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(54) Title: SPINAL SURGERY APPARATUS

(57) Abstract: A surgical method utilizes a surgical instrument having an elongate probe with a distal end having at least one egress or outlet port. The method comprises inserting a distal end portion of the elongate probe into a spinal disc space adjacent two spinal vertebrae, ejecting or streaming a plasma jet from the at least one egress or outlet port into spinal disc material in the spinal disc space, and subsequently removing the elongate probe from the spinal disc space.



WO 2022/087523 A1

SPINAL SURGERY APPARATUS
BACKGROUND OF THE INVENTION

This invention relates to surgical procedures commonly known as discectomy and nucleotomy.

5 The spinal column comprises bones or vertebrae and also fibrous discs that are disposed between the vertebrae. The discs normally function as cushions separating the vertebrae. With age, owing to a drying of the disks, the cushioning effect may be reduced. Also injury can cause a disc to bulge and press on the nerve root leaving the spinal column, possibly causing extreme pain.

10 More specifically, when the outer wall of a disc, called the annulus fibrosus, becomes weakened through age or injury, it may tear allowing the soft inner part of the disc, the nucleus pulposus, to bulge out. This is called disc herniation, disc prolapse, or a slipped or bulging disc. Once the inner disc material extends out past the regular margin of the outer disc wall, it can press against very sensitive nerve tissue in the spine. The
15 “bulging” disc can compress or even damage the nerve tissue, and this can cause weakness, tingling, or pain in the back area and into one or both legs.

 In a surgical procedure known as a discectomy a surgeon may remove part of an intervertebral disc that is putting pressure on a nerve as it leaves the spinal column. The procedure is most commonly performed on lumbar discs (located in the lower back)
20 where the patient experiences leg pain. However, the procedure may also be used for treating cervical discs in the neck.

 Open discectomy is usually performed under general anesthesia (the patient is unconscious) and typically requires a one-day hospital stay. Discectomy typically proceeds while the patient lies face down or takes a kneeling position. During the
25 procedure, the surgeon will make an approximate one-inch incision in the skin over the affected area of the spine. The surgeon removes muscle tissue from the bones above and below the affected disc while retractors hold the muscle and skin away from the surgical site to provide surgeon with a clear view of the vertebrae and disc. In some cases bone and ligaments may have to be removed for the surgeon to be able to visualize and then
30 gain access to the bulging disc without damaging the nerve tissue, this is called a laminectomy or laminotomy depending on how much bone is removed.

Once the surgeon can visualize the vertebrae, disc and other surrounding structures, he or she will remove the section of the disc that is protruding from the disc wall and any other disc fragments that may have been expelled from the disc. This is often done under magnification. No material is used to replace the disc tissue that is removed. The incision is then closed with sutures and the patient is taken to a recovery room.

The most common problem of a discectomy is that there is a chance that another fragment of disc will herniate and cause similar symptoms down the road. This is a so-called recurrent disc herniation, and the risk of this occurring is about 10-15%.

The discectomy procedure described above is limited to the removal of the herniated portion of the disc. Another disc removal procedure is intended to treat the situation where the disc is damaged to the point that it must be removed and replaced. Typically, the disc is replaced by a cage that functions to fuse the vertebral bodies located above and below the disc. Depending on approach, such procedures are called either (1) TLIF or Transforaminal Lumbar Interbody Fusion, or (2) ALIF, that is, Anterior Lumbar Interbody fusion. Both approaches entail disc space preparation that includes steps of (1) facetectomy, bone removal for obtaining access to the disc space, (2) annulotomy, or cutting through the annulus to allow access to the disc space, (3) Nucleus Pulposus removal, (4) Annulus Fibeosus removal, and (5) endplate preparation, that is, removal of soft tissue from the superior and inferior vertebral body endplate to ensure cage-bone contact needed for fusion.

SUMMARY OF THE INVENTION

The present invention aims to provide an improved approach and an associate instrument assembly and system for a discectomy procedure or a disc space preparation procedure. The present invention is useful in carrying out a surgical discectomy procedure with greater expedition and facility than conventional discectomy devices provide. The apparatus contemplates use in minimally invasive procedures.

A surgical instrument having an elongate probe with a distal end with at least one egress or outlet port, and an associated system, in accordance with the present invention is utilizable in a discectomy procedure. A distal end portion of the elongate probe is configured for insertion into a spinal disc space adjacent and between two spinal

vertebrae. The probe is connectable to a pressurized plasma source for ejecting or streaming a plasma jet from the at least one egress or outlet port into spinal disc material in the spinal disc space, the probe being subsequently removed from the spinal disc space.

A plasma jet instrument used in a method in accordance with the present
5 invention effectively vaporizes tissue and other organic material. The same result may be attained when the surgical procedure utilizes other instrumentation that works to vaporize biological tissue and other organic matter. For example, a laser may be used instead of a plasma jet instrument. Accordingly, an instrument or apparatus in accordance with the
10 invention may be used in a method that entails (a) operating on a patient to obtain access to spinal tissues at a predetermined surgical site, (b) inserting an ablative instrument into the patient so that an operative tip or end effector at a distal end of the instrument is disposed proximate the surgical site, and (c) activating the ablative instrument to deliver energy to tissues at the surgical site in a predetermined amount effective to vaporize tissue and other organic material at the surgical site at or in a spinal disc space.

15 The spinal disc space may be located (i) between the two spinal vertebrae or (ii) laterally thereof in the case of a bulging or protruding disc, of (ii) both laterally and in between the two vertebrae. In the case that the target spinal disc space is located only laterally of the two vertebrae, the use of the instrument or apparatus may consist only of ablating and removing the disc material projecting outside of the spinal column, laterally
20 of the spinal vertebrae. Otherwise, use of the instrument or apparatus may additionally include ablating and removing spinal disc material that is disposed between the two vertebrae.

Pursuant to a further feature of the present invention, the surgical instrument or apparatus further comprises means for aspirating gas and detritus from a surgical site
25 within the spinal disc space. This aspiration may be accomplished via a channel along the elongate probe, for instance, between a sheath and the probe or within a sheath wall. The aspiration channel is operatively connected at a proximal end of the instrument to a suction source. Preferably, a filter or impurity trap is provided in a suction line for capturing detritus, particles and gases removed from the surgical site via the aspiration
30 channel of the probe.

Pursuant to another feature of the present invention, the surgical instrument or apparatus further comprises means for flowing air into the spinal disc space. This infusion of clean or fresh air may be implemented through a dedicated channel or passageway along the elongate probe, for instance, between a sheath and the probe or within a sheath wall. The air conduction channel or passageway is operatively connected at a proximal end of the instrument to a pressurized air supply such as a fan or air pump.

Air flow into the confined disc space prevents the occurrence of a vacuum condition during the aspiration of gas and detritus. Therefore, the air inlet may also be at atmospheric pressure with the outlet connected to a vacuum source.

In accordance with another feature of the present invention, the apparatus may be operated, prior to the inserting of the distal end of the elongate probe into the spinal disc space, to direct a plasma jet towards a spinal disc in the spinal disc space (exemplarily towards an outer surface of the spinal disc) to thereby form at least one incision in the spinal disc, thereby enabling inserting of the distal end portion of the elongate probe into the spinal disc space.

Operative procedures using the apparatus of the present invention include conducting a laminectomy to enable access to a spinal disc space adjacent two spinal vertebrae, inserting a distal end portion of a plasma jet instrument into the spinal disc space, and operating the plasma jet instrument to ablate tissue and spinal disc material in the spinal disc space. As indicated above, the spinal disc space and thus the ablation procedure may occur laterally of the two spinal vertebrae, in the case of a bulging disc, or between the two vertebrae, for instance, in the case of a nucleotomy.

Prior to the inserting of the distal end portion of the plasma jet instrument into the spinal disc space, one may operate the plasma jet instrument to direct a plasma jet towards an outer surface of a spinal disc in the spinal disc space between the adjacent spinal vertebrae and thereby form at least one incision in the spinal disc, to enable insertion of the distal end portion of a plasma jet instrument into the spinal disc space.

Pursuant to a supplemental feature of the present invention, the surgical apparatus or system may further entail a scanning apparatus to obtain 3D structural data pertaining to organic structures at a contemplated surgical site in the patient, that is, in a region including the spinal disc and the adjacent vertebrae. The scanning apparatus may be used

prior to the surgical procedure, with the resulting internal structural information being stored in a computer memory for display on a video or computer monitor during the spinal disc ablation procedure. The plasma jet instrument may then be guided or directed in accordance with the structural data.

5 The present invention additionally contemplates means for automatically tracking a position of the plasma jet instrument during inserting of a distal end portion thereof into the spinal disk space, comparing a position of the distal end portion in real time with the 3D structural data, and directing movement and activation of the plasma jet instrument in
10 structural data. The comparing of the position data and controlling the movement and activation of the plasma jet instrument may be undertaken manually, exemplarily under visual observation of the structures as imaged on a video monitor, or may be implemented by a robotic system.

 According to yet another feature of the present invention, the surgical apparatus
15 or system may further comprise means for transmitting waveform energy (e.g., light, via an optical fiber or cable) into the patient in a region about the contemplated surgical site. The distal end portion of the plasma jet instrument may then be guided or directed in accordance with organic structural information obtained in response to transmitting of waveform energy into the patient.

20 A surgical device for use in discectomy procedures, including minimally invasive operations, comprises, in accordance with the present invention, an elongate instrument having at least two channels or lumens. A first one of the channels or lumens is operatively connectable to a source of pressurized plasma gas while a second one of the channels or lumens is operatively couplable to a source of vacuum underpressure or
25 suction. A filter or trap may be provided in a line to the vacuum or suction source for extracting debris, toxins, gases, etc. The elongate instrument of the surgical device may include a third channel or lumen configured to conduct air to a distal end of the elongate instrument for infusing a surgical site with air.

 The elongate instrument may include an elongate probe or shaft that is steerable.
30 More specifically, the elongate probe or shaft has a distal end portion that is flexible. Mechanical elements such as tension wires or piezoelectric actuators are disposed in

physical contact or operative engagement with the distal end portion of the probe or shaft and configured to bend or turn the distal end portion and thereby direct a plasma jet ejected from the distal end of the probe or shaft in different directions.

In an alternative embodiment of the instrument, an elongate probe or shaft of the instrument has a distal end provided with a first egress or output port for directing plasma energy in a distal or forward direction, parallel to a longitudinal axis of at least a distal end portion of the elongate shaft or probe. The distal end portion of the elongate probe or shaft is further provided with at least one second egress or output port for directing plasma energy in a lateral direction, transverse to the longitudinal axis of the elongate shaft or probe.

Probe steering or a laterally directed plasma jet facilitates control of disc ablation, to shape the disc material as desired.

The surgical device may further comprise a scanning apparatus for monitoring 3D structure of organic tissues of the patient, a position feedback system operatively connected to the elongate instrument to automatically continuously monitor position and optionally orientation of the elongate instrument, and comparison componentry operatively connected to the scanning apparatus and the position feedback system to enable proper positioning of the elongate instrument relative to the organic tissues of the patient. The comparison componentry may take the form of a video monitor enabling the surgeon to undertake the comparison or, alternatively, may include robot software that controls instrument positioning and activation in accordance with relative positions of instrument and internal organic structures of the patient.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic perspective view of a plasma jet instrument pursuant to the present invention inserted into a spinal disc space between two spinal vertebrae for carrying out a procedure in accordance with the invention.

FIG. 2 is partially a schematic side perspective view of a probe with a navigation array for tracking the position of the probe and enabling at least partially automatic control of probe positioning and activation relative to internal organic spinal structures of a patient; FIG. 2 is also partially a block diagram showing functional units of a signal

processing system for monitoring position and orientation of the probe and controlling probe position and activation.

FIG. 3 is a schematic side elevational view of a steerable plasma jet probe utilizable with processing and control functional apparatus of FIG. 2 for use in performing a surgical procedure in accordance with the present invention.

FIG. 4 depicts a plasma jet probe with a distally directed gas outlet and a laterally directed plasma outlet for use in performing a surgical procedure in accordance with the present invention.

DETAILED DESCRIPTION

As illustrated in FIG. 1, a surgical instrument system 100 includes a plasma jet probe 10 that ejects a plasma jet 3 for use in spinal surgery to ablate spinal disc material 4 in a spinal disc space 2 between two adjacent vertebrae 1A and 1B. Probe 10 includes a channel or lumen 6 (see FIGS. 3 and 4) operatively connected at a proximal end to a pressurized plasma source 8. Any medically safe and effective plasma can be used, for instance, argon plasma. A distal end portion (not separately designated) of the probe 10 may be introduced proximate to the spinal disc space 2 via an open incision OI in a patient's skin PS and sub-dermal tissues SDT and optionally via a laparoscopic cannula 12 and/or a working channel 14 of an endoscope 16.

Visualization of the surgical site may be obtained in the case of an open incision via direct inspection or in the case of a laparoscopic or endoscopic procedure via a conventional endoscopic or laparoscopic optical viewing system 18 including illumination optics 19, a CCD camera 20, a computer 22 operatively connected to the camera, and a video monitor 24. Computer 22 operates under known digital processing software to convert CCD signals into an image displayed on video monitor 24.

Alternatively, as in a surgical system 200 depicted in FIG. 2, a navigation array 26 comprising a plurality of radio-opaque or MRI detectible markers (not shown) or optically visible elements 30 detectible via an optical or video system 32 may be used to monitor the position and orientation of the plasma jet probe 10 in real-time. Navigation array 26 is rigidly connected to plasma jet probe 10 and includes, for instance, a plurality of spokes 33 holding optically detectable exemplarily spherical or cubical elements 30 whose locations are picked up preferably by video system 32. This allows referencing the

information related to instrument location to that of the patient's anatomy. Prior to the surgery a similar array is connected to the patient body and used to acquire anatomical data in a pre-scan procedure conducted with a scanning apparatus 90, whether an MRI apparatus, a CAT scanner, a camera system (34, 34'), or possibly ultrasound. In this manner, the instrument location can be linked directly to the patient. Video system 32 includes at least one and preferably a plurality of video cameras 34, 34' (e.g., charge coupled devices) disposed at mutually spaced locations about an operating room table (not shown) and operatively connected to a computer 36 with software-implemented image processing functionality. Computer 36 is connected to a video monitor 44 for displaying images to inform surgeons and other operating room personnel. In addition, computer 36 may execute software-realized control of probe 10 during a surgical procedure. To that end, computer 36 is operatively connected to (i) a memory 38 containing organic structural information obtained during a pre-operative patient scan and (ii) a robotic servomechanism 40 including actuators such as articulated armatures, electric motors, position encoders, hydraulic cylinders, etc. Computer 36 receives scan data from apparatus 90 and stores patient structural information in memory 38. Computer 36 includes comparison circuitry or functionality 37 for comparing probe position and orientation information from navigation system 26 with patient anatomy stored in digitized form in memory 38. Computer 36 selectively energizes robot actuators 40 to change the position and orientation of probe 10 preferably partially in response to operator instructions entered via an input device 42 such as a mouse, keyboard, touchpad, or joystick. Memory 38, actuators 40 input device 42, and scanning apparatus 90 may be included in the system of FIG. 1 as well, for controlling probe 10 thereof partially separately from movements of endoscope 16.

The position and orientation of probe 10 may be displayed on video monitor 24 or 44 together with previously recorded structures (stored in memory, e.g., memory 38) of the internal organs of the patient at the surgical site, including vertebrae 1A and 1B flanking and defining the spinal disc space 2, thereby enabling a surgeon to manipulate the probe relative to the organic structures and activate the instrument to direct plasma jet 3 to ablate disc material, and optionally cauterize, tissue and organic material.

Pursuant to FIG. 3, the surgeon may also turn a flexibly configured distal end 82 of a plasma jet probe 10' to laterally direct ejected plasma jet 3 alternately towards vertebra 1A and 1B and inwardly facing surfaces 46 and 48 thereof (see FIGS. 1, 2, and 4) to clean and prepare the surfaces for receiving a prosthetic insert (not shown) in the spinal disc space 2. To that end plasma jet probe 10' may be provided with mechanical elements for effectuating directional control, such as wires or cables 50 such as those exhibited by steerable catheters. Distal ends of wires or cables 50 are connected at 84, 86 to the distal end of probe 10 while proximal ends (not labeled) of wires or cables 50 are operatively coupled to actuators 52 activated by computer 24 or 36 pursuant to instructions provided by a surgeon via input device 42 or in accordance with a pre-programmed surgical procedure. Probe 10 of FIGS. 1 and 2 may be provided with the steering or direction control of probe 10'.

The same sideways directional control or orienting of plasma jet 3 may be alternatively accomplished by providing one or two lateral outlets or openings 54 and 56 at the distal end of a plasma jet probe 10", as illustrated in FIG. 4. In the event of a single lateral opening 54, probe 10" may be rotated about its longitudinal axis 64 to direct the plasma jet 3 alternately towards one vertebral surface 46 or the other 48. In the case of two or more lateral openings 54, 56 and a single lumen or channel 6, probe 10" may be provided at a distal end with one or more gates (not shown). Alternatively or additionally, probe 10" may have multiple plasma guidance conduits or lumens 6 and 58 used to separately convey plasma jet material to a distal end orifice 62 and to lateral outlets 54 and 56, respectively, in accordance with an actuation configuration of a valve set and manifold 59.

It is contemplated to use the plasma jet instrument and probe 10, 10', 10" in a discectomy procedure. Such a procedure involves removing at least a portion of a spinal lamina to form an access path in a patient. This laminectomy is adapted to, and utilizes techniques consistent with, the mode of access, that is, open, laparoscopic, or endoscopic. The surgeon inserts the plasma jet instrument and particularly a distal end portion of the probe 10 along the access path so that a distal tip of the instrument is positioned near spinal disc material 4 in spinal disc space 2. That space, in the case of a bulging or herniated disc, occupies at least in part a lateral position adjacent to and outside the two

vertebrae 1A and 1B. The plasma jet instrument is operated to direct plasma jet 3 in a desired direction towards the spinal disc material 4 in the spinal disc space 2 to ablate the disc material as necessary.

5 The elongate probe 10 of plasma jet instrument system 100 has at least one egress or outlet port or orifice 62 at the distal end (see FIGS. 3 and 4). FIG. 4 shows three jet ejection ports 54, 56, and 62. A plasma jet 3 may be emitted from lateral port 54 or 56 of probe 10" largely perpendicular to longitudinal axis 64, or through distal end port 62 in a distal direction parallel to axis 64.

10 The distal end portion of probe 10, 10', or 10" may be inserted into spinal disc space 2 beside and between spinal vertebrae 1A and 1B, with plasma jet 3 streaming from egress or outlet port 62 (or 54, 56) into spinal disc material 4 in the spinal disc space 2. Subsequently, upon completion of a discectomy or ablation procedure, probe 10, 10', 10" is removed from the spinal disc space 2.

15 The method also contemplates removal of bulging or protruding spinal disc material 4 located outside of spinal disc space 2 between vertebrae 1A and 1B, in the case of a herniated disc. The procedure may additionally include ablating and removing spinal disc material 4 disposed between the two vertebrae 1A and 1B.

20 The surgical method further comprises aspirating gas and detritus from the surgical site within the spinal disc space 2. As illustrated in FIG. 1, this aspiration may be accomplished via a channel 66 preferably disposed alongside probe 10, for instance, between a sheath 80 and the probe or within a sheath wall. Aspiration channel 66 is operatively connected at a proximal end of the instrument to a suction source 68. Preferably, a filter or impurity trap 70 is provided in a suction line 72 for capturing detritus, particles and gases removed from the spinal disc space 2 via aspiration channel
25 66.

The surgical method may further comprise flowing air into the spinal disc space 2. As indicated in FIG. 1, this infusion of clean, filtered fresh air may be implemented through a dedicated channel or passageway 74 in sheath 80 or between the sheath and probe 10 or within a sheath wall. The air conduction channel or passageway 74 is
30 operatively connected at a proximal end of the instrument to a pressurized air supply 76 such as a fan or air pump.

The method may entail forming an initial incision 88 (FIGS. 1, 2, and 4) into disc material 4 in spinal disc space 2, with the plasma jet probe being then inserted into or through the incision to operate further on the spinal disc material 4 in disc space 2. More specifically, prior to the inserting of the distal end of the elongate probe into the spinal disc space 2, one operates the surgical instrument to direct plasma jet 3 towards spinal disc material 4 in the spinal disc space 2 (exemplarily towards an outer surface of a spinal disc) and, by operating the surgical instrument to direct the plasma jet 3 towards the spinal disc, forming at least one incision 88 in the spinal disc. The inserting of the distal end portion of the elongate probe 10 into spinal disc space 2 may then include inserting the distal end portion of the probe into and through the incision 88.

As discussed above, the position and orientation of the plasma jet probe 10, 10', 10" may be automatically tracked during inserting of a distal end portion thereof into the spinal disk space 2. A position (and optionally orientation) of the distal end portion in real time is compared with the 3D structural data, so that the movement and activation of the plasma jet instrument may be controlled in accordance with the position of the distal end portion in real time and with the 3D structural data. The comparing of the position data and controlling the movement and activation of the plasma jet instrument may be undertaken manually, exemplarily under visual observation of the structures as imaged on a video monitor, or may be implemented by a robotic system. In the latter case, the plasma jet instrument is mounted to an electromechanical servomechanism with actuators 40 (FIG. 2) controlled by a computer to manipulate the probe 10, 10', 10" pursuant to a preprogrammed protocol and/or in response to instructions input by a surgeon during the spinal disc ablation procedure. The plasma jet 3 may be directed in part to remove material adhering to inwardly facing surfaces 46, 48 of spinal vertebrae 1A, 1B. (See FIGS. 3 and 4.)

A surgical method utilizing the apparatus disclosed herein contemplates the transmitting of waveform energy (e.g., light, via illumination optics 19, FIG. 1, or an optical fiber or fiber bundle 78, FIGS. 2 and 4, connected to a light source 79) into the patient in a region about the contemplated surgical site. The inserting of the distal end portion of the plasma jet probe 10, 10', 10" then includes guiding or directing the distal

end portion of the probe in accordance with organic structural information obtained in response to directing of the waveform energy into the patient.

Plasma jet instrument system 100 or 200 as contemplated herein comprises cooperating components including elongate probe 10, 10', 10" and a sheath 80 or 80' (FIGS. 2 and 3) having at least two channels or lumens 6, 66 (see FIG. 1). Channel or lumen 6 is operatively connectable to source 8 of pressurized plasma gas while channel or lumen 66 is operatively couplable to a source 68 of vacuum underpressure or suction. Channel or lumen 74 is optional and configured to conduct air to a distal end of probe 10 for infusing an surgical site with air. Sheath 80' in FIGS. 2 and 3 include optical fiber 78 connected to light source 79, while illumination in plasma jet instrument assembly 100 of FIG. 1 is provided by endoscope optics 19. Sheath 80' (also utilizable with probe 10" of FIG. 4) may be further provided with optics such as a fiber optic cable or a CCD camera connected to signal processing apparatus such as a computer for providing visual feedback via a video monitor (none shown).

A surgical system may include plasma jet instrument assembly 100, 200, as well as a position feedback apparatus or system including navigation array 26 connected to probe 10 and cameras 34, 34' for automatically and continuously monitoring position and optionally orientation of the probe 10, 10', 10". This position feedback apparatus is preferably connected to computer 22, 36 which stores structural information in memory 38 as to the patient's spinal structures at the preselected surgical site, the information being stored as a result or a previous scan or by a contemporaneous scan by a scanning apparatus for monitoring 3D structure of organic tissues of the patient. Computer 22, 36 may be configured to compare the real-time position of the plasma jet probe with the organic structural information to enable proper positioning of the elongate instrument relative to the organic tissues of the patient, either automatically via a robotic apparatus or manually by the attending surgeon. In the latter case, the comparison is undertaken with the aid of video monitor 24, 44.

Plasma jet instrument assembly 100, 200 is registered prior to use by placing it in a fixture that allows for precise calculation of the exit point location of plasma jet 3. Also for the steerable instrument (FIG. 3), the curvature of the distal end is induced in

incremental steps by pulling a trigger or rotating a dial. Once this is registered the instrument is used its curved configuration.

System 100, 200 may include robotic servomechanism actuators 40 operatively connected to probe 10, 10', 10" or another tissue vaporization instrument such as a laser probe, for automatically moving the instrument, scanning apparatus 300 including navigation array 26 for monitoring position and optionally orientation of probe 10 relative to internal tissue structures of a patient, and computer 36 operatively connected to the robotic servomechanism 40 and the scanning apparatus 300 for actuating and controlling the robotic servomechanism to maneuver tissue-vaporization plasma jet probe 10, 10', 10" in accordance with position and optionally orientation of elongate instrument relative to the internal tissue structures of the patient at the surgical site.

CLAIMS:

1. A surgical instrument for discectomy procedures comprising an elongate probe having a distal end insertable into an inter-vertebral spinal disc space, said surgical instrument having at least two channels or lumens, a first one of said channels or lumens extending through said probe and being operatively connectable to a source of pressurized plasma gas, a second one of said channels or lumens being operatively couplable to a source of vacuum underpressure or suction.

2. The surgical instrument defined in claim 1, further having a third channel or lumen configured to conduct air to a distal end of said surgical instrument for infusing a surgical site with air.

3. The surgical instrument defined in claim 2, further comprising a sheath, said probe traversing a lumen of said sheath, said second one of said channels or lumens and said third channel or lumen being disposed in or on said sheath.

4. The surgical instrument defined in claim 1, further comprising a sheath, said probe traversing a lumen of said sheath, said second one of said channels or lumens being disposed in or on said sheath.

5. The surgical instrument defined in claim 1 wherein at least a distal end portion of said elongate probe is flexible, further comprising mechanical elements in physical contact with said distal end portion and configured to bend or turn said distal end portion.

6. The surgical instrument defined in claim 1 wherein a distal end of said elongate probe is provided with a first egress or output port for directing plasma energy in a distal direction, parallel to a longitudinal axis of at least a distal end portion of said elongate probe, said distal end portion of said elongate probe being provided with at least

one second egress or output port for directing plasma energy in a lateral direction, transverse to said longitudinal axis.

7. A surgical system for discectomy procedures, comprising the surgical instrument defined in claim 1, further comprising:

a scanning apparatus for monitoring 3D structure of organic tissues of the patient;
a position feedback system configured to automatically continuously monitor position and optionally orientation of said surgical instrument; and

comparison componentry operatively connected to said scanning apparatus and said position feedback system to enable proper positioning of said surgical instrument relative to the organic tissues of the patient.

8. A surgical system for discectomy procedures, comprising the surgical instrument defined in claim 1, further comprising:

a robotic servomechanism operatively connected to said surgical instrument for automatically moving the surgical instrument;

scanning apparatus and/or memory for monitoring position and optionally orientation of said surgical instrument relative to internal tissue structures; and

a computer operatively connected to the robotic servomechanism and the scanning apparatus for actuating said robotic servomechanism to maneuver said surgical instrument in accordance with position and optionally orientation of said surgical elongate instrument relative to said internal tissue structures.

9. A surgical device comprising:

a surgical instrument including an elongate probe with a distal end having at least one egress or outlet port, said surgical instrument adapted for insertion of a distal end portion of said elongate probe into a spinal disc space adjacent and between two spinal vertebrae;

a pressurized plasma source operatively connected to said surgical instrument, said plasma source and said surgical instrument being adapted to eject a plasma jet from

said at least one egress or outlet port into spinal disc material in said spinal disc space;
and

a suction source operatively connected to said surgical instrument for aspirating gas and detritus from a surgical site within said spinal disc space.

10. The surgical device defined in claim 9, further comprising a pressurized air source operatively connected to said surgical instrument, said pressurized air source and said surgical instrument being adapted for flowing clean filtered air into said spinal disc space.

11. A surgical method comprising:
conducting a surgical procedure on a patient to enable access to a spinal disc space adjacent two spinal vertebrae;
inserting a distal end portion of a plasma jet instrument into the spinal disc space;
and
operating said plasma jet instrument to ablate tissue and spinal disc material in said spinal disc space.

12. The surgical method defined in claim 11, further comprising:
prior to the inserting of said distal end portion of said plasma jet instrument into said spinal disc space, operating said plasma jet instrument to direct a plasma jet towards an outer surface of a spinal disc in said spinal disc space between said adjacent spinal vertebrae; and
by the operating of said plasma jet instrument to direct said plasma jet towards said outer surface of said spinal disc, forming at least one incision in said spinal disc, thereby enabling the inserting of said distal end portion of a plasma jet instrument into said spinal disc space.

13. The surgical method defined in claim 12, wherein the inserting of said distal end portion of a plasma jet instrument into said spinal disc space includes inserting said distal end portion into said incision.

14. The surgical method defined in claim 11, further comprising operating a scanning apparatus to obtain 3D structural data pertaining to organic structures at a contemplated surgical site in the patient, the inserting of said distal end portion of said plasma jet instrument being guided or directed in accordance with said structural data.

15. The surgical method defined in claim 14, further comprising:
automatically tracking a position of said plasma jet instrument during inserting of a distal end portion thereof into the spinal disc space;
comparing a position of said distal end portion in real time with the 3D structural data; and
directing movement and activation of said plasma jet instrument in accordance with the position of said distal end portion in real time and with the 3D structural data.

16. The surgical method defined in claim 11, further comprising transmitting waveform energy into the patient in a region about said contemplated surgical site, the inserting of said distal end portion of said plasma jet instrument including guiding or directing said distal end portion of said plasma jet instrument in accordance with organic structural information obtained in response to directing of the waveform energy into the patient.

17. The surgical method defined in claim 11, further comprising aspirating gas and detritus from said spinal disc space.

18. The surgical method defined in claim 11, further comprising flowing air into said spinal disc space.

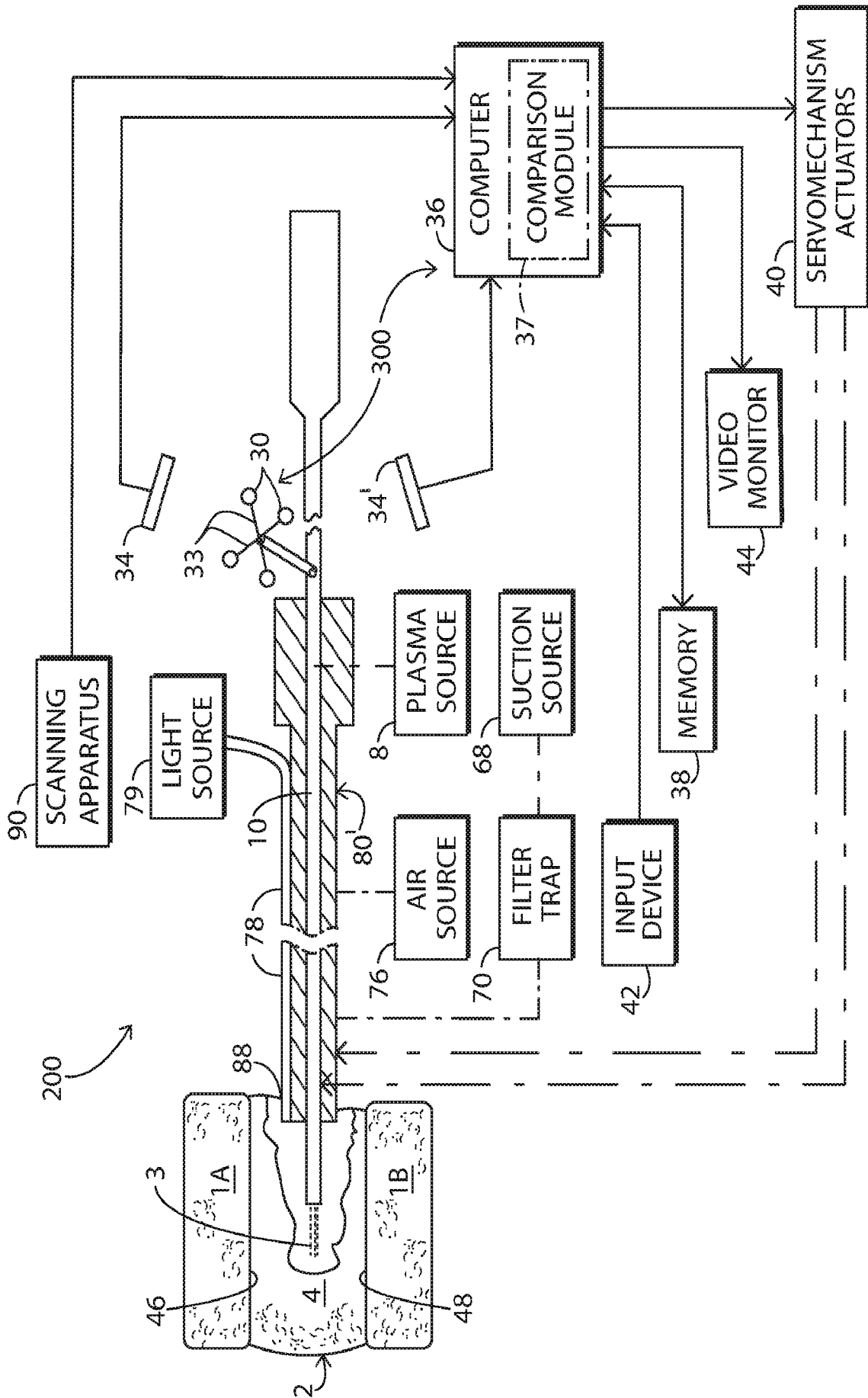


FIG. 2

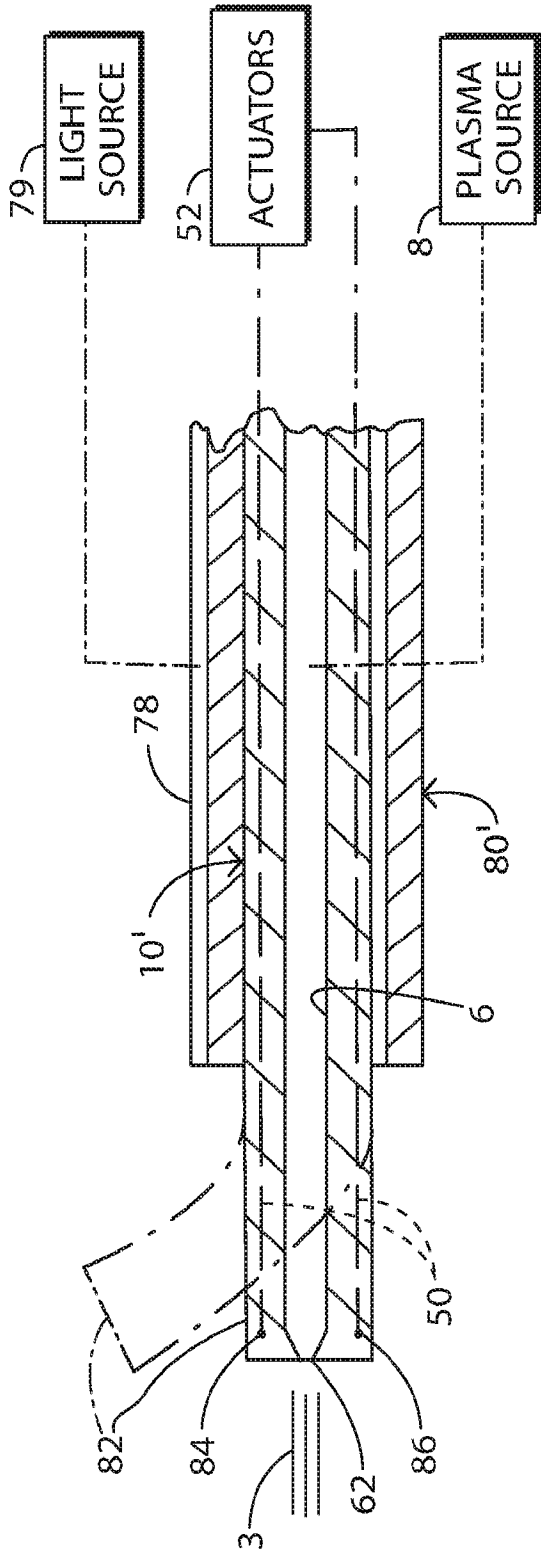


FIG. 3



FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2021/056455

A. CLASSIFICATION OF SUBJECT MATTER		
<i>A61B 18/04 (2006.01)</i> <i>A61B 34/20 (2016.01)</i>		
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 18/14, 18/00, 18/04, 34/20		
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 practicable, search terms used)		
PatSearch (RUPTO Internal), USPTO, PAJ, Espacenet, Information Retrieval System of FIPS		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2001/0029370 A1 (ARTHROCARE CORPORATION) 11.10.2001, abstract, figures 1, 4, 18-25, paragraphs [0011], [0097], [0134], [0136]-[0141], [0142], [0148]	1, 4-6, 9, 11-13, 16, 17
Y		2, 3, 7, 8, 10, 14, 15, 18
Y	US 2020/0121374 A1 (WARSAW ORTHOPEDIC INC) 23.04.2020, paragraphs [0006], [0065], [0070], [0071], [0092]	7, 14, 15
Y	US 2014/0350567 A1 (SCHMITZ GREGORY P) 27.11.2014, paragraphs [0043], [0172], [0182], [0183], [0236], [0241], [0274]	8
Y	US 2012/0014868 A1 (WARSAW ORTHOPEDIC, INC) 19.01.2012, paragraph [0184]	2, 3, 10, 18
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "D" document cited by the applicant in the international application "E" earlier document but published on or after the international filing date "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) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"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 "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 "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 "&" document member of the same patent family	
Date of the actual completion of the international search		Date of mailing of the international search report
26 November 2021 (26.11.2021)		29 December 2021 (29.12.2021)
Name and mailing address of the ISA/RU: Federal Institute of Industrial Property, Berezhkovskaya nab., 30-1, Moscow, G-59, GSP-3, Russia, 125993 Facsimile No: (8-495) 531-63-18, (8-499) 243-33-37		Authorized officer A. Amelin Telephone No. 8(495)531-64-81