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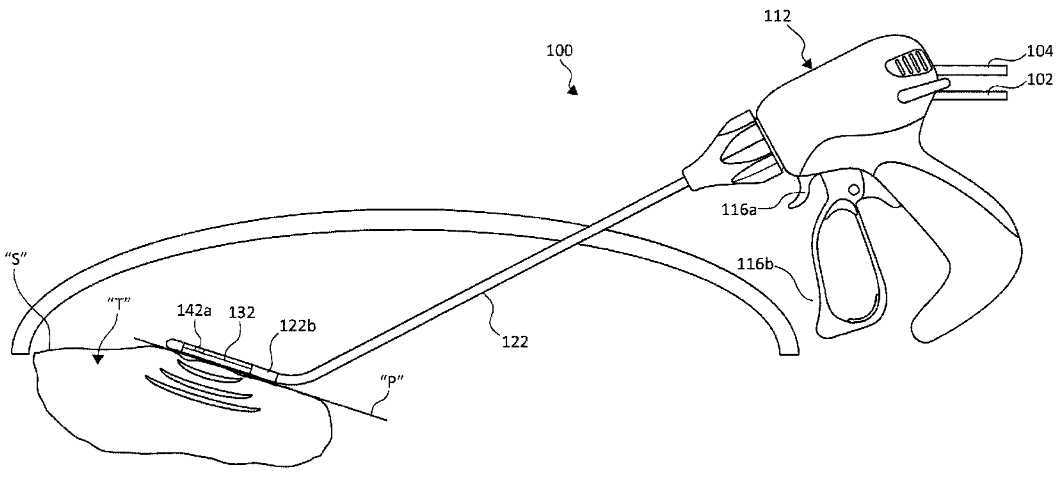

(57) Abrégé/Abstract:
A surgical instrument for ablating tissue includes a handle portion and a shaft assembly extending distally from the handle portion. The shaft assembly includes an outer shaft, a coaxial cable extending through the outer shaft, and an electrode coupled to a distal portion of the outer shaft. The coaxial cable has a distal portion that forms a microwave antenna configured to transmit microwave energy radially outward and through the outer shaft. The electrode is configured to transmit radiofrequency energy. An actuation of the handle portion activates the transmission of the microwave energy from the microwave antenna and/or the transmission of the radiofrequency energy from the at least one electrode.

ABSTRACT

A surgical instrument for ablating tissue includes a handle portion and a shaft assembly extending distally from the handle portion. The shaft assembly includes an outer shaft, a coaxial cable extending through the outer shaft, and an electrode coupled to a distal portion of the outer shaft. The coaxial cable has a distal portion that forms a microwave antenna configured to transmit microwave energy radially outward and through the outer shaft. The electrode is configured to transmit radiofrequency energy. An actuation of the handle portion activates the transmission of the microwave energy from the microwave antenna and/or the transmission of the radiofrequency energy from the at least one electrode.

MICROWAVE AND RADIOFREQUENCY ENERGY-TRANSMITTING TISSUE ABLATION SYSTEMS

BACKGROUND

1. Technical Field

[0001] The present disclosure relates to a tissue ablation system, and more particularly to a combination microwave/radiofrequency ablation system for coagulating and resecting tissues.

2. Discussion of Related Art

[0002] Electrosurgical devices utilizing electromagnetic radiation have been developed for a variety of uses and applications. Typically, apparatus for use in ablation procedures include a power generation source, e.g., a microwave or radio frequency (RF) electrosurgical generator that functions as an energy source and a surgical instrument (e.g., microwave ablation probe having an antenna assembly) for directing energy to the target tissue. The generator and surgical instrument are typically operatively coupled by a cable assembly having a plurality of conductors for transmitting energy from the generator to the instrument, and for communicating control, feedback, and identification signals between the instrument and the generator.

[0003] There are several types of microwave probes in use, e.g., monopole, dipole, and helical, which may be used in tissue ablation applications. In monopole and dipole antenna assemblies, microwave energy generally radiates perpendicularly away from the axis of the conductor. Monopole antenna assemblies typically include a single, elongated conductor. A typical dipole antenna assembly includes two elongated conductors that are linearly-aligned and positioned end-to-end relative to one another with an electrical insulator placed therebetween. Helical antenna assemblies include helically-shaped conductor configurations of various dimensions, e.g., diameter and length. The main modes of operation of a helical antenna assembly are normal mode (broadside), in which the field radiated by the helix is maximum in a perpendicular plane to the helix axis, and axial mode (end fire), in which maximum radiation is along the helix axis.

[0004] One use for a microwave probe is to dissect solid organs, such as liver or kidney, to remove entire diseased portions of the organ. During these procedures, it is important that blood loss from the dissected organ is minimized without compromising the efficacy of the procedure. It is also of particular importance to keep the procedure simple by reducing the number of surgical instruments used while also keeping the overall procedure time at a minimum.

[0005] Accordingly, it would be advantageous to provide one surgical instrument that performs a plurality of tasks during a tissue ablation procedure to effectively dissect a diseased portion of a solid organ.

SUMMARY

[0006] In one aspect of the present disclosure, a surgical instrument for ablating tissue is provided and includes a handle portion and a shaft assembly extending distally from the handle portion. The shaft assembly includes an outer shaft, a coaxial cable extending through the outer shaft, and an electrode coupled to a distal portion of the outer shaft and disposed proximally of a distal end of the outer shaft. The coaxial cable has a distal portion disposed within the distal portion of the outer shaft. The distal portion of the coaxial cable forms a microwave antenna configured to transmit microwave energy radially outward and through the outer shaft. An actuation of the handle portion activates the transmission of the microwave energy from the microwave antenna or the transmission of the radiofrequency energy from the at least one electrode.

[0007] In some embodiments, the electrode may be disposed distally of the microwave antenna.

[0008] In some embodiments, the electrode may be disposed radially outward from the microwave antenna and out of alignment with the direction of travel of the microwave energy transmitted from the microwave antenna. The electrode may be a pair of bipolar electrodes.

[0009] In some embodiments, the distal portion of the outer shaft may have a wedge-shaped configuration.

[00010] In some embodiments, the shaft assembly may further include a reflector disposed within the distal portion of the outer shaft and about the microwave antenna.

[00011] In some embodiments, the reflector may have a semi-circular shape and be configured to direct the transmission of the microwave energy toward an edge of the outer shaft. The edge of the outer shaft may extend parallel with a longitudinal axis defined by the shaft assembly.

[00012] In some embodiments, the shaft assembly may further include a dielectric region disposed within the distal portion of the outer shaft.

[00013] In some embodiments, the reflector and a pair of adjoined lateral sides of the outer shaft may cooperatively define a cavity therein. The dielectric region may fill the cavity.

[00014] In some embodiments, the surgical instrument may further include a tube extending through the outer shaft and may be disposed radially outward from the microwave antenna. The tube may have a proximal portion configured to receive suction.

[00015] In some embodiments, the electrode may include a hooked distal portion disposed distally of the microwave antenna. The shaft assembly may further include an outer sheath disposed about the outer shaft and may be axially movable relative to the outer shaft between a first position, in which the hooked distal portion is disposed within the outer sheath, and a second position, in which the hooked distal portion is disposed distally of the outer sheath.

[00016] In another aspect of the present disclosure, a tissue ablation system is provided and includes a microwave generator configured to generate and transmit microwave energy, an electrosurgical generator configured to generate and transmit radiofrequency energy, and a surgical instrument. The surgical instrument includes a handle portion configured to be coupled to both of the microwave and electrosurgical generators, and a shaft assembly extending distally from the handle portion. The shaft assembly includes an outer shaft, a coaxial cable extending through the outer shaft, and an electrode coupled to a distal portion of the outer shaft. The coaxial cable has a proximal portion configured to be in electrical communication with the microwave generator, and a distal portion disposed within the distal portion of the outer shaft. The distal portion of the coaxial cable forms a microwave antenna configured to transmit the microwave energy radially outward and through the outer shaft. The electrode is coupled to the distal portion of the outer shaft and configured to be in electrical communication with the electrosurgical generator to transmit the radiofrequency energy. An actuation of the handle portion activates the transmission of the microwave energy from the microwave antenna or the transmission of the radiofrequency energy from the electrode.

A reflector may be disposed within the distal portion of the outer shaft and about the microwave antenna wherein the reflector is configured to direct the microwave energy from the microwave antenna toward a first apex defined by the outer shaft.

[00017] In yet another aspect of the present disclosure, a method of resecting a portion of tissue is provided and includes positioning a microwave antenna of a surgical instrument adjacent a portion of tissue, transmitting microwave energy into the portion of the tissue, thereby precoagulating the portion of the tissue, deactivating the transmission of the microwave energy, and moving a distal portion of an outer shaft of the surgical instrument along the tissue

while transmitting radiofrequency energy from an electrode of the surgical instrument into the tissue, thereby resecting the portion of the tissue.

[00018] As used herein, the terms parallel and perpendicular are understood to include relative configurations that are substantially parallel and substantially perpendicular up to about + or – 10 degrees from true parallel and true perpendicular.

BRIEF DESCRIPTION OF THE DRAWINGS

[00019] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the disclosure and, together with a general description of the disclosure given above, and the detailed description of the embodiment(s) given below, serve to explain the principles of the disclosure, wherein:

[0010] FIG. 1 is perspective view of a tissue ablation system including a surgical instrument, an electrosurgical generator, a microwave generator, and a surgical suction pump in accordance with the principles of the present disclosure;

[0011] FIG. 2 is a side view of the surgical instrument of FIG. 1, illustrating a microwave antenna disposed at a distal portion of a shaft assembly;

[0012] FIG. 3A is a cross-section, taken along line 3A-3A of FIG. 2, of a proximal portion of the shaft assembly;

[0013] FIG. 3B is a cross-section, taken along line 3B-3B of FIG. 2, of a distal portion of the shaft assembly;

[0014] FIG. 4 is a side view of another embodiment of a shaft assembly having bipolar electrodes disposed distally of a microwave antenna;

[0015] FIG. 5 is a perspective view of the surgical instrument of FIG. 4, illustrating an exemplary ablation procedure;

[0016] FIG. 6 is a perspective view of another embodiment of a tissue ablation system including a surgical instrument, an electrosurgical generator, a microwave generator, and a surgical suction pump in accordance with the principles of the present disclosure;

[0017] FIG. 7 is a side view of the surgical instrument of FIG. 6, illustrating an outer sheath covering a monopolar electrode;

[0018] FIG. 8 is a side view of the surgical instrument of FIG. 6, illustrating the monopolar electrode disposed outside of the outer sheath; and

[0019] FIG. 9 is a perspective view of the surgical instrument of FIG. 6, illustrating an exemplary ablation procedure.

DETAILED DESCRIPTION

[0020] Embodiments of the presently disclosed tissue ablation systems including various embodiments of a surgical instrument and methods of use thereof are described in detail with reference to the drawings, in which like reference numerals designate identical or corresponding elements in each of the several views. As used herein the term "distal" refers to that portion of the tissue ablation system or component thereof, that is closer to the patient, while the term "proximal" refers to that portion of the tissue ablation system or component thereof, that is farther from the patient.

[0021] As will be described in detail below, provided are embodiments of a surgical instrument of a tissue ablation system that switches between microwave energy transmission and radiofrequency energy transmission. For example, one embodiment of the disclosed surgical instruments includes a wedge-shaped outer shaft, a microwave antenna disposed within a distal portion of the outer shaft, and a monopolar electrode or bipolar electrodes disposed on the distal portion of the outer shaft. In operation, the microwave antenna is activated to transmit microwave energy out of an apex of the outer shaft and into tissue to precoagulate tissue. After the tissue is precoagulated, the microwave antenna is deactivated, and the electrode is activated to transmit radiofrequency energy into the tissue while moving the distal portion of the outer shaft along an outer surface of the tissue. The radiofrequency energy cuts or resects the precoagulated tissue to remove a portion of the tissue with minimal to no bleeding occurring.

[0022] As used herein, the term "pre-coagulate" means heating tissue to the extent necessary to prevent blood from flowing from the heated tissue upon resecting the tissue.

[0023] As used herein, "microwave" generally refers to electromagnetic waves in the frequency range of 300 megahertz (MHz) (3 x 108 cycles/second) to 300 gigahertz (GHz) (3 x 1011 cycles/second).

[0024] As used herein, "tissue ablation" generally refers to any ablation procedure, such as, for example, microwave ablation, radiofrequency (RF) ablation, or microwave or RF ablation-assisted resection.

[0025] As used herein, "transmission line" generally refers to any transmission medium that can be used for the propagation of signals from one point to another.

[0026] As used herein, "fluid" generally refers to a liquid, a gas or both.

[0027] As used herein, "controller" generally refers to any electrical device that employs digital and/or analog components to generate digital and/or analog signals to control or drive another device. The term "controller" may refer to a digital signal processor, a microcontroller, or a computer having a processor, a memory, and input/output ports for carrying out some of the methods described herein.

[0028] Various embodiments of the presently disclosed surgical instruments are suitable for tissue ablation and for use to pre-coagulate tissue for microwave ablation-assisted surgical resection. Although various methods described hereinbelow are targeted toward microwave ablation and the destruction and/or resection of targeted tissue, methods for directing electromagnetic radiation may be used with other therapies in which the target tissue is partially destroyed, damaged, or dissected. In addition, the teachings of the present disclosure may apply to a dipole, monopole, helical, or other suitable type of microwave antenna.

[0029] With reference to FIG. 1, a dual microwave/RF energy ablation and cutting system 10 is illustrated and generally includes a tissue ablation instrument 100 operably coupled to a microwave generator 12, an electrosurgical generator 14, and a surgical suction pump 16. The microwave generator 12 generates a microwave energy signal that is transmitted to a radiating section "R" (FIG. 2) of the surgical instrument 100 via a coaxial cable 102. The microwave energy generated by the microwave generator 12 may be in the range of about 915 MHz to about 25.0 GHz. In some embodiments, the microwave generator 12 may operate at 915 MHz, 2450 MHz, and/or 5800 Mhz. The electrosurgical generator 14 generates a radiofrequency signal and outputs it to bipolar electrodes 142a, 142b (FIG. 3B) of the surgical instrument 100 via a transmission line 104. The surgical suction pump 16 produces suction and applies the suction to a port 140 (FIG. 2) located a distal portion of the surgical instrument 100 via a suction tube 106. In some embodiments, the tissue ablation system 10 may further include a source of coolant 18 (e.g., saline) and a pump 20 for conveying the coolant to the surgical instrument 100 to cool various components therein during operation.

[0030] The surgical instrument 100 of the tissue ablation system 10 includes a handle portion 112 and a shaft assembly 120 extending distally from the handle portion 112. The handle portion 112 has a body portion 114 through which each of the coaxial cable 102, the transmission line 104, and the suction tube 106 extend. The handle portion 112 includes first and second controls 116a, 116b such as buttons, switches, or triggers, movably coupled to the body portion 114 of the handle portion 112. The first control 116a may be in electrical communication (e.g., wirelessly or wired connection) with the microwave generator 12 and configured to selectively actuate a microwave function of the surgical instrument 100, and the second control 116b may be in electrical communication (e.g., wirelessly or wired connection) with the electrosurgical generator 14 and configured to selectively actuate a radiofrequency function of the surgical instrument 100. In some embodiments, an actuation of the microwave function and/or the radiofrequency function of the surgical instrument 100 may be accomplished via a button or a footswitch external to the surgical instrument 100.

[0031] With reference to FIGS. 1, 2, 3A, and 3B, the shaft assembly 120 of the surgical instrument 100 includes a hollow, elongated body or outer shaft 122 and an outer coating or sheath 124 covering an outer surface of the outer shaft 122. The outer shaft 122 has a proximal portion 122a coupled to the handle portion 112 and a distal portion 122b. The outer shaft 122 defines a longitudinal axis "X" and has a wedge-shaped or triangular cross-sectional profile. The outer shaft 122 has a planar base 126a and a pair sides 126b, 126c extending at acute angles downwardly from the base 126a. The sides 126b, 126c of the outer shaft 122 form an acuminate apex or edge 128 at the point at which they are adjoined. The edge 128 of the outer shaft 122 extends parallel with and along the longitudinal axis "X" thereof and is configured to contact and move along a tissue surface, as will be described. In some embodiments, the outer shaft 122 may assume any suitable cross-sectional configuration, such as, for example, circular, V-shaped, U-shaped, oval, square, and/or polygonal.

[0032] The distal portion 122b of the outer shaft 122 may be configured to articulate relative to the proximal portion 122a thereof. In particular, the distal portion 122b of the outer shaft 122 may move relative to the proximal portion 122a between a non-articulated configuration as shown in FIG. 2, in which the distal portion 122b is coaxial with the longitudinal axis "X" of the outer shaft 122, and an articulated position as shown in FIG. 5, in which the distal portion 122b extends at a non-zero angle relative to the longitudinal axis "X" of the outer shaft 122. It is contemplated that the distal portion 122b of the outer shaft 122 may

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be resiliently biased toward the non-articulated position via a biasing member (not shown) or a shape-memory alloy, and may be articulated by applying external pressure on the distal portion 122b. Alternatively, articulation wires and articulated segments may be employed to achieve the depicted articulation as is common in the surgical arts.

[0033] With reference to FIGS. 3A and 3B, the coaxial cable 102 of the surgical instrument 100 extends axially through a channel 130 defined through the outer shaft 122 and has a proximal portion 102a disposed with the proximal portion 122a of the outer shaft 122 and a distal portion 102b disposed within the distal portion 122b of the outer shaft 122. The proximal portion 102a of the coaxial cable 102 has a larger diameter, e.g., 1.5X – 3X the diameter of the distal portion 102a, such that the proximal portion 102a is well-suited for dissipating heat therefrom during the transmission of microwave energy therethrough. The coaxial cable 102 has an outer conductor 108a, an inner conductor 108b extending coaxially through the outer conductor 108a, and a dielectric 108c disposed between the inner and outer conductors 108a, 108b. The inner conductor 108b extends distally beyond a distal end of the outer conductor 108a to form or define the microwave antenna 132, from which microwave energy originating from the microwave generator 12 is emitted radially outward.

[0034] The shaft assembly 120 of the surgical instrument 100 may further include a solid core dielectric region 134 disposed within the distal portion 122b of the outer shaft 122, and a reflector 136 disposed about an upper portion 134b of the dielectric region 134 and about the microwave antenna 132. The dielectric region 134 has a bottom portion 134a received between the two lateral sides 126b, 126c of the outer shaft 122, and an upper portion 134b. The lower portion 134a of the dielectric region 134 has a generally triangular configuration and the upper portion 134b has a generally semicircular configuration. The lower portion 134a includes a bottom acuminate edge 138 through which microwave energy is transmitted. The bottom edge 138 of the lower portion 134a is disposed adjacent the edge 128 of the outer shaft 122 and is exposed (i.e., not covered by the reflector 136). The upper portion 134b of the dielectric region 134 has the distal portion 102b of the coaxial cable 102 extending therethrough.

[0035] The dielectric region 134 may be formed from any suitable dielectric material having low-loss dielectric loading properties that possesses sufficient mechanical and biocompatible properties to withstand conditions associated with surgical procedures, including without limitation ceramic material; PTFE; Teflon®; or Ultem™ amorphous thermoplastic polyetherimide (PEI) resin distributed by SABIC Innovative Plastics of Pittsfield, Mass., USA.

[0036] The reflector 136 of the shaft assembly 120 surrounds the upper portion 134b of the dielectric region 134 and has a semi-circular shape, which facilitates directing or focusing microwave energy toward the edge 128 of the outer shaft 122. In some embodiments, the reflector 136 may assume any suitable shape for focusing microwave energy through the dielectric region 134 and toward the edge 128 of the outer shaft 122, such as, for example, parabolic, semi-hemispherical, or the like. It is contemplated that the reflector 136 and the pair of lateral sides 126b, 126c of the outer shaft 122 cooperatively define a cavity 139 therein, which is filled by the dielectric region 134. The reflector 136 may be a layer or coating and may be formed from any suitable material having the capability to reflect microwave energy, such as, without limitation, copper plating, copper foil, or Polyflon™ electroplated PTFE.

[0037] With reference to FIGS. 2, 3A, and 3B, the suction tube 106 of the surgical instrument 100 extends axially through the outer shaft 122. The tube 106 has a proximal portion 106a coupled to the surgical suction pump 16 and a distal portion 106b disposed radially outward from the microwave antenna 132 and out of the pathway of microwave energy transmitted from the microwave antenna 132. The distal portion 106b of the tube 106 extends distally beyond the microwave antenna 132 and terminates adjacent a distal tip of the outer shaft 122. The outer shaft 122 and the outer sheath 124 define a port 140 therethrough that is fluidly coupled to the distal portion 106b of the tube 106 such that the port 140 acts as a suction port when the surgical suction pump 16 is activated.

[0038] With reference to FIGS. 3A and 3B, the shaft assembly 120 of the surgical instrument 100 further includes a pair of bipolar electrodes 142a, 142b disposed within the distal portion 122b of the outer shaft 122 and radially outward from the microwave antenna 132. The location of the electrodes 142a, 142b is selected so as to position the electrodes 142a, 142b out of alignment with the pathway of the microwave energy transmitted from the microwave antenna 132. The electrodes 142a, 142b are electrically coupled to the electrosurgical generator 14 via the transmission line 104. The transmission line 104 splits into two electrode leads 104a, 104b in the outer shaft 122. A first electrode 142a of the pair of bipolar electrodes may be disposed on the base 126a of the outer shaft 122, and a second electrode 142b of the pair of bipolar electrodes may be disposed on the second the lateral side 126c of the outer shaft 122, such that the first and second electrodes 142a, 142b are angled relative to one another. The first and second electrodes 142a, 142b are in close proximity to one another (e.g., within about 0.025 and 0.050 inches from one another) while remaining electrically insulated along their length.

[0039] As illustrated in the embodiment of FIG. 4, instead of positioning the bipolar electrodes 142a, 142b radially outward from the microwave antenna 132, the bipolar electrodes 142a, 142b may be disposed distally of the microwave antenna 132. In this way, the microwave energy transmitted from the microwave antenna 132, which is directed perpendicularly relative to the longitudinal axis "X" of the outer shaft 122, will not travel through the distally-located electrodes 142a, 142b.

[0040] In operation, as shown in FIG. 5, a portion of tissue, such as a section of liver tissue "T" may be ablated and resected using the tissue ablation system 10 of the present disclosure. The edge 128 of the distal portion 122b of the outer shaft 122 may be placed in contact with a surface “S” of the liver tissue “T” to be resected. Due to the acuminate design of the edge 128 of the outer shaft 122, contacting the edge 128 of the outer shaft 122 with the tissue surface “S” forms a depression or valley in the tissue “T.” With the edge 128 of the outer shaft 122 engaged with the tissue “T,” the first control 116a of the handle portion 112 is actuated to activate the microwave function of the surgical instrument 100, whereby the microwave generator 12 transmits microwave energy to the microwave antenna 132 via the coaxial cable 102.

[0041] The reflector 136 of the shaft assembly 120 redirects a portion of the microwave energy towards the edge 138 of the dielectric region 134, the edge 128 of the outer shaft 122, and ultimately into the valley of the tissue “T.” As the microwave energy is transmitted into the valley of the tissue “T,” the surgical instrument 100 is manipulated to move or slide the edge 128 of the outer shaft 122 along a resection plane “P” of the liver tissue “T,” thereby pre-coagulating the underlying tissue at a depth proportional to the frequency of the microwave energy and the length of time the microwave antenna 132 is activated.

[0042] Movement of the edge 128 of the outer shaft 122 of the surgical instrument 100 along the resection plane “P” is continued until a desired depth and/or width of pre-coagulation is achieved. Upon achieving the desired depth and width of tissue pre-coagulation, transmission of the microwave energy is deactivated and the bipolar electrodes 142a, 142b are placed adjacent the tissue surface “S” of the pre-coagulated tissue “T.”

[0043] As shown in FIG. 3A in conjunction with FIG. 2, to orient the bipolar electrodes 142a, 142b adjacent the tissue surface “S,” (FIG. 5) the outer shaft 122 of the surgical instrument 100 is rotated about the longitudinal axis “X” from approximately 5° - to approximately 180°, and in some embodiments approximately 130°, to engage a second edge 129 (FIG. 3B) of the outer shaft 122 with the tissue surface “S” (FIG. 5). The second edge 129 is defined by the second lateral side 126c of the outer shaft 122 and the base 126a of the outer shaft 122. In the embodiment illustrated in FIG. 4, to orient the bipolar electrodes 142a, 142b adjacent the tissue surface "S," the outer shaft 122 of the surgical instrument 100 is tilted toward the distal tip of the outer shaft 122 rather than be rotated about the longitudinal axis "X."

[0044] While moving the second edge 129 of the outer shaft 122 along the resection plane "P," the second control 116b is actuated to activate the radiofrequency function of the surgical instrument, whereby the electrosurgical generator 14 transmits radiofrequency energy to the bipolar electrodes 142a, 142b via the electrode leads 104a, 104b. The radiofrequency energy is directed out of the second edge 129 of the outer shaft 122 to resect the liver tissue "T" along the resection plane "P."

[0045] The above-noted steps may be repeated to pre-coagulate the tissue "T" at increasingly greater depths, and then resect along the pre-coagulation line until a desired portion of the tissue "T" is separated from the remainder of the organ. The surgical suction pump 16 may be activated at any point during and/or after the procedure to remove surgical debris and/or surgical smoke via the port 140 of the surgical instrument 100. By pre-coagulating the tissue using microwave energy, blood loss is minimized since the resection line for the bi-polar resection or cutting is within the boundaries of the pre-coagulated tissue. Further, this procedure reduces the opportunities for reseeding of cancerous tissue by this same pre-coagulation process prior to any resection or cutting of the organ.

[0046] With reference to FIGS. 6-9, another embodiment of a dual microwave/RF energy ablation system is illustrated as system 210, which is similar to the tissue ablation system 10 described above with reference to FIGS. 1-5. Due to the similarity between the tissue ablation systems 10, 210 of the present disclosure, only those details viewed as important in elucidating selected differences between the two ablation systems 10, 210 will be described in detail.

[0047] The dual microwave/RF energy ablation system 210 generally includes a tissue ablation instrument 200 operably coupled to the microwave generator 12, the radiofrequency generator 14, and the surgical suction pump 16. The microwave generator 12 generates a microwave signal and outputs it to a microwave antenna 232 of the surgical instrument 200 via a coaxial cable 202. The electrosurgical generator 14 generates a radiofrequency signal and outputs it to a monopolar electrode 242 of the surgical instrument 200 via a transmission line 204. A return signal, originating from the transmission line 204, may be received by a ground pad 205 coupled to the electrosurgical generator 14. The surgical suction pump 16 produces suction and applies the suction to a port 240 located a distal portion of the surgical instrument 200 via a suction tube 206. In some embodiments, the tissue ablation system 210 may further include a coolant 18 (e.g., saline) and a pump 20 for conveying the coolant to the surgical instrument 200 to cool various components therein during operation.

[0048] The surgical instrument 200 of the tissue ablation system 210 includes a handle portion 212 and a shaft assembly 220 extending distally from the handle portion 212. The shaft assembly 220 includes a hollow, elongated body or outer shaft 222 and an outer coating or sheath 224 covering an outer surface of the outer shaft 222. The outer sheath 224 is operably coupled to a control 216, such as a button, switch, or trigger, of the handle portion 212. The outer sheath 224, in response to an actuation of the control 216, axially moves relative to the handle portion 212 and the outer shaft 222 between a proximal position and a distal position to selectively expose a hook-shaped monopolar electrode 242 of the surgical instrument 200, as will be described in detail below.

[0049] The shaft assembly 220 further includes a coaxial cable 202 that forms the microwave antenna 232 at its terminal end. The microwave antenna 232 and its associated components (e.g., a reflector and dielectric region) are similar to the microwave antenna 132 described above, and will therefore not be described in further detail herein. The monopolar electrode 242 is disposed between an outer surface of the outer shaft 222 and an inner surface of the outer sheath 224, and is electrically coupled to the electrosurgical generator 14. The monopolar electrode 242 has a proximal portion 242a in communication with the transmission line 204, and a distal portion 242b extending distally beyond the microwave antenna 232. In some embodiments, the proximal portion 242a of the monopolar electrode 242 may be mechanically coupled to the control 216 such that an actuation of the control 216 moves the monopolar electrode 242 between proximal and distal positions relative to the outer sheath 224.

[0050] The distal portion 242b of the monopolar electrode 242 may have a hooked configuration for depressing tissue upon contact therewith. In particular, the distal portion 242b extends at a perpendicular angle relative to the longitudinal axis defined by the outer shaft 222. In some embodiments, the distal portion 242b of the monopolar electrode 242 may extend at a variety of angles relative to the longitudinal axis of the outer shaft 222, e.g., 0° to 180°. In other embodiments, rather than the distal portion 242b of the monopolar electrode 242 assuming a hooked configuration, the distal portion 242b may assume a helical configuration, a curved configuration, or the like.

[0051] In operation, as shown in FIG. 9, a portion of tissue, such as a section of liver tissue "T" may be ablated and resected using the tissue ablation system 210 of the present disclosure. With the outer sheath 224 of the surgical instrument 200 covering the distal portion 242b of the monopolar electrode 242b, an edge of the distal portion of the outer shaft 222 may be placed in contact with a surface "S" of the liver tissue "T" to be resected. Contacting the edge of the outer shaft 222 with the tissue surface "S" forms a depression or valley in the tissue "T." The handle portion 212 is actuated to activate the microwave function of the surgical instrument 200, whereby the microwave generator 12 transmits microwave energy to the microwave antenna 232 via the coaxial cable 202.

[0052] The microwave antenna 232 directs the microwave energy radially outward therefrom and toward the edge of the outer shaft 222 and into the valley formed in the tissue "T." As the microwave energy is transmitted into the valley of the tissue "T," the surgical instrument 200 is manipulated to move or slide the edge of the outer shaft 222 along a resection plane "P" of the liver tissue "T," thereby pre-coagulating the underlying tissue at a depth proportional to the frequency of the microwave energy and the length of time the microwave antenna 232 is activated.

[0053] Movement of the edge of the outer shaft 222 of the surgical instrument 200 along the resection plane "P" is continued until a desired depth and/or width of tissue pre-coagulation is achieved. Upon achieving the desired depth and width of tissue pre-coagulation, transmission of the microwave energy is deactivated and the outer sheath 224 of the shaft assembly 220 is moved proximally toward the proximal position to expose the distal portion 242b of the monopolar electrode 242. In some embodiments, instead of moving the outer sheath 242 proximally to expose the monopolar electrode distal portion 242b, the monopolar electrode 242 may be moved distally beyond the outer sheath 224. With the distal portion 242b of the monopolar electrode 242 exposed, the distal portion 242b of the monopolar electrode 242 contacts the tissue surface "S" of the pre-coagulated tissue along the resection plane "P."

[0054] While moving the monopolar electrode 242 along the resection plane "P," the control 216 of the handle portion 212 is actuated to activate the radiofrequency function of the surgical instrument 200, whereby the electrosurgical generator 14 transmits radiofrequency energy to the monopolar electrode 242, whereby the radiofrequency energy is directed into the liver tissue "T" to resect the liver tissue "T" along the resection plane "P."

[0055] The above-noted steps may be repeated to pre-coagulate the tissue "T" at increasingly greater depths until the desired volume of the tissue "T" is pre-coagulated and resected from the remainder of the organ. The surgical suction pump 16 may be activated at any point during and/or after the procedure to remove surgical debris and/or surgical smoke via the port 240 of the surgical instrument 200.

[0056] The above-described tissue ablation systems are capable of directing microwave and radiofrequency energy into tissue, and may be suitable for use in a variety of procedures and operations. The above-described tissue ablation systems may be suitable for utilization with hand-assisted, endoscopic, and laparoscopic surgical procedures. The above-described tissue ablation systems may also be suitable for utilization in open surgical applications.

[0057] An effective method of identifying cancerous or diseased target tissue involves the use of a computed tomographic (CT) image. The use of CT as a diagnostic tool has now become routine and CT results are now frequently the primary source of information available to the practitioner regarding the size and location of a lesion. This information is used by the practitioner in planning an operative procedure such as a biopsy, but is only available as "offline" information which must typically be memorized to the best of the practitioner's ability prior to beginning a procedure. In addition to inputting target information, integration with the CT data provides improved system functionality, thereby greatly facilitating the planning of a pathway to an identified target as well as providing the ability to navigate through the body to the target location.

[0058] Although embodiments have been described in detail with reference to the accompanying drawings for the purpose of illustration and description, it is to be understood that the inventive processes and apparatus are not to be construed as limited thereby. It will be apparent to those of ordinary skill in the art that various modifications to the foregoing embodiments may be made without departing from the scope of the disclosure.

The embodiments of the present invention for which an exclusive property or privilege is claimed are defined as follows:

1. A surgical instrument for ablating tissue, comprising:

a handle portion; and

a shaft assembly extending distally from the handle portion and including:

an outer shaft having a distal portion;

a coaxial cable extending through the outer shaft and having a distal portion disposed within the distal portion of the outer shaft, the distal portion of the coaxial cable forming a microwave antenna configured to transmit microwave energy radially outward and through a first apex of the outer shaft; and

at least one electrode coupled to the distal portion of the outer shaft and disposed closer to a second apex defined by the outer shaft than the first apex, the at least one electrode configured to transmit radiofrequency energy, wherein an actuation of the surgical instrument activates at least one of the transmission of the microwave energy from the microwave antenna or the transmission of the radiofrequency energy from the at least one electrode.

2. The surgical instrument according to claim 1, wherein the at least one electrode is disposed distally of the microwave antenna.

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3. The surgical instrument according to claim 1, wherein the at least one electrode is disposed radially outward from the microwave antenna and out of alignment with the direction of travel of the microwave energy being transmitted from the microwave antenna.

4. The surgical instrument according to any one of claims 1 to 3, wherein the at least one electrode is a pair of bipolar electrodes.

5. The surgical instrument according to any one of claims 1 to 4, wherein the distal portion of the outer shaft has a wedge-shaped configuration.

6. The surgical instrument according to claim 5, wherein the shaft assembly further includes a reflector disposed within the distal portion of the outer shaft and about the microwave antenna.

7. The surgical instrument according to claim 6, wherein the reflector has a semi-circular shape and is configured to direct the transmission of the microwave energy toward the first apex of the outer shaft, the first apex of the outer shaft extending parallel with a longitudinal axis defined by the shaft assembly.

8. The surgical instrument according to claim 7, wherein the shaft assembly further includes a dielectric region disposed within the distal portion of the outer shaft.

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9. The surgical instrument according to claim 8, wherein the reflector and a pair of adjoined lateral sides of the outer shaft cooperatively define a cavity therein, the dielectric region filling the cavity.

10. The surgical instrument according to claim 1, further comprising a tube extending through the outer shaft and disposed radially outward from the microwave antenna, wherein the tube has a proximal portion configured to receive suction.

11. The surgical instrument according to any one of claims 1 to 10, wherein the at least one electrode includes a hooked distal portion disposed distally of the microwave antenna.

12. The surgical instrument according to claim 11, wherein the shaft assembly further includes an outer sheath disposed about the outer shaft and axially movable relative to the outer shaft between a first position, in which the hooked distal portion is disposed within the outer sheath, and a second position, in which the hooked distal portion is disposed distally of the outer sheath.

13. The surgical instrument according to any one of claims 1 to 12, wherein the at least one electrode is disposed on a lateral side of the outer shaft.

14. A tissue ablation system, comprising:

a microwave generator configured to generate and transmit microwave energy;

an electrosurgical generator configured to generate and transmit radiofrequency energy; and

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a surgical instrument including:

a handle portion configured to be coupled to both of the microwave and electrosurgical generators; and

a shaft assembly extending distally from the handle portion and including:

an outer shaft having a distal portion;

a coaxial cable extending through the outer shaft and having a proximal portion configured to be in electrical communication with the microwave generator, and a distal portion disposed within the distal portion of the outer shaft, the distal portion of the coaxial cable forming a microwave antenna configured to transmit the microwave energy radially outward and through the outer shaft;

at least one electrode coupled to the distal portion of the outer shaft and configured to be in electrical communication with the electrosurgical generator to transmit the radiofrequency energy, wherein an actuation of the surgical instrument activates at least one of the transmission of the microwave energy from the microwave antenna or the transmission of the radiofrequency energy from the at least one electrode; and

a reflector disposed within the distal portion of the outer shaft and about the microwave antenna, wherein the reflector is configured to direct the microwave energy from the microwave antenna toward a first apex defined by the outer shaft, the at least one electrode being disposed closer to a second apex defined by the outer shaft than the first apex.

15. The tissue ablation system according to claim 14, wherein the distal portion of the outer shaft has a wedge-shaped configuration.

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16. The tissue ablation system according to claim 15, wherein the reflector has a semi-circular shape, the first apex of the outer shaft extending parallel with a longitudinal axis defined by the shaft assembly.

17. The tissue ablation system according to claim 16, wherein the shaft assembly further includes a dielectric region filling a cavity cooperatively defined by the reflector and a pair of adjoined lateral sides of the outer shaft.

18. The tissue ablation system according to claim 14, wherein the shaft assembly further includes an outer sheath disposed about the outer shaft, the at least one electrode including a hooked distal portion disposed distally of the microwave antenna and within the outer sheath.

19. The tissue ablation system according to claim 14, wherein the outer shaft has a wedge-shaped configuration, the at least one electrode including a pair of bipolar electrodes disposed on a respective pair or adjoined, lateral sides of the outer shaft.

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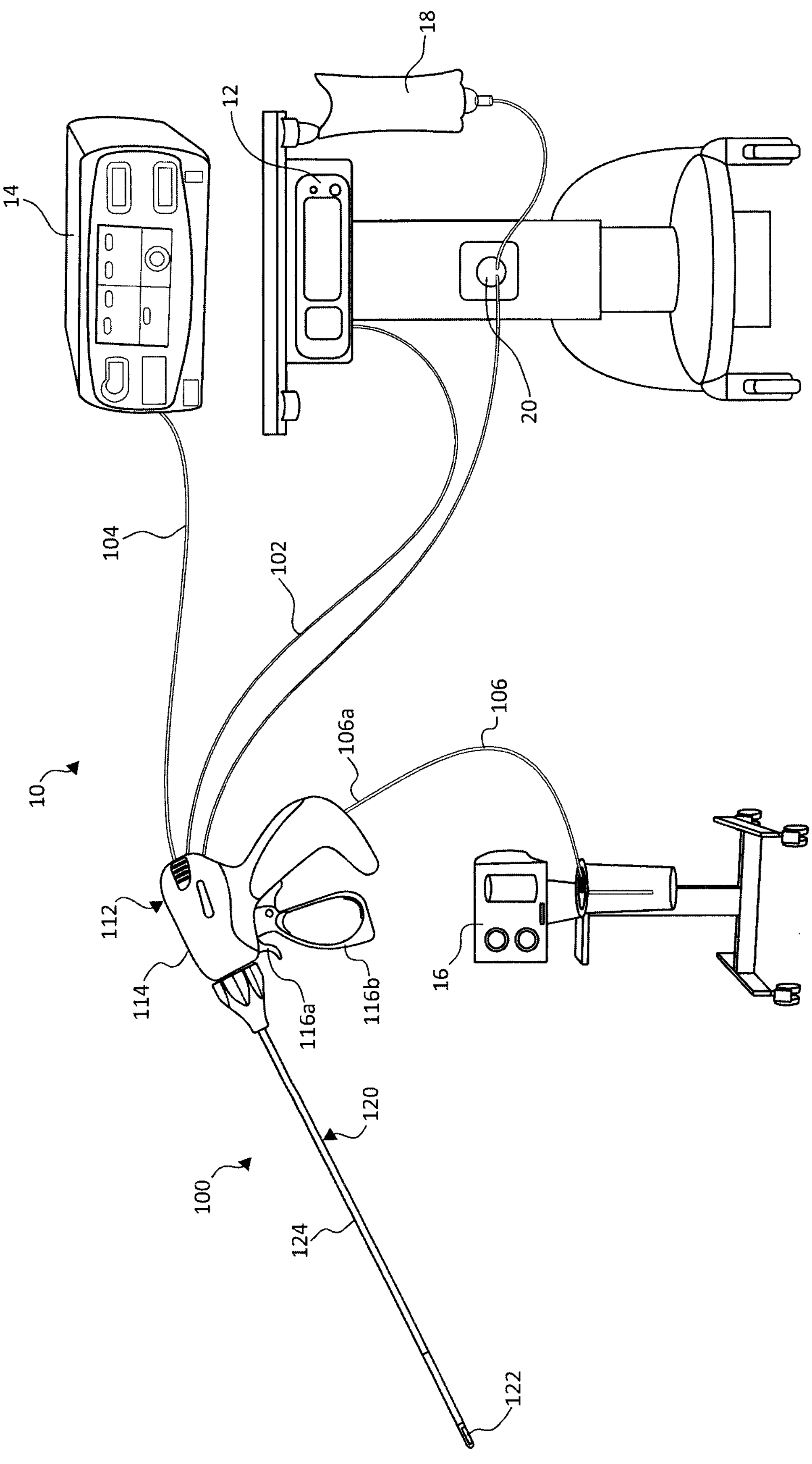
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FIG. 1

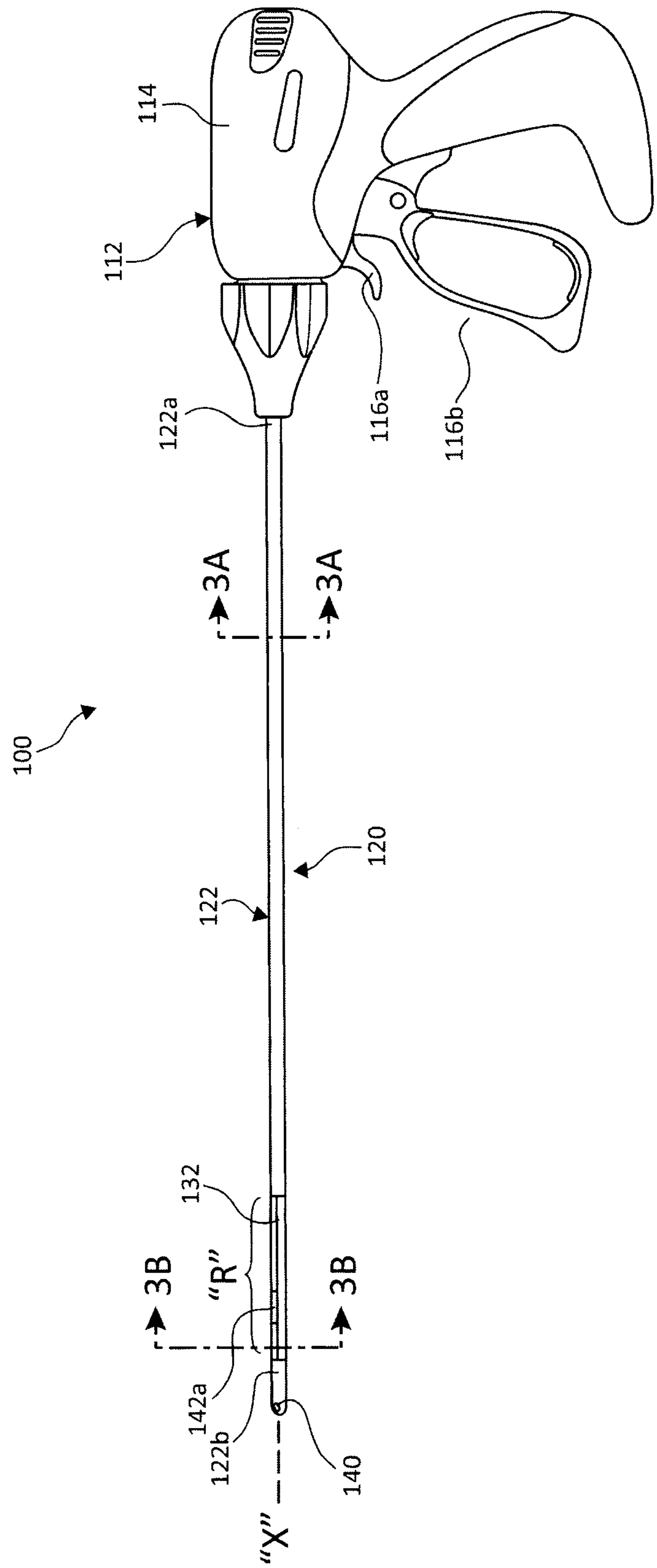
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FIG. 2

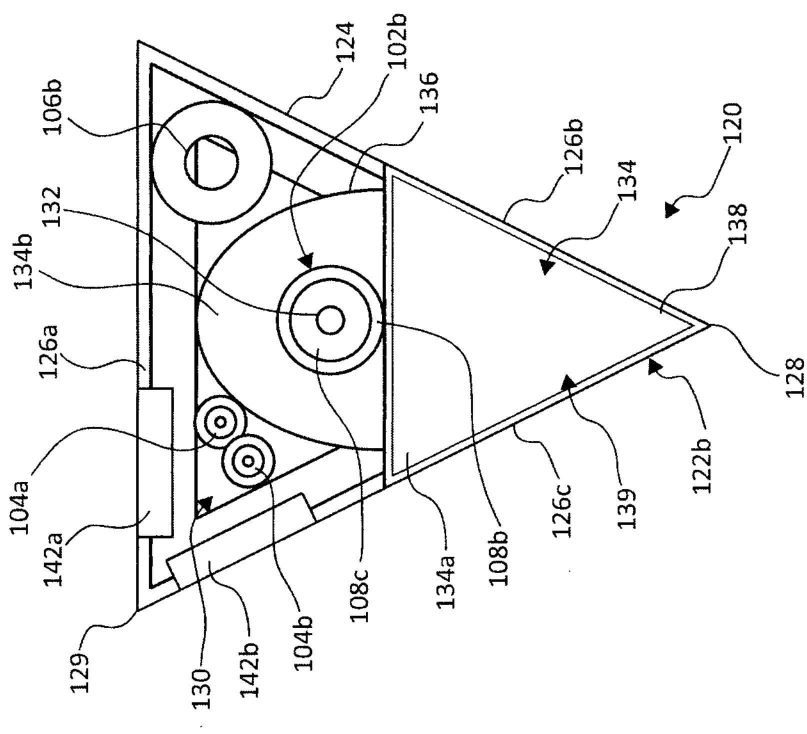
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FIG. 3B

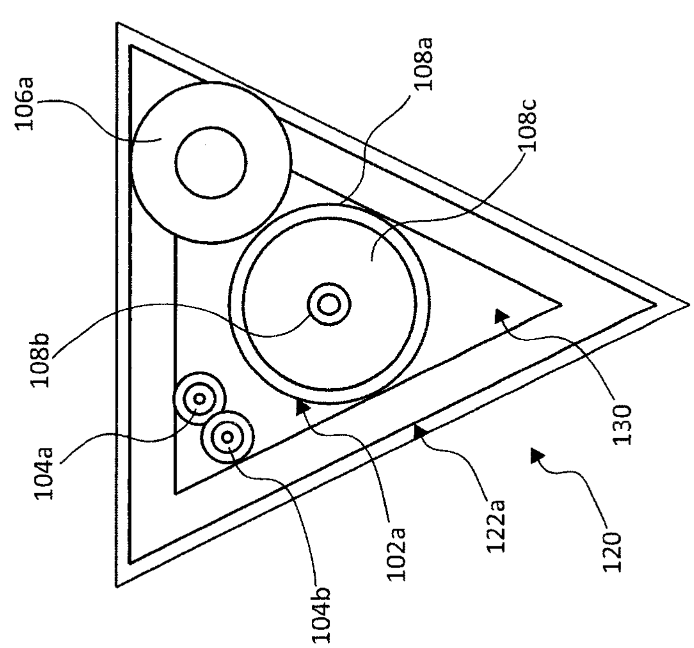
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FIG. 3A

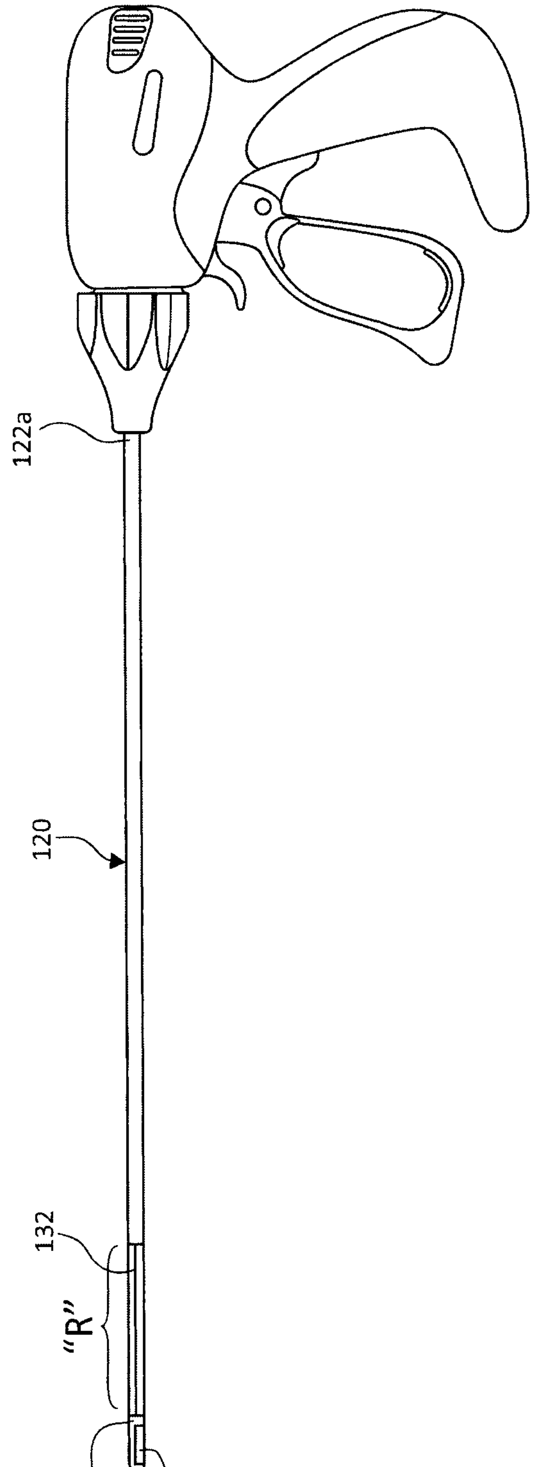


FIG. 4

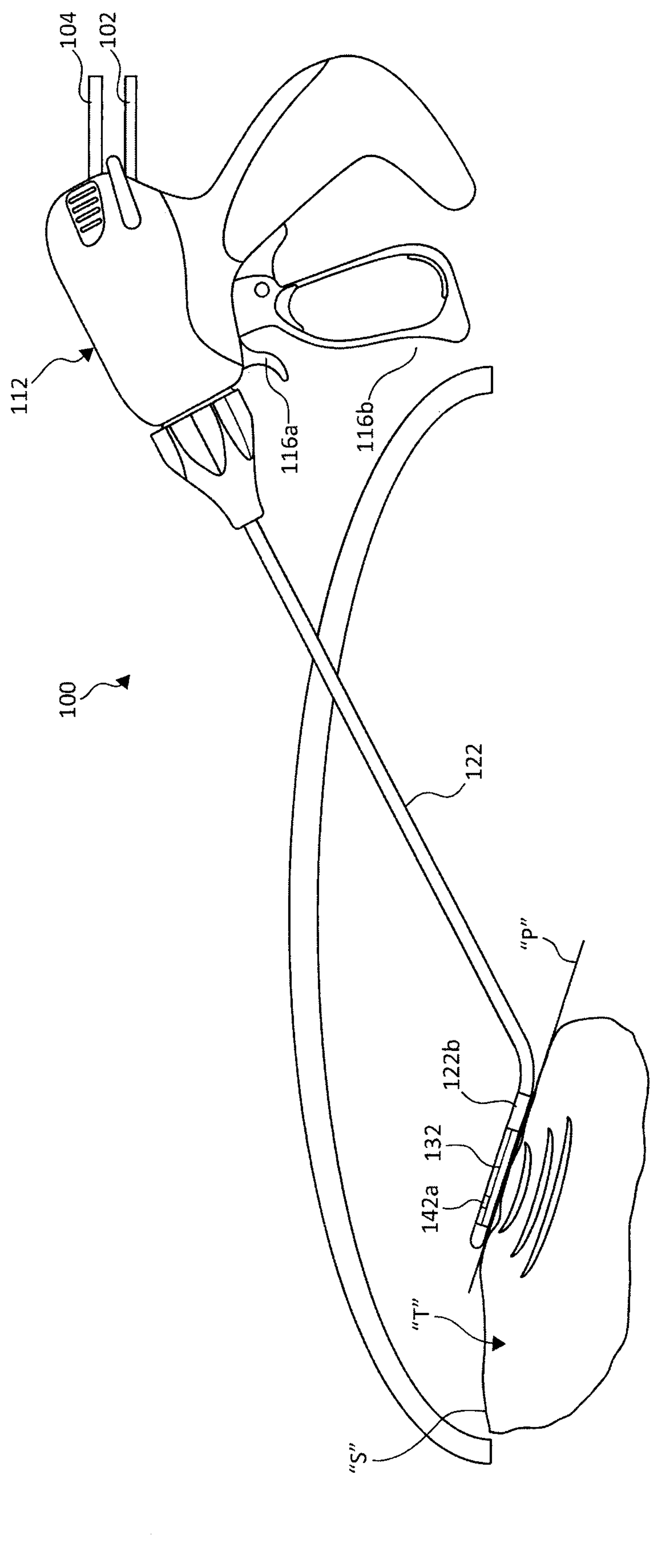


FIG. 5

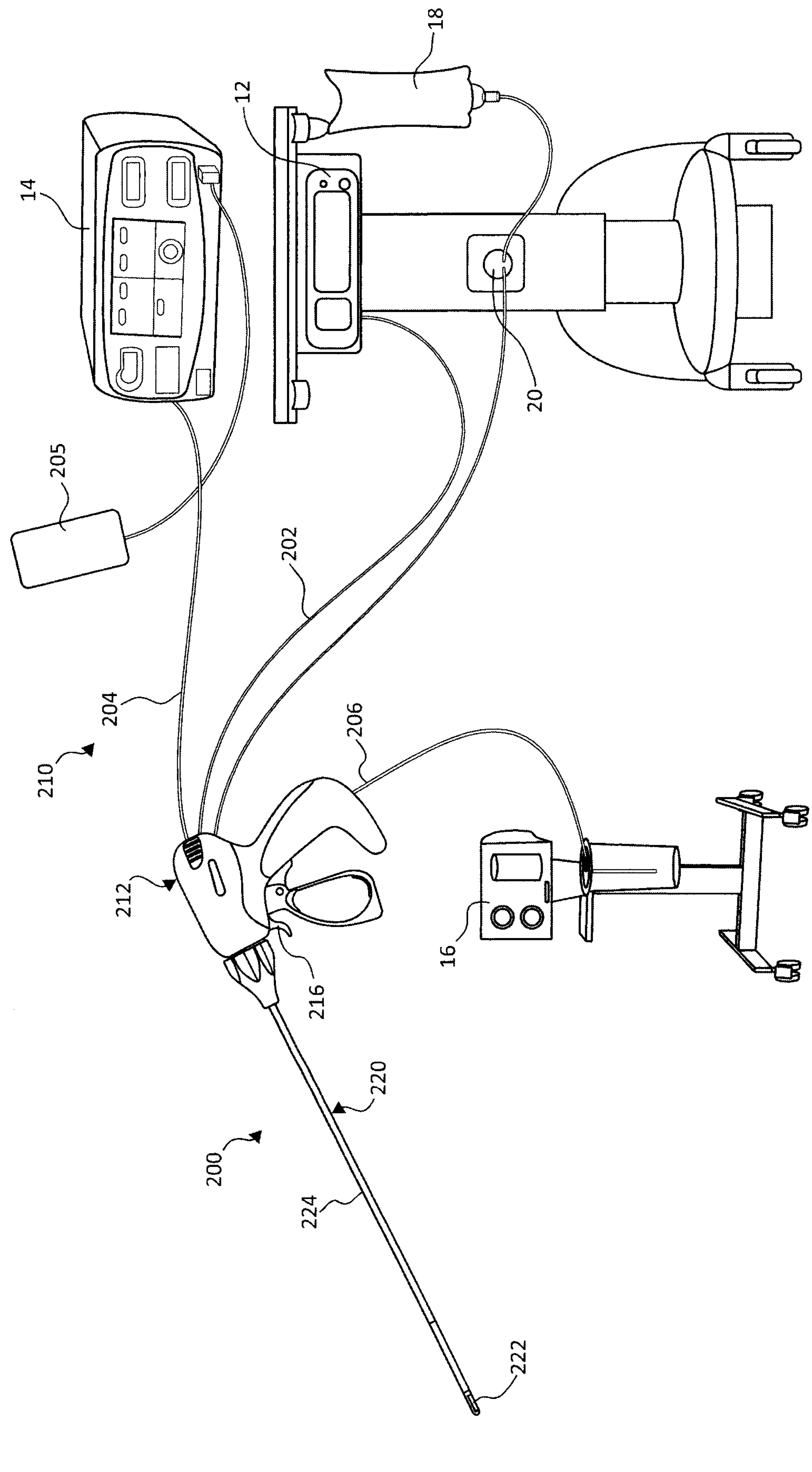


FIG. 6

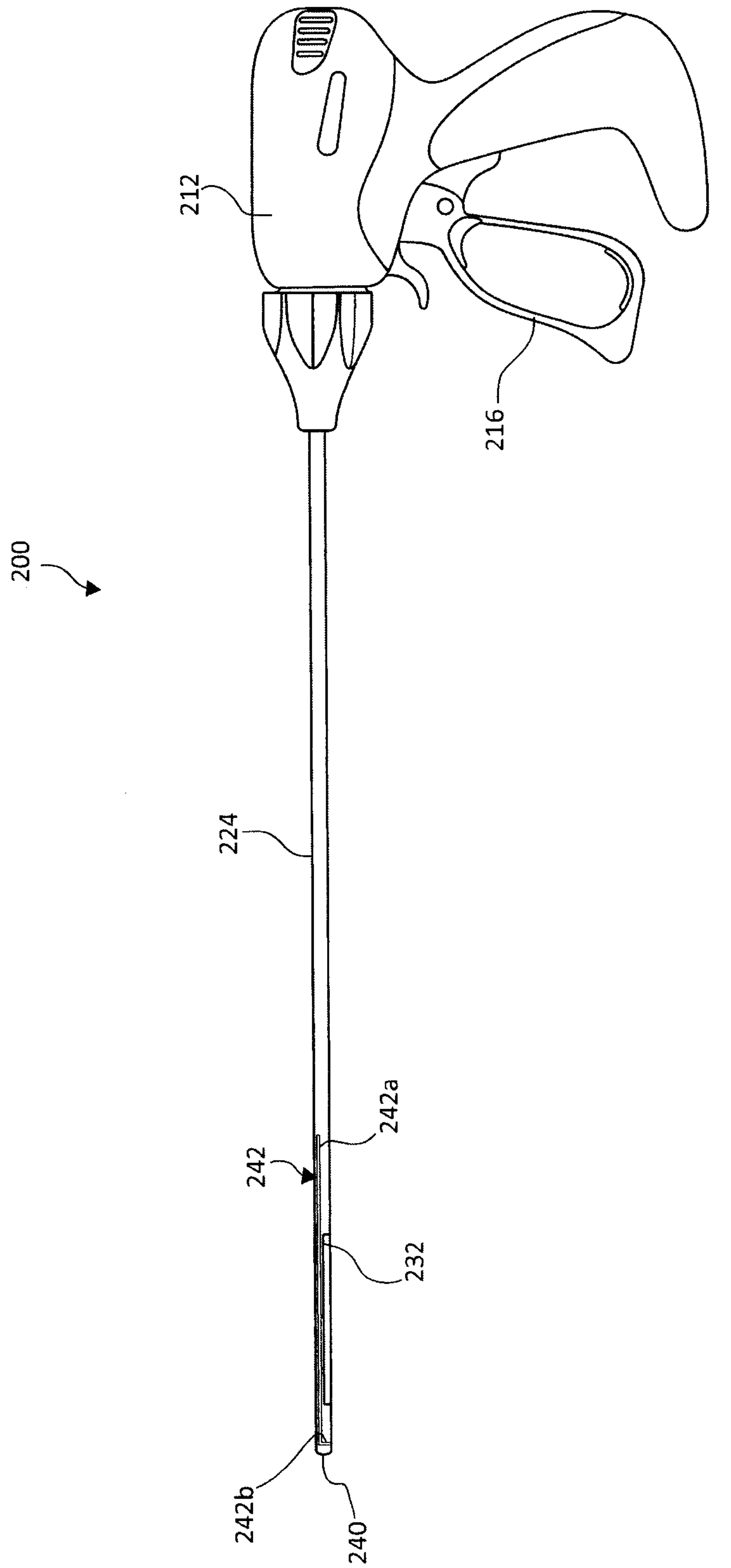


FIG. 7

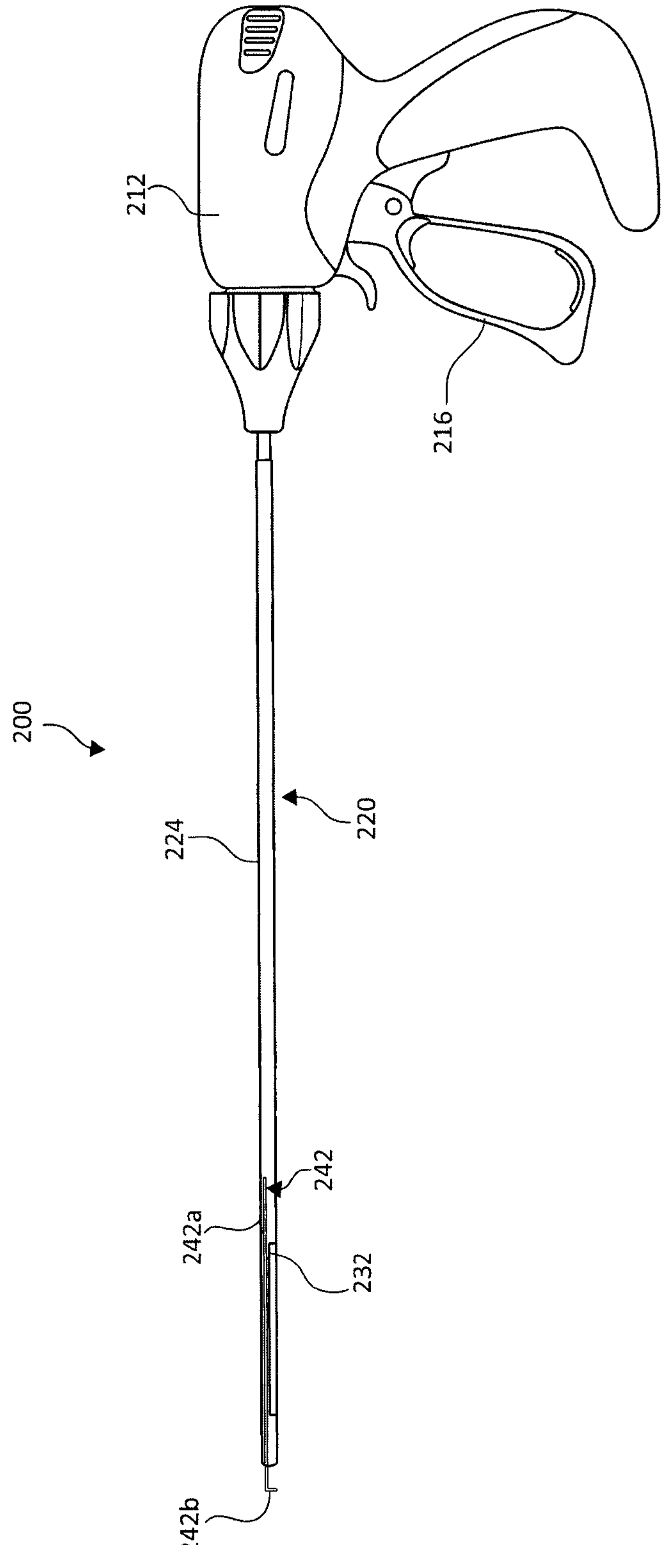


FIG. 8

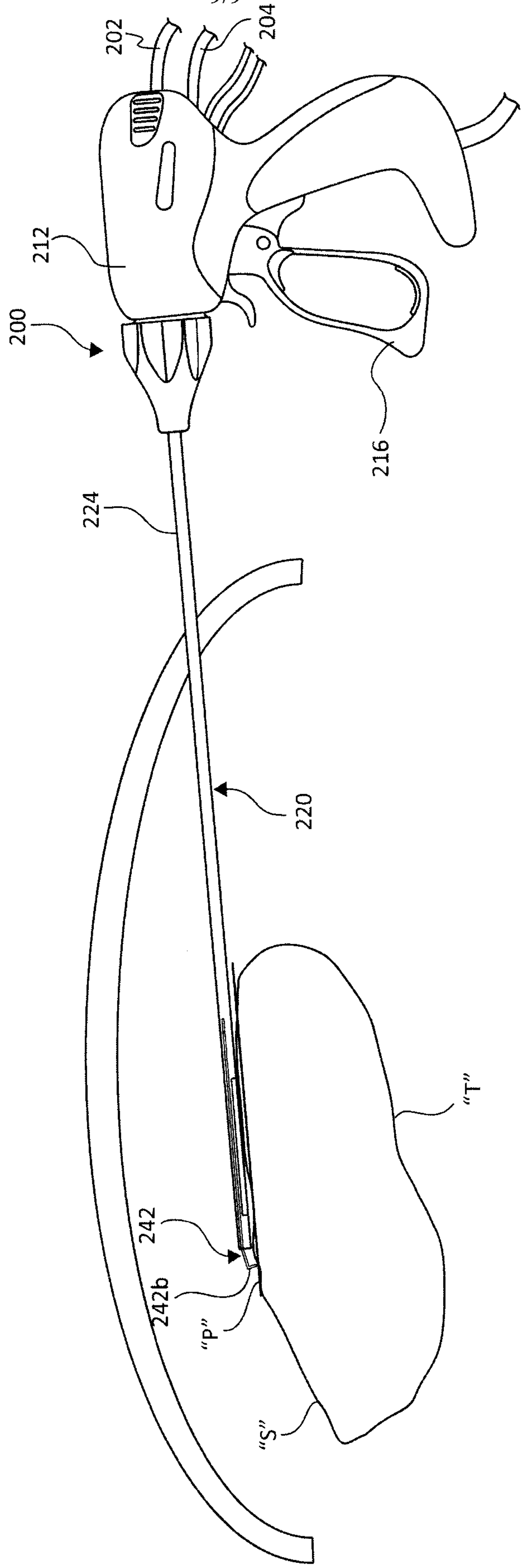
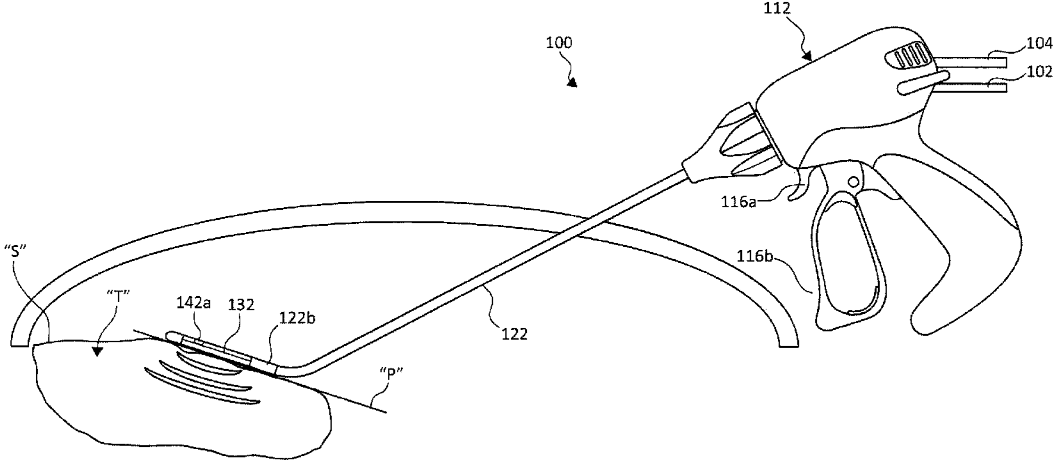


FIG. 9



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