US 20250228507A1

(19) United States
(12) Patent Application Publication
(10) Pub. No.: US 2025/0228507 A1
(43) Pub. Date: Jul. 17, 2025
Wagner et al.

(54) APPARATUS FOR X-RAY CT IMAGING WITH REDUCED PROBE ARTIFACTS

(71) Applicant: **Wisconsin Alumni Research Foundation**, Madison, WI (US)

(72) Inventors: **Martin Wagner**, Madison, WI (US); **Timothy Peter Szczykutowicz**, Madison, WI (US); **Allison Couillard**, Oconomowoc, WI (US); **Fred Lee**, Madison, WI (US)

(21) Appl. No.: **18/411,131**

(22) Filed: **Jan. 12, 2024**

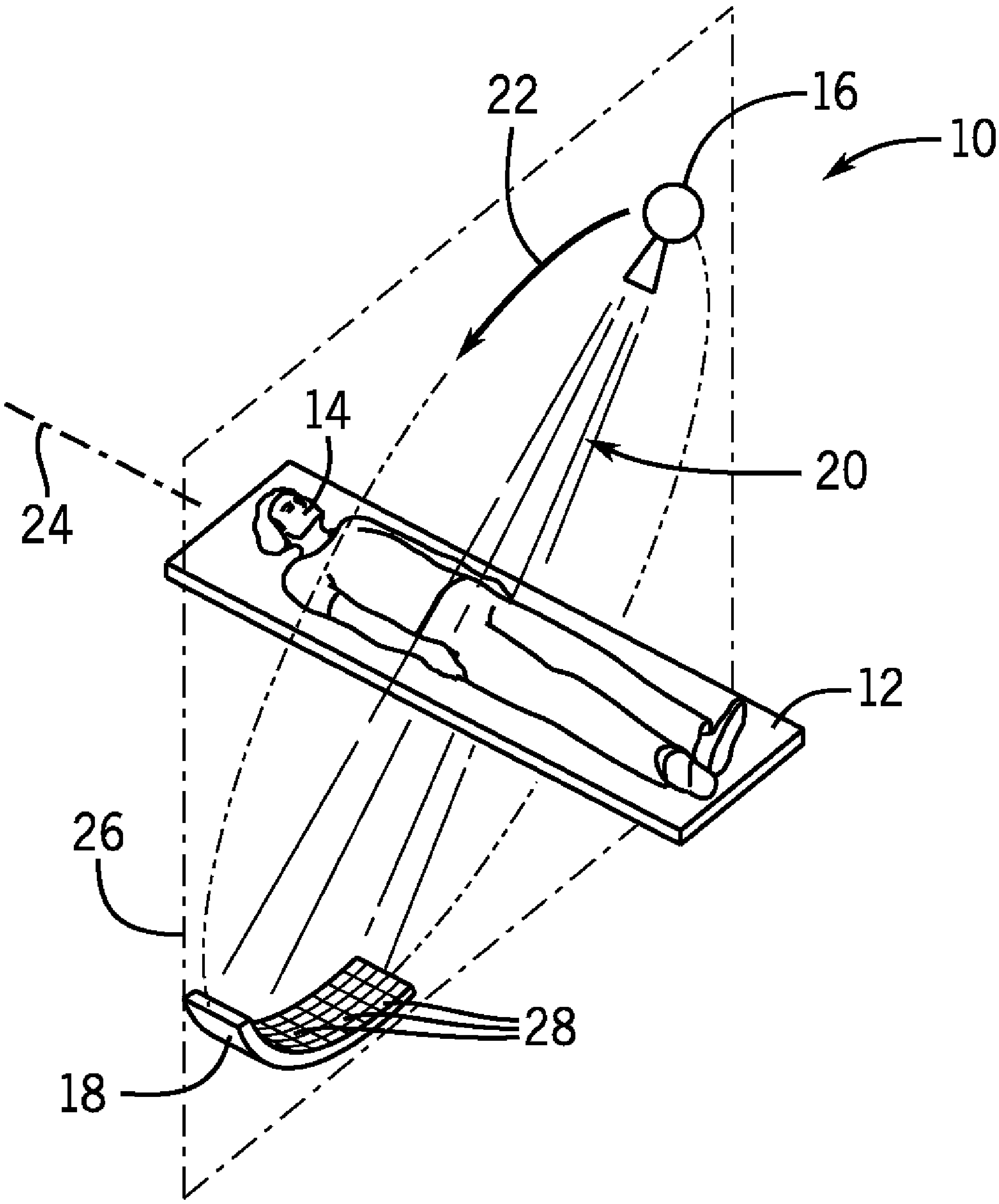
**Publication Classification**

(51) **Int. Cl.**
*A61B 6/02* (2006.01)
*A61B 6/03* (2006.01)

(52) **U.S. Cl.**
CPC .............. ***A61B 6/027*** (2013.01); ***A61B 6/025*** (2013.01); ***A61B 6/035*** (2013.01)

(57) **ABSTRACT**

Tomographic projection data is acquired in an acquisition plane angled with respect to a trajectory plane of a probe, such as a biopsy probe, to reconstruct an image in the trajectory plane, reducing probe-induced artifacts at the tip of the probe. Patient table position and angulation may be adjusted automatically and dynamically during probe insertion for this purpose.



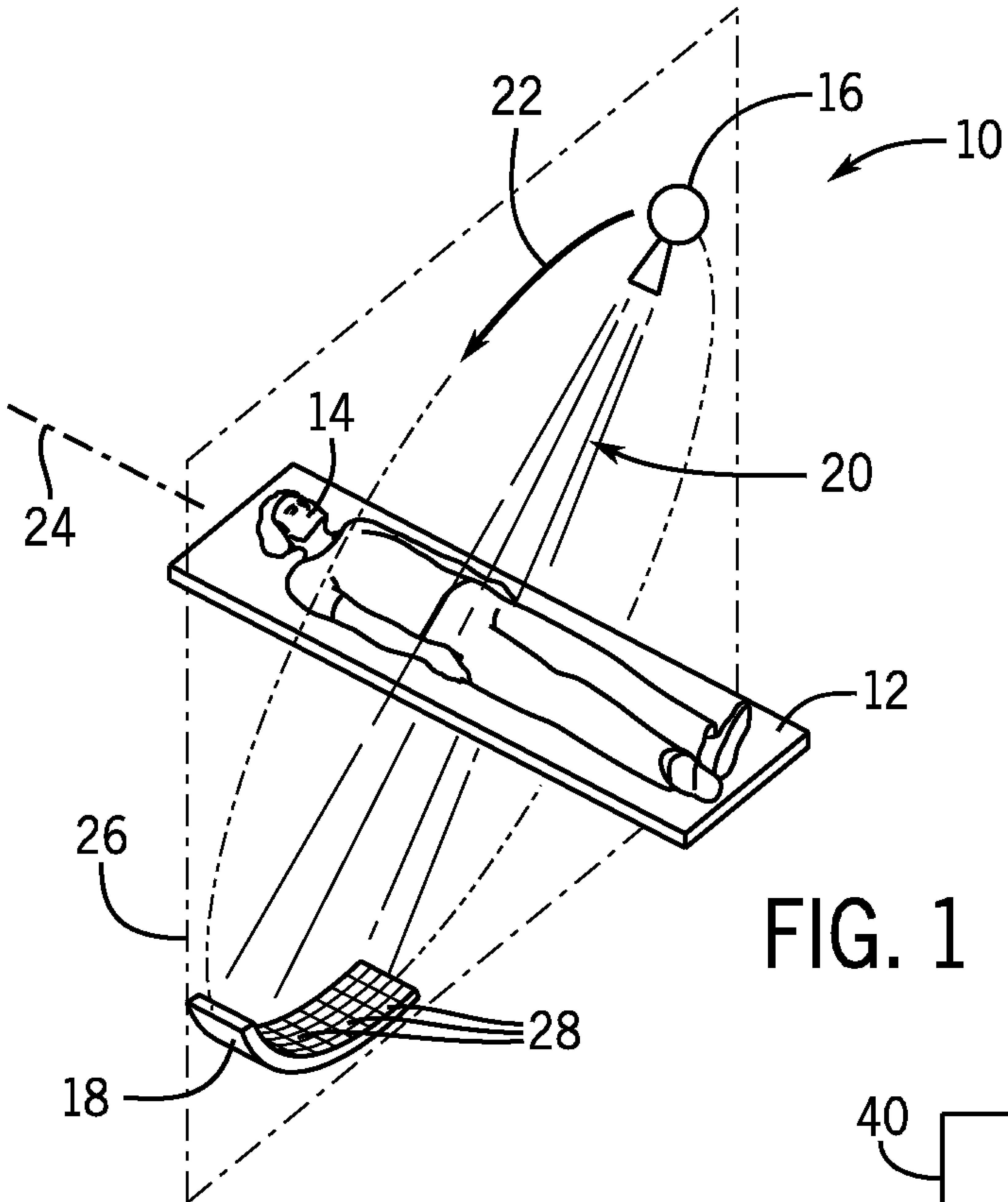

22
16
10
14
20
24
12
26
28
18

FIG. 1

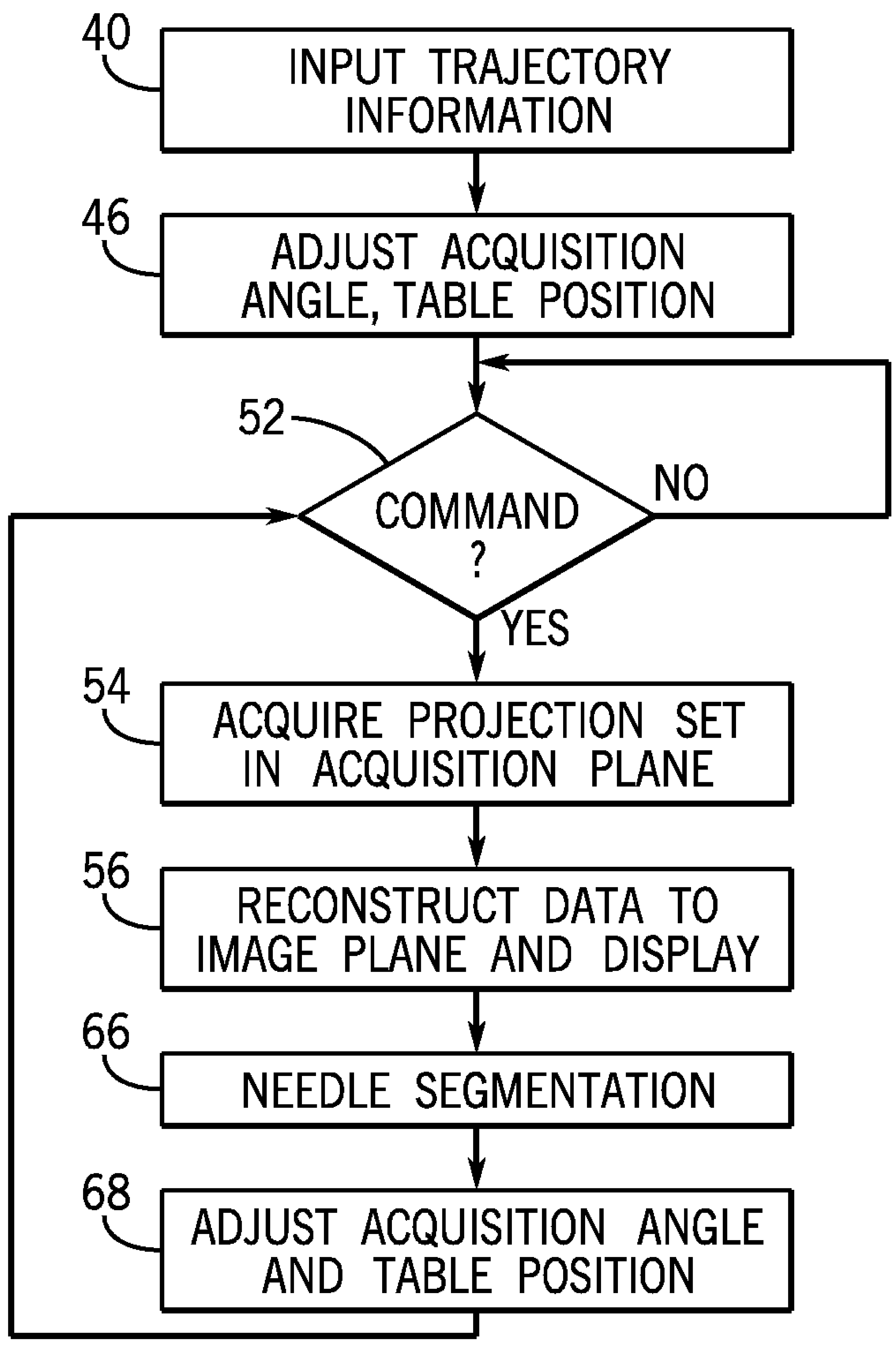

40
INPUT TRAJECTORY INFORMATION
46
ADJUST ACQUISITION ANGLE, TABLE POSITION
52
COMMAND ?
NO
YES
54
ACQUIRE PROJECTION SET IN ACQUISITION PLANE
56
RECONSTRUCT DATA TO IMAGE PLANE AND DISPLAY
66
NEEDLE SEGMENTATION
68
ADJUST ACQUISITION ANGLE AND TABLE POSITION

FIG. 2

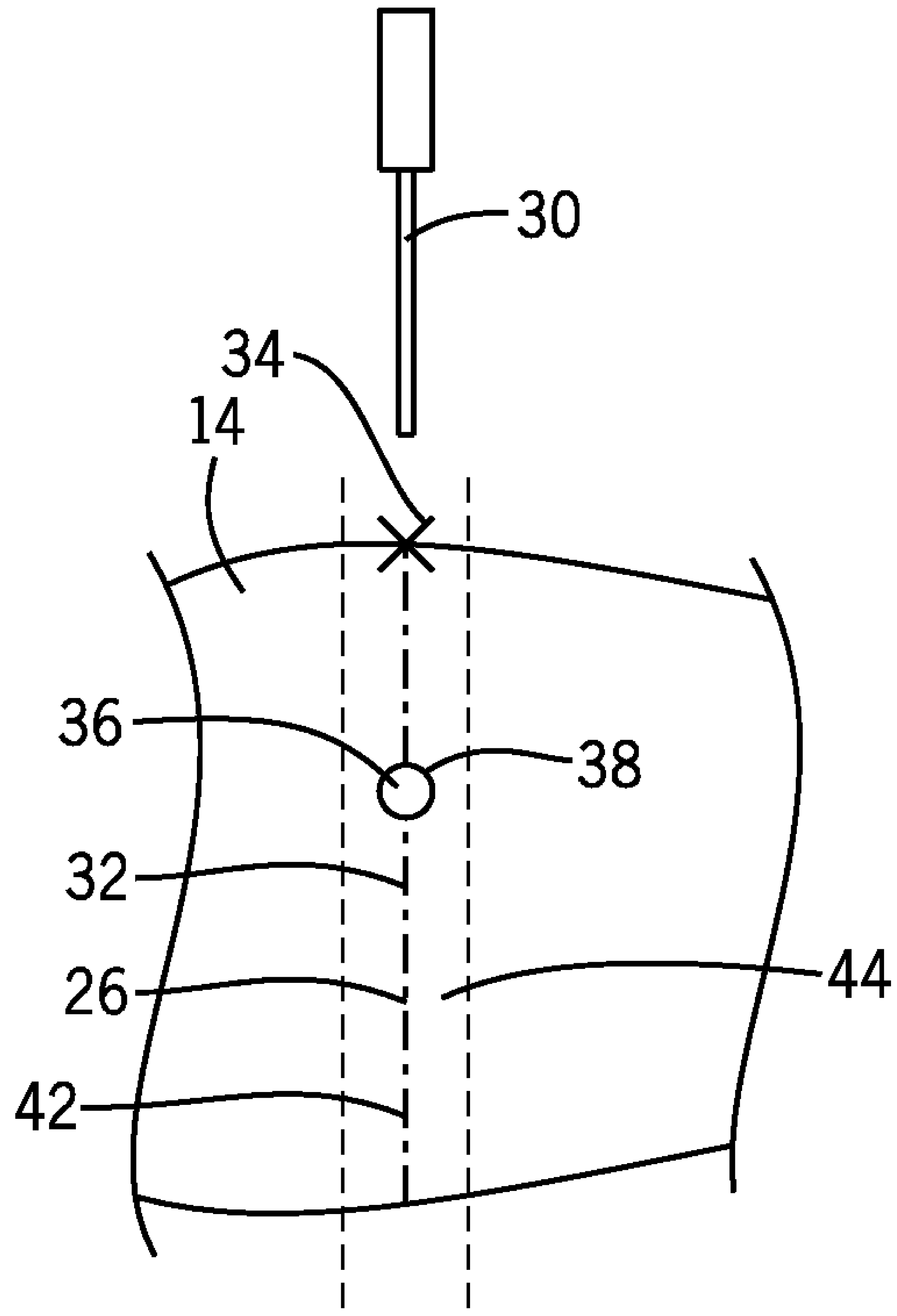



FIG. 3a

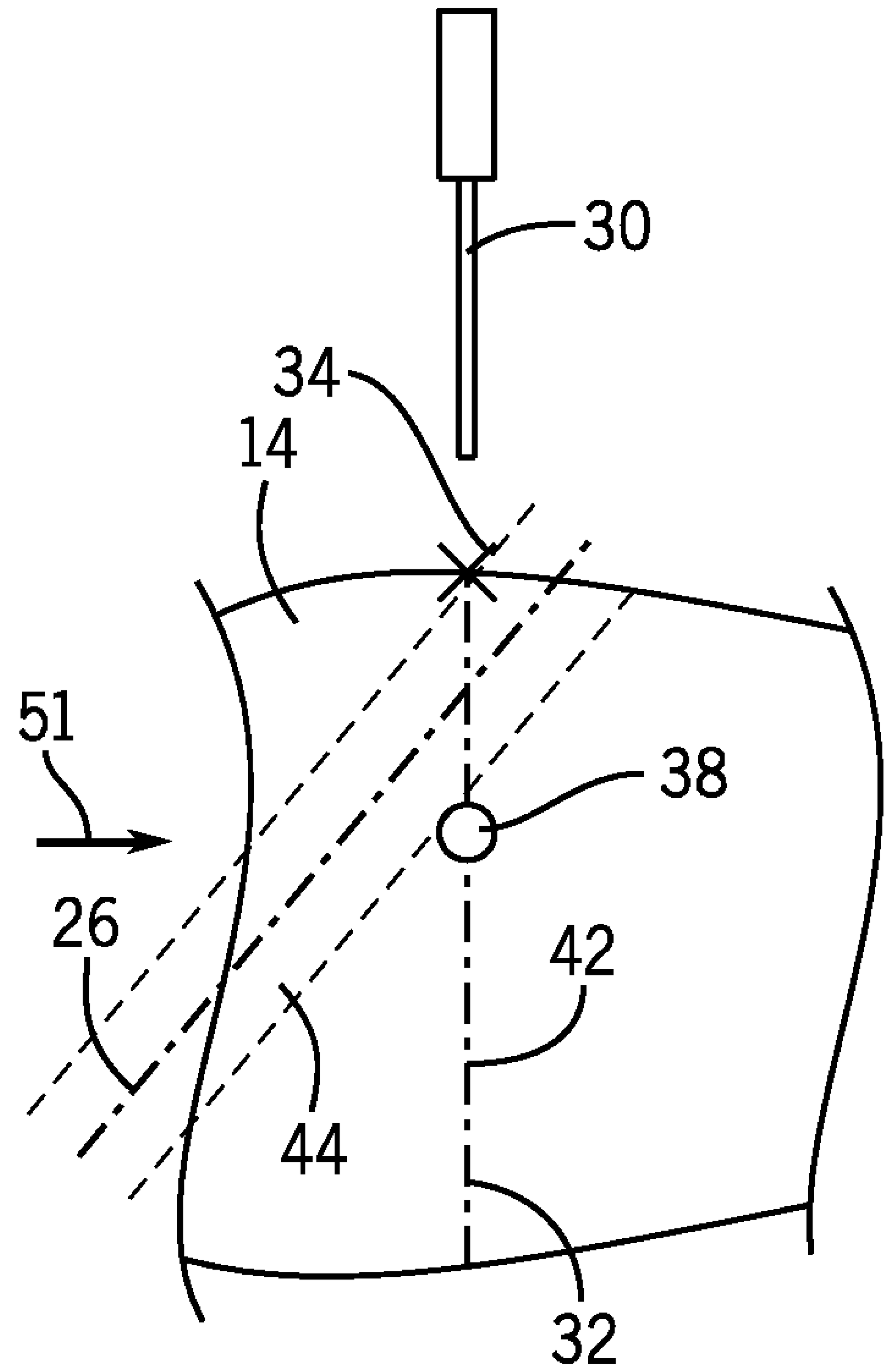



FIG. 3b

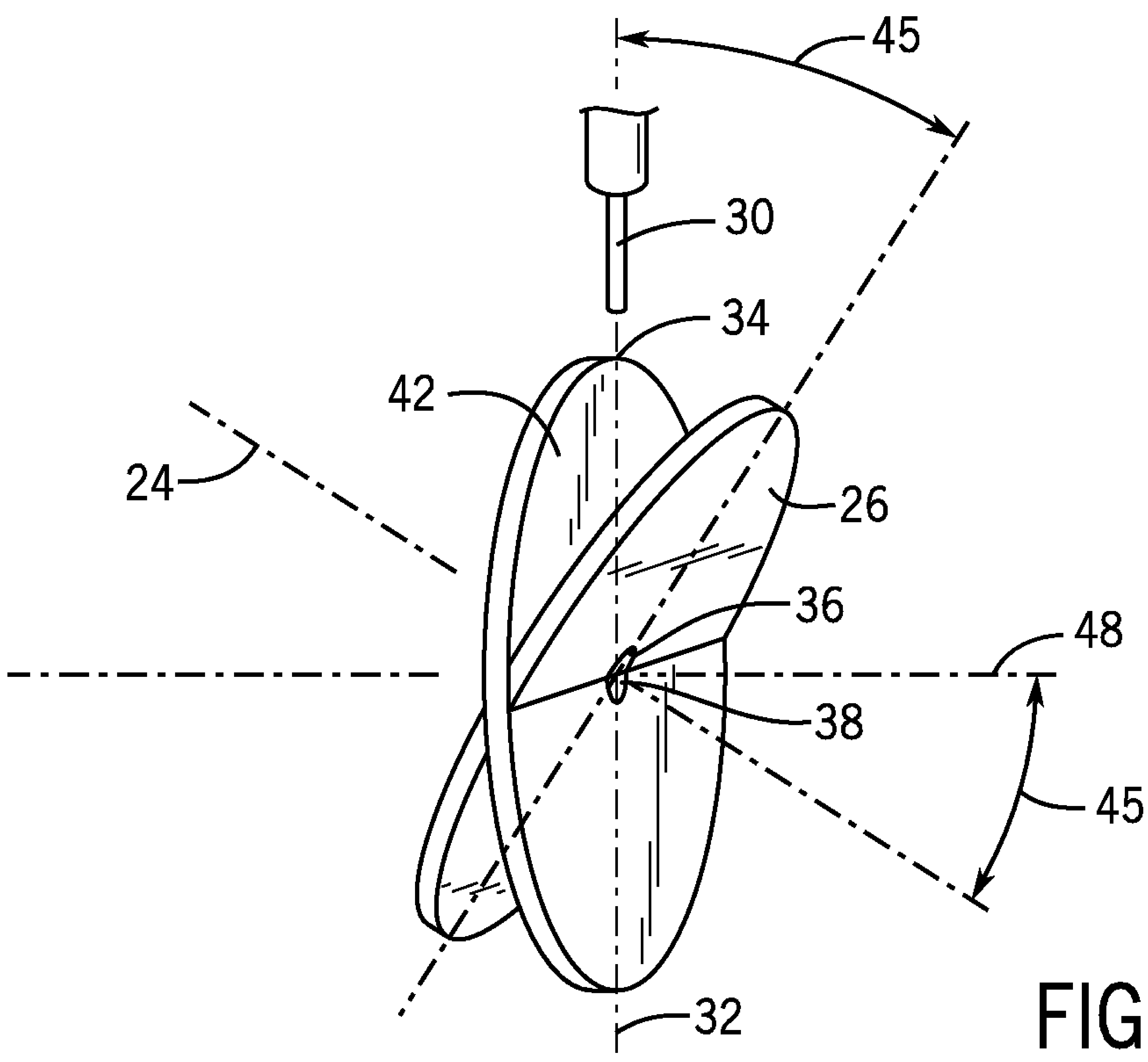



FIG. 4

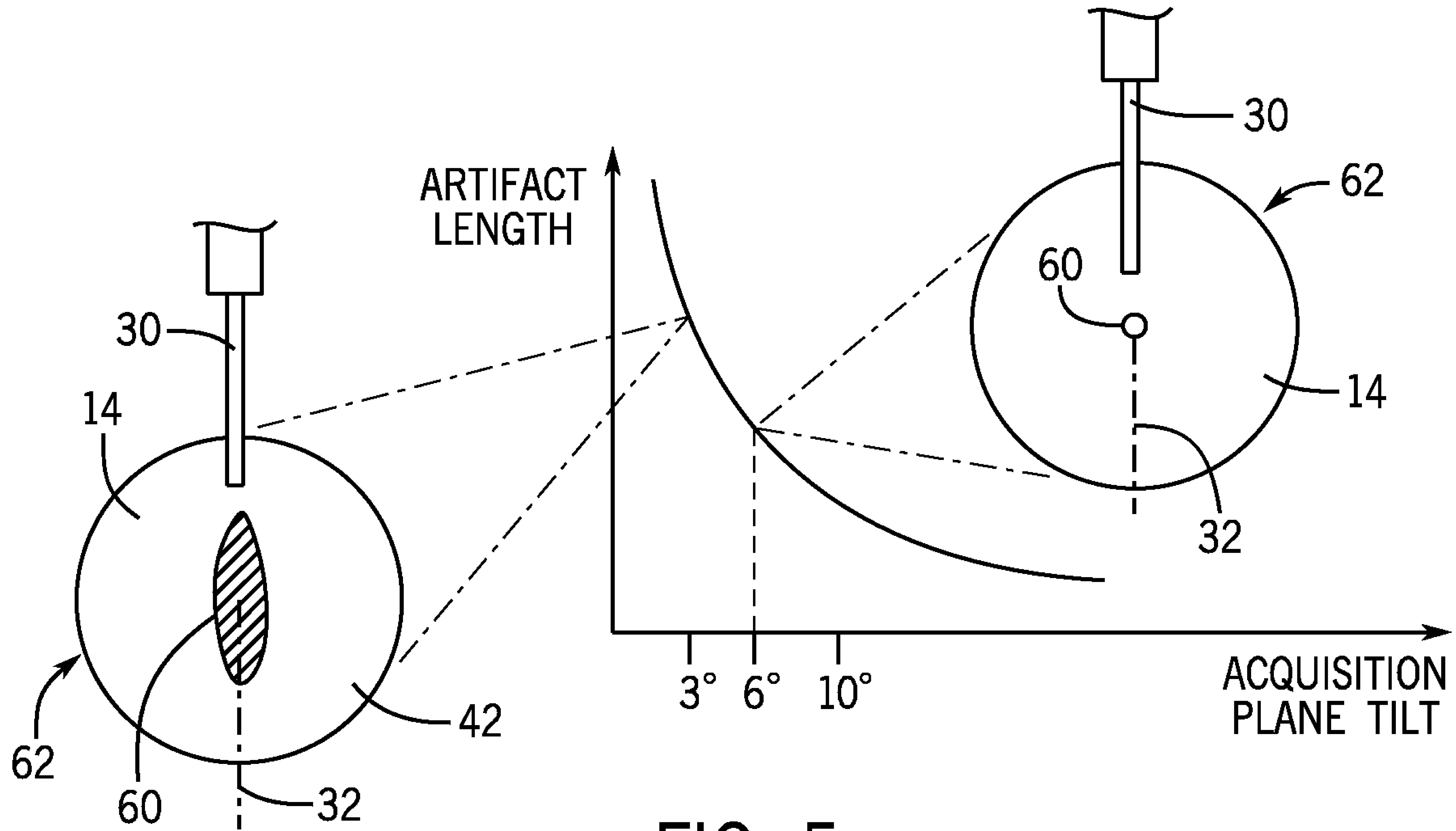



FIG. 5

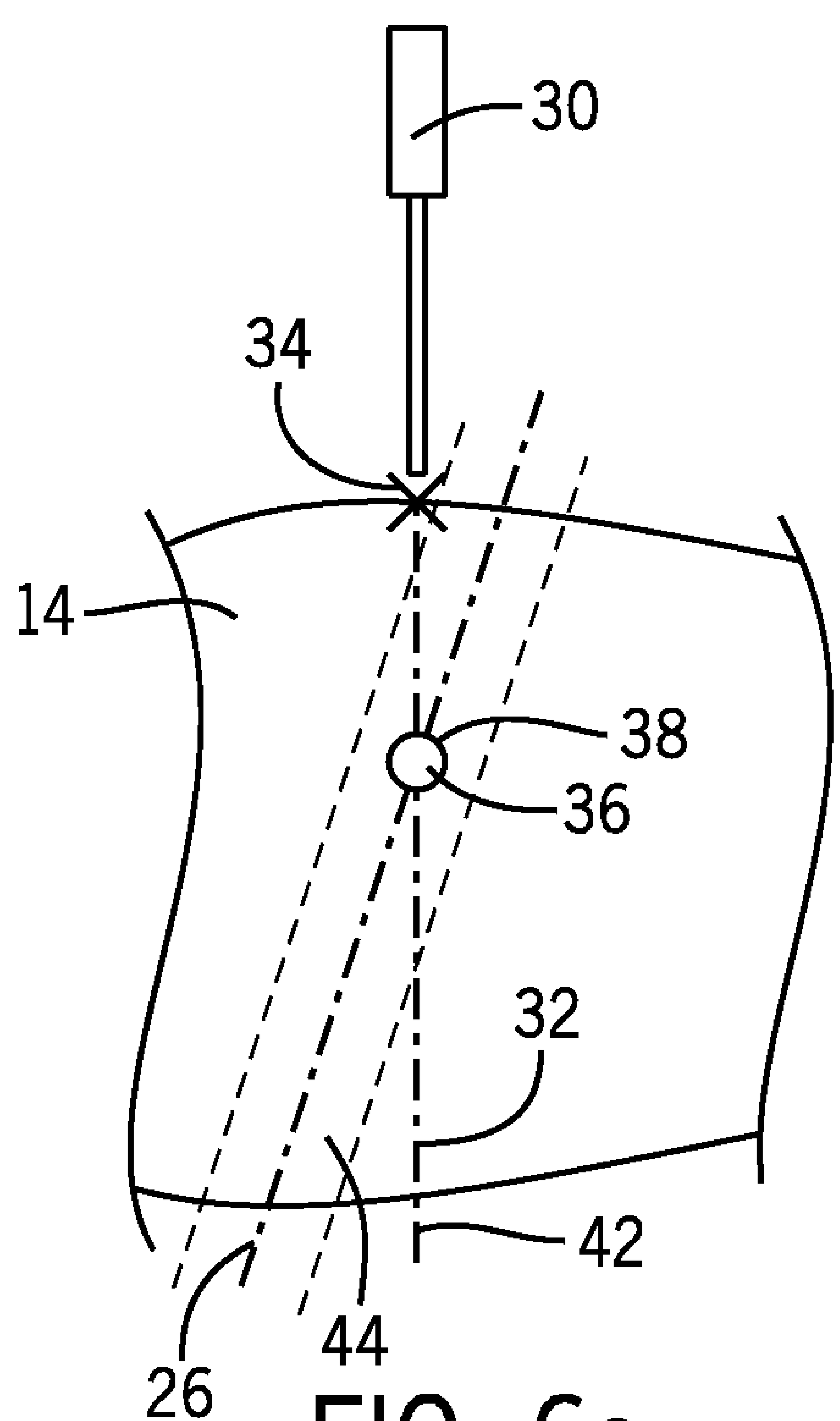



FIG. 6a

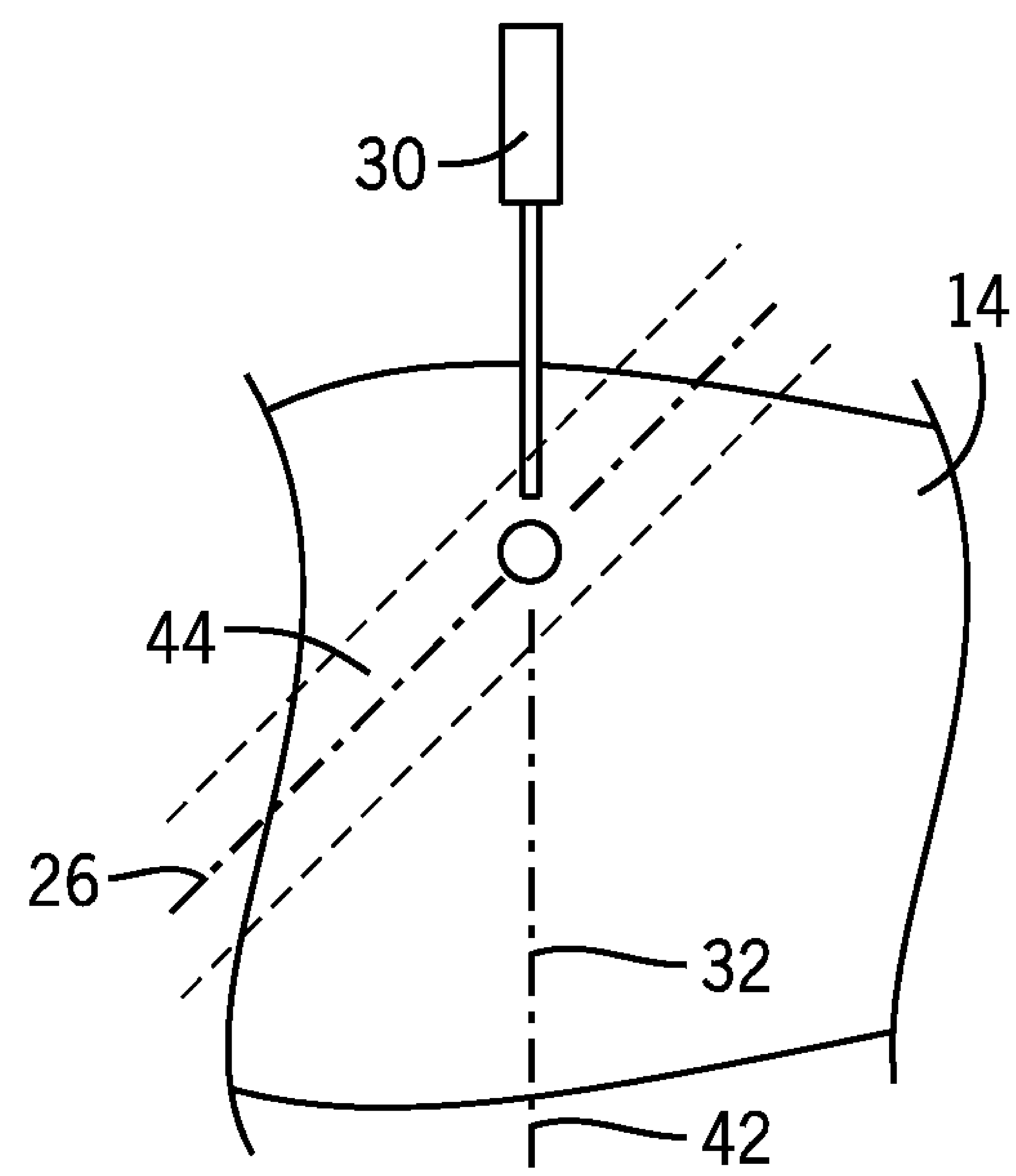



FIG. 6b

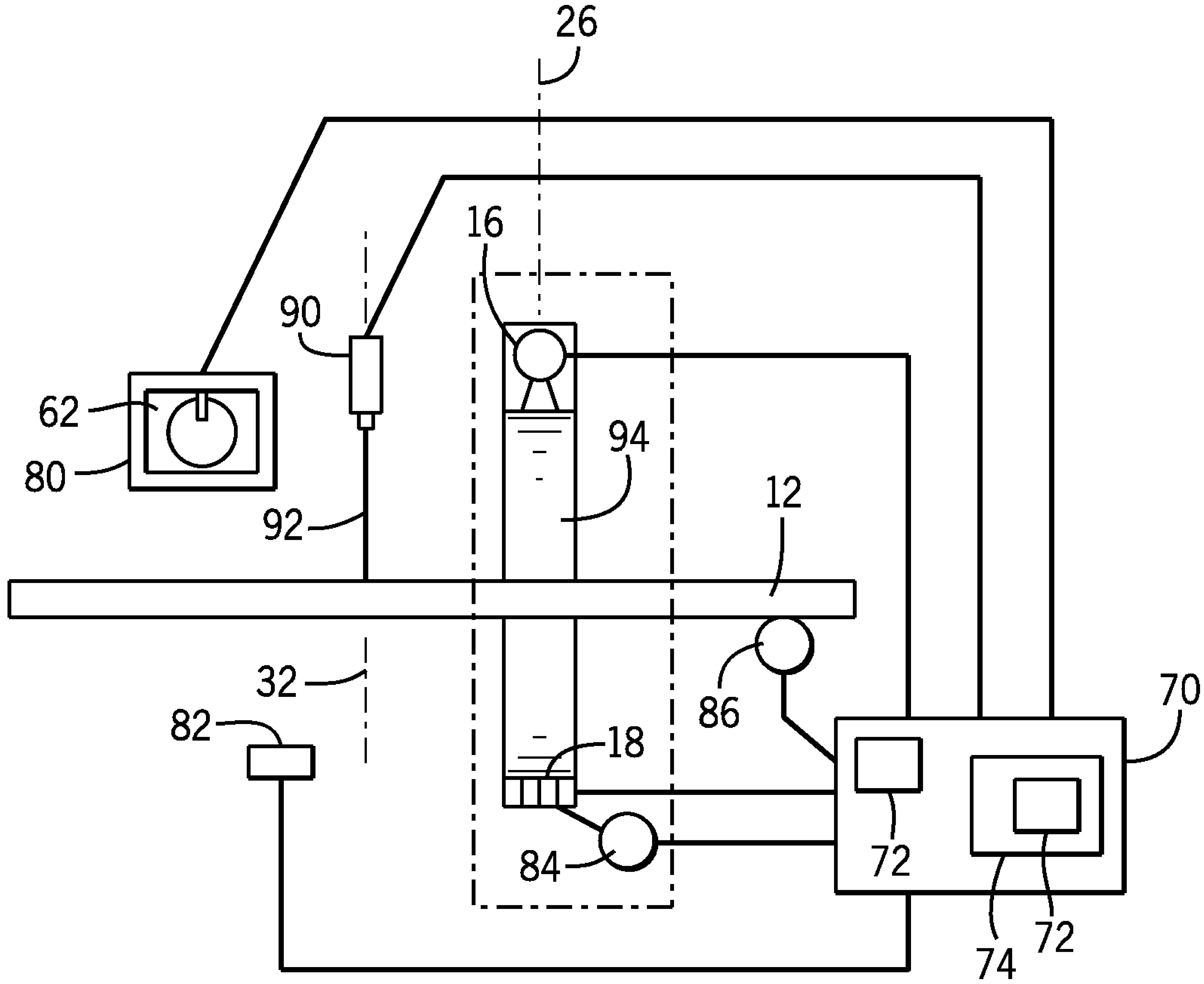



FIG. 7

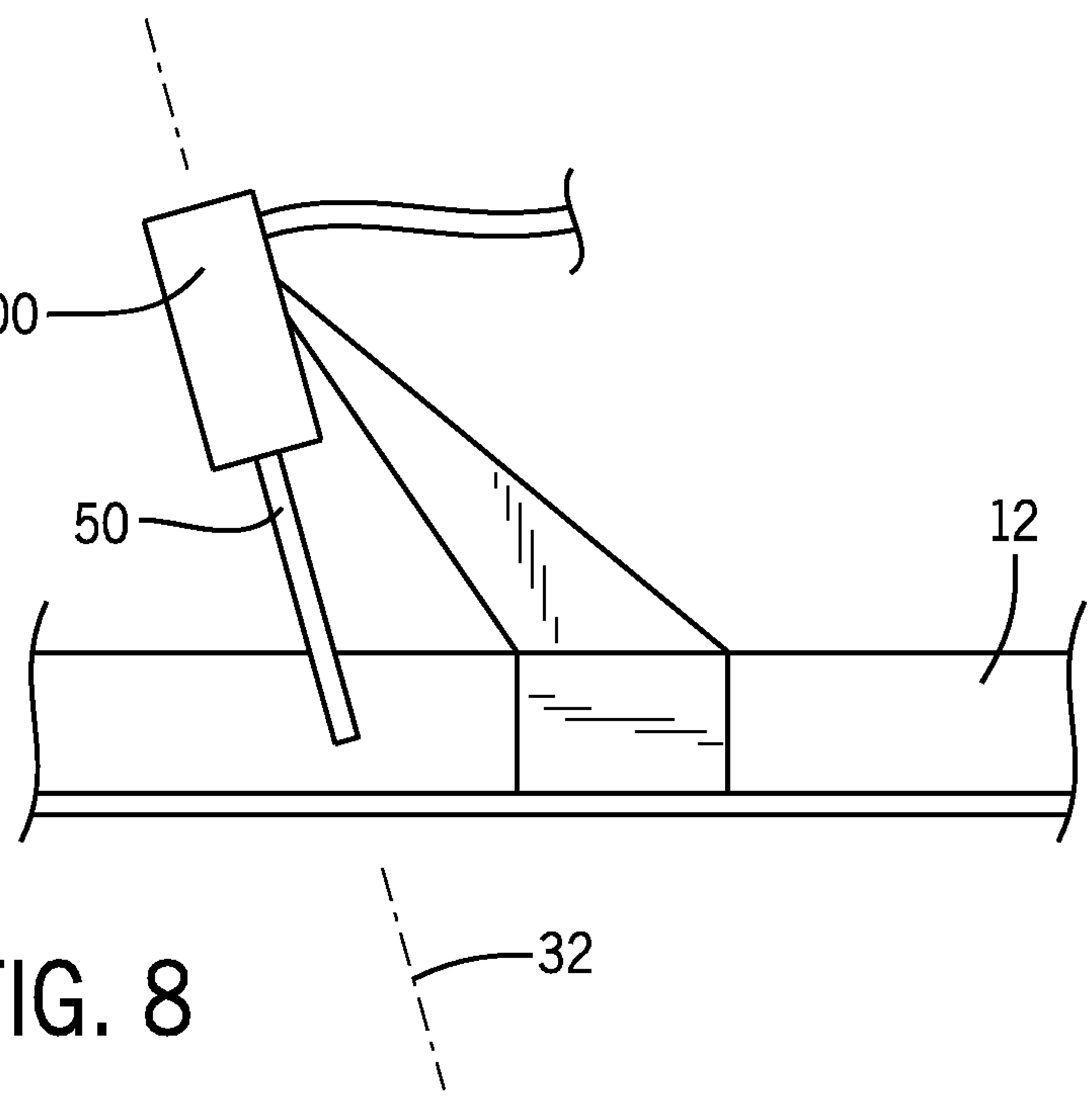



FIG. 8

# APPARATUS FOR X-RAY CT IMAGING WITH REDUCED PROBE ARTIFACTS

## STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

## Cross Reference to Related Application

## Background of the Invention

**[0001]** The present invention relates generally to medical computed tomography (CT) and in particular to an x-ray CT machine operating to reduce artifacts associate with needle-like probes.

**[0002]** Many medical procedures utilize an introducer needle (cannula) that can be inserted through the skin of the patient of the patient to a target region for a specific intervention, for example, biopsy, injection, aspiration, drain placement, ablation, etc. During the insertion, a solid stylet maybe placed coaxially within the introducer needle to help to pierce the tissue and to help prevent coring of tissue. Some stylets may also have a blunt tip that prevents coring by the introducer needle but without the cutting tip.

**[0003]** Once the target is reached, the stylet can be removed in preparation for the specific intervention, for example, insertion of a biopsy device.

**[0004]** The process of guiding the introducer needle to the target is often aided by CT imaging which can provide an image showing the target and helping visualize and align the needle with the target. The CT machine may further provide a laser guide aligned with the image slice providing a reference against which the needle angle may be compared.

**[0005]** While CT imaging can help in guiding the needle, the material of the needle (often a metal such as stainless steel) and its length can result in severe image artifacts at the needle tip extending along the needle axis and can substantially block x-ray transmission along rays aligned with the needle. This artifact is positioned to obscure the region of greatest interest in guiding the tip of the needle around a critical structure and to a location within the lesion or other target.

**[0006]** Image artifacts in computed tomography arise from the underlying mathematical process that is used to develop cross-sectional slice images from attenuation (projection) data collected edgewise through the slices. A condition of this reconstruction process is that each voxel in the imaged volume be illuminated over a range of angles in excess of 180° plus the angle subtended by the x-ray beam in the imaging plane. The needle material causes x-ray photon starvation at certain angles in this required range. The result is a reconstruction artifact manifest as a dark streak extending from the tip of the needle along axis of the needle. These same artifacts can occur with other slender interventional probes including ablation electrodes and the like. Henceforth these needles, electrodes and similar medical devices for percutaneous insertion into the body will be collectively referred to as "probes".

**[0007]** Current approaches to reducing artifacts caused by photon starvation may attempt to estimate missing x-ray attenuation values; however, estimation can introduce additional errors into the image. These techniques may not be practical for real-time imaging or may require additional features such as dual energy imaging that are not found in many x-ray machines.

## SUMMARY OF THE INVENTION

**[0008]** The present invention provides a tomographic x-ray machine that acquires tomographic projection data in an acquisition plane that is angled with respect to a plane holding the insertion axis of the probe and the target within the patient. This angulation decreases the length and size of the image artifact aligned with the probe and proximate to the tip in an image plane holding the probe. This ability to acquire the data at an angle with respect to the plane of the probe is possible because of the small amount of angulation required that is compatible with imaging volume provided in current multislice CT machines. Several methods for identifying of the probe trajectory on which the angulation is based are provided, permitting automatic gantry angulation and, in some embodiments, permitting dynamic adjustment of the angulation of the acquisition plane and repositioning of the CT couch during the probe insertion, further improving probe visualization.

**[0009]** More specifically, and in one embodiment, the invention provides an x-ray imaging machine having an x-ray source and x-ray detector opposed along an x-ray axis and supported to orbit in opposition about a rotational axis to collect tomographic projection data with respect to an acquisition plane perpendicular to the rotational axis, the tomographic projection data comprising measured x-ray attenuation along multiple rays over a range of rotational angles. The x-ray imaging machine also includes an image display and a tomography control processor receiving the tomographic projections data. The tomography control processor operates to (a) receive data defining, within a trajectory plane, a probe insertion trajectory along which a probe will be inserted; (b) position the rotational axis of the x-ray source and x-ray detector to tilt the acquisition plane; (c) reconstruct the tomographic projection data into an image aligned with the trajectory planes; (d) display the image on the image display; and (e) repeat (b)-(e) during a probe insertion interval.

**[0010]** It is thus a feature of at least one embodiment of the invention to reduce image artifacts in the critical area of the probe tip aligned with the probe trajectory by using an angled acquisition plane.

**[0011]** The x-ray imaging machine may further include a patient support, and the data defining the probe insertion trajectory may include a probe target location with respect to the patient support. In this case, the tomographic control processor may also determine a necessary positioning of the patient support to automatically place the probe target location within an intersection between the trajectory plane and an acquisition volume about the acquisition plane.

**[0012]** It is thus a feature of at least one embodiment of the invention to ensure that the artifact-reducing angulation maintains a positioning of the patient allowing acquisition of relevant data for imaging the trajectory of the probe.

**[0013]** In some embodiments, the input describing probe trajectory includes identification of a puncture point, where the probe is inserted through skin of the patient, and a target point for the probe tip. The tomographic control processor may then control the patient support and the tilt so that the acquisition volume around the acquisition plane subtends the distance between the puncture point and the target point.

**[0014]** It is thus a feature of at least one embodiment to provide an initial reduced artifact image fully covering the relevant trajectory of the probe insertion from skin to target.

**[0015]** The tomographic control processor may position the rotational axis to be about 6° (or generally between 3° and 30°) from a normal to the trajectory plane.

**[0016]** It is thus a feature of at least one embodiment of the invention to provide substantial artifact reduction within a range of angulations achievable with current x-ray systems and acquisition volumes.

**[0017]** The x-ray imaging machine may further receive a probe target location within the patient, and the tomographic control processor may receive data indicating progress of the probe along the probe insertion trajectory and operate to change the tilt of the acquisition plane with respect to the trajectory plane as a function of probe insertion depth, increasing the tilt between the rotational axis and a normal to the trajectory plane as the probe approaches the target.

**[0018]** It is thus a feature of at least one embodiment of the invention to adjust acquisition plane tilt dynamically to effect a trade-off between artifact reduction and trajectory path visualization length, imaging a greater length at the beginning of the probe insertion and near the end of probe insertion providing a greater reduction in image artifact.

**[0019]** The data indicating progress of the probe along the probe insertion axis may be obtained by processing of the image to monitor the position of the probe with respect to at least one of insertion depth and angle. In an alternative or additional embodiment, a sensor may be mechanically attached to the probe indicating either or both of insertion depth and angle.

**[0020]** It is thus a feature of at least one embodiment of the invention to provide an automatic method of monitoring probe insertion depth to implement this dynamic tilt control.

**[0021]** The data defining the probe insertion trajectory may be obtained from at least one of an initial alignment of the acquisition plane and the trajectory plane and a probe alignment guide (such as but not limited to a laser) positionable in alignment with the probe trajectory and providing sensors producing the data defining the probe insertion trajectory.

**[0022]** It is thus a feature of at least one embodiment of the invention to implement artifact reduction without the need for additional trajectory-defining steps or inputs by the physician.

**[0023]** The tomographic projection processor may monitor the trajectory of the probe in an acquisition volume around the acquisition plane to adjust the angles of the image plane according to changes in the monitored trajectory during probe insertion.

**[0024]** It is thus a feature of at least one embodiment of the invention to accommodate changes in the probe trajectory to adjust the imaging plane in addition to the acquisition plane as is done to minimize artifacts.

**[0025]** These particular objects and advantages may apply to only some embodiments falling within the claims and thus do not define the scope of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0026]** FIG. **1** is a simplified perspective view of an x-ray machine suitable for use with the present invention showing an x-ray source and x-ray detector that may rotate within an acquisition plane to collect tomographic data;

**[0027]** FIG. **2** is a flowchart describing the steps of the present invention in reducing probe-induced artifacts in an image produced by the x-ray machine of FIG. **1**;

**[0028]** FIGS. **3***a* and **3***b* are side views in phantom of the patient showing a probe trajectory and an initial alignment of the image plane and acquisition plan (FIG. **3***a*) and subsequent tipping of the acquisition plane with respect to the image plane used in the present invention (FIG. **3***b*);

**[0029]** FIG. **4** is a geometric representation of the divergence between the image plane and the acquisition plane of FIG. **3** illustrating various angles and dimensions used in the description;

**[0030]** FIG. **5** is a plot of artifact length versus tip angle with depictions of a reduction in artifact at the tip of the probe along the trajectory of insertion as provided by the present invention;

**[0031]** FIGS. **6***a* and **6***b* are figures similar to FIG. **3** showing the process of dynamically changing angulation as the probe progresses along the trajectory to further reduce image artifacts;

**[0032]** FIG. **7** is a functional block diagram of the x-ray machine of FIG. **1** showing interconnections between a tomographic processor and elements of the x-ray machine for automatic control according to the present invention, and further showing a laser probe insertion guide; and

**[0033]** FIG. **8** is a fragmentary detail of an alternative insertion guide providing a mechanical connection to the probe that may be used together with or in lieu of the laser insertion guide of FIG. **7**.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

**[0034]** Referring now to FIG. **1**, an x-ray machine **10** suitable for use with the present invention may provide a patient support **12** such as a radiolucent patient table upon which a patient **14** may be positioned. An x-ray source **16** and x-ray detector **18** may be mounted on a gantry (not shown in FIG. **1** for clarity) in opposition about the patient support **12** and positioned so that an x-ray beam **20** from the x-ray source **16** is directed toward the detector **18** through the patient support **12**. As fixed in opposition, the x-ray source **16** and x-ray detector **18** may orbit the patient table as indicated by arrow **22** about a rotational axis **24** typically roughly directed along the craniocaudal axis of the patient **14**. As so arranged, the x-ray source **16** and x-ray detector **18** rotate within an acquisition plane **26** normal to the rotational axis **24**.

**[0035]** In one nonlimiting example, the x-ray machine **10** may be a medical computed tomography machine having a detector **18** for acquiring volumetric data over two-dimensionally arrayed detector elements **28**. The detector elements **28**, as so positioned, may each provide x-ray attenuation measurements along different individual rays of the x-ray beam **20** through the patient in a generally conical volume. When the gantry is rotated, the x-ray machine **10** may acquire a tomographic projections set of x-ray attenuation measurements collected at multiple different angles (projections) over a range of at least 180° plus the in-plane angular extent of the x-ray beam **20** within the acquisition plane **26**. This tomographic projections set is sufficient to generate a slice image providing a cross-section along the acquisition plane **26**.

**[0036]** Alternatively, the x-ray machine **10** may be any of a variety of x-ray devices capable of providing tomographic projections set acquisitions including, for example, C-arm type devices and the like and devices in which the x-ray source **16** and x-ray detector **18** are mounted on robotic arms.

**[0037]** Referring now to FIGS. **2** and **3***a*, during an interventional procedure, a probe **30** may be inserted along a trajectory **32** of the probe **30** into the patient **14**, the trajectory **32** extending from a puncture site **34** to a target **36**, the latter at or within a lesion **38** or the like. Probes **30** suitable for use with the present invention are described in co-pending U.S. application Ser. No. 18/487,228 filed Nov. 21, 2023, and entitled "Introducer Needle and Stylet for Interventional Procedures," assigned to the assignee of the present application, and hereby incorporated by reference. More generally, the probe **30** may also be of conventional design constructed of materials that are substantially more x-ray absorbing than the surrounding tissue. Such materials include but are not limited to materials with an atomic number comparable to or greater than metals like stainless steel.

**[0038]** The trajectory **32** must be selected to avoid critical structures such as arteries or the like and, in this regard, it is desirable to be able to image the tip of the probe **30** as it moves along the trajectory **32** using computed tomography imaging of a slice encompassing the probe trajectory **32**.

**[0039]** In realizing this goal and, as indicated by process block **40** of FIG. **2**, in a first step, trajectory information defining the trajectory **32** is collected. In one embodiment this information may be provided as a coordinate of the puncture site **34** and of the target **36**, for example, in three dimensional space, as referenced with respect to the patient support **12** presuming a previous registration of the patient **14** with those table coordinates as is understood in the art.

**[0040]** In one embodiment, this trajectory information may be collected by aligning the gantry holding the x-ray source **16** and x-ray detector **18** so that the acquisition plane **26** is aligned with the trajectory **32**. This initial alignment may be facilitated, for example, using an alignment laser (not shown) frequently provided with the x-ray machine **10** demarcating the acquisition plane **26**. In addition or alternatively, this alignment may be confirmed by an initial tomographic acquisition in this position with the probe **30** removed to eliminate artifacts.

**[0041]** Alternatively, the information describing the trajectory **32** is provided with respect to pre-procedure images obtained of the patient **14**, where the puncture site **34** and target **36** are identified on those images and then matched to table position during a registration of the patient **14**. This determination of the trajectory **32** may be done by viewing a three-dimensional volume of pre-procedure images or by viewing two-dimensional images.

**[0042]** Other methods of determining this trajectory information with respect to the patient and table will be described further below.

**[0043]** As noted, the information describing the trajectory **32** will be used to identify a desired image plane **42** containing the trajectory **32**.

**[0044]** Referring now also to FIGS. **2**, **3***b* and **4**, once the information defining the trajectory **32** has been obtained, rotational axis **24** of the x-ray source **16** and detector **18** is adjusted to tip the acquisition plane **26** out of alignment with the image plane **42** and the trajectory **32** per process block **46**. This degree of angulation **45** will typically be at least 3° and in some cases greater than 5°, for example 6°, but may be greater. In many situations, the degree of angulation **45** will be less than 30° and in some cases less than 10°. This angulation describes an angle between the image plane **42** and acquisition plane **26** or between a surface normal **48** of the image plane **42** and the rotational axis **24** of acquisition plane **26**. Note that the image plane **42** need not be and will typically not be a 0° angular gantry tilt with respect to the table axis. Generally, the acquisition plane **26** is, as mentioned above, the rotational plane of the x-ray source **16** and detector **18**.

**[0045]** As indicated in FIG. **3***b*, this angulation will be accompanied with a table motion **51** to retain a region of interest of the trajectory **32** within an acquisition volume **44** about the acquisition plane **26**. The acquisition volume **44** defines voxels that can be reconstructed for a given angulation of the acquisition plane **26**. Initially, this region of interest of the trajectory **32** will be the entire length between the puncture site **34** and the target **36**.

**[0046]** As indicated by decision block **52**, upon command by the physician performing the procedure, the x-ray machine **10** then acquires a projection set along the tipped acquisition plane **26**, typically but not necessarily with a single gantry rotation. This data set typically includes the puncture site and target.

**[0047]** At succeeding process block **56**, the data so acquired is reconstructed into an image aligned with the image plane **42**. This is contrary to a typical reconstruction of an image that is aligned with the acquisition plane **26**. The process of making this image reconstruction that is angled with respect to the acquisition plane **26** may, in one example, reconstruct the data within the acquisition plane **26** to a set of voxels and then select and assemble the voxel aligned with the image plane **42**. A nonlimiting technique for this transformation is described, for example, in Defrise M, Noo F, Kudo H, Rebinning-Based Algorithms for Helical Cone-Beam CT, Phys Med Biol. 2001 November; 46 (11): 2911-37, doi: 10.1088/0031-9155/46/11/311, PMID: 11720355, hereby incorporated by reference.

**[0048]** This image reconstructed in the image plane **42** that holds the trajectory **32** is then displayed to the physician to confirm the location of the probe **30** along the trajectory **32** with respect to other body structures, including the target **36**.

**[0049]** Referring now to FIG. **5**, the present inventors have determined that relatively small angulation of the acquisition plane **26** with respect to the image plane **42** substantially reduces a size of the image artifact **60** in an image **62** of the patient in the image plane **42**. The size of the image artifact **60** is a rapidly decreasing function of the angulation of the acquisition plane **26** and thus can provide acceptable minimization of the image artifacts **60** at an angle of 6° with diminishing reductions thereafter. While the inventors do not wish to be bound by a particular theory, the reduction in the length and size of the artifact **60** appears to be driven by a reduced path length of x-rays through the material of the probe **30** with respect to voxels in the relevant area proximate to the tip of the probe **30**.

**[0050]** Referring now to FIGS. **2** and **6**, as indicated by process block **66**, the acquired data at process block **54** may optionally be reviewed to identify the location of the probe **30** using an automatic probe segmentation program of a type understood in the art. This information allows both a determination of change in the trajectory **32** of the probe **30** and a determination of the position of the tip of the probe **30** as it progresses along the trajectory **32**. This information may be used at process block **68** for two purposes. The first is to make any adjustments to the positioning of the image plane **42** to ensure that displayed images of process block **56** contain the trajectory **32**. These adjustments also make necessary adjustments in the acquisition plane **26**, which are based on the trajectory **32**.

**[0051]** Independent of whether the image plane **42** has changed, as indicated by FIGS. **6***a* and **6***b*, the changing position of the tip of the probe **30** may be used to change the relative angulation of the acquisition plane **26** with respect to the trajectory **32** and optionally the collimation of the x-ray beam **20**. As previously noted, initially and as indicated in FIG. **6***a*, the angulation of the acquisition plane **26** with respect to the trajectory **32** and it's collimation may be such as to allow for a complete reconstruction of data along the trajectory of the probe **30** between the puncture **34** and the target **36**. This information assists in initial insertion of the probe **30** in the proper direction.

**[0052]** As the probe **30** progresses along the trajectory, and as indicated in FIG. **6***b*, the angulation of the acquisition plane **26** may be increased (and necessary adjustments in the table position made) so that the acquired data does not fully span the trajectory **32** between the puncture site **34** and the target **36**. This will result in an incomplete image in the image plane **42** but will provide additional attenuation of the image artifacts **60** at the relevant portions of the trajectory **32** between the tip of the probe **30** and the target **36**. Optionally the collimation of the x-ray beam **20** may be changed either to be narrower consistent with the need to image less of the trajectory **32**, or wider offset the angulation depending on dose concerns.

**[0053]** In some embodiments, the missing data of the image plane **42** may be spliced from earlier data acquired, for example, in the imaging associated with FIG. **6***a*, or the size of the image may be simply decreased in radius.

**[0054]** Process blocks **54**, **56**, **66**, **68** may be repeated as desired during the insertion of the probe **30** under control of the physician per decision block **52**.

**[0055]** Referring now to FIG. **7**, the various steps described in FIG. **2** may be implemented automatically using a programmable tomographic control processor **70** having one or more computer processors **72** communicating with electronic memory **74** holding a stored program **76**. The stored program **76** may implement the steps of FIG. **2**. For this purpose, the tomographic control processor **70** may communicate with a monitor **80** for displaying an image **62** taken along the image plane **42**. Generally, the tomographic control processor **70** may also communicate with a foot switch **82** providing the commands at decision block **52** and with gantry control motors and sensors **84** controlling motion of the gantry **94** holding the x-ray source **16** and x-ray detector **18**. Additional paths of communication to the tomographic control processor **70** allows a collecting and relaying of data from that x-ray detector **18** and the control of the x-ray source **16**.

**[0056]** The tomographic control processor **70** may also communicate with table control actuators **86** to control motion of the patient support **12**. In some embodiments, the tomographic control processor **70** may also perform the necessary calculations for image reconstruction generally known in the art.

**[0057]** In one embodiment, the x-ray machine **10** may provide a laser projector **90** that may be positioned independently of the data acquisition plane **26** to be aligned with the desired probe trajectory **32** offering the physician assistance in aligning the probe **30**. This laser projector **90** may be fixed with respect to the patient support **12** or other stationary reference point. Sensors on the laser projector **90** may be used to provide the trajectory information at process block **40** of FIG. **2** as discussed above.

**[0058]** Referring now to FIG. **8**, in an alternative embodiment, the information at process block **40** may be provided by a mechanical fixture **100** that may be angulated to hold the probe **30** at a desired angle for insertion along the probe trajectory **32** and instrumented to provide this information.

**[0059]** It will be generally understood that a tilting of the acquisition plane **26** with respect to the image plane **32** can be done by angulation of the gantry (with respect to the room) or by a similar angulation of the patient table **12** (with respect to the room) to produce the desired relative offset between the image plane **32** and the acquisition plane **26**.

**[0060]** Certain terminology is used herein for purposes of reference only, and thus is not intended to be limiting. For example, terms such as "upper", "lower", "above", and "below" refer to directions in the drawings to which reference is made. Terms such as "front", "back", "rear", "bottom" and "side", describe the orientation of portions of the component within a consistent but arbitrary frame of reference which is made clear by reference to the text and the associated drawings describing the component under discussion. Such terminology may include the words specifically mentioned above, derivatives thereof, and words of similar import. Similarly, the terms "first", "second" and other such numerical terms referring to structures do not imply a sequence or order unless clearly indicated by the context.

**[0061]** When introducing elements or features of the present disclosure and the exemplary embodiments, the articles "a", "an", "the" and "said" are intended to mean that there are one or more of such elements or features. The terms "comprising", "including" and "having" are intended to be inclusive and mean that there may be additional elements or features other than those specifically noted. It is further to be understood that the method steps, processes, and operations described herein are not to be construed as necessarily requiring their performance in the particular order discussed or illustrated, unless specifically identified as an order of performance. It is also to be understood that additional or alternative steps may be employed.

**[0062]** References to a processor should be understood to include one or more processing devices that can communicate in a stand-alone and/or a distributed environment(s), and can thus be configured to communicate via wired or wireless communications with other processors, where such one or more processor can be configured to operate on one or more processor-controlled devices that can be similar or different devices. Furthermore, references to memory, unless otherwise specified, can include one or more processor-readable and accessible memory elements and/or components that can be internal to the processor-controlled device, external to the processor-controlled device, and can be accessed via a wired or wireless network.

**[0063]** It is specifically intended that the present invention not be limited to the embodiments and illustrations contained herein and the claims should be understood to include modified forms of those embodiments including portions of the embodiments and combinations of elements of different embodiments as come within the scope of the following claims. All of the publications described herein, including patents and non-patent publications, are hereby incorporated herein by reference in their entireties.

**[0064]** To aid the Patent Office and any readers of any patent issued on this application in interpreting the claims appended hereto, applicants wish to note that they do not intend any of the appended claims or claim elements to invoke 35 U.S.C. 112 (f) unless the words "means for" or "step for" are explicitly used in the particular claim.

What we claim is:

**1**. An x-ray imaging machine comprising:

an x-ray source and x-ray detector opposed along an x-ray axis and supported to orbit in opposition about a rotational axis to collect tomographic projection data with respect to an acquisition plane perpendicular to the rotational axis, the tomographic projection data comprising measured x-ray attenuation along multiple rays over a range of rotational angles;

an image display; and

a tomography control processor receiving the tomographic projections data and operating to:

(a) receive data defining, within a trajectory plane, a probe insertion trajectory along which a probe will be inserted;

(b) position the rotational axis of the x-ray source and x-ray detector to tilt the acquisition plane with respect to the trajectory plane;

(c) acquire a tomographic projection set in the acquisition plane;

(d) reconstruct the tomographic projection data into an image aligned with the trajectory planes;

(e) display the image on the image display; and

(f) repeat (c)-(e) during a probe insertion interval.

**2**. The x-ray imaging machine of claim **1** further including a patient support; and

wherein the data defining the probe insertion trajectory provides a probe target location with respect to the patient support; and

wherein the tomographic control processor determines a necessary positioning of the patient support to place the probe target location within an intersection between the trajectory plane and an acquisition volume about the acquisition plane.

**3**. The x-ray imaging machine of claim **2** wherein the data defining the probe insertion trajectory includes a puncture point where a probe is to be inserted through skin of the patient and a target point for the probe tip and wherein the tomographic control processor controls the patient support and the tilt so that the acquisition volume around the acquisition plane subtends a distance between the puncture point and the target point.

**4**. The computed tomography machine of claim **2** wherein the tomographic control processor positions the rotational axis to be greater than 3° from a normal to the trajectory plane.

**5**. The x-ray imaging machine of claim **1** further including a patient support; and

wherein the probe insertion trajectory provides a probe target location within the patient and with respect to the patient support; and

wherein the tomographic control processor receives data indicating progress of the probe along the probe insertion trajectory and operates to change the tilt of the acquisition plane with respect to the trajectory plane as a functional of probe insertion depth, increasing the tilt between the rotational axis and a normal to the trajectory plane as the probe approaches the target.

**6**. The x-ray imaging machine of claim **5** wherein the data indicating progress of the probe along the probe insertion axis is obtained from at least one of a processing of the image to monitor the position of the probe and a sensor mechanically attached to the probe, both indicating at least one of insertion depth and angle.

**7**. The x-ray imaging machine of claim **1** wherein the data defining the probe insertion trajectory is obtained from at least one of an initial alignment of the acquisition plane and the trajectory plane and a probe alignment guide positionable in alignment with the trajectory of the probe and providing sensors producing the data defining the probe insertion trajectory.

**8**. The x-ray imaging machine of claim **7** wherein the probe alignment guide is a laser projecting an alignment beam along the trajectory of the probe positionable independently of the rotation axis.

**9**. The x-ray imaging machine of claim **1** wherein the probe insertion interval is defined by operator-initiated scan requests during which a tomographic projections set is acquired.

**10**. The x-ray imaging machine of claim **1** wherein the tomographic projection processor monitors the trajectory of the probe in an acquisition volume around the acquisition plane to adjust the angles of the image plane according to changes in the monitored trajectory during probe insertion.

**11**. The x-ray imaging machine of claim **1** wherein the image is produced solely with data acquired in the acquisition plane.

**12**. A method of guiding a probe to a target within patient tissue employing a tomographic imaging on a CT machine providing an x-ray source and x-ray detector opposed along an x-ray axis and supported to orbit in opposition about a rotational axis to collect tomographic projection data with respect to an acquisition plane perpendicular to the rotational axis, the tomographic projection data comprising measured x-ray attenuation along multiple rays over a range of rotational angles and an image display, the method comprising:

(a) receiving data defining, within a trajectory plane, a probe insertion trajectory along which a probe will be inserted;

(b) positioning the rotational axis of the x-ray source and x-ray detector to tilt the acquisition plane with respect to the image plane;

(c) acquire a tomographic projection set in the acquisition plane

(d) reconstructing tomographic projection data into an image aligned with the trajectory planes;

(e) displaying the image on an image display; and

(f) repeating (c)-(e) while guiding the probe along the trajectory.

**13**. The method of claim **12** further including a patient support; and

wherein the data defining the probe insertion trajectory provides a probe target location with respect to the patient support; and

further including positioning of the patient support to place the probe target location within an intersection between the trajectory plane and an acquisition volume about the acquisition plane.

**14**. The method of claim **13** wherein the data describing the probe insertion trajectory includes a puncture point where a probe is to be inserted through skin of the patient and a target point for the probe tip and further including controlling the patient support and the tilt so that an acquisition volume around the acquisition plane subtends a distance between the puncture point and the target point.

**15**. The method of claim **13** wherein the rotational axis is positioned to be greater than 3° from a normal to the trajectory plane.

**16**. The method of claim **12** wherein the probe insertion trajectory provides a probe target location within a patient and with respect to the patient support; and further including

receiving data indicating progress of the probe along the probe insertion trajectory and changing the tilt of the acquisition plane with respect to the trajectory plane as a function of probe insertion depth to increase the tilt between the rotational axis and a normal to the trajectory plane as the probe approaches the target.

**17**. The method of claim **16** wherein the data indicating progress of the probe along the probe insertion axis is obtained from at least one of a processing of the image to monitor the position of the probe and a sensor mechanically attached to the probe indicating its insertion depth.

**18**. The method of claim **12** wherein the data defining the probe insertion trajectory is obtained from at least one of an initial alignment of the acquisition plane and the trajectory plane and a probe alignment guide positionable in alignment with the trajectory of the probe and providing sensors producing the data defining the probe insertion trajectory.

**19**. The method of claim **12** wherein the probe insertion interval is defined by operator-initiated scan requests during which a tomographic projections set is acquired.

**20**. The method of claim **12** including monitoring the trajectory of the probe in an acquisition volume around the acquisition plane to adjust the angle of the image plane according to changes in the monitored trajectory during probe insertion.

* * * * *