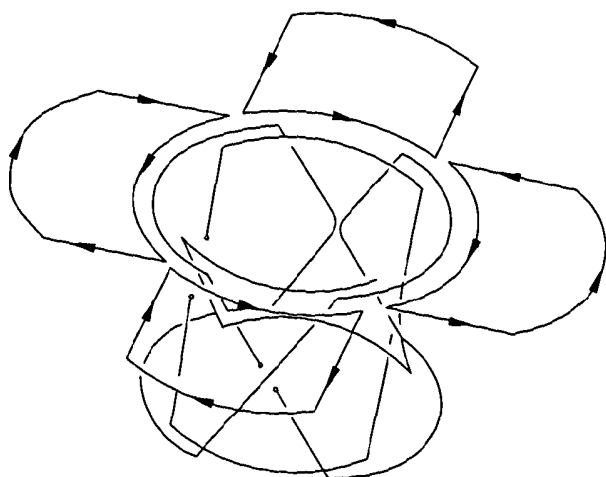


Fig. 31

INTERNATIONAL SEARCH REPORT

International application No PCT/GB2011/001333

A. CLASSIFICATION OF SUBJECT MATTER
 INV. A61B5/055 A61B6/00 A61B6/04
 ADD. A61B19/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
 A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
 EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 97/18751 A1 (DIAGNOSTIC INSTR INC [US]) 29 May 1997 (1997-05-29) the whole document -----	1,3-13
X	US 5 971 998 A (RUSSELL DONALD G [US] ET AL) 26 October 1999 (1999-10-26) the whole document -----	1,3,13
X	US 2009/259122 A1 (LARSON BLAKE TIMOTHY [US] ET AL) 15 October 2009 (2009-10-15) the whole document -----	1,2
X	WO 2005/117551 A2 (MARVEL MEDTECH LLC [US]; HARTER RAYMOND D [US]) 15 December 2005 (2005-12-15) the whole document -----	1,2
	-/--	

Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents :

<p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p>	<p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&" document member of the same patent family</p>
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Date of the actual completion of the international search 9 December 2011	Date of mailing of the international search report 19/12/2011
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Anscombe, Marcel
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INTERNATIONAL SEARCH REPORT

International application No PCT/GB2011/001333

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 93/17620 A1 (FISCHER IMAGING CORP [US]) 16 September 1993 (1993-09-16) the whole document -----	1-13
A	WO 2010/092565 A1 (HELIX MEDICAL SYSTEMS LTD [IL]; AMARA ARIE [IL]; AMARA AVI [IL]) 19 August 2010 (2010-08-19) the whole document -----	1-13
A	DE 196 10 802 A1 (SIEMENS AG [DE]) 25 September 1997 (1997-09-25) the whole document -----	1-13
A	WO 95/08293 A2 (HUSSMAN KARL L [US]) 30 March 1995 (1995-03-30) the whole document -----	1-13
A	WO 2004/006755 A2 (ALFRED E MANN INST BIOMED ENG [US]; MARMARELIS VASILIS Z [US]) 22 January 2004 (2004-01-22) the whole document -----	1-13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB2011/001333

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.: **14**
because they relate to subject matter not required to be searched by this Authority, namely:
see FURTHER INFORMATION sheet PCT/ISA/210
2. Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.1

Claims Nos.: 14

Claim 14 comprises the step "using a medical intervention tool to access the breast for medical intervention...". In light of the description the interventions potentially encompassed are surgical ("contact", page 4, line 11; "engage any part of the surface", page 10, line 11 & page 12, line 3; "for medical intervention", page 12, line 35 - page 13, line 1; "move the medical intervention tool to an appropriate location in an appropriate orientation to approach a desired target area of a lesion", page 14, line 34 - page 15, line 1) because the interventional tool can be a biopsy needle which is insertable into the breast (page 1, line 11-12). The wording of the claim "using to access for medical intervention " does not limit the claim to simply pre-positioning .The claim encompasses in its meaning the accessing by a puncturing device. Since accessing also means "to go into", the puncturing action is encompassed in the meaning. Claim 14 is therefore a method of surgery and was therefore not searched (Art. 17(2)(a)(i) & Rule 39.1(iv)) and is not examined (Art. 34(4)(a)(i) & Rule 67.1(iv) / 43bis.1(b)).

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2011/001333

Patent document cited in search report	Publication date	Publication date	Patent family member(s)	Publication date
WO 9718751	A1	29-05-1997	EP 0866670 A1	30-09-1998
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