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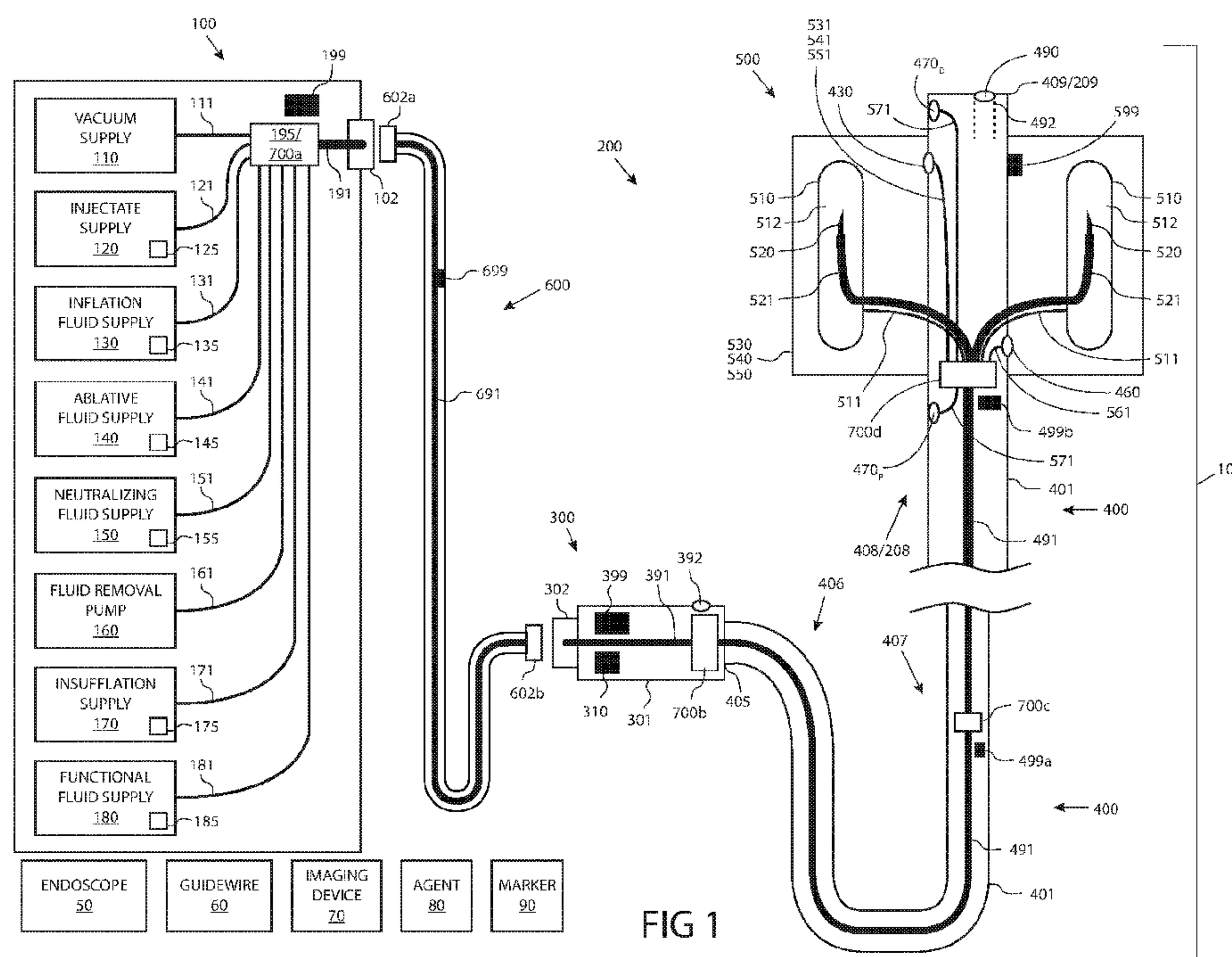


FIG 1

(57) Abstract: Systems, devices and methods for performing medical procedures in the intestine of a patient are provided. A medical device for performing a treatment and/or a diagnostic procedure can include an elongate shaft assembly comprising at least a shaft assembly first section comprising a distal section of the shaft assembly, and a shaft assembly second section proximal to the first section, and a functional assembly positioned on the shaft assembly first section. Additional sections of the shaft assembly can be included, and each section can comprise a different construction, such as to achieve a different stiffness as described herein. Variable stiffness along the length of the shaft assembly can be provided to aid in translation of the device through the patient's GI tract (e.g. through the stomach and into the small intestine), as described herein.

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TISSUE TREATMENT DEVICES, SYSTEMS, AND METHODS**CROSS-REFERENCE TO RELATED APPLICATIONS**

[001] This application claims the benefit of United States Provisional Patent Application Serial Number 62/960,340 (Attorney Docket No. 41714-721.101; Client Docket No. MCT-039-PR1), entitled "Tissue Treatment Devices, Systems, and Methods", filed January 13, 2020, the content of which is incorporated herein by reference in its entirety.

[002] This application is related to: United States Patent Application Serial Number 13/945,138 (Attorney Docket No. 41714-703.301; Client Docket No. MCT-001-US), entitled "Devices and Methods for the Treatment of Tissue", filed July 18, 2013; United States Patent Application Serial Number 15/917,480 (Attorney Docket No. 41714-703.302; Client Docket No. MCT-001-US-CON1), entitled "Devices and Methods for the Treatment of Tissue", filed March 9, 2018; United States Patent Application Serial Number 16/438,362 (Attorney Docket No. 41714-704.302; Client Docket No. MCT-002-US-CON1), entitled "Heat Ablation Systems, Devices and Methods for the Treatment of Tissue", filed June 11, 2019; United States Patent Application Serial Number 14/515,324 (Attorney Docket No. 41714-705.301; Client Docket No. MCT-003-US), entitled "Tissue Expansion Devices, Systems and Methods", filed October 15, 2014; United States Patent Application Serial Number 16/711,236 (Attorney Docket No. 41714-706.302; Client Docket No. MCT-004-US-CON1), entitled "Electrical Energy Ablation Systems, Devices and Methods for the Treatment of Tissue", filed December 11, 2019; United States Patent Application Serial Number 14/609,334 (Attorney Docket No. 41714-707.301; Client Docket No. MCT-005-US), entitled "Ablation Systems, Devices, and Methods for the Treatment of Tissue", filed January 29, 2015; United States Patent Application Serial Number 14/673,565 (Attorney Docket No. 41714-708.301; Client Docket No. MCT-009-US), entitled "Methods, Systems and Devices for Performing Multiple Treatments on a Patient", filed March 30, 2015; United States Patent Application Serial Number 16/379,554 (Attorney Docket No. 41714-709.302; Client Docket No. MCT-013-US-CON1), entitled "Methods, Systems and Devices for Reducing the Luminal Surface Area of the Gastrointestinal Tract", filed April 9, 2019; United States Patent Application Serial Number 14/917,243 (Attorney Docket No. 41714-710.301; Client Docket No. MCT-023-US), entitled "Systems, Methods and Devices for Treatment of Target Tissue", filed March 7, 2016; United States Patent Application Serial Number 16/742,645 (Attorney Docket No. 41714-715.301; Client Docket No. MCT-025-US), entitled "Intestinal Catheter Device and System", filed January 14, 2020; United States Provisional Patent Application Serial Number 62/961,340 (Attorney Docket No. 41714-722.101; Client Docket No. MCT-051-PR1), entitled "Automated Tissue Treatment Devices, Systems, and Methods", filed January 15, 2020; United States Patent Application Serial Number 16/900,563 (Attorney Docket No.

41714-712.501; Client Docket No. MCT-027-US-CIP1), entitled "Injectate Delivery Devices, Systems and Methods", filed June 12, 2020; United States Patent Application Serial Number 16/798,117 (Attorney Docket No. 41714-714.303; Client Docket No. MCT-028-US-CIP1-CON2), entitled "Systems, Devices and Methods for Performing Medical Procedures in the Intestine", filed February 21, 2020; United States Patent Application Serial Number 15/812,969 (Attorney Docket No. 41714-714.302; Client Docket No. MCT-028-US-CIP2-CON1), entitled "Systems, Devices and Methods for Performing Medical Procedures in the Intestine", filed November 14, 2017; United States Patent Application Serial Number 16/400,491 (Attorney Docket No. 41714-716.301; Client Docket No. MCT-035-US), entitled "Systems, Devices and Methods for Performing Medical Procedures in the Intestine", filed May 1, 2019; United States Patent Application Serial Number 16/905,274 (Attorney Docket No. 41714-717.301; Client Docket No. MCT-036-US), entitled "Material Depositing System for Treating a Patient", filed June 18, 2020; International PCT Patent Application Serial Number PCT/US2019/54088 (Attorney Docket No. 41714-718.301; Client Docket No. MCT-037-PCT), entitled "Systems and Methods for Deposition Material in a Patient", filed October 1, 2019; International PCT Patent Application Serial Number PCT/US2020/025925 (Attorney Docket No. 41714-719.601; Client Docket No. MCT-040-PCT), entitled "Systems, Devices and Methods for Treating Metabolic Medical Conditions", filed March 31, 2020; United States Provisional Patent Application Serial Number 62/991,219 (Attorney Docket No. 41714-723.101; Client Docket No. MCT-041-PR1), entitled "Systems, Devices and Methods for Treating Diabetes", filed March 18, 2020; United States Provisional Patent Application Serial Number 63/042,356 (Attorney Docket No. 41714-724.101; Client Docket No. MCT-034-PR1), entitled "Tissue Treatment System with Fluid Delivery Console", filed June 22, 2020; United States Provisional Patent Application Serial Number 63/076,737 (Attorney Docket No. 41714-723.102; Client Docket No. MCT-041-PR2), entitled "Systems, Devices and Methods for Treating Diabetes", filed September 10, 2020; United States Provisional Patent Application Serial Number 63/085,375 (Attorney Docket No. 41714-723.103; Client Docket No. MCT-041-PR3), entitled "Systems, Devices and Methods for Treating Diabetes", filed September 30, 2020; International PCT Patent Application Serial Number PCT/US2020/056627 (Attorney Docket No. 41714-720.601; Client Docket No. MCT-050-PCT), entitled "Systems, Devices, and Methods for Performing Medical Procedures in the Intestine", filed October 21, 2020; United States Patent Application Serial Number 17/095,108 (Attorney Docket No. 41714-711.303; Client Docket No. MCT-024-US-CON2), entitled "Systems, Devices and Methods for the Creation of a Therapeutic Restriction in the Gastrointestinal Tract", filed November 11, 2020; United States Patent Application Serial Number 17/096,855 (Attorney Docket No. 41714-713.302; Client Docket No. MCT-029-US-CON1), entitled "Methods and Systems for Treating Diabetes and Related Diseases and Disorders", filed November 12, 2020;

and United States Patent Application Serial Number 17/110,720 (Attorney Docket No. 41714-712.302; Client Docket No. MCT-027-US-CIP1-CON1), entitled "Injectate Delivery Devices, Systems and Methods", filed December 3, 2020; the contents of each of which is incorporated herein by reference in its entirety for all purposes.

BACKGROUND OF THE INVENTION

[003] Field of the Invention. The present invention relates generally to devices, systems, and method for treating tissue, and in particular, catheter devices for treating tissue of the gastrointestinal tract of a patient.

[004] Various medical devices are inserted through the patient's mouth and advanced into the stomach and more distal locations to perform a medical procedure, such as a diagnostic and/or therapeutic procedure. These devices are often difficult to advance, retract, rotate, and/or otherwise manipulate, often due to the tortuosity of the pathway into which they are placed. There is a need for medical devices that have enhanced performance under these challenging conditions.

BRIEF SUMMARY OF THE INVENTION

[005] According to an aspect of the present inventive concepts, a device for performing a medical procedure in the intestine of a patient comprises: an elongate shaft assembly comprising at least a shaft assembly first section comprising a distal section of the shaft assembly, and a shaft assembly second section proximal to the first section, and a functional assembly positioned on the shaft assembly first section; wherein the shaft assembly first section comprises a first stiffness. The shaft assembly second section comprises a second stiffness, and the first stiffness is less stiff than the second stiffness.

[006] In some embodiments, the intestine comprises at least a portion of the small intestine. The intestine can comprise at least a portion of the duodenum.

[007] In some embodiments, the shaft assembly comprises a multi lumen shaft. The elongate shaft assembly can further comprise at least one conduit positioned within a lumen of the multi lumen shaft.

[008] In some embodiments, the shaft assembly first section comprises a length of at least 2 inches.

[009] In some embodiments, the shaft assembly second section comprises a length of at least 10 inches.

[010] In some embodiments, the shaft assembly further comprises a shaft assembly third section proximal to the shaft assembly second section. The shaft assembly third section can comprise a length of at least 32 inches. The shaft assembly third section can be longer than the shaft assembly second section and the shaft assembly second section can be longer than the shaft assembly first

section. The shaft assembly first section can comprise a material with a durometer of approximately 40D, the shaft assembly second section can comprise a material with a durometer of approximately 55D, and the shaft assembly third section can comprise a material with a durometer of approximately 63D. The shaft assembly third section can comprise a length of approximately 57 inches, the shaft assembly second section can comprise a length of approximately 10 inches, and the shaft assembly first section can comprise a length of approximately 5 inches. The shaft assembly first section can comprise a material with a durometer of approximately 40D, the shaft assembly second section can comprise a material with a durometer of approximately 55D, and the shaft assembly third section can comprise a material with a durometer of approximately 63D. The shaft assembly can be constructed and arranged to bend as follows: a midpoint of a 2 inch span of a section deflects a distance of approximately 0.125 inches when the following force is applied: at least 10lbf, at least 13lbf, or at least 16lbf applied to the shaft assembly third section; at least 8lbf, at least 10lbf, or at least 11lbf applied to the shaft assembly second section; and/or at most 14lbf, at most 11lbf, or at most 8lbf applied to the shaft assembly first section. The shaft assembly can be constructed and arranged to bend as follows: a midpoint of a 2 inch span of the first section deflects a distance of approximately 0.125 inches when a first force is applied; and a midpoint of a 2 inch span of the second section deflects a distance of approximately 0.125 inches when a second force is applied; and the second force can be at least 3lbf more than the first force. The shaft assembly can be constructed and arranged to bend as follows: a midpoint of a 2 inch span of the second section deflects a distance of approximately 0.125 inches when a second force is applied; and a midpoint of a 2 inch span of the third section deflects a distance of approximately 0.125 inches when a third force is applied; and the third force can be at least 4lbf more than the second force. The shaft assembly can be constructed and arranged to bend as follows: a midpoint of a 2 inch span of the first section deflects a distance of approximately 0.125 inches when a first force is applied; and a midpoint of a 2 inch span of the third section deflects a distance of approximately 0.125 inches when a third force is applied; and the third force can be at least 7lbf more than the first force.

[011] In some embodiments, the shaft assembly further comprises a fourth section comprising a distal tip fixedly attached to a distal end of the shaft assembly first section, and the fourth section comprises a stiffness less than the stiffness of the shaft assembly first section. The distal tip can comprise a tapered distal tip.

[012] In some embodiments, the functional assembly is configured to expand tissue within the intestine of the patient.

[013] In some embodiments, the functional assembly is configured to ablate tissue within the intestine of the patient.

[014] In some embodiments, the functional assembly is configured to remove tissue within the intestine of the patient.

[015] In some embodiments, the functional assembly is configured to expand and ablate tissue within the intestine of the patient.

[016] In some embodiments, the functional assembly comprises a balloon. The functional assembly can be configured to ablate tissue within the intestine of the patient with a hot fluid.

[017] In some embodiments, the device further comprises an injection assembly including at least one needle, at least one port, and at least one fluid delivery tube.

[018] According to another aspect of the present inventive concepts, a device for performing a medical procedure in the intestine of a patient comprises: an elongate shaft assembly comprising a proximal portion, a distal portion, and at least two lumens therethrough, a functional assembly positioned on the distal portion of the elongate shaft assembly, and an injection assembly comprising at least one port attached to the functional assembly and at least one conduit operably connecting one of the at least two lumens of the shaft assembly to the at least one port. The at least one conduit is rotated about the distal portion of the shaft assembly.

[019] In some embodiments, the at least one port comprises at least two ports and the at least one conduit comprises at least two conduits.

[020] In some embodiments, the at least one port comprises at least three ports and the at least one conduit comprises at least three conduits.

[021] In some embodiments, the at least one conduit is rotated at least 25°, at least 50°, or at least 100° about the distal portion of the shaft assembly. The at least one conduit can be rotated approximately 180° about the distal portion of the shaft assembly.

[022] In some embodiments, the at least one conduit comprises a biased shape. The biased shape can comprise an “S” shape.

[023] In some embodiments, the at least one conduit comprises at least one lumen therethrough. The at least one lumen can comprise at least two lumens.

[024] In some embodiments, the shaft assembly further comprises a manifold, and the manifold operably connects at least one of the at least two shaft lumens to the at least one conduit.

[025] The technology described herein, along with the attributes and attendant advantages thereof, will best be appreciated and understood in view of the following detailed description taken in conjunction with the accompanying drawings in which representative embodiments are described by way of example.

INCORPORATION BY REFERENCE

[026] All publications, patents, and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication, patent, or patent application was specifically and individually indicated to be incorporated by reference. The content of all publications, patents, and patent applications mentioned in this specification are herein incorporated by reference in their entirety for all purposes.

BRIEF DESCRIPTION OF THE DRAWINGS

[027] **Fig. 1** illustrates a system for treating and/or diagnosing gastrointestinal tissue, consistent with the present inventive concepts.

[028] **Fig. 1A** illustrates a schematic view of a system for performing a medical procedure in the intestine of a patient, consistent with the present inventive concepts.

[029] **Fig. 1B** illustrates a flow chart of a method of treating target tissue of a patient, consistent with the present inventive concepts.

[030] **Fig. 1C** illustrates a sectional anatomical view of a treatment device inserted into a gastrointestinal lumen, consistent with the present inventive concepts.

[031] **Figs. 2A and 2B** illustrate schematic views of a catheter inserted into a patient and that catheter shown in an anatomical shape, consistent with the present inventive concepts.

[032] **Figs. 3A and 3B** illustrate a side view and an end view of the distal portion of a catheter for treating tissue, consistent with the present inventive concepts.

[033] **Fig. 4** illustrates a perspective view of a portion of a shaft assembly of a catheter for treating tissue, consistent with the present inventive concepts.

[034] **Figs. 5A and 5B** illustrate side views of an elongate sample being tested in a test fixture, consistent with the present inventive concepts.

DETAILED DESCRIPTION OF THE DRAWINGS

[035] Reference will now be made in detail to the present embodiments of the technology, examples of which are illustrated in the accompanying drawings. Similar reference numbers may be used to refer to similar components. However, the description is not intended to limit the present disclosure to particular embodiments, and it should be construed as including various modifications, equivalents, and/or alternatives of the embodiments described herein.

[036] It will be understood that the words "comprising" (and any form of comprising, such as "comprise" and "comprises"), "having" (and any form of having, such as "have" and "has"), "including" (and any form of including, such as "includes" and "include") or "containing" (and any form of containing, such as "contains" and "contain") when used herein, specify the presence of

stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[037] It will be further understood that, although the terms first, second, third, etc. may be used herein to describe various limitations, elements, components, regions, layers and/or sections, these limitations, elements, components, regions, layers and/or sections should not be limited by these terms. These terms are only used to distinguish one limitation, element, component, region, layer or section from another limitation, element, component, region, layer or section. Thus, a first limitation, element, component, region, layer or section discussed below could be termed a second limitation, element, component, region, layer or section without departing from the teachings of the present application.

[038] It will be further understood that when an element is referred to as being "on", "attached", "connected" or "coupled" to another element, it can be directly on or above, or connected or coupled to, the other element, or one or more intervening elements can be present. In contrast, when an element is referred to as being "directly on", "directly attached", "directly connected" or "directly coupled" to another element, there are no intervening elements present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g. "between" versus "directly between," "adjacent" versus "directly adjacent," etc.).

[039] It will be further understood that when a first element is referred to as being "in", "on" and/or "within" a second element, the first element can be positioned: within an internal space of the second element, within a portion of the second element (e.g. within a wall of the second element); positioned on an external and/or internal surface of the second element; and combinations of one or more of these.

[040] As used herein, the term "proximate", when used to describe proximity of a first component or location to a second component or location, is to be taken to include one or more locations near to the second component or location, as well as locations in, on and/or within the second component or location. For example, a component positioned proximate an anatomical site (e.g. a target tissue location), shall include components positioned near to the anatomical site, as well as components positioned in, on and/or within the anatomical site.

[041] Spatially relative terms, such as "beneath," "below," "lower," "above," "upper" and the like may be used to describe an element and/or feature's relationship to another element(s) and/or feature(s) as, for example, illustrated in the figures. It will be further understood that the spatially relative terms are intended to encompass different orientations of the device in use and/or operation in addition to the orientation depicted in the figures. For example, if the device in a figure is turned over, elements described as "below" and/or "beneath" other elements or features would then be

oriented "above" the other elements or features. The device can be otherwise oriented (e.g. rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[042] The terms “reduce”, “reducing”, “reduction” and the like, where used herein, are to include a reduction in a quantity, including a reduction to zero. Reducing the likelihood of an occurrence shall include prevention of the occurrence. Correspondingly, the terms “prevent”, “preventing”, and “prevention” shall include the acts of “reduce”, “reducing”, and “reduction”, respectively.

[043] The term "and/or" where used herein is to be taken as specific disclosure of each of the two specified features or components with or without the other. For example "A and/or B" is to be taken as specific disclosure of each of (i) A, (ii) B and (iii) A and B, just as if each is set out individually herein.

[044] The term “one or more”, where used herein can mean one, two, three, four, five, six, seven, eight, nine, ten, or more, up to any number.

[045] The terms “and combinations thereof” and “and combinations of these” can each be used herein after a list of items that are to be included singly or collectively. For example, a component, process, and/or other item selected from the group consisting of: A; B; C; and combinations thereof, shall include a set of one or more components that comprise: one, two, three or more of item A; one, two, three or more of item B; and/or one, two, three, or more of item C.

[046] In this specification, unless explicitly stated otherwise, “and” can mean “or”, and “or” can mean “and”. For example, if a feature is described as having A, B, or C, the feature can have A, B, and C, or any combination of A, B, and C. Similarly, if a feature is described as having A, B, and C, the feature can have only one or two of A, B, or C.

[047] As used herein, when a quantifiable parameter is described as having a value “between” a first value X and a second value Y, it shall include the parameter having a value of: at least X, no more than Y, and/or at least X and no more than Y. For example, a length of between 1 and 10 shall include a length of at least 1 (including values greater than 10), a length of less than 10 (including values less than 1), and/or values greater than 1 and less than 10.

[048] The expression “configured (or set) to” used in the present disclosure may be used interchangeably with, for example, the expressions “suitable for”, “having the capacity to”, “designed to”, “adapted to”, “made to” and “capable of” according to a situation. The expression “configured (or set) to” does not mean only “specifically designed to” in hardware. Alternatively, in some situations, the expression “a device configured to” may mean that the device “can” operate together with another device or component.

[049] As used herein, the terms “about” or “approximately” shall refer to $\pm 10\%$.

[050] As used herein, the term “threshold” refers to a maximum level, a minimum level, and/or range of values correlating to a desired or undesired state. In some embodiments, a system parameter is maintained above a minimum threshold, below a maximum threshold, within a threshold range of values, and/or outside a threshold range of values, such as to cause a desired effect (e.g. efficacious therapy) and/or to prevent or otherwise reduce (hereinafter “prevent”) an undesired event (e.g. a device and/or clinical adverse event). In some embodiments, a system parameter is maintained above a first threshold (e.g. above a first temperature threshold to cause a desired therapeutic effect to tissue) and below a second threshold (e.g. below a second temperature threshold to prevent undesired tissue damage). In some embodiments, a threshold value is determined to include a safety margin, such as to account for patient variability, system variability, tolerances, and the like. As used herein, “exceeding a threshold” relates to a parameter going above a maximum threshold, below a minimum threshold, within a range of threshold values and/or outside of a range of threshold values.

[051] As described herein, “room pressure” shall mean pressure of the environment surrounding the systems and devices of the present inventive concepts. Positive pressure includes pressure above room pressure or simply a pressure that is greater than another pressure, such as a positive differential pressure across a fluid pathway component such as a valve. Negative pressure includes pressure below room pressure or a pressure that is less than another pressure, such as a negative differential pressure across a fluid component pathway such as a valve. Negative pressure can include a vacuum but does not imply a pressure below a vacuum. As used herein, the term “vacuum” can be used to refer to a full or partial vacuum, or any negative pressure as described hereabove.

[052] The term “diameter” where used herein to describe a non-circular geometry is to be taken as the diameter of a hypothetical circle approximating the geometry being described. For example, when describing a cross section, such as the cross section of a component, the term “diameter” shall be taken to represent the diameter of a hypothetical circle with the same cross sectional area as the cross section of the component being described.

[053] The terms “major axis” and “minor axis” of a component where used herein are the length and diameter, respectively, of the smallest volume hypothetical cylinder which can completely surround the component.

[054] As used herein, the term “functional element” is to be taken to include one or more elements constructed and arranged to perform a function. A functional element can comprise a sensor and/or a transducer. In some embodiments, a functional element is configured to deliver energy and/or otherwise treat tissue (e.g. a functional element configured as a treatment element). Alternatively or additionally, a functional element (e.g. a functional element comprising a sensor) can be configured

to record one or more parameters, such as a patient physiologic parameter; a patient anatomical parameter (e.g. a tissue geometry parameter); a patient environment parameter; and/or a system parameter. In some embodiments, a sensor or other functional element is configured to perform a diagnostic function (e.g. to gather data used to perform a diagnosis). In some embodiments, a functional element is configured to perform a therapeutic function (e.g. to deliver therapeutic energy and/or a therapeutic agent). In some embodiments, a functional element comprises one or more elements constructed and arranged to perform a function selected from the group consisting of: deliver energy; extract energy (e.g. to cool a component); deliver a drug or other agent; manipulate a system component or patient tissue; record or otherwise sense a parameter such as a patient physiologic parameter or a system parameter; and combinations of one or more of these. A functional element can comprise a fluid and/or a fluid delivery system. A functional element can comprise a reservoir, such as an expandable balloon or other fluid-maintaining reservoir. A “functional assembly” can comprise an assembly constructed and arranged to perform a function, such as a diagnostic and/or therapeutic function. A functional assembly can comprise an expandable assembly. A functional assembly can comprise one or more functional elements.

[055] The term “transducer” where used herein is to be taken to include any component or combination of components that receives energy or any input, and produces an output. For example, a transducer can include an electrode that receives electrical energy, and distributes the electrical energy to tissue (e.g. based on the size of the electrode). In some configurations, a transducer converts an electrical signal into any output, such as: light (e.g. a transducer comprising a light emitting diode or light bulb), sound (e.g. a transducer comprising a piezo crystal configured to deliver ultrasound energy); pressure (e.g. an applied pressure or force); heat energy; cryogenic energy; chemical energy; mechanical energy (e.g. a transducer comprising a motor or a solenoid); magnetic energy; and/or a different electrical signal (e.g. different than the input signal to the transducer). Alternatively or additionally, a transducer can convert a physical quantity (e.g. variations in a physical quantity) into an electrical signal. A transducer can include any component that delivers energy and/or an agent to tissue, such as a transducer configured to deliver one or more of: electrical energy to tissue (e.g. a transducer comprising one or more electrodes); light energy to tissue (e.g. a transducer comprising a laser, light emitting diode and/or optical component such as a lens or prism); mechanical energy to tissue (e.g. a transducer comprising a tissue manipulating element); sound energy to tissue (e.g. a transducer comprising a piezo crystal); chemical energy; electromagnetic energy; magnetic energy; and combinations of one or more of these.

[056] As used herein, the term “fluid” can refer to a liquid, gas, gel, or any flowable material, such as a material which can be propelled through a lumen, a needle, a nozzle, and/or an opening.

[057] As used herein, the term “material” can refer to a single material, or a combination of two, three, four, or more materials.

[058] It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable sub-combination. For example, it will be appreciated that all features set out in any of the claims (whether independent or dependent) can be combined in any given way.

[059] It is to be understood that at least some of the figures and descriptions of the invention have been simplified to focus on elements that are relevant for a clear understanding of the invention, while eliminating, for purposes of clarity, other elements that those of ordinary skill in the art will appreciate may also comprise a portion of the invention. However, because such elements are well known in the art, and because they do not necessarily facilitate a better understanding of the invention, a description of such elements is not provided herein.

[060] Terms defined in the present disclosure are only used for describing specific embodiments of the present disclosure and are not intended to limit the scope of the present disclosure. Terms provided in singular forms are intended to include plural forms as well, unless the context clearly indicates otherwise. All of the terms used herein, including technical or scientific terms, have the same meanings as those generally understood by an ordinary person skilled in the related art, unless otherwise defined herein. Terms defined in a generally used dictionary should be interpreted as having meanings that are the same as or similar to the contextual meanings of the relevant technology and should not be interpreted as having ideal or exaggerated meanings, unless expressly so defined herein. In some cases, terms defined in the present disclosure should not be interpreted to exclude the embodiments of the present disclosure.

[061] Provided herein are systems, devices and method for performing medical procedures in the intestine of a patient. A medical device for performing a treatment and/or a diagnostic procedure can include an elongate shaft assembly comprising at least a shaft assembly first section comprising a distal section of the shaft assembly, and a shaft assembly second section proximal to the first section, and a functional assembly positioned on the shaft assembly first section. Additional sections of the shaft assembly can be included, and each section can comprise a different construction, such as to achieve a different stiffness as described herein. Variable stiffness along the length of the shaft assembly can be provided to aid in translation of the device through the patient's GI tract (e.g. through the stomach and into the small intestine), as described herein. The medical device can include a shaft assembly comprising a proximal portion and a distal portion, with at least two lumens passing therethrough. A functional assembly for performing a treatment and/or a diagnosis can be

positioned on the distal portion of the shaft assembly. An injection assembly can also be included, and the assembly can comprise at least one attached port and at least one conduit operably connecting one of the at least two lumens of the shaft assembly to the at least one port. The at least one conduit can be rotated about the distal portion of the shaft assembly.

[062] **Referring now to Fig. 1**, a system for treating and/or diagnosing (“treating” herein) gastrointestinal tissue is illustrated, consistent with the present inventive concepts. System 10 includes console 100 that operably attaches to a catheter, catheter 200. System 10 and catheter 200 can be used by an operator (e.g. one or more clinicians) to perform a medical procedure, such as a therapeutic procedure and/or a diagnostic procedure. Catheter 200 can be constructed and arranged to treat and/or diagnose target tissue, such as tissue of the small intestine (e.g. mucosal tissue of the duodenum and/or jejunum) and/or other locations within the gastrointestinal (GI) tract. Catheter 200 can be constructed and arranged to ablate or remove tissue, such as by delivering energy and/or an agent (e.g. a necrotic agent) to tissue. Alternatively or additionally, catheter 200 can be constructed and arranged to expand one or more layers of tissue of the GI tract, such as when a submucosal tissue expansion procedure is performed in one segment of the GI tract after which an energy delivery to mucosal tissue is performed in that same segment. Catheter 200 can be constructed and arranged to treat multiple relatively contiguous segments (“contiguous segments” herein) or non-contiguous segments of the GI tract. In some embodiments, two or more axial segments of submucosal tissue of intestine are expanded, after which a single ablation procedure is performed (e.g. an ablation of a length of tissue of similar or lesser length as compared to the cumulative length of submucosal tissue expanded, such as when the length treated by a single ablation step is greater than the length expanded in a single tissue expansion step), such as is described herein in reference to Figs. 1B and 1C. Alternatively or additionally, a single axial segment of submucosal tissue of the intestine is expanded, after which a single ablation procedure is performed (e.g. in the same axial location without movement of catheter 200). In some embodiments, a pre-treatment (e.g. pre-cooling) procedure is performed during the submucosal expansion, after which the tissue is treated (e.g. ablated via heat and/or other thermal ablation). Pre-treating of the target tissue and/or tissue proximate the target tissue is described herein. In some embodiments, an ablation procedure is performed in a segment of the intestine where a submucosal tissue expansion has not been performed.

[063] In some embodiments, system 10 comprises one or more body access devices, such as endoscope 50 shown. Catheter 200 can be configured to be inserted through one or more working channels of endoscope 50 and/or alongside endoscope 50. In some embodiments, catheter 200 is inserted through a sheath attached to endoscope 50. Catheter 200 can comprise a length such that it

can be inserted through the patient's mouth and into one or more locations within the stomach, the duodenum, the jejunum and/or the ileum.

[064] In some embodiments, system 10 comprises one or more guidewires, such as guidewire 60 shown. In these embodiments, catheter 200 can be advanced over guidewire 60, such as by using standard over-the-wire techniques, through one or more lumens of catheter 200.

[065] Console 100 can include one or more conduits, conduit 191 configured to transport fluid to and/or from console 100. Console 100 can include pump assembly 195 that includes one or more pumps or other fluid delivery mechanisms ("pump" herein) that deliver fluid (e.g. a liquid, a gas, and/or a gel) into one or more fluid pathways or other locations within catheter 200. Console 100 can include one or more reservoirs that store these fluids to be delivered. Alternatively or additionally, console 100 can be attachable to a fluid-storing reservoir separate from console 100 (or positioned in a second housing of console 100). Pump assembly 195 and/or another component of console 100 can include one or more pumps or other fluid removal mechanisms ("pump" herein) that extract fluid from one or more lumens or other locations within catheter 200. Console 100 can include one or more reservoirs that store these removed fluids, or they can be stored in a reservoir separate from console 100 (or positioned in a second housing of console 100). Pump assembly 195 and/or another component of console 100 can include one or more pumps or other vacuum generating mechanisms ("pump" herein) that generate a vacuum that can cause a negative pressure within one or more lumens or other locations within catheter 200.

[066] Console 100 can comprise one or more discrete components, such as one or more components each with a discrete (i.e. separate) housing that surrounds one or more pumps and/or reservoirs.

[067] In some embodiments, console 100 comprises vacuum supply 110. Vacuum supply 110 can comprise one or more pumps configured to generate a vacuum within catheter 200 and/or other component of system 10. In some embodiments, vacuum supply 110 includes one or more reservoirs configured to reduce variations in vacuum pressure. Vacuum supply 110 can provide a vacuum to one, two, three or more ports configured to engage tissue, such as tissue capture chambers 510 described herein. Vacuum supply 110 can be configured to provide a vacuum pressure of between -2psi and -14.7psi, such as between -4psi and -14.7psi. In some embodiments, system 10 can be configured to operate with vacuum supply 110 providing a vacuum pressure of between -6psi and -12.5psi. Additionally or alternatively, vacuum supply 110 and/or another component of console 100 can comprise at least one sensor, such as a sensor-based functional element 199, configured to monitor the pressure of vacuum supply 110, and provide an alert (e.g. an alert to the operator and/or enter a system wide alert mode) if the vacuum pressure is insufficient or otherwise undesired (e.g. if the vacuum pressure is above or below a desired level, an expected level, and/or other threshold). In

some embodiments, a minimum vacuum threshold can comprise a threshold of at least -4.4 psi, at least -6psi, and/or at least -12psi. In some embodiments, vacuum supply 110 includes or otherwise provides an aspiration reservoir, such as to remove a fluid from locations proximate the distal end of catheter 200 (e.g. gas or other fluid within the GI tract removed in a desufflation procedure and/or a fluid within a distal portion of catheter 200).

[068] In some embodiments, console 100 comprises injectate fluid supply 120. Injectate supply 120 can comprise one or more pumps configured to deliver one or more injectates, injectate 125 shown, to catheter 200 and/or other component of system 10. In some embodiments, injectate supply 120 includes one or more reservoirs configured to store injectate 125. In some embodiments, injectate supply 120 comprise a pump (e.g. a syringe pump configured to drive 1, 2, 3 or more syringes simultaneously or sequentially), such as a pump that is part of pump assembly 195. In some embodiments, injectate supply 120 comprises injectate 125. Injectate supply 120 can deliver fluid to one, two, three or more elements configured to deliver injectate 125 onto and/or into tissue, such as injectate delivery elements 520 described herein. In some embodiments, a single pump (e.g. a single syringe pump) is configured to deliver fluid to two or more injectate delivery elements 520. Injectate supply 120 can be configured to deliver fluid at a flow rate of at least 10mL/min, such as at a flow rate of at least 15mL/min, 20mL/min, 40mL/min, 60mL/min, or 120mL/min. In some embodiments, injectate supply 120 delivers fluid via two or more injectate delivery elements 520 simultaneously (e.g. in a tissue expansion procedure), the fluid delivered at a rate of at least 10mL/min per injectate delivery element 520, such as at a rate of at least 12.5mL/min, 15mL/min, 20mL/min, 40mL/min, 60mL/min, or 120mL/min per fluid delivery element. In some embodiments, injectate supply 120 is configured to deliver a volume between 2mL and 20mL (e.g. approximately 10mL) to each of multiple injectate delivery elements 520 simultaneously (e.g. two, three or four injectate delivery elements 520 simultaneously), such as a delivery provided in a time period of less than 60 seconds, less than 40 seconds, less than 30 seconds, less than 20 seconds, less than 10 seconds, and/or less than 5 seconds (e.g. in a tissue expansion procedure). Injectate supply 120 can be further configured to deliver fluid (e.g. to injectate delivery elements 520, conduits 521, and/or another component of system 10) at a pressure of at least 40psi, such as fluid delivered at a pressure of at least 75psi, 100psi, 200psi, or 300psi. Injectate supply 120 can be configured to provide a bolus of injectate 125 to two, three or more injectate delivery elements 520 (simultaneously or sequentially) in order to expand an axial segment of submucosal tissue (e.g. a full or partial circumferential band of submucosal tissue with a length of at least 0.25cm, at least 0.5cm, at least 0.75cm, at least 1cm, at least 2cm, or at least 3cm), such as to achieve an expansion of the submucosal layer to a thickness (e.g. an expanded thickness) of at least 250µm, at least 400µm, or at least 650µm (e.g. in the area surrounding the volume of mucosal tissue to be subsequently ablated).

[069] Injectate 125 can comprise one or more liquids, gels, and/or other flowable materials (“fluids” herein) for injecting into tissue, such as to expand one or more layers of tissue (e.g. submucosal tissue expanded prior to a mucosal ablation procedure) and/or to narrow a lumen of the intestine and/or other segment of the GI tract (e.g. to create a therapeutic restriction). Alternatively or additionally, injectate 125 can comprise an agent configured to cause tissue necrosis. Alternatively or additionally, injectate 125 can comprise a warming and/or cooling fluid delivered onto and/or into tissue (e.g. a neutralizing fluid such as neutralizing fluid 155 configured to limit, stop and/or at least reduce ablation performed by functional assembly 500). In some embodiments, injectate 125 comprises one, two or more materials selected from the group consisting of: a peptide polymer (e.g. a peptide polymer configured to stimulate fibroblasts to produce collagen); polylactic acid; polymethylmethacrylate (PMMA); a hydrogel; ethylene vinyl alcohol (EVOH); a material configured to polymerize EVOH; dimethyl sulfoxide (DMSO); saline; material harvested from a mammalian body; autologous material; fat cells; collagen; autologous collagen; bovine collagen; porcine collagen; bioengineered human collagen; dermis; a dermal filler; hyaluronic acid; conjugated hyaluronic acid; calcium hydroxylapatite; fibroblasts; a sclerosant; an adhesive; cyanoacrylate; a pharmaceutical agent; a visualizable material; a radiopaque material; a visible dye; ultrasonically reflective material; a combination of materials configured to cause an endothermic reaction when mixed (e.g. when mixed in tissue); a combination of materials configured to cause an exothermic reaction when mixed (e.g. when mixed in tissue); a combination of material configured to expand when mixed (e.g. when mixed in tissue); and combinations of one or more of these. In some embodiments, injectate 125 comprises beads (e.g. pyrolytic carbon-coated beads) suspended in a carrier (e.g. a water-based carrier gel). In some embodiments, injectate 125 comprises a solid silicone elastomer (e.g. heat-vulcanized polydimethylsiloxane) suspended in a carrier, such as a bio-excretable polyvinylpyrrolidone (PVP) carrier gel. In some embodiments, injectate 125 has an adjustable degradation rate, such as an injectate 125 comprising one or more cross linkers in combination with polyalkyleneimines at specific concentrations that result in hydrogels with adjustable degradation properties. In some embodiments, injectate 125 and/or agent 80 (e.g. as described herein) comprises living cells, such as living cells injected into the mucosa or submucosa of the intestine to provide a therapeutic benefit.

[070] In some embodiments, injectate 125 comprises a visualizable and/or otherwise detectable (e.g. magnetic) material (e.g. in addition to one or more materials of above) selected from the group consisting of: a dye; a visible dye; indigo carmine; methylene blue; India ink; SPOT™ dye; a visualizable media; radiopaque material; radiopaque powder; tantalum; tantalum powder; ultrasonically reflective material; magnetic material; ferrous material; and combinations of one or more of these.

[071] In some embodiments, a volume of injectate 125 is delivered into tissue to create a therapeutic restriction (e.g. a therapeutic restriction with an axial length between 1mm and 20mm), as described herein, and/or as is described in applicant's co-pending United States Patent Application Serial Number 17/095,108, entitled "Systems, Devices and Methods for the Creation of a Therapeutic Restriction in the Gastrointestinal Tract", filed November 11, 2020. In some embodiments, a volume of injectate 125 is delivered into tissue to create a safety margin of tissue prior to an ablation procedure configured to ablate target tissue, as is described herein.

[072] In some embodiments, injectate 125 comprises a fluorescent-labeled material or other biomarker configured to identify the presence of a biological substance, such as to identify diseased tissue and/or other tissue for treatment by functional assembly 500 (e.g. to identify target tissue). For example, injectate 125 can comprise a material configured to be identified by imaging device 70 (described below), such as to identify a visualizable change to injectate 125 that occurs after contacting one or more biological substances. In these embodiments, imaging device 70 can comprise a molecular imaging device, such as when imaging device 70 comprises a molecular imaging probe and injectate 125 comprises an associated molecular imaging contrast agent. In these embodiments, injectate 125 can be configured to identify diseased tissue and/or to identify a particular level of one or more of pH, tissue oxygenation, blood flow, and the like. Injectate 125 can be configured to be delivered onto an inner surface of intestinal or other tissue, and/or to be delivered into tissue (i.e. beneath a tissue surface).

[073] In some embodiments, console 100 comprises inflation fluid supply 130. Inflation fluid supply 130 can comprise one or more pumps configured to deliver one or more fluids, inflation fluid 135 shown, to inflate one or more portions of catheter 200 and/or other component of system 10. In some embodiments, inflation fluid supply 130 includes one or more reservoirs configured to store inflation fluid 135. In some embodiments, inflation fluid supply 130 comprises inflation fluid 135. Inflation fluid supply 130 can deliver inflation fluid 135 to a balloon or other reservoir (e.g. other fluid expandable component), such as expandable element 530 described herein. Inflation fluid supply 130 can be configured to deliver a bolus volume of fluid to expandable element 530, such as a bolus of between 0.1mL and 12mL, such as an operator selectable bolus volume of 6mL, 8mL, and/or 10mL. Inflation fluid supply 130 can be configured to deliver fluid to expandable element 530 at a pressure of between 0.1psi and 5psi. In some embodiments, inflation fluid supply 130 delivers fluid to expandable element 530 prior to a tissue expansion procedure as described herein, in which a separate fluid, e.g. injectate 125, is delivered directly into submucosal or other tissue via one, two or more injectate delivery elements 520. In these embodiments, the fluid provided to expandable element 530 by inflation fluid supply 130 can comprise inflation fluid 135 and/or a different fluid, such as neutralizing fluid 155. Neutralizing fluid 155 can be delivered to expandable

element 530 in a submucosal expansion procedure, such as to provide the additional function of pre-cooling or pre-warming tissue proximate element 530 prior to a subsequent thermal ablation procedure (e.g. a heat ablation or cryogenic ablation, respectively, performed by element 530).

Alternatively or additionally, inflation fluid supply 130 can deliver neutralizing fluid 155 to element 530 in a tissue expansion procedure performed shortly after a (previous) ablation procedure, such as to perform a post-cooling and/or post-warming of tissue configured to limit the effects of a heat ablation or cryogenic ablation, respectively. For example, pre or post-cooling, and/or pre or post-warming can be performed to reduce time in a previous and/or a subsequent ablation step.

[074] In some embodiments, console 100 comprises ablative fluid supply 140. Ablative fluid supply 140 can comprise one or more pumps configured to deliver one or more ablative fluids, ablative fluid 145 shown, to one or more portions of catheter 200 and/or other component of system 10. In some embodiments, ablative fluid supply 140 includes one or more reservoirs configured to store ablative fluid 145. In some embodiments, ablative fluid supply 140 comprises ablative fluid 145. Ablative fluid supply 140 can deliver ablative fluid 145 to a balloon and/or other fluid storing assembly and/or component of catheter 200, such as an ablative fluid reservoir (e.g. a balloon), expandable element 540 and/or another expandable element 530 described herein. Alternatively or additionally, ablative fluid supply 140 can deliver ablative fluid 145 to one, two, three or more fluid delivery elements configured to deliver fluid onto and/or within tissue, such as injectate delivery elements 520 described herein. Ablative fluid supply 140 can be configured to deliver ablative fluid at a flow rate of at least 5mL/s, such as at least 8mL/s, 9mL/s, 10mL/s, 15mL/s, and/or 20mL/s. In some embodiments, catheter 200 comprises a hydraulic inflow resistance (resistance to ablative fluid supply 140 and/or another fluid supply described herein) of less than 0.05 psi/(mL/min), such as less than 0.036psi/(mL/min) (e.g. when measured at 85°C at a flow rate of 570mL/min). In some embodiments, catheter 200 comprises a hydraulic inflow resistance of at least 0.020 psi/(mL/min), such as at least 0.030psi/(mL/min) (e.g. when measured at 85°C at a flow rate of 570mL/min). In some embodiments, catheter 200 comprises a hydraulic outflow resistance less than 0.070 psi/(mL/min), such as less than 0.63psi/(mL/min) (e.g. when measured at 85°C at a flow rate of 570mL/min). In some embodiments, catheter 200 comprises a hydraulic outflow resistance of at least 0.040psi/(mL/min), such as at least 0.53psi/(mL/min) (e.g. when measured at 85°C at a flow rate of 570mL/min). Additionally or alternatively, ablative fluid supply 140 can be configured to deliver ablative fluid at a pressure of approximately 40psi (pressure leaving console 100), such that the pressure of the ablative fluid within expandable element 530 is approximately 20psi. In some embodiments, ablative fluid supply 140 provides fluid at an ablative temperature (e.g. sufficiently hot or sufficiently cold temperature) in a recirculating manner.

[075] In some embodiments, catheter 200 comprises an inflow pressure drop (e.g. a pressure drop due to flow resistance) of between 17psi and 21psi, such as when tested with a flow rate of 10mL/s of water at 80°C. Additionally or alternatively, catheter 200 can comprise an inflow pressure drop of between 21psi and 25psi, such as when tested with a flow rate of 10mL/s of water at 20°C. In some embodiments, the inflow pressure drop is no more than 50psi, such as no more than 30psi, such as no more than 20.5psi. In some embodiments, the inflow pressure drop is at least 0.5psi, such as at least 1psi, such as at least 5psi, such as at least 15psi. In some embodiments, catheter 200 comprises a total pressure drop (e.g. a pressure drop due to the flow resistance throughout the entire fluid path) of between 30psi and 40psi, such as when tested with a flow rate of 10mL/s of water at 80°C.

Additionally or alternatively, catheter 200 can comprise a total pressure drop of between 39psi and 50psi, such as when tested with a flow rate of 10mL/s of water at 20°C. In some embodiments the total inflow pressure drop is no more than 80psi, such as no more than 60psi, such as no more than 50psi. In some embodiments, the total pressure drop is at least 1psi, such as at least 5psi, such as at least 15psi, such as at least 30psi, such as at least 35psi.

[076] In some embodiments, console 100 comprises neutralizing fluid supply 150. Neutralizing fluid supply 150 can comprise one or more pumps configured to deliver one or more neutralizing fluids, neutralizing fluid 155 shown, to one or more portions of catheter 200 and/or other component of system 10 (e.g. a fluid configured to neutralize ablative effects of an ablative fluid delivered by ablative fluid supply 140). In some embodiments, neutralizing fluid supply 150 includes one or more reservoirs configured to store neutralizing fluid 155. In some embodiments, neutralizing fluid supply 150 comprises neutralizing fluid 155. Neutralizing fluid supply 150 can deliver neutralizing fluid 155 to a balloon and/or other fluid storing assembly or component of catheter 200, such as a neutralizing fluid reservoir, expandable element 550, expandable element 540, and/or other expandable element 530 described herein. Alternatively or additionally, neutralizing fluid supply 150 can deliver neutralizing fluid 155 to one, two, three or more fluid delivery elements configured to deliver fluid onto and/or within tissue, such as injectate delivery elements 520 described herein. Neutralizing fluid supply 150 can be configured to deliver neutralizing fluid at a flow rate of at least 5mL/s, such as at least 8mL/s, 9mL/s, 10mL/s, 15mL/s, or 20mL/s. Additionally or alternatively, neutralizing fluid supply 150 can be configured to deliver neutralizing fluid at a pressure of approximately 40psi (pressure leaving console 100), such that the pressure of the neutralizing fluid within expandable element 530 is approximately 20psi. In some embodiments, neutralizing fluid supply 150 is configured to deliver neutralizing fluid 155 at a pressure of between 20psi and 60psi, such as between 30psi and 50psi. In some embodiments, neutralizing fluid 155 pressure is delivered at less than 100psi. In some embodiments, ablative fluid 145 provided by ablative fluid supply 140 is delivered to a fluid storing component of catheter 200 (e.g. expandable element 530) and

neutralizing fluid 155 provided by neutralizing fluid supply 150 is delivered onto and/or within tissue (e.g. via one or more injectate delivery elements 520). Alternatively or additionally, ablative fluid 145 provided by ablative fluid supply 140 can be delivered onto and/or within tissue (e.g. via one or more injectate delivery elements 520), while neutralizing fluid 155 provided by neutralizing fluid supply 150 is delivered to a balloon and/or other fluid storing assembly or component of catheter 200, such as expandable element 530, expandable element 540, and/or expandable element 550 described herein. In some embodiments, ablative fluid supply 140 comprises neutralizing fluid supply 150 (e.g. a single assembly comprising one or more pumps that provide both ablative fluid 145 and neutralizing fluid 155 from one, two or more reservoirs).

[077] In some embodiments, inflation fluid supply 130, ablative fluid supply 140, neutralizing fluid supply 150 and/or another fluid delivery assembly of console 100 is configured to provide fluid (e.g. inflation fluid 135, ablative fluid 145 and/or neutralizing fluid 155) to functional assembly 500 (e.g. to one or more expandable elements 530) at a flow rate of at least 2mL/sec, such as at least 5mL/sec, or at a flow rate of approximately 9.5mL/sec. In some embodiments, console 100 provides fluid to functional assembly 500 at a flow rate of no more than 30mL/sec.

[078] In some embodiments, console 100 comprises fluid removal pump 160. Fluid removal pump 160 can comprise one or more pumps configured to remove fluid from one or more portions of catheter 200 or other component of system 10. In some embodiments, fluid removal pump 160 includes one or more reservoirs configured to store the one or more removed fluids. In some embodiments, fluid removed by fluid removal pump 160 is recirculated to one or more other assemblies of console 100, such as inflation fluid supply 130, ablative fluid supply 140, neutralizing fluid supply 150, insufflation supply 170 (described herein) and/or functional fluid supply 180 (also described herein). Fluid removal pump 160 can remove fluid from a balloon or other fluid storing assembly or component of catheter 200, such as expandable element 530, expandable element 540, and/or expandable element 550 described herein. In some embodiments, fluid removal pump 160 is configured to remove (e.g. from catheter 200 and/or any component of system 10) injectate 125, inflation fluid 135, ablative fluid 145, neutralizing fluid 155, insufflation fluid 175, and/or functional fluid 185, each as described herein. In some embodiments, catheter 200 comprises a hydraulic outflow resistance as described herein in reference to ablation fluid supply 140. In some embodiments, ablative fluid supply 140 and/or neutralizing fluid supply 150 comprise fluid removal pump 160. In some embodiments, pump assembly 195 comprises fluid removal pump 160.

[079] In some embodiments, console 100 comprises insufflation supply 170. Insufflation supply 170 can comprise one or more pumps configured to deliver a gas or other insufflation fluid, insufflation fluid 175 shown, to inflate the duodenum or other segment of the patient's GI tract. Alternatively or additionally, insufflation supply 170 can be configured to remove insufflation fluid

175 and/or other fluid from the duodenum or other segment of the patient's GI tract (i.e. perform a desufflation). In some embodiments, insufflation supply 170 includes one or more reservoirs configured to store insufflation fluid 175 (to be provided and/or recently removed). In some embodiments, insufflation supply 170 comprises insufflation fluid 175. Insufflation supply 170 can deliver and/or remove fluids via catheter 200 and/or a separate component of system 10, such as an endoscope or other body access device, endoscope 50.

[080] In some embodiments, console 100 comprises functional fluid supply 180. Functional fluid supply 180 can provide functional fluid 185 to one or more components or assemblies of catheter 200 and/or other component of system 10. In some embodiments, functional fluid 185 comprises a hydraulic or pneumatic fluid ("hydraulic fluid" herein). In some embodiments, functional fluid 185 comprises a conductive fluid, such as a fluid configured to transmit electrical power and/or electrical signals between functional assembly 500 and console 100.

[081] As described herein, console 100 can comprise one or more pumps, pump assembly 195. Pump assembly 195 can be configured to deliver and/or extract fluids from catheter 200 (e.g. with or without an intermediate connection device such as umbilical 600 described herein). In some embodiments, pump assembly 195 is fluidly attached to at least injectate supply 120 and/or inflation supply 130, such as to supply injectate 125 and/or inflation fluid 135, respectively, to catheter 200. In some embodiments, pump assembly 195 is fluidly attached to injectate supply 120, inflation fluid supply 130, ablative fluid supply 140, neutralizing fluid supply 150, insufflation supply 170, and/or functional fluid supply 180, such as to deliver and/or remove their associated fluids to and/or from catheter 200. In some embodiments, one or more of injectate supply 120, inflation fluid supply 130, ablative fluid supply 140, neutralizing fluid supply 150, insufflation supply 170, and/or functional fluid supply 180 comprise one or more pumps integrated into their assembly (e.g. one or more pumps of pump assembly 195 are integrated into the supply). In some embodiments, pump assembly 195 is configured as described herebelow in reference to Fig. 1A.

[082] Console 100 comprises one or connectors, connector 102 shown, which fluidly connects to one or more of assemblies 110, 120, 130, 140, 150, 160, 170, and/or 180 of console 100 described herein, via conduits 111, 121, 131, 141, 151, 161, 171, and/or 181, respectively. In some embodiments, console 100 comprises pump assembly 195, which fluidly connects conduits 111, 121, 131, 141, 151, 161, 171, and/or 181 to connector 102 via one or more other conduits, such as conduit 191 shown. Alternatively or additionally, console 100 can comprise one or more manifolds, manifold 700a shown, which fluidly connects conduits 111, 121, 131, 141, 151, 161, 171, and/or 181 to connector 102 via one or more other conduits, such as conduit 191 shown. Alternatively, conduits 111, 121, 131, 141, 151, 161, 171, and/or 181 directly attach to connector 102 (i.e. without pump assembly 195 and/or without manifold 700a). Manifold 700a can be constructed and arranged to

fluidly combine one or more of conduits 111, 121, 131, 141, 151, 161, 171 and/or 181. Alternatively or additionally, manifold 700a can be constructed and arranged to split (divide) one or more of conduits 111, 121, 131, 141, 151, 161, 171, and/or 181 into multiple conduits. In some embodiments, manifold 700a includes one or more valves configured to control flow of fluid in a conduit. In some embodiments, manifold 700a includes one or more sensors (e.g. temperature and/or pressure sensors) configured to provide a signal related to a parameter (e.g. temperature and/or pressure) of fluid within a conduit.

[083] In some embodiments, system 10 comprises a connecting device, umbilical 600 which operably connects (e.g. at least fluidly connects) catheter 200 to console 100. Alternatively or additionally, catheter 200 can attach directly to console 100 (e.g. connector 102 of console 100 attaches directly to connector 302 of catheter 200). Umbilical 600 comprises one or more proximal connectors, connector 602a shown, which operably attaches to mating connector 102 of console 100. Umbilical 600 comprises one or more distal connectors, connector 602b shown, which operably attaches to mating connector 302 of handle assembly 300 of catheter 200. Umbilical 600 can comprise one or more fluid delivery tubes or other fluid-transporting conduits, conduit 691 shown. Conduit 691 comprises one or more lumens or other conduits configured to allow passage of one or more similar and/or dissimilar fluids between console 100 and catheter 200. Each conduit can be configured to receive one or more shafts or other conduits which transport one or more fluids. In some embodiments, umbilical 600 further comprises one or more of: wires or other electrical filaments configured to transmit electrical power and/or signals; optical fibers or other conduits configured to transmit optical power and/or signals; waveguides or other sound conduits configured to transmit sonic power and/or signals; mechanical linkages (e.g. translatable rods); and/or other elongate structures configured to transmit energy, signals, and/or mechanical motion between console 100 and catheter 200. In some embodiments, umbilical 600 comprises one or more sensors, transducers, and/or other functional elements, such as functional element 699 described herein. Functional element 699 can be positioned proximate conduit 691 as shown, positioned proximate connector 602a, and/or positioned proximate connector 602b.

[084] Catheter 200, including distal portion 208 and distal end 209, comprises handle assembly 300, shaft assembly 400, and functional assembly 500. Handle assembly 300 is positioned on the proximal end or at least a proximal portion of shaft assembly 400, and functional assembly 500 is positioned on catheter 200 distal portion 208 (e.g. on the distal end or at least a distal portion of shaft assembly 400).

[085] Shaft assembly 400 includes at least one elongate shaft, shaft 401, which comprises one or more lumens or other conduits, conduit 491, each of which can be configured to attach to one or more conduits of handle 300, conduit 391. In some embodiments, one or more conduits of conduit

491 simply passes through handle 300 (e.g. to operably attach to umbilical 600 and/or console 100). Each conduit of shaft 401 can be configured to transport fluid and/or it can be sized to receive (e.g. slidably receive) one or more separate shafts, such as one or more shafts that transport fluid. In some embodiments, one or more lumens of shaft 401 receive a separate shaft, and fluid is transported within the received shaft and/or between the outer diameter of the received shaft and the wall of the lumen of shaft 401, such as is described herein. Alternatively or additionally, each lumen of shaft 401 and/or one or more shafts inserted within the lumen can surround (e.g. slidably or fixedly surround) one or more conduits configured to transmit energy, signals, and/or mechanical motion between console 100 and catheter 200, as described herein. In some embodiments one or more conduits 491 are fixedly attached within shaft 401 with adhesive, such as with one or more rings of adhesive positioned about the outer wall of a conduit 491 and a surrounding wall (e.g. the inner wall of a sleeve, lumen, or other tube) onto which conduit 491 is to be fixedly attached. For example, two or more rings of adhesive can be positioned between the outer wall of a conduit 491 and a surrounding wall (e.g. a surrounding wall of a sleeve) to prevent undesired translation of the conduit 491.

[086] Shaft assembly 400 comprises proximal end 405, proximal portion 406, middle portion 407, distal portion 408, and distal end 409. Distal portion 408 is shown in a magnified view. Positioned on distal portion 408 is functional assembly 500, configured as a treatment assembly and/or diagnostic assembly (e.g. an assembly configured to treat and/or diagnose tissue of the intestine or other GI tract tissue). In some embodiments, shaft 401 extends through and beyond functional assembly 500 (as shown in Fig. 1, where catheter 200 distal end 209 is the same as shaft assembly 400 distal end 409). Alternatively, functional assembly 500 can be positioned on the distal end of shaft 401. In some embodiments, shaft 401 comprises a twist, such as is described herebelow in reference to Fig. 4. In some embodiments, shaft 401 comprises a bulbous tip. In some embodiments, shaft 401 comprises a tapered tip, such as is described herebelow in reference to Figs. 3A and 3B.

[087] In some embodiments, shaft assembly 400 comprises a lumen to slidably receive a guidewire, such as a passageway including a lumen which exits at a location proximate the distal end 409 of shaft assembly 400 at an opening, port 490. In some embodiments, shaft assembly 400 comprises one or more lumens for performing insufflation and/or desufflation (“insufflation” herein), such as conduit 571 comprising one or more lumens which terminate in one or more openings, such as port 470_D positioned distal to functional assembly 500 and port 470_P positioned proximal to functional assembly 500, each as shown and described herein. In some embodiments, port 470_P and/or port 470_D is configured to perform desufflation only, or insufflation only.

[088] In some embodiments, shaft assembly 400 comprises one or more manifolds, manifold 700c and/or 700d shown, which fluidly connects one or more conduits of conduit 491 to one or more other conduits (e.g. one or more other conduits of conduit 491 or one or more other conduits of catheter 200). Manifolds 700c and/or 700d can be constructed and arranged to fluidly combine one or more of lumens of conduit 491. Alternatively or additionally, manifolds 700c and/or 700d can be constructed and arranged to split (divide) one or more of lumens of conduit 491 into multiple lumens. In some embodiments, manifolds 700c and/or 700d includes one or more valves (e.g. one or more one-way valves) configured to control flow of fluid in a conduit. In some embodiments, manifolds 700c and/or 700d includes one or more sensors (e.g. temperature and/or pressure sensors) configured to provide a signal related to a parameter (e.g. temperature and/or pressure) of fluid within a conduit.

[089] In some embodiments, shaft assembly 400 comprises one or more sensors, transducers, and/or other functional elements, such as functional element 499a (e.g. positioned in a mid-portion of shaft 401 and/or proximate manifold 700c) and/or functional element 499b (e.g. positioned proximate manifold 700d and/or functional assembly 500) as shown and described herein. In some embodiments, functional element 499a and/or 499b comprises a radiopaque marker and/or other visualizable marker, as described herein, configured to allow an operator to visualize translation and/or rotation of shaft assembly 400 (e.g. to visualize translation and/or rotation of functional assembly 500), such as via imaging device 70 (e.g. a fluoroscope or other imaging device).

[090] Shaft 401 can comprise a length of at least 60", such as at least 72". In some embodiments, shaft 401 comprises an outer diameter of less than 0.3", such as a diameter less than 0.256", 0.1", or 0.08". Shaft 401 can comprise a material selected from the group consisting of: a polyether block amide such as PebaxTM; a thermoplastic elastomer, such as TygonTM, ArnitelTM, or HytrelTM; and combinations of one or more of these. In some embodiments, at least a portion of shaft 401 comprises a radiopaque additive, such as barium sulfate. In some embodiments, at least a portion of shaft 401 comprises a lubricious coating or additive, such as PropellTM low friction compound manufactured by Foster Corporation of Putnam, CT. In some embodiments, at least a portion of shaft 401 comprises a heat stabilizer, a light stabilizer, and/or other stabilizing agent, such as an HLSTM heat and light stabilizer manufactured by the Foster Corporation of Putnam, CT.

[091] Functional assembly 500 comprises one or more assemblies configured to treat and/or diagnose tissue. In some embodiments, functional assembly 500 is configured to both treat and diagnose tissue. Functional assembly 500 can be configured to treat and/or diagnose duodenal tissue or other tissue of the GI tract. Functional assembly 500 can be positioned on distal portion 408 of shaft assembly 400 as shown. Functional assembly 500 can be configured to radially expand and/or radially contract, such as when functional assembly comprises one or more expandable reservoirs,

such as one or more of expandable elements 530, 540 and/or 550 shown (singly or collectively, expandable element 530). Each expandable element 530, 540 and/or 550 (singly or collectively expandable element 530) can comprise a balloon or other expandable reservoir (“balloon” herein), an expandable cage, a furlable element, and the like. Expandable element 530 can comprise one or more balloons that circumferentially surround shaft 401 (e.g. in a linear arrangement), or multiple partially circumferential balloons (e.g. in a radial arrangement). Expandable elements 530 can comprise one or more balloons that expand radially out from shaft 401, at the same or different axial locations along shaft 401. An expandable element 530 can comprise an array of balloons in a lobed configuration, circumferentially spaced. An expandable element 530 can comprise one or more inner balloons surrounded by one or more outer balloons (e.g. where the inner balloon receives a first fluid at a first temperature and the space between the inner and outer balloons receives a second fluid at a second temperature, different than the first temperature). Expandable element 530 can comprise a balloon or other element configured to expand to a diameter of less than or equal to 35mm, such as less than or equal to 30mm or 25mm. Expandable element 530 can comprise a material as described herein. Expandable element 530 can comprise a balloon with a wall thickness as described herein. In some embodiments, one or more portions of expandable element 530 comprise a non-compliant material and one or more other portions of expandable element 530 comprises a compliant material. In some embodiments, expandable element 530 is configured to withstand an inflation pressure of up to 50psi, such as up to 60psi, 100psi, or 200psi. In some embodiments, a first expandable element 530 comprises at least a portion comprising a non-compliant material and a second expandable element 540 comprises at least a portion comprising a compliant material.

[092] Functional assembly 500 can comprise one or more balloons configured to receive one or more fluids, such as an expandable element 540 configured to receive an ablative fluid (e.g. a fluid at an ablative temperature received from ablative fluid supply 140), an expandable element 550 configured to receive a neutralizing fluid (e.g. a fluid received from neutralizing fluid supply 150 and comprising a temperature configured to cool or warm tissue after a heat or cryogenic ablation, respectively), or other expandable element 530. In some embodiments, at least expandable element 540 and expandable element 550 are the same reservoir (e.g. the same one or more balloons) that receive both ablative fluid and neutralizing fluid.

[093] In some embodiments, functional assembly 500 is configured to expand one or more layers of tissue, such as to expand one or more layers of submucosal tissue prior to a tissue treatment procedure in which a mucosal layer of tissue is treated (e.g. thermally or chemically ablated). In these embodiments, functional assembly 500, catheter 200 and/or any component of system 10 can be of similar construction and arrangement to that described in: applicant’s co-pending United States

Patent Application Serial Number 14/515,324, entitled “Tissue Expansion Devices, Systems and Methods”, filed October 15, 2014; applicant’s co-pending United States Patent Application Serial Number 17/095,108, entitled "Systems, Devices and Methods for the Creation of a Therapeutic Restriction in the Gastrointestinal Tract", filed November 11, 2020; and applicant’s co-pending United States Patent Application Serial Number 17/110,720, entitled "Injectate Delivery Devices, Systems and Methods", filed December 3, 2020.

[094] In some embodiments, functional assembly 500 is configured to receive an ablative fluid (e.g. a recirculating hot or cold fluid at a tissue-ablating temperature) to treat tissue. In some embodiments, functional assembly 500 is configured to deliver an ablation fluid directly onto tissue (e.g. a hot or cold liquid or gas at a tissue-ablating temperature, and/or a chemically ablative fluid). In these embodiments, functional assembly 500, catheter 200 and/or any component of system 10 can be of similar construction and arrangement to that described in: applicant’s co-pending United States Patent Application Serial Number 16/438,362, entitled " Heat Ablation Systems, Devices and Methods for the Treatment of Tissue", filed June 11, 2019 and applicant’s co-pending United States Patent Application Serial Number 14/917,243, entitled “Systems, Methods and Devices for Treatment of Target Tissue”, filed March 7, 2016.

[095] Functional assembly 500 can include one or more ports configured to capture and/or engage tissue (singly or collectively “capture” or “engage” herein) or otherwise stabilize functional assembly 500 within a GI lumen, such as tissue capture chambers 510 shown and described herein. Each tissue capture chamber 510 includes an opening, opening 512. In some embodiments, functional assembly 500 (or another portion of catheter 200) includes two, three, four or more tissue capture chambers 510. Each tissue capture chamber 510 can be attached to a source of vacuum, such as conduit 511 which is fluidly attached to a source of vacuum provided by console 100, such as vacuum supply 110. Each tissue capture chamber 510 can be of similar construction and arrangement to any chamber 510 described herein. In some embodiments, injectate delivery element 520 is positioned above (radially out from) a source of vacuum that is provided to tissue capture chamber 510. In some embodiments, one or more tissue capture chambers 510 is constructed of a metal or other material with a relatively high thermal conductance, such as to efficiently transfer heat from and/or to expandable element 530 (e.g. from and/or to temperature-ablative fluid within expandable element 530), such as to avoid non-ablated tissue regions proximate tissue capture chambers 510.

[096] Functional assembly 500 can comprise one or more elements configured to deliver fluid into tissue, such as injectate delivery elements 520 shown, each positioned within or at least proximate a tissue capture chamber 510. In some embodiments, functional assembly 500 (or another portion of catheter 200) includes two, three, four or more injectate delivery elements 520. Injectate delivery

elements 520 can comprise one or more elements selected from the group consisting of: needle; fluid jet; iontophoretic element; and combinations of one or more of these. Each injectate delivery element 520 can be operably attached to one or more conduits of catheter 200, such when fluidly connected to conduit 521 shown or when fluidly attached to a separate conduit slidably received by conduit 521 as described herein. Each injectate delivery element 520 can be connected to a source of fluid, such as a fluid provided by console 100 via injectate supply 120, ablative fluid supply 140, neutralizing fluid supply 150, and/or functional fluid supply 180. One or more injectate delivery elements 520 can comprise a needle with a diameter between 16 gauge and 34 gauge, such as a needle with a 27 gauge or 29 gauge diameter. One or more injectate delivery elements 520 can comprise a needle with a bevel angle of approximately 10° (e.g. with a bevel length of 0.008"), such as a bevel angle of at least 5° and/or a bevel angle no more than 45° or no more than 80° . One or more injectate delivery elements 520 can be advanced into the tissue contained in the associated tissue capture chambers 510, while avoiding the potential of the injectate delivery elements 520 penetrating an outer layer and/or outside of the GI wall tissue (e.g. injectate delivery elements 520 do not exit chambers 510). In some embodiments, tissue is penetrated by a needle-based injectate delivery element 520 at the time of the application of the vacuum to chamber 510, without the advancement of injectate delivery elements 520 (e.g. when the distal end of each injectate delivery element 520 is positioned within the associated chamber 510). In some embodiments, one or more injectate delivery elements 520 comprises a fluid jet, and injectate 125 or other fluid can be delivered into tissue captured within chamber 510 without advancement of the fluid jet. Each tissue capture chamber 510 can be configured to slidably receive an injectate delivery element 520 (e.g. at a time in which tissue is captured within chamber 510 and the injectate delivery element 520 penetrates the captured tissue upon advancement), such as when a tissue capture chamber 510 is configured to slidably receive at least a 29 gauge needle, or at least a 27 gauge needle. Each injectate delivery element 520 can be configured to be advanced a distance of at least 2.5mm, at least 3.5mm, or at least 4.5mm. Each tissue capture chamber 510 can comprise a width of at least 0.010", at least 0.040" or at least 0.060". Each tissue capture chamber 510 can comprise a width of no more than 0.25", or no more than 0.35". Each tissue capture chamber 510 can comprise a length of at least 0.010", at least 0.040" at least 0.060", at least 0.090", or at least 0.120". Each tissue capture chamber 510 can comprise a length of no more than 0.9", no more than 0.7", or no more than 0.5". Each tissue capture chamber 510 can comprise a depth of at least 300 μ m, at least 500 μ m, at least 700 μ m, or at least 1000 μ m. Each tissue capture chamber 510 can comprise a depth of no more than 2500 μ m, such as no more than 2000 μ m.

[097] In some embodiments, one or more of tissue capture chambers 510 each include a functional element 599 comprising one, two, or more springs configured to bias injectate delivery element 520

in an advanced position. Alternatively or additionally, chambers 510 can each include a functional element 599 comprises one, two, or more springs configured to bias the injectate delivery elements 520 in the retracted position. In some embodiments, catheter 200 includes a functional element 599 comprising one or more linkages each operably attached to an injectate delivery element 520. The one or more linkages can be operably attached to one or more controls of handle 300, such that an operator of system 10 can manipulate the position of the one or more injectate delivery elements 520 via handle 300 (e.g. by translating the linkages). In some embodiments, injectate delivery elements 520 are configured to be advanced and/or retracted within tissue capture chambers 510 via hydraulic pressure. For example, one or more injectate delivery elements 520 can be configured to be advanced by the hydraulic pressure of injectate 125 being delivered via injectate delivery element 520. In these embodiments, injectate delivery element 520 can be biased in a retracted position (e.g. via a spring) such that element 520 returns to the retracted position when the hydraulic pressure is removed. In some embodiments, one or more injectate delivery elements 520 can be advanced and/or retracted via magnetic activation and/or deactivation (e.g. via a functional element 599 comprising one or more magnetic elements).

[098] Functional assembly 500 of Fig. 1 can comprise two tissue capture chambers 510 (e.g. separated circumferentially at approximately 180°) or three tissue capture chambers 510 (e.g. separated circumferentially at approximately 120°), and each can surround an injectate delivery element 520. In some embodiments, four or more tissue capture chambers 510 are included. Each tissue capture chamber 510 can be configured to engage with tissue, such as to maintain contact between functional assembly 500 and tissue (e.g. during delivery and/or removal of energy to and/or from tissue). Alternatively or additionally, tissue capture chamber 510 can be configured to capture tissue within tissue capture chamber 510, via application of a vacuum, as described herein, such as to allow delivery of fluid or a fluid delivery element (e.g. a needle) into the captured tissue.

[099] Functional assembly 500 can comprise one or more ports (e.g. openings) in shaft assembly 400 that are configured to deliver fluid into and/or remove fluid from expandable element 530, such as ports 430 and 460 shown. Ports 430 and 460 can be positioned in various locations within expandable element 530. In some embodiments, port 460 is configured to remove fluid from expandable element 530, and is positioned in a proximal portion of functional assembly 500. In some embodiments, port 430 is configured to deliver fluid into expandable element 530, and can be positioned in a distal (as shown), middle or proximal portion of functional assembly 500. Port 430 can comprise one or more openings which are fluidly attached to one or more conduits, such as conduits 531, 541, and/or 551 as shown, which are fluidly connected to one or more of inflation fluid supply 130, ablative fluid supply 140 and/or neutralizing fluid supply 150, respectively, or other fluid supply of console 100 (e.g. functional fluid supply 180). Port 460 can comprise one or more

openings fluidly connected to one or more conduits, such as conduit 561 as shown, which is fluidly connected to fluid removal pump 160 of console 100. In some embodiments, port 460 is fluidly attached to conduits 531, 541, and/or 551, which are fluidly connected to one or more of inflation fluid supply 130, ablative fluid supply 140 and/or neutralizing fluid supply 150, respectively, or other fluid supply of console 100 (e.g. functional fluid supply 180).

[100] In some embodiments, functional assembly 500 comprises one or more sensors, transducers, and/or other functional elements, such as functional element 599 shown and described herein. In some embodiments, functional element 599 comprises a radiopaque marker and/or other visualizable marker, as described herein, configured to allow an operator to visualize translation and/or rotation of functional assembly 500, such as via imaging device 70 (e.g. a fluoroscope or other imaging device). In some embodiments, functional element 599 comprises a heat-generating transducer, such as an element comprising one, two, or more electrodes through which radiofrequency (RF) energy is passed, such as to heat expandable element 530, 540, and/or 550, and/or to heat fluid (e.g. saline) contained within expandable element 530, 540, and/or 550. Alternatively or additionally, functional element 599 can comprise a cooling transducer (e.g. a Peltier cooling element), such as to cool expandable element 530, 540, and/or 550, and/or to cool fluid contained within expandable element 530, 540, and/or 550.

[101] Handle assembly 300 comprises a handle for an operator to manipulate catheter 200, including housing 301. Handle assembly 300 can be positioned in proximal end 405 of shaft assembly 400 as shown. Handle assembly 300 comprises one or more conduits, conduit 391. Conduit 391 can be configured to operably attach (e.g. on its proximal end or ends) to connector 102 of console 100 or to conduit 691 of umbilical 600. Conduit 391 is configured to operably attach (e.g. on its distal end or ends) to conduit 491 of shaft assembly 400. In some embodiments, handle assembly 300 comprises a reusable portion and a disposable portion. In some embodiments, handle assembly 300 comprises a reusable handle assembly constructed and arranged to operably connect to a disposable catheter 200 (e.g. a single use catheter). Alternatively or additionally, handle assembly 300 comprises a disposable handle assembly. In some embodiments, catheter 200 comprises one or more reusable portions and one or more disposable portions (e.g. one or more disposable portions configured to operably attach to a reusable portion). For example, one or more conduits of catheter 200 can comprise reusable conduits, such as one or more reusable conduits configured to operably attach to one or more disposable injectate delivery elements 520 (e.g. operably attached prior to a clinical procedure). In some embodiments, handle assembly 300 comprises one or more manifolds, manifold 700b shown, which fluidly connects one or more conduits of conduit 391 to one or more other conduits (e.g. one or more other conduits of conduit 391 and/or conduit 491). Manifold 700b can be constructed and arranged to fluidly combine one or more of lumens of conduit 391.

Alternatively or additionally, manifold 700b can be constructed and arranged to split one or more of lumens of conduit 391 into multiple lumens. In some embodiments, manifold 700b includes one or more valves configured to control flow of fluid in a conduit. In some embodiments, manifold 700b includes one or more sensors (e.g. temperature and/or pressure sensors) configured to provide a signal related to a parameter (e.g. temperature and/or pressure) of fluid within a conduit.

[102] Handle assembly 300 can include one or more controls, control 310, which can be configured to activate, manipulate and/or otherwise operate one or more functions of catheter 200. In some embodiments control 310 comprises a control for advancing and/or retracting one or more injectate delivery elements 520 (e.g. simultaneously advancing and/or retracting two, three or more injectate delivery elements 520). In some embodiments, control 310 is configured to adjust one or more operating parameters of console 100 (e.g. via a wired or wireless connection). In some embodiments, control 310 comprises a software-enabled control, for example when handle assembly 300 includes a touch screen display configured to display a graphical user interface (GUI) comprising one or more icons for controlling one or more functions of system 10. In some embodiments, functional element 599 comprises a sensor. System 10 can be configured for closed loop control of one or more functions of system 10 based on feedback from the sensor. In some embodiments, system 10 can be configured as a “manual system”, where the operator is the primary controller of the actions of the system (e.g. positioning of catheter 200 and/or the advancement of injectate delivery elements 520). Alternatively or additionally, the operator can be assisted by system 10, for example when the operator initiates one or more robotic actions of system 10, thereby controlling the procedure through a series of inputs to system 10 (e.g. inputs via the GUI). For example, system 10 can comprise a robotic system of similar construction and arrangement to similar robotic systems described in applicant’s co-pending United States Provisional Patent Application Serial Number 62/961,340, titled "Automated Tissue Treatment Devices, Systems, and Methods", filed January 15, 2020.

[103] Handle assembly 300 can include an entry port, such as port 392, for passage of a guidewire or other filament, such as guidewire 60. In some embodiments, port 392 is positioned on a proximal portion of shaft assembly 400. Port 392 can be operably connected to a lumen of shaft 401, such as is described herein.

[104] In some embodiments, handle assembly 300 comprises one or more sensors, transducers, and/or other functional elements, such as functional element 399 shown and described herein. In some embodiments, functional element 399 comprises a tactile transducer configured to alert an operator of a particular state of catheter 200 (e.g. an alarm or warning state, a “ready” state, a “function completed” state, and the like). For example, functional element 399 can alert an operator that a particular function is being performed, such as a function selected from the group consisting

of: heating of tissue is being performed (e.g. via hot fluid present in functional assembly 500); a cooling of tissue is being performed (e.g. via cold fluid present in functional assembly 500); injectate is being delivered into tissue (e.g. injectate 125 is being delivered into submucosal or other tissue via one, two, three or more injectate delivery elements 520); needles or other injectate delivery elements 520 have been advanced into tissue; and combinations of one or more of these. Functional element 399 can comprise a tactile transducer selected from the group consisting of: a vibrational transducer (e.g. a vibrational transducer that alerts an operator that injectate is being delivered into tissue and/or injectate delivery elements 520 are presently advanced into tissue); a heating element (e.g. a heating element that alerts an operator that a heat ablation and/or warming of tissue is in process); a Peltier element or other cooling element (e.g. a cooling element that alerts an operator that a cryogenic ablation and/or cooling of tissue is in process); and combinations of one or more of these. In some embodiments, handle assembly 300 includes a portion configured to alert an operator of one or more particular functional states of catheter 200.

[105] One or more functional elements can be included in system 10, such as functional element 199 of console 100, functional element 399 of handle assembly 300, functional element 499a and/or 499b of shaft assembly 400, functional element 599 of functional assembly 500, and/or functional element 699 of umbilical 600.

[106] Endoscope 50 can comprise one or more endoscopes configured to reach at least one or more portions of the duodenum from the patient's mouth. In some embodiments, endoscope 50 comprises an endoscope similar to Olympus model number PCF-PH190.

[107] Guidewire 60 can comprise an outside diameter of approximately 0.035". Guidewire 60 can comprise a "stiff" or "super stiff" configuration, such as a guidewire similar to a Jagwire Stiff Straight guidewire, a Wallstent Super Stiff guidewire, a Dreamwire Superstiff, and/or a Savary Gilliard guidewire. Guidewire 60 can comprise a length of at least twice the length of catheter 200 and/or endoscope 50, such that one or more devices can be "exchanged" over guidewire 60. Guidewire 60 can comprise a material selected from the group consisting of: nitinol; stainless steel; and combinations of one or more of these. Guidewire 60 can comprise a hydrophilic or other lubricious coating, such as a Teflon coating.

[108] In some embodiments, system 10 further comprises imaging device 70, which can comprise an imaging device constructed and arranged to provide an image of the patient's anatomy (e.g. inner wall or any part of the intestine of the patient) and/or an image of all or part of catheter 200 or other portion of system 10, as described in detail herein. Imaging device 70 can comprise an imaging device selected from the group consisting of: endoscope camera; visible light camera; infrared camera; X-ray imager; fluoroscope; CT Scanner; MRI; PET Scanner; ultrasound imaging device; molecular imaging device; and combinations of one or more of these. In some embodiments, a

patient image is used to set, confirm and/or adjust one or more system 10 parameters, such as when imaging device 70 comprises a sensor of the present inventive concepts configured to produce a signal.

[109] In some embodiments, system 10 further comprises one or more agents, agent 80 shown. Agent 80 can be delivered by one or more components of system 10, such as by endoscope 50 (via one or more working channels of endoscope 50) and/or by catheter 200 (e.g. via one or more injectate delivery elements 520 or ports 470). Agent 80 can comprise a material selected from the group consisting of: anti-peristaltic agent, such as L-menthol (i.e. oil of peppermint); glucagon; buscopan; hyoscine; somatostatin; a diabetic medication; an analgesic agent; an opioid agent; a chemotherapeutic agent; a hormone; and combinations of one or more of these. In some embodiments, agent 80 comprises cells delivered into the intestine, such as living cells delivered into intestinal mucosa or submucosa via one or more injectate delivery elements 520. In some embodiments, agent 80 comprises one or more agents configured to be delivered into expandable element 530 and to pass through at least a portion of expandable element 530 and into the intestine (e.g. when expandable element 530 comprises at least a portion that is porous). In some embodiments, agent 80 comprises a mucolytic agent configured to remove mucus from a tissue surface.

[110] In some embodiments, system 10 comprises a tissue marker, marker 90 shown, which can comprise a dye or other visualizable media configured to mark tissue (e.g. a dye delivered using a needle-based tool, and/or a visualizable temporary implant used to mark tissue, such as a small, temporary anchor configured to be attached to tissue and removed at the end of the procedure or otherwise passed by the natural digestive process of the patient shortly after procedure completion). Marker 90 can be deposited or deployed in reference to (e.g. to allow an operator to identify) non-target tissue (e.g. a marker positioned proximate the ampulla of Vater to be visualized by an operator to avoid damage to the ampulla of Vater), and/or to identify target tissue (e.g. tissue to be ablated). In some embodiments, marker 90 is deposited or deployed in reference to tissue selected from the group consisting of: gastrointestinal adventitia; duodenal adventitia; the tunica serosa; the tunica muscularis; the outermost partial layer of the submucosa; ampulla of Vater; pancreas; bile duct; pylorus; and combinations of one or more of these.

[111] Shaft 401 can comprise at least six lumens, at least eight lumens, or at least ten lumens. In some embodiments, shaft 401 comprises a single shaft comprising the at least six lumens or at least eight lumens. In these embodiments, a first pair of lumens of shaft 401 can be in fluid communication with a first tissue capture chamber 510, a second pair of lumens of shaft 401 can be in fluid communication with a second tissue capture chamber 510; and a third pair of lumens of shaft 401 can be in fluid communication with expandable element 530 (e.g. via openings in shaft 401,

ports 430 and 460). The first pair of lumens of shaft 401 can comprise a vacuum lumen and a lumen that slidably receives a first tube attached to a first injectate delivery element 520. The second pair of lumens of shaft 401 can comprise a vacuum lumen and a lumen that slidably receives a second tube attached to a second injectate delivery element 520. The third pair of lumens of shaft 401 can comprise a fluid delivery lumen that delivers fluid to expandable element 530 and a fluid removal lumen that removes fluid from expandable element 530 (e.g. via ports 430 and 460, respectively), as described herein. In some embodiments, the at least one flexible elongate shaft comprises at least eight lumens, and a fourth pair of lumens are in fluid communication with a third tissue capture chamber 510. In some embodiments, shaft 401 further comprises, as described herein, one or more of: a guidewire lumen; a first insufflation lumen; and/or a second insufflation lumen. In some embodiments, shaft 401 comprises multiple shafts, such as two shafts 401 that each include at least a pair of lumens, or three shafts 401 that each include at least a pair of lumens.

[112] In some embodiments, shaft 401 comprises a first lumen for delivering fluid to expandable element 530 (e.g. delivering to element 530 one or more of: inflation fluid 135, ablative fluid 145 and/or neutralizing fluid 150), and a second lumen for removing fluid from expandable element 530 (e.g. removing from element 430 one or more of inflation fluid 135, ablative fluid 145 and/or neutralizing fluid 155). In some embodiments, shaft 401 comprises two, three or more lumens configured to provide and remove fluid from expandable element 530 in a recirculating manner.

[113] Expandable element 530, 540 and/or 550 (singly or collectively expandable element 530) can comprise various materials and dimensions that are configured to optimize the performance of one or more functions, such as submucosal tissue expansion (e.g. duodenal submucosal tissue expansion), mucosal tissue treatment (e.g. duodenal mucosal tissue ablation or other treatment), and/or substance delivery (e.g. delivery of one or more substances into the mucosa, submucosa, and/or other luminal wall location of the duodenum, jejunum, ileum, and/or other GI wall location). In some embodiments, expandable element 530 comprises a diameter (e.g. an expanded diameter of a balloon-based expandable element 530) of at least 5mm and/or of no more than 45mm, such as a diameter of at least 18mm and/or of no more than 32mm, such as a diameter of at least 23.5mm and/or no more than 26.5mm, such as a diameter of approximately 24mm or 25mm. In some embodiments, expandable element 530 comprises a balloon with a wall thickness (e.g. thickness of a single wall of the balloon) of at least 0.0001in and/or of no more than 0.01in, such as a wall thickness of at least 0.00025in and/or no more than 0.003in, such as a wall thickness of at least 0.0005in and/or no more than 0.001in, such as a wall thickness of approximately 0.00075in. In some embodiments, expandable element 530 comprises a balloon with varied wall thickness, such as wall thickness that varies and has a thickness of at least 0.00025in and/or no more than 0.003in. For example, expandable element 530 can comprise an increased wall thickness proximate tissue capture

cambers 510. In some embodiments, expandable element 530 comprises a material selected the group consisting of: a compliant material; a non-compliant material; both a compliant and a non-compliant material; PET; polyimide; nylon; nylon 12; PEEK; a silicone elastomer; polyether block amide; a polyurethane; a thermoplastic elastomer; and combinations thereof. In some embodiments, expandable element 530 (e.g. a balloon-based expandable element 530) comprises a compliance of at least 0.0001% and/or no more than 200%, such as a compliance of at least 0.0001% and/or no more than 15%, such as a compliance between at least 0.0001% and/or no more than 8%. In some embodiments, expandable element 530 comprises one or more materials with a thermal conductivity (W/(m*K)) of at least 0.01 and/or no more than 10, such as a thermal conductivity of at least 0.1 and/or no more than 0.6, such as a thermal conductivity of approximately 0.29. In some embodiments, expandable element 530 comprises a contact length (e.g. a length of expandable element 530 in contact with duodenal or other luminal wall tissue when inflated or otherwise expanded) of at least 5mm and/or no more than 500mm, such as a contact length of at least 10mm and/or no more than 50mm, such as a contact length of at least 19mm and/or no more than 21mm, such as a contact length of approximately 20mm. In some embodiments, expandable element 530 (e.g. an inflated balloon-based expandable element 530) comprises a tapered proximal and/or distal end, such as a tapered end with a taper angle (e.g. a proximal and/or distal taper angle) of at least 5° and/or no more than 120°, such as a taper angle of at least 30° and/or no more than 90°, such as a taper angle of at least 57° and/or no more than 63°, such as a taper angle of approximately 60°. Expandable element 530 can comprise proximal and distal tapers that are similar or dissimilar. In some embodiments, expandable element 530 comprises a balloon which includes a braid on and/or within its wall, such as a metal braid and/or non-metal braid (e.g. a nylon braid).

[114] Injectate delivery elements 520 can comprise one or more needles or other fluid delivery elements as described herein. Injectate delivery elements 520 can comprise one or more needles or other fluid delivery elements that are configured to deliver fluid or other material to tissue to perform one or more functions, such as submucosal tissue expansion (e.g. duodenal submucosal tissue expansion), mucosal tissue treatment (e.g. duodenal mucosal tissue ablation or other treatment), and/or substance delivery (e.g. delivery of one or more substances into the mucosa, submucosa, and/or other luminal wall location of the duodenum, jejunum, ileum, and/or other GI wall location). In some embodiments, injectate delivery elements 520 comprise elements (e.g. needles) constructed of a material selected from the group consisting of: metal; stainless steel, plastic; PEEK, liquid crystal polymer; and combinations of these. In some embodiments, injectate delivery element 520 comprises one or more needles with an inner diameter of at least 0.0014in and/or no more than 0.033in, such as an inner diameter of at least 0.00625in and/or no more than 0.01325in, such as an inner diameter of at least 0.0075in and/or no more than 0.009in, such as an inner diameter of

approximately 0.008in. In some embodiments, injectate delivery element 520 comprises one or more needles constructed and arranged to have an exposed length of at least 0.125mm and/or no more than 10mm, such as an exposed length of at least 1mm and/or no more than 5mm, such as an exposed length of at least 2mm and/or no more than 3mm, such as an exposed length of approximately 2.5mm. In some embodiments, injectate delivery element 520 comprises one or more needles with a diameter (e.g. Birmingham gauge) of at least 36gauge and/or no more than 10gauge, such as a gauge of at least 35 and/or no more than 20, such as a gauge of at least 27 and/or no more than 26. In some embodiments, injectate delivery element 520 comprises one or more needles with a bevel angle of at least 1° and/or no more than 90°, such as a bevel angle of at least 5° and/or no more than 45°, such as a bevel angle of at least 9° and/or no more than 11°, such as a bevel angle of approximately 10°.

[115] Console 100 can comprise one or more fluid supplies, as described herein, such as to deliver fluid to one or more injectate delivery elements 520. In some embodiments, console 100 is configured (e.g. during a submucosal tissue expansion procedure) to provide fluid to each injectate delivery element 520 at a flow rate of at least 0.1mL/min and/or no more than 120mL/min, such as a flow rate of at least 1mL/min and/or no more than 60mL/min, such as a flow rate of at least 5mL/min and/or no more than 20mL/min, such as a flow rate of approximately 12.5mL/min. In some embodiments, console 100 is configured (e.g. during a submucosal tissue expansion procedure) to provide, to each injectate delivery element 520, an injection volume (e.g. for delivery at each injection site) of at least 0.1mL and/or no more than 100mL, such as an injection volume of at least 1mL and/or no more than 30mL, such as an injection volume of at least 8mL and/or no more than 12mL, such as an injection volume of at least 9mL and/or no more than 11mL, such as an injection volume of approximately 10mL. In some embodiments, console 100 is configured to provide fluid, to each injectate delivery element 520 (e.g. during a submucosal tissue expansion procedure), at a pressure of at least 1psi and/or no more than 400psi, such as at a pressure of at least 20psi and/or no more than 200psi, such as at a pressure of at least 90psi and/or no more than 110psi, such as at a pressure of approximately 100psi.

[116] Catheter 200 can comprise multiple fluid-carrying conduits as described herein. For example, multiple conduits 521, also described herein, can each attach to a fluid delivery element 520 and travel to the proximal end or at least a proximal portion of catheter 200 (e.g. conduits 521 positioned within shaft 501 and fluidly attached to a port of handle assembly 300). In some embodiments, one or more conduits 521 comprises an inner diameter of at least 0.005in and/or no more than 0.125in, such as an inner diameter of at least 0.04in and/or no more than 0.10in, such as an inner diameter of at least 0.0177in and/or no more than 0.0183in, such as an inner diameter of approximately 0.018in. In some embodiments, one or more conduits 521 each comprises a length of

at least 12in and/or no more than 250in, such as a length of at least 36in and/or no more than 120in, such as a length of approximately 78in.

[117] Functional assembly 500 can comprise one, two, three, or more tissue capture chambers 510, such as are described herein. Tissue capture chambers 510 can comprise one or more materials selected from the group consisting of: a plastic; a liquid crystal polymer; a metal; stainless steel; a thermally conductive material; and combinations of these. Tissue capture chambers 510 can comprise a durometer of less than 63D, such as less than 50D, such as approximately 40D. Each tissue capture chamber 510 can be sized and arranged to capture tissue when a vacuum is applied to tissue capture chamber 510. Each tissue capture chamber 510 can be attached (e.g. fixedly attached) to expandable element 530 via an adhesive with a glass transition temperature (T_g) of at least -60°C and/or no more than 200°C , such as a T_g of at least 60°C and/or no more than 90°C , such as a T_g of approximately 77°C . Alternatively or additionally, one or more tissue capture chambers 510 can be attached to expandable element 530 via visco elastic tape and/or thermal welding. Each tissue capture chamber 510 can be attached (e.g. fixedly attached) to expandable element 530 via an adhesive configured to support an elongation (e.g. without failure) of at least 1% and/or no more than 500%, such as an elongation of at least 100% and/or no more than 400%, such as an elongation of approximately 300%. Each tissue capture chamber 510 can comprise an outer diameter of at least 0.1mm and/or no more than 10mm, such as a diameter of at least 1mm and/or no more than 5mm, such as at diameter of at least 2.28mm and/or no more than 2.30mm, such as a diameter of approximately 2.29mm. Each tissue capture chamber can comprise a length of at least 2.5mm and/or no more than 500mm, such as a length of at least 10mm and/or no more than 50mm, such as a length of at least 17.25mm and/or no more than 17.75mm, such as a length of approximately 17.5mm. Each tissue capture chamber 510 comprises an opening 512. Each opening 512 can comprise a length of at least 0.25mm, or at least 0.5mm, or at least 1mm, and/or no more than 20mm, such as a length of at least 2mm and/or no more than 10mm, such as a length of at least 3.45mm and/or no more than 3.65mm, such as a length of approximately 3.55mm. Each opening 512 can comprise a width of at least 0.1mm and/or no more than 10mm, such as a width of at least 0.5mm and/or no more than 4mm, such as a width of at least 1.48mm and/or no more than 1.68mm, such as a width of approximately 1.58mm. Each opening 512 can comprise a depth of at least 0.1mm and/or no more than 10mm, such as a depth of at least 1mm and/or no more than 4mm, such as a depth of at least 1.9mm and/or no more than 2.1mm, such as a depth of approximately 2.0mm. Each opening 512 can be defined by walls that extend from the outer surface of port 510.

[118] Referring now to Fig. 1A, a schematic view of a system for performing a medical procedure in the intestine of a patient is illustrated, consistent with the present inventive concepts. System 10 comprises console 100 and catheter 200. Console 100, catheter 200, and/or other components of

system 10 of Fig. 1A can be of similar construction and arrangement to those described hereabove in reference to Fig. 1. Console 100 of Fig. 1A comprises at least vacuum supply 110, injectate supply 120, ablative fluid supply 140, and neutralizing fluid supply 150, each of which can be included within a single housing or multiple housings of console 100. Console 100 can include other fluid supplies and assemblies as described herein. Console 100 is fluidly and otherwise operatively attached to catheter 200, such as via an umbilical or other conduit, not shown but such as umbilical 600 described herein. Console 100 comprises one or more pumps, pumping assembly 195, which propels fluids between console 100 and catheter 200, also as described herein.

[119] Catheter 200 comprises a distal portion 208 and a functional assembly 500 which can be positioned on distal portion 208. Functional assembly 500 comprises one or more balloons or other expandable reservoirs, such as reservoir 5301 shown. Console 100 can be configured to transport fluids into and out of reservoir 5301, such as to expand and contract, respectively, reservoir 5301, as described herein.

[120] Catheter 200 further comprises a tissue expansion subsystem 201 configured to expand sub-surface tissue, such as submucosal tissue of the GI tract. Tissue expansion subsystem 201 can comprise conduits within catheter 200 which transport tissue expansion fluids to functional assembly 500 and provide a vacuum to functional assembly 500, each as described herein. Tissue expansion subsystem 201 can comprise at least two tissue capture chambers 510 configured to capture tissue when vacuum is applied via at least two vacuum delivery conduits 511 (e.g. vacuum provided by vacuum supply 110 of console 100). Tissue expansion subsystem 201 can comprise at least two injectate delivery elements 520 (e.g. needles or fluid jets) which can receive the tissue expansion fluid (e.g. injectate 125 provided by injectate supply 120 of console 100) via at least two injectate delivery conduits 521. Injectate delivery elements 520 can be configured to deliver the tissue expansion fluid to tissue captured by tissue capture chambers 510. One or more injectate delivery elements 520 can each comprise a needle configured to penetrate tissue (e.g. via advancement of the needle into chamber 510 when tissue is captured within the chamber 510 via the applied vacuum), after which fluid can be delivered into the tissue. Alternatively or additionally, one or more injectate delivery elements 520 can each comprise a fluid jet configured to deliver fluid through a surface of and into tissue captured within chamber 510.

[121] Catheter 200 further comprises tissue ablation subsystem 202 comprising conduits within catheter 200 which transport ablation fluids and neutralizing fluids to and from functional assembly 500. Tissue ablation subsystem 202 comprises a first conduit, conduit 531, configured to provide fluid to functional assembly 500 (e.g. to reservoir 5301) and a second conduit, conduit 561, configured to remove fluid from functional assembly 500 (e.g. from reservoir 5301). Conduit 531 can be configured to provide to functional assembly 500 ablative fluid (e.g. fluid at an ablative

temperature that is provided by ablative fluid supply 140 of console 100), as well as neutralizing fluid (e.g. neutralizing fluid provided by neutralizing fluid supply 150 of console 100 for cooling or warming of tissue prior to and/or after heat ablation or cryogenic ablation, respectively). Conduit 561 can be configured to remove ablative fluid and neutralizing fluid from functional assembly 500. In some embodiments, console 100 is configured to recirculate ablative fluid within functional assembly 500 (e.g. within one or more reservoirs of functional assembly 500), and to also recirculate neutralizing fluid within functional assembly 500 (e.g. within similar or dissimilar reservoirs of functional assembly 500). In some embodiments, console 100 is configured to sequentially recirculate ablative fluid and neutralizing fluid in a single reservoir (e.g. reservoir 5301) of functional assembly 500, such as to heat ablate tissue and subsequently cool tissue, or to pre-cool tissue and subsequently ablate tissue. In some embodiments, console 100 is configured to sequentially recirculate ablative fluid and neutralizing fluid in functional assembly 500 to pre-cool tissue, then ablate tissue, and then cool tissue.

[122] Referring now to Fig. 1B, a flow chart of a method of treating target tissue of a patient is illustrated, consistent with the present inventive concepts. In some embodiments, the method 2200 of Fig. 1B is accomplished using system 10 of Fig. 1 or otherwise as described herein. In Step 2210, a patient is selected for treatment, such as a patient selected to treat and/or diagnose ("treat" herein) a patient disease or disorder selected from the group consisting of: Type 2 diabetes; Type 1 diabetes; "Double Diabetes"; gestational diabetes; hyperglycemia; pre-diabetes; impaired glucose tolerance; insulin resistance; non-alcoholic fatty liver disease (NAFLD); non-alcoholic steatohepatitis (NASH); obesity; obesity-related disorder; polycystic ovarian syndrome (PCOS); hypertriglyceridemia; hypercholesterolemia; psoriasis; GERD; coronary artery disease (e.g. as a secondary prevention); stroke; TIA; cognitive decline; dementia; Alzheimer's Disease; neuropathy; diabetic nephropathy; retinopathy; heart disease; diabetic heart disease; heart failure; diabetic heart failure; and combinations of these. In some embodiments, the patient is selected to treat two or more of the above diseases or disorders, such as a patient selected to treat two or more of diabetes, insulin resistance, NAFLD, NASH, and/or PCOS.

[123] The patient selected can be taking one or more medicines to treat their diabetes. The patient selected can have an HbA1c level between 7.5% and 12.0%, between 7.5% and 10%, or between 7.5% and 9.0%. In some embodiments, the patient selected can have an HbA1c level between 6.0% and 12.0%. Patients with higher HbA1c levels and/or other higher disease burden can receive more aggressive treatments (e.g. more tissue treated and/or higher number of repeated treatments over time) as described herebelow in reference to Step 2250.

[124] Patient selection can be based on the current level of one or more parameters representing one or more various biomarkers or other representative values of physiologic conditions (e.g. as

compared to an average among diabetic and/or non-diabetic patients), such as a level of a parameter selected from the group consisting of: body mass index (BMI) level; waist circumference; HbA1c level; fasting glucose; insulin resistance; liver fibrosis; cholesterol or triglyceride level; duration of years exhibiting type 2 diabetes; fasting insulin, fasting C-peptide or C-Peptide stimulation in response to a meal; age; and combinations of these.

[125] Prior to placing one or more devices into the patient (e.g. catheter 200), or at any time thereafter (e.g. during or after the procedure), one or more agents can be introduced into the patient. In some embodiments, one or more agents are introduced into the GI tract directly, such as agent 80 described hereabove in reference to Fig. 1. In some embodiments, agent 80 comprises L-menthol (i.e. oil of peppermint) or other agent configured to provide an anti-peristalsis effect. In these embodiments, a few drops of agent 80 can be placed in an irrigation or other lumen of an inserted device (e.g. endoscope 50). In some embodiments, approximately 8mL of L-menthol is mixed with approximately 0.2mL of Tween 80 (polysorbate 80) in approximately 500mL of distilled water (i.e. to create an approximately 1.6% solution). Approximately 20mL of this mixture can be sprayed through a working channel of endoscope 50, or more as required to dampen peristalsis. In some embodiments, the solution can vary between approximately 1.6% and 3.2%. Tween and/or sorbitan monostearate can be used as an emulsifier.

[126] One or more agents 80 can be delivered once endoscope 50 or any other agent delivery device of system 10 enters the duodenum. In some embodiments, agent 80 comprises one or more agents that are delivered intravenously, and can include glucagon and/or buscopan.

[127] As described herein, in some embodiments, an endoscope is inserted into the patient (e.g. endoscope 50 of Fig. 1). In these embodiments, subsequently inserted devices can be placed through a working channel of endoscope 50 and/or alongside endoscope 50. In some embodiments, endoscope 50 and an attachable sheath are both inserted into the patient, and subsequently inserted devices can be placed through a working channel of endoscope 50, through the attachable sheath, and/or alongside endoscope 50 and the attached sheath. Each device placed within the patient can be inserted over a guidewire. In some embodiments, an endoscope stiffening device is used, such as an endoscope stiffening system provided by Zutron Medical of Lenexa, Kansas, USA.

[128] In some embodiments, non-target tissue is identified. Non-target tissue can be identified with a visualization device, such as endoscope 50 and/or imaging device 70 described herein. The non-target tissue can comprise the ampulla of Vater, the pancreas, and/or other tissue to which treatment (e.g. ablation) may adversely affect the patient. Marking of the non-target tissue (or tissue proximate the non-target tissue) can be performed, such as with a tattoo, ink or other visualizable substance, such as a visual agent or clip placed in and/or on the mucosa and/or submucosa in or proximate the ampulla of Vater. In some embodiments, one or more markers similar to marker 90 described

hereabove in reference to Fig. 1 are deployed in the patient to provide a reference location relative to non-target tissue. Tissue expansion and/or tissue treatment performed in subsequent steps can avoid treating (e.g. avoiding delivering ablative energy to) the non-target tissue identified and potentially marked (e.g. with one or more markers 90).

[129] Next in Step 2210, a treatment catheter, such as catheter 200 of Fig. 1, is inserted through the patient's mouth and advanced through the stomach and into the small intestine. Step 2210 can include selecting a particular model of catheter 200, such as a particular size (e.g. treatment element length and/or diameter) or other configuration of catheter 200. Catheter 200 can be inserted over guidewire 60, such as are described hereabove in reference to Fig. 1. Guidewire 60 can be advanced such that its distal end is in the jejunum or more distal location. During advancement of catheter 200, guidewire 60 can be held taut in order to prevent catheter 200 from forming a loop in the stomach. As described herein, catheter 200 can be inserted through a working channel of endoscope 50 and/or alongside endoscope 50.

[130] Catheter 200 is advanced (e.g. over guidewire 60) such that functional assembly 500 is positioned in the duodenum (or another GI location). One or more tissue capture chambers 510 (e.g. three tissue capture chambers 510 positioned on expandable element 530 of functional assembly 500) can be positioned at a first location in the intestine. The first location can be a most-proximal target location to be treated, such as a location in the duodenum at least 0.5cm or at least 1cm, but not more than 5cm or 10cm from the ampulla of Vater. In some embodiments, tissue capture chambers 510 are positioned based on the location of a previously placed marker, such as marker 90 described herein. Prior to and/or during insertion of catheter 200, a stiffening wire can be inserted within catheter 200. Endoscope 50 can be positioned adjacent catheter 200, such that the distal ends of each are positioned beyond the ampulla of Vater (e.g. beyond marker 90).

[131] In Step 2220, submucosal tissue expansion is performed, or at least attempted, at the first location (e.g. a first axial segment of the duodenum). Saline and/or other fluid or material (injectate 125) is injected into submucosal tissue. In some embodiments, injectate 125 is delivered (e.g. simultaneously injected) by multiple injectate delivery elements 520 of functional assembly 500, each element 520 positioned in a corresponding tissue capture chamber 510 (e.g. three chambers 510 spaced approximately 120° apart along a circumference). Each injection (by a single injectate delivery element 520) can comprise at least 1mL, such as at least 2mL, at least 5mL or at least 8mL per each injectate delivery element 520 (e.g. when the cumulative amount of fluid delivered by the multiple injectate delivery element 520 comprises at least 3mL, such as at least 6mL, at least 15mL, or at least 24mL). Each injection can comprise no more than 20mL, such as no more than 15mL, or when each injection comprises approximately 10mL (e.g. when the cumulative amount of fluid delivered by the multiple injectate delivery element 520 comprises no more than 60mL, such as no

more than 45mL, or when the cumulative amount comprises approximately 30mL). In some embodiments, each injection comprises at least 4mL, at least 6mL, or at least 8mL. In some embodiments, the volume of injectate delivered (e.g. via three circumferentially positioned injectate delivery elements 520) can be configured to achieve an expansion of the submucosal layer to a thickness of at least 250 μ m, or approximately 400 μ m, in the area surrounding the volume of mucosal tissue to be ablated. Console 100 can be configured to deliver injectate 125 at a flow rate of at least 1mL/min, or at least 10mL/min, such as a flow rate of 50mL/min, or 100mL/min. In some embodiments, console 100 is configured to deliver the full volume of injectate for a single injectate delivery element 520 at a single site within a time period of no more than 2 minutes, no more than 1 minute, or no more than 30 seconds. In some embodiments, injectate 125 is injected into tissue in a closed loop fashion, such as until a pressure threshold is reached (e.g. pressure within a delivery element), until the pressure within a balloon or other functional element placed proximate the injection site increases above a threshold, and/or until the inner diameter of the duodenum is reduced to a certain size or by a percentage of its pre-injection size.

[132] Volumes injected by the multiple injectate delivery elements 520 can be selected to achieve near full circumferential expansion of submucosal tissue (e.g. without gaps, full 360° expansion). Each submucosal tissue expansion step is configured to create a safety margin of expanded submucosal tissue, as described herein, this expanded tissue volume (e.g. a partial or full circumferential tubular volume of the intestine) defining an “expanded tissue periphery”. In some embodiments, functional assembly 500 is constructed and arranged (e.g. the ablative portion is sized) such that a submucosal tissue expansion performed at a single axial location of the small intestine (e.g. via delivery of injectate 125 via two, three or more injectate delivery elements 520, simultaneously or sequentially at the single axial location) creates an expanded tissue periphery that is sufficiently sized to surround an “ablation periphery” that is created during ablation via functional assembly 500 (as described herebelow in reference to Step 2250). This sufficiently sized expanded tissue periphery avoids transmission of significant energy beyond the submucosal layer (e.g. avoids transmission of energy at a level sufficient to ablate the deeper, muscular layers of the GI tract). For example, in cases of full circumferential submucosal tissue expansion, if the axial length of the expanded submucosal tissue achieved by injectate 125 delivery in Step 2220 is greater than the axial length of the tissue to be ablated, the submucosal tissue expanded is sufficient to provide a safety margin for the ablation (e.g. when during ablation functional assembly 500 is relatively centered within the expanded length of tissue).

[133] In some embodiments, the expanded tissue periphery created in a single submucosal tissue expansion step is not sufficiently sized to support the ablation periphery created by functional assembly 500, and an optional Step 2225 is performed (e.g. one or more times), comprising

additional submucosal tissue expansion. For example, a second submucosal tissue expansion can be performed at a neighboring (e.g. relatively adjacent and more distal) axial segment of the duodenum, such as by translating (e.g. advancing) catheter 200 to reposition functional assembly 500.

Functional assembly 500 can be at least partially collapsed (e.g. ablation fluid 145, neutralizing fluid 155, and/or other fluid is removed from functional assembly 500) prior to translation. Translations of catheter 200 (advancements and/or retractions of functional assembly 500 or other portion of catheter 200) can be performed under visualized guidance, such as when functional elements 499a, 499b and/or 599 described herein comprise a radiopaque band or other visualization marker that can be visualized by imaging device 70 (e.g. a fluoroscope). Alternatively or additionally, rotations of catheter 200 (e.g. rotations of functional assembly 500 or other portion of catheter 200) can be performed under similar visualized guidance. In Step 2225, catheter 200 can be translated (e.g. advanced) a pre-determined distance (e.g. a distance of at least 0.3cm, or at least 0.6cm), after which delivery of injectate 125 can begin. Delivery of injectate 125 via the injectate delivery elements 520, as described hereabove in reference to Step 2220, creates a second (e.g. contiguous) volume of expanded submucosal tissue that in combination with the first expanded volume of submucosal tissue defines a larger expanded tissue periphery than that which is created in a single tissue expansion step. This larger expanded tissue periphery can support larger ablation peripheries (e.g. longer full circumferential lengths of tissue to be ablated), such as may be required by functional assembly 500 in a single ablation. For example, in cases of full circumferential submucosal tissue expansion, if the axial length of the expanded submucosal tissue achieved by injectate 125 delivery in the combined deliveries of Step 2220 and Step 2225 is greater than the axial length of the tissue to be ablated, the submucosal tissue expanded is sufficient to provide a safety margin for the ablation.

[134] Referring additionally to Fig. 1C, a representative expanded periphery and ablation periphery of two full circumferential expansions followed by a single full circumferential ablation, each performed by catheter 200 via console 100 as described herein, are illustrated. A first and second circumferential submucosal tissue expansion combine to form an expanded tissue periphery with a length as shown. Functional assembly 500 can deliver energy to an ablation periphery that is positioned within the expanded tissue periphery.

[135] Optional Step 2225 can be performed two or more times, resulting in three or more injections of fluid into tissue (e.g. submucosal tissue), with or without an intervening ablation performed via Step 2250. Sequential injections of injectate 125 can be performed at an axial separation distance of between 1cm and 2cm apart from a previous injection (e.g. 1cm to 2cm distally in the duodenum, jejunum, or other GI location). In some embodiments, multiple injections are positioned at least 0.5cm apart along the axis of the small intestine, such as between 1.0cm and 5.0cm apart, such as approximately 1.0cm, 2.0cm, 3.0cm, 4.0cm and/or 5.0cm apart from one another along the axis of

the small intestine. In some embodiments, axial separation of injection sites (i.e. translation distance of catheter 200 between injections) can approximate half the length of expandable element 530 onto which injectate delivery elements 520 are mounted, such as half the length of expandable element 530 of Fig. 1. In some embodiments, a series of 5-15 sets (e.g. 8-12 sets) of injections (e.g. each set comprising injections from 2, 3 or more injectate delivery elements 520) can be performed (with or without an intervening ablation step) by delivering injectate 125 (e.g. a fluid containing a visualizable dye) to the tissue to be expanded and subsequently translating catheter 200 to a new axial location (e.g. after proper expansion of tissue is confirmed visually as described herebelow in Steps 2230 and 2235, or otherwise). Each advancement and/or retraction of catheter 200 can be made in unison with advancement and/or retraction of an endoscope positioned alongside catheter 200.

[136] As described herein, tissue expansion can begin at a location proximate but distal to the ampulla of Vater, such as at a location at least 1cm distal to but not more than 5cm or 10cm from the ampulla of Vater. A series of relatively contiguous, full circumferential submucosal tissue expansions can be performed (e.g. moving distally), for example to a distal location up to the Ligament of Treitz. In alternate embodiments, multiple full circumferential tissue expansions are performed by moving catheter 200 from distal to proximal locations, or in a discontinuous (back and forth) manner.

[137] Volumes of injections and/or axial separation of injection sites can be chosen to avoid axial gaps between neighboring expanded volumes of tissue (e.g. when an ablation step is to be performed proximate one or both expanded volumes of tissue). After injections, gaps identified circumferentially and/or axially (e.g. via endoscope camera, fluoroscope or ultrasound imaging device), can be filled in as deemed necessary via additional injection (e.g. with or without rotation and/or translation of catheter 200).

[138] In some embodiments, console 100 is configured to reduce the amount of fluid (e.g. liquid such as water or gas such as air or carbon dioxide) in expandable element 530 supporting injectate delivery elements 520 as the injectate 125 is delivered into tissue, such as to prevent excessive force being applied to tissue proximate the expanding tissue (i.e. due to the decreasing lumen of the intestine proximate the expanding tissue in contact with expandable element 530).

[139] Multiple injections (e.g. two, three or more injections from two, three or more equally separated injectate delivery elements 520) can be performed simultaneously or sequentially in a single axial segment of the intestine (e.g. without moving functional assembly 500). A vacuum can be applied (e.g. automatically or otherwise via system 10, such as via a working channel of endoscope 50 and/or via ports 470P or 470D of catheter 200) to the intestinal lumen (e.g. desufflation) prior to delivery of injectate 125, such as to draw tissue toward each injectate delivery

element 520 (e.g. into the associated chambers 510). After injectate 125 delivery, the vacuum can be removed and an ablation performed (e.g. in Step 2250 below without additional translation or other movement of functional assembly 500), or catheter 200 can be advanced (or retracted) for a subsequent (additional) tissue expansion.

In Step 2230, an assessment of submucosal tissue expansion is performed (e.g. manually by an operator and/or automatically by system 10). Step 2230 can be performed after Step 2225, as shown in Fig. 1B (e.g. if Step 2225 is performed), and/or directly after Step 2220 (e.g. when a single tissue expansion is sufficient for the subsequent ablation or simply when an assessment is desired directly after a tissue expansion). In some embodiments, assessment of submucosal tissue expansion is performed via a camera view provided by endoscope 50 (e.g. an endoscope with a camera positioned to view the submucosal tissue expansion). Alternatively or additionally, submucosal tissue expansion can be performed using a visualization device of system 10, such as when imaging device 70 described hereabove in reference to Fig. 1 provides one or more images used to perform the assessment. Injectate 125 delivered in Steps 2220 and/or 2225 can include an agent that is directly visualizable by an operator and/or an agent whose location (e.g. a volume of tissue that has been expanded by injectate 125) can be (at least partially) assessed by system 10 (e.g. via an image processing algorithm of console 100 or other component of system 10). For example, injectate 125 can comprise a material selected from the group consisting of: a visible material (such as India Ink, Indigo Carmine, and the like) visualized by an endoscope 50 camera, catheter 200 camera (e.g. when functional element 599 comprises a camera), or other camera; a radiopaque material visualizable by an imaging device 70 comprising a fluoroscope or other X-ray imaging device; an ultrasonically reflectable material visualizable by an imaging device 70 comprising an ultrasound imaging device; any visualizable material; and combinations of one or more of these. Visualization of the expanded tissue can be used to determine (e.g. automatically determine by algorithm 11) that a proper volume of injectate has been delivered as well as sufficient tissue expansion has been achieved, such as to ensure sufficient thickness, elimination of gaps, sufficient axial length, and/or sufficient circumferentiality (e.g. full or near-full circumferential nature) of tissue expansion has occurred. The pressure of expandable element 530 or the volume of fluid within expandable element 530 can also be monitored to determine if a proper volume of injectate has been delivered to achieve adequate tissue expansion. In particular, the expanded tissue can be analyzed to identify areas of relatively poor expansion which may indicate regions of adherent submucosal tissue (such as scarred and/or fibrotic submucosal tissue not amenable to tissue expansion).

[140] As described above, in some embodiments, assessment of submucosal tissue expansion performed in Step 2230 is performed (at least) using a camera of endoscope 50. In these embodiments, prior to and/or during the assessment of submucosal tissue expansion performed in

Step 2230, functional assembly 500 can be at least partially collapsed (e.g. inflation fluid 135, and/or other fluid is removed from functional assembly 500), to provide an increased view of the expanded tissue. Alternatively or additionally, functional assembly 500 is at least partially collapsed to allow advancement of endoscope 50 toward and potentially into the axial segment of intestinal tissue to which the submucosal tissue has been expanded, to provide a closer view of the expanded tissue.

[141] In Step 2235, adequacy of submucosal tissue expansion is determined (e.g. a qualitative assessment performed by a clinician and/or a quantitative assessment performed automatically and/or semi-automatically using system 10). If submucosal tissue expansion is determined to be inadequate, Step 2240 is performed, in which a new (alternative) area for tissue expansion and subsequent ablation is selected, or the procedure is terminated (e.g. after limited or no ablations have been performed). In some embodiments, the method 2200 of Fig. 1B is included in a medical procedure that is performed on a patient after (e.g. at least 24 hours after) a similar procedure has been performed on that same patient (e.g. a similar ablation procedure in the duodenum or other location of the patient's small intestine or GI tract). The assessment of submucosal expansion performed in Step 2230 can be an important diagnostic test that can confirm that it is safe to perform a repeated, similar procedure (e.g. the procedure of the present inventive concepts). Alternatively, the assessment may enable the identification of patients who may have: an active infection in their small intestine; a history of infection (such as tuberculosis) and/or malignancy that can cause a GI segment injury (e.g. a condition that may make submucosal expansion challenging or even impossible); and combinations of these, such as patients to which no or limited ablations should be performed. For example, there may be significant fibrosis and/or significant scar present at a target location (from a previous procedure or otherwise), which could prevent proper submucosal tissue expansion. In these instances, ablation should not be performed, at least not at that location of the intestine.

[142] If the submucosal tissue expansion is determined to be adequate, Step 2250 is performed in which target tissue is treated (e.g. ablated) by functional assembly 500 of catheter 200. The target tissue can comprise one or more portions of the mucosal layer of the duodenum, jejunum, and/or other GI location proximate (e.g. on top of) the submucosal tissue that has been previously expanded (e.g. in one or more expansion steps 2220 and/or 2225). Treated tissue can further comprise at least an inner layer of neighboring submucosal tissue (e.g. a partial depth of the submucosal tissue layer previously expanded). In some embodiments, the ablation of Step 2250 is performed without repositioning (e.g. without translating) functional assembly 500, such as without repositioning after Step 2220 or without repositioning after Step 2225 (if the optional step is performed), such as to ensure that ablation is performed over an area of expanded submucosal tissue (e.g. over a sufficiently sized expanded tissue periphery as defined herein) that provides a safety margin to avoid adversely affecting tissue layers beyond (deeper than) the submucosal layer. One or more circumferential

ablations, partial circumferential ablations, and/or other treatments can be performed along a length of the GI tract (e.g. along one or more axial segments of the GI tract), such as along a length of the duodenum at least 1cm distal to the ampulla of Vater, such as at a location at least 1cm distal to but within 3cm, 5cm or 10cm of the ampulla of Vater. In some embodiments, all ablations are performed at least 2cm or at least 3cm distal to the ampulla of Vater (e.g. tissue within 1cm, 2cm or 3cm of the ampulla of Vater is not ablated). In some embodiments, tissue treatments are only performed at locations that have had submucosal tissue expansion performed and/or confirmed (e.g. visually as described hereabove in reference to Step 2230 and 2235).

[143] In some embodiments, step 2250 is performed immediately following step 2220 or step 2225 (e.g. without performing an assessment of the submucosal tissue expansion). Step 2250 can be performed without repositioning functional assembly 500 between the expansion and step 2250. In some embodiments, system 10 is configured to monitor (e.g. via one or more functional elements of system 10 as described herein) one or more parameters of the submucosal tissue expansion (e.g. during steps 2220 and/or 2225), for example the volume of expansion fluid delivered. If the parameters are within acceptable values, step 2250 can be performed without performing steps 2230 and/or 2235.

[144] In some embodiments, a thermal ablation is provided by sufficiently hot or sufficiently cold fluid introduced into expandable element 530 to ablate tissue. Alternatively or additionally, different forms of energy delivery or other tissue treatments can be performed (e.g. electromagnetic energy, light energy, mechanical energy and/or chemical energy).

[145] Catheter 200 and console 100 can be configured to treat a series of axial segments of GI tract tissue comprising lengths between 1cm and 5cm each, such as approximately 2cm in length each. Catheter 200 and console 100 can be configured to treat a cumulative axial length of GI tract tissue (e.g. an axial length of duodenal mucosal tissue) of less than or equal to 3cm, 6cm, 9cm, 15cm, or 20cm. Catheter 200 and console 100 can be configured to treat more than 3cm of axial length of duodenal mucosa, such as more than 3.4cm, more than 6cm, more than 7cm, more than 8cm or more than 9cm (e.g. approximately 9.3cm). In some embodiments, at least 10%, 15%, 25%, 30% and/or 50% of the duodenal mucosa distal to the ampulla of Vater is treated. The axial length and/or overall volume of tissue treated can correspond to a patient parameter, such as the longevity of the disease or other disease parameter as described herein (e.g. higher disease burden correlating to larger volumes of tissue treated).

[146] In some embodiments, at least 3 axial segments of duodenal mucosal tissue are treated (e.g. sequentially ablated, such as a sequential treatment including at least one submucosal tissue expansion step performed before each ablation), such as with a functional assembly 500 configured to deliver energy to a delivery zone with a length between 0.5cm and 4.0cm (e.g. tissue contacting

length of expandable element 530 filled with ablative fluid), such as a delivery zone length (e.g. tissue contacting length) between 0.5cm and 4.0cm, between 1.5cm and 3.3 cm, or approximately 2cm in length. In some embodiments, at least 4 axial segments of duodenal mucosal tissue are treated, such as when at least 6 axial segments of duodenal mucosal tissue are treated. In these embodiments, functional assembly 500 can be configured to deliver energy to a delivery zone with a length between 0.7cm and 2.0cm (e.g. tissue contacting length of expandable element 530 filled with ablative fluid). In some embodiments, functional assembly 500 comprises ablative fluid delivered into expandable element 530 (e.g. ablative fluid 145 provided by console 100). Multiple tissue treatments are performed by repositioning functional assembly 500, which can further include contracting expandable element 530 to reposition functional assembly 500. Contact between the target tissue and functional assembly 500 can be accomplished using desufflation techniques to bring the tissue toward expandable element 530 and/or via expansion of expandable element 530. Tissue treatment is performed, such as by filling expandable element 530 with ablative temperature fluid and/or delivering any form of energy to the target tissue. In embodiments where catheter 200 is delivered over a guidewire, the guidewire can be retracted (e.g. at least retracted to a location proximal to the treatment element) prior to any tissue treatments (e.g. prior to any energy deliveries).

[147] Multiple treatments can be performed by advancing or retracting functional assembly 500 and/or catheter 200. In some embodiments, functional assembly 500 is positioned at a distal location and a series of tissue treatments are performed, such as at least 3 tissue treatments performed in which catheter 200 is retracted approximately the length of the tissue contacting portion of functional assembly 500 such as to treat relatively contiguous, non-overlapping, full circumferential axial segments of the duodenum (e.g. where at least one submucosal tissue expansion is performed prior to each ablation or other treatment). Prior to each treatment, an assessment of adequate submucosal tissue expansion can be performed, as described herein. Also prior to each tissue treatment, confirmation of being away from (e.g. distal to) any non-target tissue marked and/or otherwise identified can be performed (e.g. by visualizing a previously placed marker 90). In some embodiments, a marker 90 is placed to avoid any damage to the ampulla of Vater. In some embodiments, after three axial segments of duodenal mucosa are treated (e.g. treated distally to proximally), an assessment of the linear distance between the most-proximal treatment segment and the ampulla of Vater is performed (e.g. one or more components of system 10 is used to determine the distance). If sufficient length is determined (e.g. the determined distance is above a threshold), additional (more proximal) axial tissue segments can be treated. During translation of catheter 200 over a guidewire, undesired movement of the guidewire is prevented or otherwise reduced by the operator.

[148] In some embodiments, the system of the present inventive concepts (e.g. system 10 of Fig. 1) is configured to allow only one ablation per (pre-determined) time period, such as to prevent two ablations within the time period such as to prevent repetitive ablation in the same or at least similar (e.g. overlapping) portions of the GI tract (e.g. rapid treatment of similar treatment zones).

[149] In some embodiments, the tissue treatment of Step 2250 should be completed within approximately 120 minutes or within approximately 60 minutes of the initiation of tissue expansion performed in Step 2220 and/or step 2225, such as within approximately 45 minutes, 30 minutes and/or 20 minutes. Performance of tissue treatment within this time window prevents an unacceptable amount of injectate 125 from dissipating beyond the expanded submucosal tissue space (e.g. prevents an insufficient amount of submucosal tissue expansion being present during the tissue treatment). In some embodiments, system 10 is configured to prevent a tissue treatment (e.g. ablation) until an adequate submucosal expansion step has been performed and/or confirmed, such as is described in Step 2230. After one or more axial segments of duodenum or other GI segment is ablated in Step 2250, a determination is made in Step 2260 regarding additional axial segments to be treated. In some embodiments, a single axial segment is ablated in Step 2250, after which additional submucosal tissue is expanded (e.g. in one or more of Steps 2220 and/or 2225) and an additional ablation is performed proximate the additionally expanded submucosal tissue. In some embodiments, two axial segments of submucosal tissue are expanded for each single axial segment of mucosal tissue ablated. In some embodiments, a first ablation is performed proximate an area of two submucosal expansions (e.g. directly after the two submucosal expansions are performed), and subsequent ablations are performed after (e.g. directly after) two or less (e.g. one) submucosal expansions are performed (e.g. expansions performed in the area of the subsequent ablations).

[150] The cumulative amount of target tissue treated and/or the number of treatments performed can correlate to (e.g. be proportional to) one or more patient conditions (e.g. more severe correlates to more tissue treated and/or more treatments performed over time). This increased treatment can comprise an increased axial length of tissue treated (e.g. an increased cumulative axial length of duodenum ablated), an increased volume of tissue treated (e.g. an increased volume of duodenal mucosa treated via an increased mucosal surface area receiving ablation energy from functional assembly 500), a deeper depth of treatment, and/or a larger number of treatments performed over time in order to achieve a sustained treatment response. In some embodiments, the tissue treatment is modified to avoid creation of a duodenal stenosis or stricture, such as to limit one or more of: amount of energy delivered; peak energy delivered; duration of energy delivered; length of tissue treated; depth of tissue treated; and combinations of these.

[151] **Referring now to Figs. 2A and 2B**, schematic views of a catheter inserted into a patient and that catheter shown in an anatomical shape (e.g. a shape the catheter assumes when inserted into a

patient) are illustrated, respectively, consistent with the present inventive concepts. As described herein, catheter 200 is configured to be inserted into a patient's GI tract via the mouth. In Fig. 2A, catheter 200 is shown inserted through an introduction device 40, such as a bite block. Catheter 200 can be configured to track within the anatomy of the patient (e.g. follow a natural anatomic path, such as the GI tract) to reach one, two, or more locations to perform a treatment procedure (e.g. a mucosal or other tissue treatment procedure). In some embodiments, catheter 200 is configured to be advanced over a guidewire, such as when the distal portion of a guidewire has been positioned within the small intestine of the patient prior to the introduction of catheter 200 into the small intestine. Catheter 200 is shown inserted into the patient with functional assembly 500 positioned within the patient's duodenum, specifically with assembly 500 positioned distal to the pylorus and the ampulla of Vater. For example, catheter 200 can be advanced through the mouth of the patient, through the esophagus, and into the patient's stomach. Once in the stomach, catheter 200 can be further advanced, such that the distal end of catheter 200 tracks through the pylorus and enters the small intestine. Functional assembly 500 is shown advanced through the pylorus, into the duodenum, and positioned at a treatment location (e.g. in contact with target tissue) distal to the ampulla of Vater. Catheter 200 is shown in both a "long position" and a "short position", depicted with long and short dashes, respectively. The long position is achieved when a portion of shaft 401 is pressing against a wall of the stomach, following the curvature of the stomach from the end of the esophagus to the pylorus. The short position is achieved when catheter 200 follows a shorter path between the end of the esophagus and the pylorus. In Fig. 2B, catheter 200 is shown in the long position.

[152] As described herein, catheter 200 can be advanced into the small intestine of a patient, where at least one (such as two) submucosal expansions can be performed prior to an ablative treatment. Catheter 200 can then be advanced, and a subsequent set of expansions and ablation can be performed. In some embodiments, an operator first places guidewire 60 into the small intestine of the patient following the long position illustrated (e.g. using endoscope 50, not shown). Catheter 200 is then advanced into the proximal end of the duodenum following guidewire 60 (along the long position illustrated). Endoscope 50 can then be positioned next to (e.g. parallel to) catheter 200, such that the proximal end of expandable element 530 is visible via endoscope 50. In some embodiments, at least the distal portion of endoscope 50 is positioned next to catheter 200 (e.g. in the small intestine of the patient), and at least a proximal portion of endoscope 50 is next to at least a proximal portion of catheter 200 (e.g. in the esophagus of the patient). Once both catheter 200 and endoscope 50 are positioned at least through the pylorus, catheter 200 and endoscope 50 can be advanced simultaneously into the duodenum, such that expandable element 530 is positioned distal to the ampulla of Vater. In some embodiments, catheter 200 and endoscope 50 are advanced simultaneously to reduce friction between the two devices and/or to limit the force required to

advance either of the two devices individually. A set of expansions and an ablation can then be performed, with an approximately 1cm advancement of both catheter 200 and endoscope 50 between each expansion. After each ablation, catheter 200 and endoscope 50 can be advanced such that expandable element 530 is distal to a previous ablation site using endoscopic visualization, such as to prevent ablating the same site twice.

[153] Shaft assembly 400 of catheter 200 can comprise one, two, or more discrete, contiguous axial sections (“sections” herein), where each section can comprise a different hardness and/or stiffness (“stiffness” herein). Alternatively or additionally, shaft assembly 400 and/or a section of shaft assembly 400 can comprise a continuously variable stiffness. A stiffness profile for shaft assembly 400 can be selected to enhance the pushability, rotation, and/or trackability (“trackability” herein) of catheter 200 (e.g. the ease at which catheter 200 is advanced through and/or retracted within the anatomy of the patient). Stiffness of each section of shaft assembly 400 is determined by the properties (e.g. hardness) of the materials used to manufacture (e.g. extrude) the particular section of shaft 401, the geometry of shaft 401 of that section (e.g. geometry of lumens, wall thicknesses, and the like), as well as the properties of the components positioned within one or more lumens of that section of shaft 401.

[154] Shaft 401 can comprise multiple sections, each with a different stiffness (e.g. a minimally varying stiffness along the length of the section), and/or it can include one or more sections with a varying (e.g. continuously varying) stiffness. In some embodiments, shaft assembly 400 of catheter 200 comprises three sections, sections S_P , S_M , and S_D , shown in Fig. 2B, each with a different stiffness. Catheter 200 can comprise a distal tip, tip 410, such as a tip with a tapered shape as shown. In some embodiments, shaft 401 terminates at the distal end of functional assembly 500, and tip 410 comprises a shaft that extends from the distal end of shaft 401. Alternatively or additionally, tip 410 can comprise the distal portion of shaft 401, such as a tapered portion of shaft 401 extending beyond the distal end of functional assembly 500. Section S_P can comprise the proximal portion of shaft 401, extending distally from handle 300; section S_M can comprise a middle section of shaft 401, adjacent and distal to section S_P ; and section S_D can comprise a distal section of shaft 401 adjacent and distal to section S_M (e.g. the portion of shaft 401 immediately proximal to functional assembly 500), each as shown. In some embodiments, catheter 200 comprises a fourth section, section S_T , comprising at least the distal tip 410 of shaft 401, also as shown. Sections S_P , S_M , and S_D can be similar and/or dissimilar to proximal portion 406, middle portion 407, and distal portion 408 of shaft assembly 400, respectively, described herein in reference to Fig. 1. For example, sections S_P , S_M , and/or S_D can each comprise a discrete length of shaft assembly 400, each section spanning some or all of the length of one or more of portions 406, 407, and/or 408.

[155] Each section S_P , S_M , S_D , and/or S_T can comprise a stiffness similar or dissimilar from the stiffness of an adjacent section. In some embodiments, section S_P comprises a first stiffness, section S_M comprises a second stiffness, section S_D comprises a third stiffness, and section S_T comprises a fourth stiffness, where two, three, or four (all) of these sections comprise different stiffnesses. In some embodiments, the stiffness of section S_P can comprise the highest stiffness, the stiffness of section S_M can comprise the second highest stiffness, the stiffness of section S_D can comprise the third highest stiffness, and/or the stiffness of section S_T can comprise the lowest stiffness (e.g. each successive section of catheter 200 has a lower stiffness than the adjacent proximal section). In some embodiments, section S_P of shaft 401 comprises a higher stiffness (e.g. higher relative to the other sections of catheter 200), such as a stiffness configured to aid in the trackability of catheter 200 (e.g. the ability to advance catheter 200 into the anatomy of the patient without kinking or other undesired deformation). Section S_D of shaft 401 can comprise a relatively flexible section (e.g. lower stiffness than sections S_P and/or S_M), such as a stiffness configured to enable a smaller bend radius than the more proximal sections, enhancing the trackability of catheter 200 (e.g. the trackability of the distal portion of catheter 200 through tortuous portions of the anatomy). Section S_M can comprise a relatively medium stiffness (e.g. a stiffness at a level between that of sections S_P and S_D), configured to maintain an adequate pushability of catheter 200 while being flexible enough to follow section S_D through anatomical bends in the patient, such as the path through the stomach, pylorus, and into the duodenum.

[156] In some embodiments, a stiffness change between two adjacent sections of shaft 401 occurs over a relatively short stiffness transition (e.g. an abrupt transition) or a relatively long transition of stiffness. For example, a short stiffness transition can comprise a distance of less than 2.5", less than 1.5", or less than 1", while a long stiffness transition can comprise a distance of at least 6", at least 12", or at least 18". Stiffness transitions between two adjacent sections of shaft 401 can be created during a manufacturing process of shaft 401. For example, a butt-welding of the two sections can include a reflow of the materials of the two sections (e.g. a reflow of two materials of different hardness). Alternatively or additionally, an extrusion process used to create at least the two sections of shaft 401 can be configured to controllably vary the stiffness of the manufactured extrusion (e.g. the resultant extrusion can include a material change at the transition that includes mixing of two or more materials). Long transitions in stiffness can be included to prevent or at least limit kinking of shaft 401 (e.g. to limit kinking in the transition regions of shaft 401).

[157] In some embodiments, shaft 401 comprises an extrusion that gradually transitions from a first stiffness at the proximal end of shaft 401 to a second, lesser stiffness at the distal end of shaft 401 (e.g. via an extrusion process as described herein). In these embodiments, the stiffness transition can be uniform along the length of shaft 401. Alternatively, as described herein, the transition can be

varied, such that the sections of shaft 401 maintain a near constant stiffness and the stiffness transitions gradually (e.g. over at least 2.5") between sections S_P, S_M, S_D, and/or S_T.

[158] Section S_P can comprise at least a first S_P material, such as a material with a durometer of at least 63D or 70D, such as a material with a durometer of approximately 63D, or 80D. In some embodiments, section S_P comprises this first S_P material (e.g. polyether block amide) and one or more additives such as a lubricant, a plasticizer, and/or a radiopaque additive (e.g. barium sulfate at a 20% concentration), where the inclusion of these one or more additives can change (e.g. increase) the durometer of the section. Section S_M can comprise at least a first S_M material, such as a material with a durometer of approximately 55D. Similar to section S_P, section S_M can comprise this first S_M material (e.g. polyether block amide) and one or more additives such as a lubricant, a plasticizer, and/or a radiopaque additive (e.g. barium sulfate at a 20% concentration), where the inclusion of these one or more additives can change (e.g. increase) the durometer of the section. Section S_D can comprise at least a first S_D material, such as a material with a durometer of approximately 40D. Similar to sections S_P and/or S_M, section S_D can comprise this first S_D material (e.g. polyether block amide) and one or more additives such as a lubricant, a plasticizer, and/or a radiopaque additive (e.g. barium sulfate at a 20% concentration), where the inclusion of these one or more additives can change (e.g. increase) the durometer of the section. In some embodiments, at least one section of shaft 401 comprises a mixture of at least 5% of a radiopaque material, such as at least 10%, such as at least 20%, such as at least 30%, such as at least 40%. Section S_T can comprise at least a first S_T material, such as a material with a durometer of approximately 35D. Similar to sections S_P, S_M, and/or S_D, section S_T can comprise this first S_T material (e.g. polyether block amide) and one or more additives such as a lubricant, a plasticizer, and/or a radiopaque additive (e.g. barium sulfate at a 20% concentration), where the inclusion of these one or more additives can change (e.g. increase) the durometer of the section. Tip 410 can comprise a taper (e.g. a taper such that the distal portion of tip 410 comprises a smaller diameter than the proximal portion of tip 410). In some embodiments, the taper and/or other geometric feature (e.g. wall thickness variation) of tip 410 is configured such that the proximal portion of tip 410 comprises a stiffness greater than guidewire 60, and the distal portion of tip 410 comprises a stiffness less than guidewire 60 (e.g. guidewire 60 which can be slidably positioned within catheter 200, exiting the distal portion of tip 410). In some embodiments, the proximal end of tip 410 comprises a stiffness approximately equal to the stiffness of the distal end of section S_D. In some embodiments, section S_D and/or S_T comprises at least one material (e.g. polyether block amide) with a durometer of less than 40D, such as less than 30D, such as less than 20D, such as approximately 10D.

[159] Section S_P can comprise a length long enough to reach the pylorus of the patient when catheter 200 is fully inserted into the patient. In some embodiments, the length of sections S_P, S_M,

and/or S_D are selected to enable catheter 200 to be advanced into the patient such that functional assembly 500 can be positioned at least 15" into the duodenum, such as at least 18" into the duodenum. In some embodiments, section S_P comprises a length of at least 32", such as at least 49", such as no more than 72", such as approximately 57". Section S_M can comprise a length of at least 10", such as approximately 17". Section S_D can comprise a length of at least 2", such as approximately 5". In some embodiments, the transition between section S_M and S_D is co-located with manifold 700d (e.g. manifold 700d is positioned over the transition point between sections S_M and S_D). In these embodiments, manifold 700d can be configured to provide a reinforcing support to shaft 401 at the transition between sections S_M and S_D, such as to prevent kinking of shaft 401 at the transition. Manifold 700d is described in further detail herein in reference to Figs. 3A and 3B.

[160] Shaft 401 of Fig. 2A and 2B has been described in terms of a shaft with at least a portion with a continuously varying stiffness (e.g. lower stiffness at distal locations), or a shaft with three or four sections with different stiffnesses (e.g. successively lower stiffnesses in each more distal section). In some embodiments, shaft 401 comprises two sections with different stiffnesses, such as a proximal section with a greater stiffness than a distal section, such as to improve trackability as described herein. In some embodiments, shaft 401 comprises four, five, six or more sections with different stiffnesses (e.g. successively lower stiffnesses in each more distal section), such as to improve trackability as described herein.

[161] In some embodiments, sections S_P, S_M, and/or S_D each comprise a stiffness as defined by a stiffness test performed by a test fixture, such as test fixture 800 described herein in reference to Fig. 5. The "required bending force" described herein is defined by the force required to cause the midpoint of a two-inch span of the section of shaft assembly 400 to deflect approximately 0.125" (as described herein in reference to Fig. 5). In some embodiments, section S_P of shaft assembly 400 comprises a stiffness with a required bending force of at least 10lbf, such as at least 13lbf, such as 16lbf. Section S_M of shaft assembly 400 can comprise a stiffness with a required bending force of at least 8lbf, such as at least 10lbf, such as 11lbf. Section S_D of shaft assembly 400 can comprise a stiffness with a required bending force of no more than 14lbf, such as no more than 11lbf, such as no more than 8lbf, such as no more than 5lbf. In some embodiments, section S_M comprises a required bending force of at least 3lbf more than the required bending force of section S_D. In some embodiments, section S_P comprises a required bending force of at least 4lbf more than the required bending force of section S_M. In some embodiments, section S_P comprises a required bending force of at least 7lbf more than the required bending force of section S_D.

[162] **Referring now to Figs. 3A and 3B**, a side view and an end view of the distal portion of a catheter for treating tissue are illustrated, respectively, consistent with the present inventive concepts. Catheter 200 includes shaft assembly 400 and functional assembly 500, and other components of

similar construction and arrangement to those described herein. Shaft assembly 400 comprises a multi-lumen shaft, shaft 401, and a distal tip, tip 410. Shaft assembly 400 can comprise one or more ports, port 490 shown, a port configured to allow a guidewire, such as guidewire 60, to exit shaft 401. Port 490 is operably attached to a lumen of shaft 401, lumen 492 shown, through which a guidewire can be inserted. In some embodiments, lumen 492 extends between port 490 and a more proximal opening, such as an opening proximate the distal end of functional assembly 500, the proximal end of functional assembly 500, and/or manifold 700d (described herein), such that catheter 200 can be inserted into the patient over guidewire 60 in a “rapid exchange” manner. Alternatively or additionally, a guidewire 60 lumen can extend to a proximal end of catheter 200, such as to a location proximate but distal to handle 300 and/or within handle 300, such as to support a standard “over-the-wire” delivery of catheter 200.

[163] Catheter 200 further includes manifold 700d, including housing 5002, which provides fluid connections between various lumens and other conduits within shaft 401 (proximal to manifold 700d) to various lumens and other conduits that provide and/or remove fluid to and/or from functional assembly 500. Functional assembly 500 can comprise a radially expandable and contractible element, expandable element 530 (e.g. a balloon as described herein). Positioned on expandable element 530 are one, two, three, or more tissue capture chambers 510 (e.g. three chambers 510a-c shown). Chambers 510a-c are each fluidly attached to a separate multi-lumen shaft, conduits 5010a-c respectively. In some embodiments, conduits 5010a-c each comprise at least two lumens (e.g. a lumen for a tube fluidly connected to an injectate delivery conduit 5010 and a lumen for providing a vacuum to a tissue capture chamber 510). Conduits 5010a-c are each fluidly attached to manifold 700d. A translatable needle or other fluid delivery element, injectate delivery element 520a-c, can be positioned in each respective chamber 510a-c. In some embodiments, conduits 5010a-c each comprise a material with a durometer less than or equal to the durometer of section S_D of shaft 401, as described herein. For example, conduits 5010a-c can each comprise a material with a durometer of approximately 40D. Manifold 700d, conduits 5010, and functional assembly 500 can be of similar construction and arrangement to similar components described in applicant’s co-pending United States Patent Application Serial Number 16/742,645, entitled “Intestinal Catheter Device and System”, filed January 14, 2020.

[164] In some embodiments, and as shown in Figs. 3A and 3B, conduits 5010a-c comprise a spiral geometry positioned about shaft 401 (e.g. a clockwise and/or a counterclockwise spiral). Conduits 5010a-c each attach to a separate chamber 510a-c, respectively. Chambers 510a-c are positioned at an angle θ relative to where the proximal end of conduit 5010 exits manifold 700d (angle θ shown in Fig. 3B). In some embodiments, angle θ comprises an angle of approximately 180° . In some embodiments angle θ is at least 25° , such as at least 50° , or at least 100° . In some embodiments,

conduits 5010a-c comprise a biased shape, such as a shape created via a heat set (e.g. as described herein). Conduits 5010a-c can comprise a biased shape configured to minimize stress (e.g. torsional stress) between manifold 700d and chambers 510a-c (e.g. stress caused by conduits 5010a-c on chambers 510a-c as catheter 200 flexes while advanced through the anatomy of the patient). In some embodiments, the biased shape of conduits 5010a-c comprises an “S” like shape. Additionally or alternatively, the biased shape can comprise a twist along the length of conduit 5010. In some embodiments, for example when angle θ comprises an angle of approximately 180° , conduit 5010 can comprise a bend (e.g. a heat set bend) without a twist (e.g. the orientation of chamber 510 matches the orientation of the one or more lumens of conduit 5010 without the need for a twist between manifold 700d and chamber 510 when angle θ is approximately 180°).

[165] **Referring now to Fig. 4**, a perspective view of a portion of shaft assembly 400 is illustrated, consistent with the present inventive concepts. Shaft 401 of Fig. 4 comprises a single shaft including multiple satellite lumens (e.g. lumen 4004 shown) positioned about a central lumen 4002. Specifically, the multiple satellite lumens 4004 can be configured to slidably receive one or more conduits, such as conduit 521 described herein. It can be desirable to equalize the path length of each lumen 4004 from the distal end of shaft 401 to the proximal end of shaft 401 (e.g. while shaft 401 transverses a tortuous path, such as a path through the duodenum or other portion of the gastrointestinal tract of a patient). Additionally or alternatively, it can be desirable to normalize the stiffness of shaft 401 along the length of shaft 401 at different bend planes (e.g. such that no bend shape is significantly favorable over any other along at least a portion of shaft 401). Shaft 401 can comprise a twisted geometry (e.g. a clockwise and/or a counterclockwise twist) along its length, such that each satellite lumen 4004 travels in a spiral pattern around the central axis of shaft 401. In some embodiments, shaft 401 comprises a counterclockwise twist, as shown in Fig. 4, such as to minimize path length differences encountered in the GI tract (e.g. a twist opposite to the inherent clockwise path encountered when positioned through the stomach and into the small intestine). In some embodiments, the outer surface of shaft 401 can comprise an indicator, marker 402, such as an elongate stripe along the shaft 401 that is aligned with a single satellite lumen. One or more markers 402 can provide a visual indicator of the twist in shaft 401. One or more markers 402 can provide a radial indicator of an internal lumen of shaft 401.

[166] In some embodiments, shaft 401 comprises a twist with a varying pitch along its length. For example, shaft 401 can comprise a proximal portion 401a that comprises a first length and a first pitch, and a distal portion 401b that comprises a second length and a second pitch, where the second length is different than the first length and/or the second pitch is different than the first pitch. Note that proximal portion 401a and distal portion 401b are not necessarily shown to scale in Fig. 4. In some embodiments, the second pitch is lower than the first pitch (i.e. distal portion 401b comprises

more twist per unit length than proximal portion 401a). In some embodiments, proximal portion 401a comprises a single twist (360°) and is approximately three times the length of distal portion 401b which comprises a single twist (360°). Either or both twists can comprise a counterclockwise twist (as shown in Fig. 4), which can be configured to minimize pathway length differences of tubular components within shaft 401 as described herein. In some embodiments, at least a portion of shaft 401 comprises a twist with a pitch of at least 0.5 twists per 72", such as at least 1 twist per 72", such as at least 3.5 twists per 72".

[167] In some embodiments, the twist imparted on shaft 401 is created in a heat-setting process in which shaft 401 is maintained in a fixture in a twisted state while heat is applied. Additionally or alternatively, the twist imparted on shaft 401 can be created during an extrusion process (e.g. as shaft 401 is extruded, the extrusion is twisted at a prescribed rate) to produce a shaft with a "natural" twist. Alternatively, using a multi-tube construction (e.g. instead of a multi-lumen extrusion), satellite "tubes" can be twisted about a central tube (comprising central lumen 4002), and the twisted satellite tubes can be laminated (reflowed) to the central tube in the twisted configuration.

[168] Shaft 401 can comprise a clockwise and/or counterclockwise twist. In some embodiments, shaft 401 comprises a counterclockwise twist (as shown in Fig. 4) configured to minimize pathway length difference of tubular components within shaft 401 as described herein. In some embodiments, shaft 401 can be similar to similar components described in applicant's co-pending United States Patent Application Serial Number 16/742,645, entitled "Intestinal Catheter Device and System", filed January 14, 2020.

[169] **Referring now to Figs. 5A and 5B**, side views of an elongate sample being tested in a test fixture are illustrated. As described herein, the stiffness of a portion of an elongate object can be defined by the results of a test performed on that portion of the device utilizing a test fixture according to the present inventive concepts. Test fixture 800 comprises an actuator assembly 810 and a support assembly 820. Actuator assembly 810 comprises a housing 811, and a piston 812 configured to extend from housing 811. Support assembly 820 comprises two support arms 821a and 821b, each extending from a base 822. Support arms 821a,b are separated by a distance D_s , as shown. Actuator assembly 810 is positioned relative to support assembly 820 such that piston 812 is positioned equidistant between support arms 821a and 821b. In some embodiments, test fixture 800 includes an off-the-shelf tensile tester, such as a Chatillon tensile tester, and piston 812 and support assembly 820 comprise attachments configured to operably attach to the tensile tester. Alternatively or additionally, actuator assembly 810 can comprise one, two, or more sensors and/or processors configured to actuate piston 812 and/or to measure a force applied by piston 812 to a sample being tested (e.g. an elongate object, such as a section of shaft assembly 400 described herein).

[170] Actuator assembly 810 can be configured to apply a force to an elongate object, object SAMPLE shown, via piston 812 while SAMPLE is supported by support arms 821a and 821b. Test fixture 800 can be configured to measure the force required to bend SAMPLE one or more bend distances, such as bend distance D_D shown. Alternatively or additionally, test fixture 800 can be configured to apply a predetermined force(s) to SAMPLE and to measure the corresponding bend distance(s) to determine the stiffness of SAMPLE.

[171] As described in reference to Fig. 2 herein, applicant has conducted testing using test fixture 800 to assess the stiffness of various sections of shaft assembly 400 of the present inventive concepts. In these tests, test fixture 800 was configured as follows: support arms 821a,b were separated by a distance D_S of 1 inch; and each tested section of shaft assembly 400 was bent a distance D_D of 0.125 inches. Results of the testing are described herein in reference to Fig. 2.

[172] The above-described embodiments should be understood to serve only as illustrative examples; further embodiments are envisaged. Any feature described herein in relation to any one embodiment may be used alone, or in combination with other features described, and may also be used in combination with one or more features of any other of the embodiments, or any combination of any other of the embodiments. Furthermore, equivalents and modifications not described above may also be employed without departing from the scope of the invention, which is defined in the accompanying claims.

WHAT IS CLAIMED IS:

1. A device for performing a medical procedure in the intestine of a patient comprising:
an elongate shaft assembly comprising at least a shaft assembly first section comprising a distal section of the shaft assembly, and a shaft assembly second section proximal to the first section, and
a functional assembly positioned on the shaft assembly first section;
wherein the shaft assembly first section comprises a first stiffness,
wherein the shaft assembly second section comprises a second stiffness, and
wherein the first stiffness is less stiff than the second stiffness.
2. The device as claimed in at least one of the preceding claims, wherein the intestine comprises at least a portion of the small intestine.
3. The device according to claim 2, wherein the intestine comprises at least a portion of the duodenum.
4. The device as claimed in at least one of the preceding claims, wherein the shaft assembly comprises a multi lumen shaft.
5. The device according to claim 4, wherein the elongate shaft assembly further comprises at least one conduit positioned within a lumen of the multi lumen shaft.
6. The device as claimed in at least one of the preceding claims, wherein the shaft assembly first section comprises a length of at least 2 inches.
7. The device as claimed in at least one of the preceding claims, wherein the shaft assembly second section comprises a length of at least 10 inches.
8. The device as claimed in at least one of the preceding claims, wherein the shaft assembly further comprises a shaft assembly third section proximal to the shaft assembly second section.
9. The device according to claim 8, wherein the shaft assembly third section comprises a length of at least 32 inches.
10. The device according to claim 8, wherein the shaft assembly third section is longer than the shaft assembly second section and the shaft assembly second section is longer than the shaft assembly first section.
11. The device according to claim 8, wherein the shaft assembly first section comprises a material with a durometer of approximately 40D, the shaft assembly second section comprises a material with a durometer of approximately 55D, and the shaft assembly third section comprises a material with a durometer of approximately 63D.

12. The device according to claim 8, wherein the shaft assembly third section comprises a length of approximately 57 inches, the shaft assembly second section comprises a length of approximately 10 inches, and the shaft assembly first section comprises a length of approximately 5 inches.

13. The device according to claim 12, wherein the shaft assembly first section comprises a material with a durometer of approximately 40D, the shaft assembly second section comprises a material with a durometer of approximately 55D, and the shaft assembly third section comprises a material with a durometer of approximately 63D.

14. The device according to claim 8, wherein the shaft assembly is constructed and arranged to bend as follows:

a midpoint of a 2 inch span of a section deflects a distance of approximately 0.125 inches when the following force is applied:

at least 10lbf, at least 13lbf, or at least 16lbf applied to the shaft assembly third section;

at least 8lb, at least 10lbf, or at least 11lbf applied to the shaft assembly second section; and/or at most 14lbf, at most 11lbf, or at most 8lbf applied to the shaft assembly first section.

15. The device according to claim 8, wherein the shaft assembly is constructed and arranged to bend as follows:

a midpoint of a 2 inch span of the first section deflects a distance of approximately 0.125 inches when a first force is applied; and

a midpoint of a 2 inch span of the second section deflects a distance of approximately 0.125 inches when a second force is applied;

wherein the second force is at least 3lbf more than the first force.

16. The device according to claim 8, wherein the shaft assembly is constructed and arranged to bend as follows:

a midpoint of a 2 inch span of the second section deflects a distance of approximately 0.125 inches when a second force is applied; and

a midpoint of a 2 inch span of the third section deflects a distance of approximately 0.125 inches when a third force is applied;

wherein the third force is at least 4lbf more than the second force.

17. The device according to claim 8, wherein the shaft assembly is constructed and arranged to bend as follows:

a midpoint of a 2 inch span of the first section deflects a distance of approximately 0.125 inches when a first force is applied; and

a midpoint of a 2 inch span of the third section deflects a distance of approximately 0.125 inches when a third force is applied;

wherein the third force is at least 7lbf more than the first force.

18. The device as claimed in at least one of the preceding claims, wherein the shaft assembly further comprises a fourth section comprising a distal tip fixedly attached to a distal end of the shaft assembly first section, wherein the fourth section comprises a stiffness less than the stiffness of the shaft assembly first section.

19. The device according to claim 18, wherein the distal tip comprises a tapered distal tip.

20. The device as claimed in at least one of the preceding claims, wherein the functional assembly is configured to expand tissue within the intestine of the patient.

21. The device as claimed in at least one of the preceding claims, wherein the functional assembly is configured to ablate tissue within the intestine of the patient.

22. The device as claimed in at least one of the preceding claims, wherein the functional assembly is configured to remove tissue within the intestine of the patient.

23. The device as claimed in at least one of the preceding claims, wherein the functional assembly is configured to expand and ablate tissue within the intestine of the patient.

24. The device as claimed in at least one of the preceding claims, wherein the functional assembly comprises a balloon.

25. The device according to claim 24, wherein the functional assembly is configured to ablate tissue within the intestine of the patient with a hot fluid.

26. The device as claimed in at least one of the preceding claims, further comprising an injection assembly including at least one needle, at least one port, and at least one fluid delivery tube.

27. A device for performing a medical procedure in the intestine of a patient comprising:

an elongate shaft assembly comprising a proximal portion, a distal portion, and at least two lumens therethrough,

a functional assembly positioned on the distal portion of the elongate shaft assembly, and

an injection assembly comprising at least one port attached to the functional assembly and at least one conduit operably connecting one of the at least two lumens of the shaft assembly to the at least one port;

wherein the at least one conduit is rotated about the distal portion of the shaft assembly.

28. The device as claimed in at least one of the preceding claims, wherein the at least one port comprises at least two ports and the at least one conduit comprises at least two conduits.

29. The device as claimed in at least one of the preceding claims, wherein the at least one port comprises at least three ports and the at least one conduit comprises at least three conduits.

30. The device as claimed in at least one of the preceding claims, wherein the at least one conduit is rotated at least 25° , at least 50° , or at least 100° about the distal portion of the shaft assembly.

31. The device according to claim 30, wherein the at least one conduit is rotated approximately 180° about the distal portion of the shaft assembly.

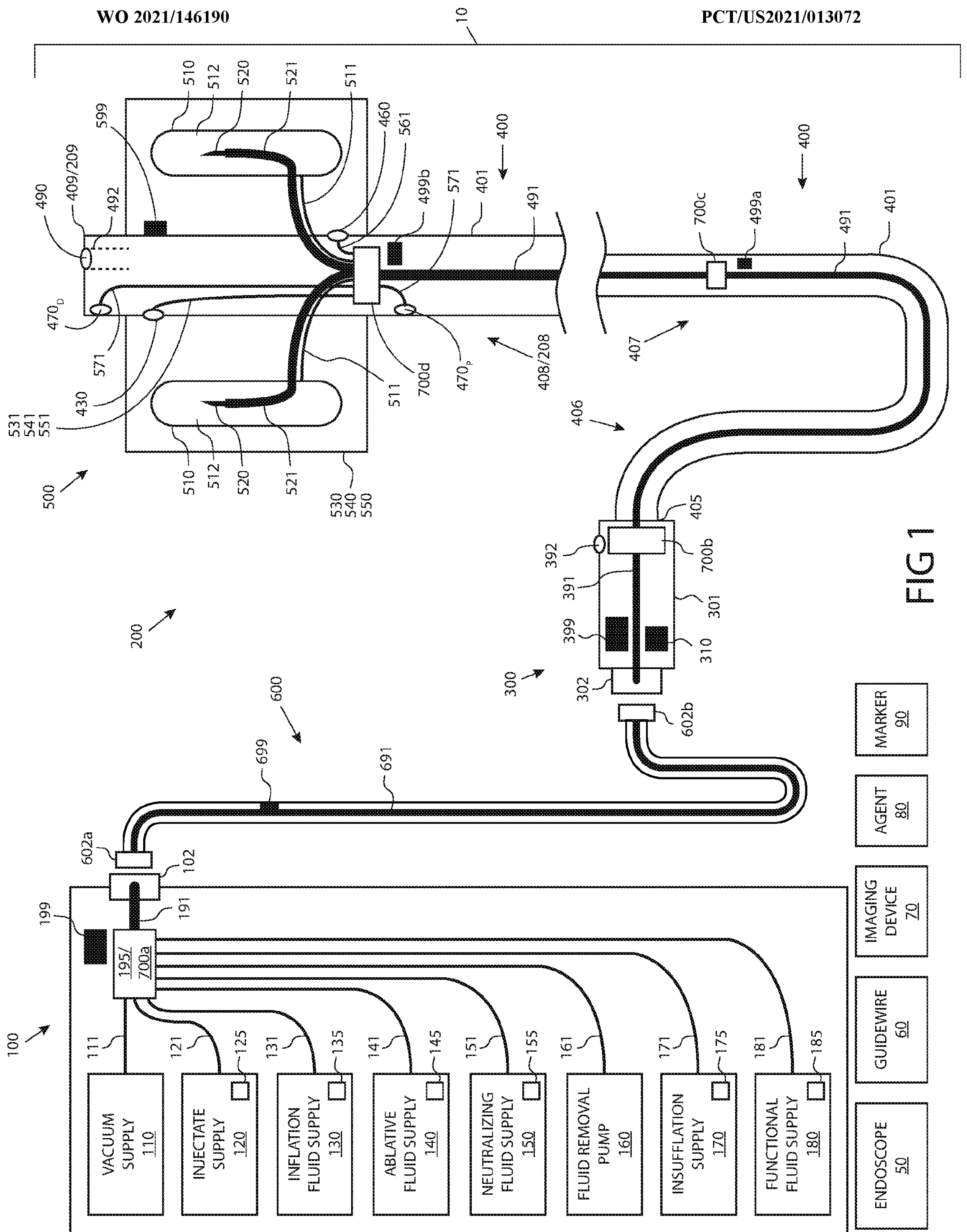
32. The device as claimed in at least one of the preceding claims, wherein the at least one conduit comprises a biased shape.

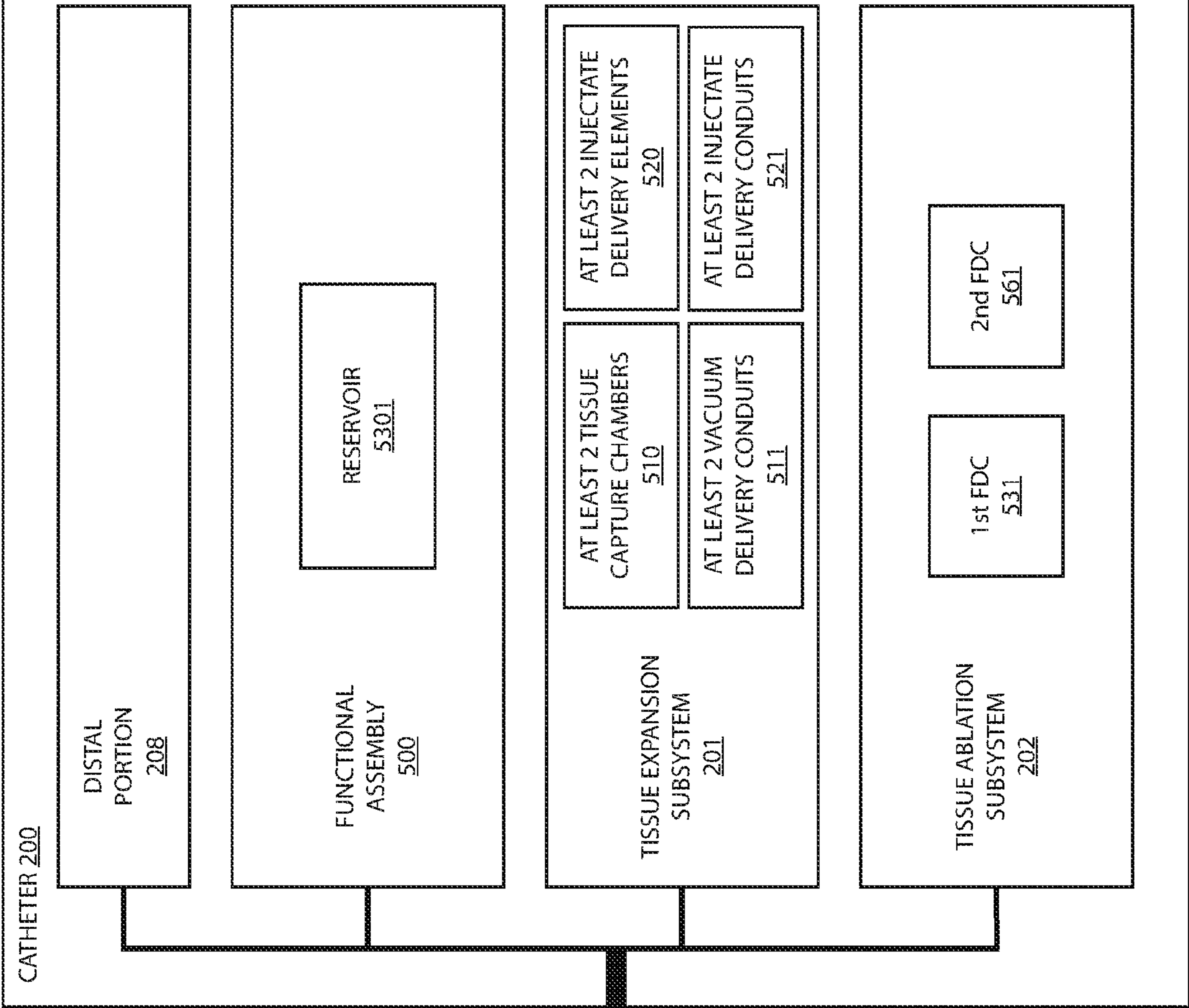
33. The device according to claim 32, wherein the biased shape comprises an “S” shape.

34. The device as claimed in at least one of the preceding claims, wherein the at least one conduit comprises at least one lumen therethrough.

35. The device according to claim 34, wherein the at least one lumen comprises at least two lumens.

36. The device as claimed in at least one of the preceding claims, wherein the shaft assembly further comprises a manifold, and wherein the manifold operably connects at least one of the at least two shaft lumens to the at least one conduit.





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FIG 1A

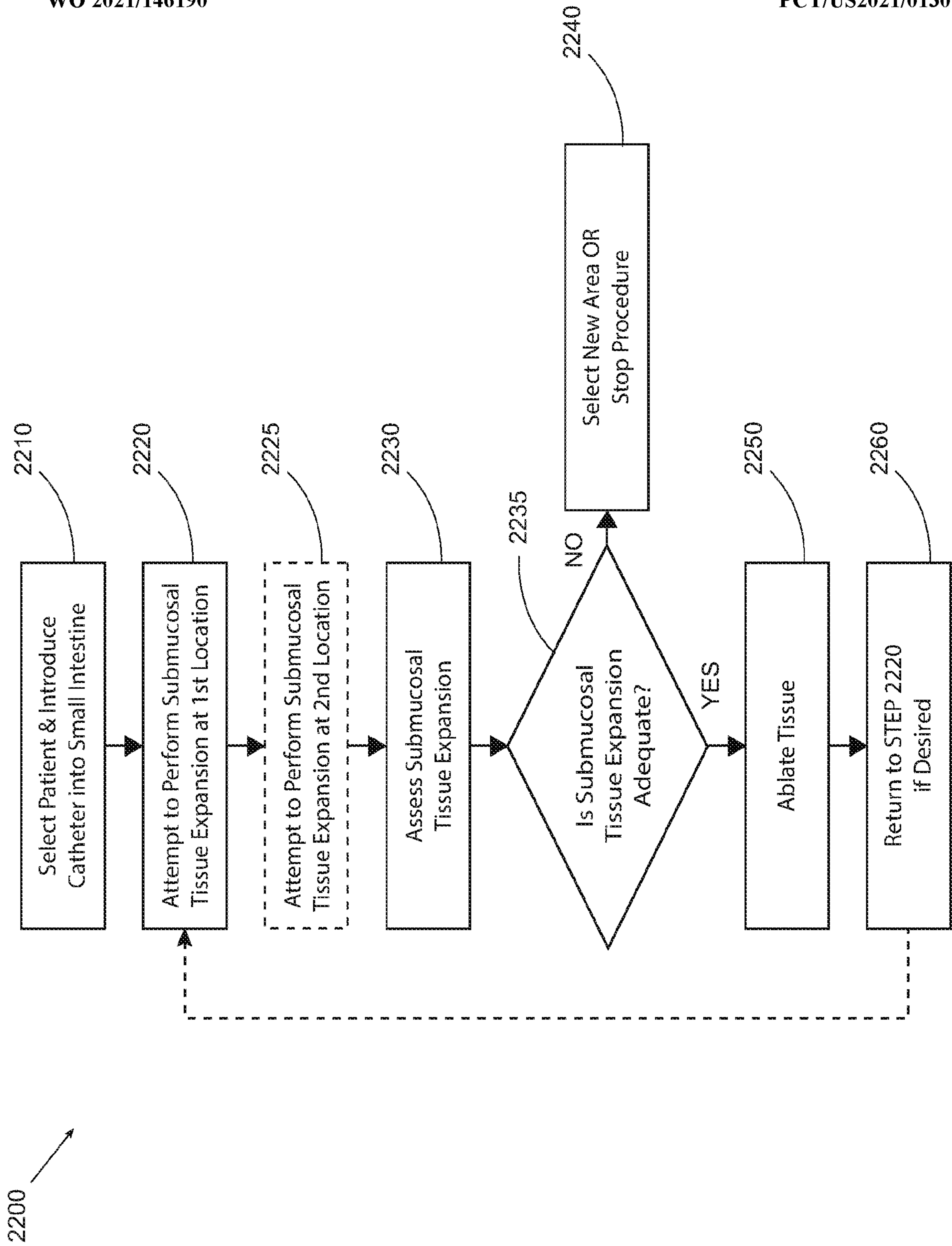


FIG 1B

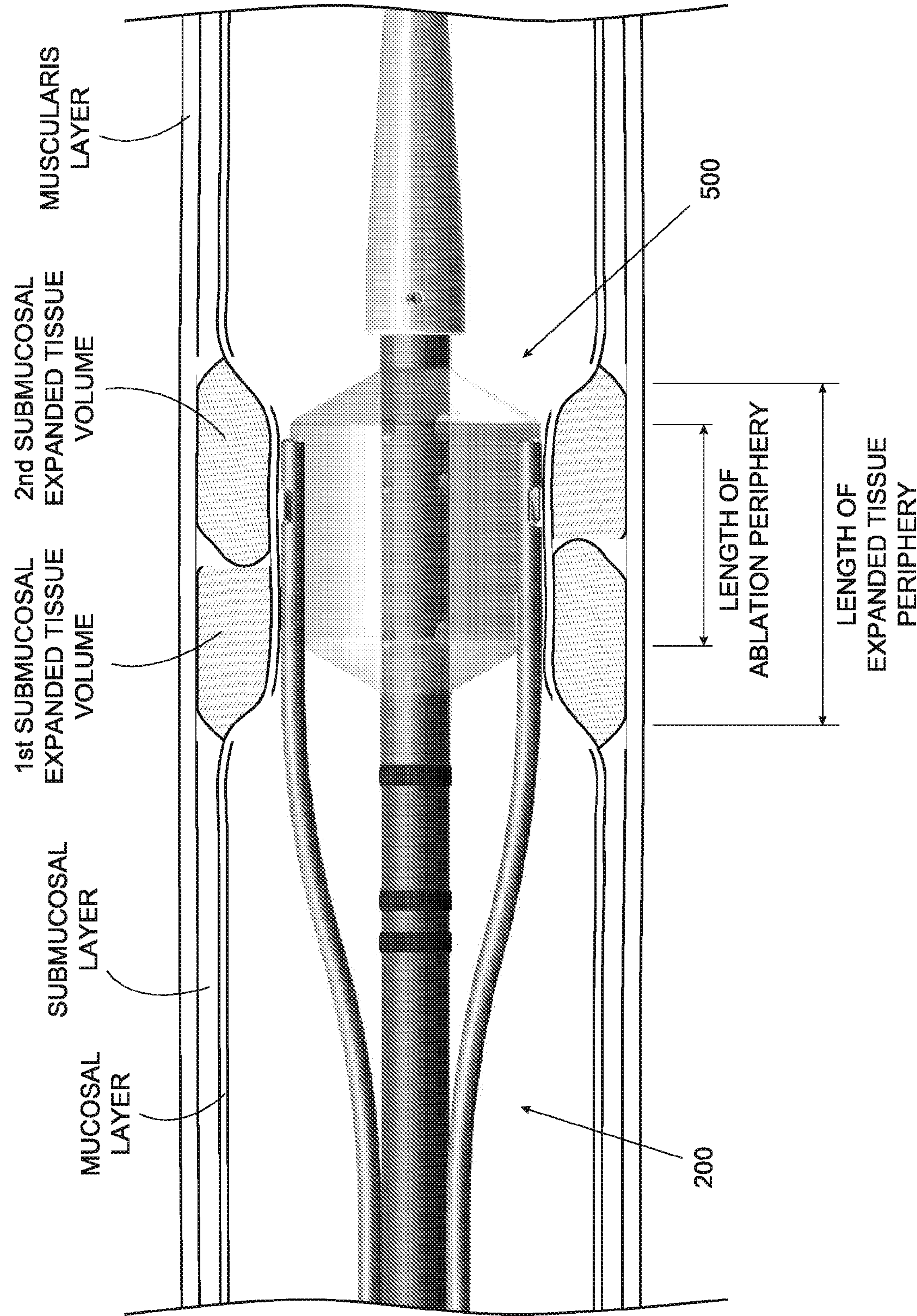


FIG 1C

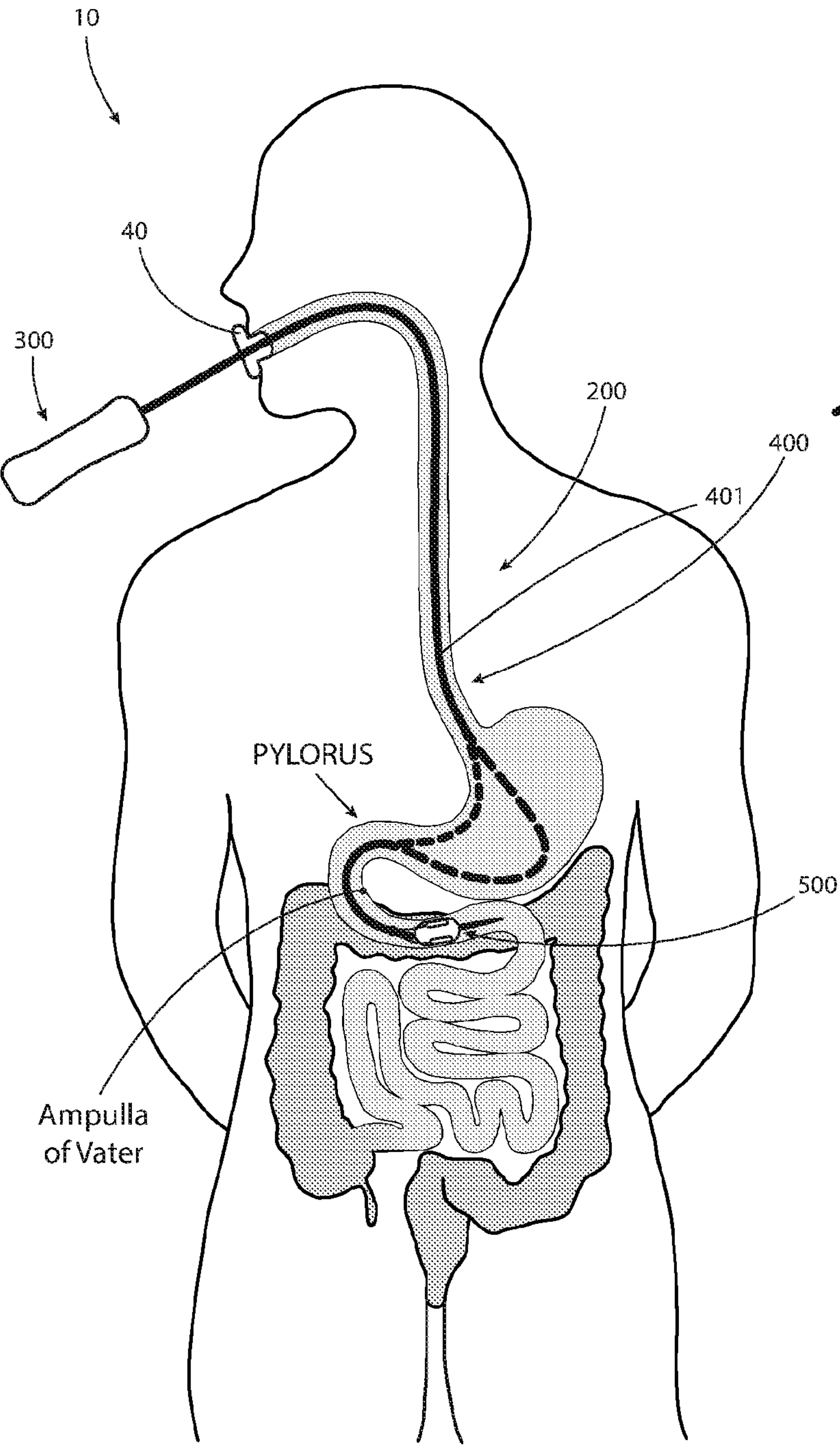


FIG 2A

FLEXIBILITY REGIONS

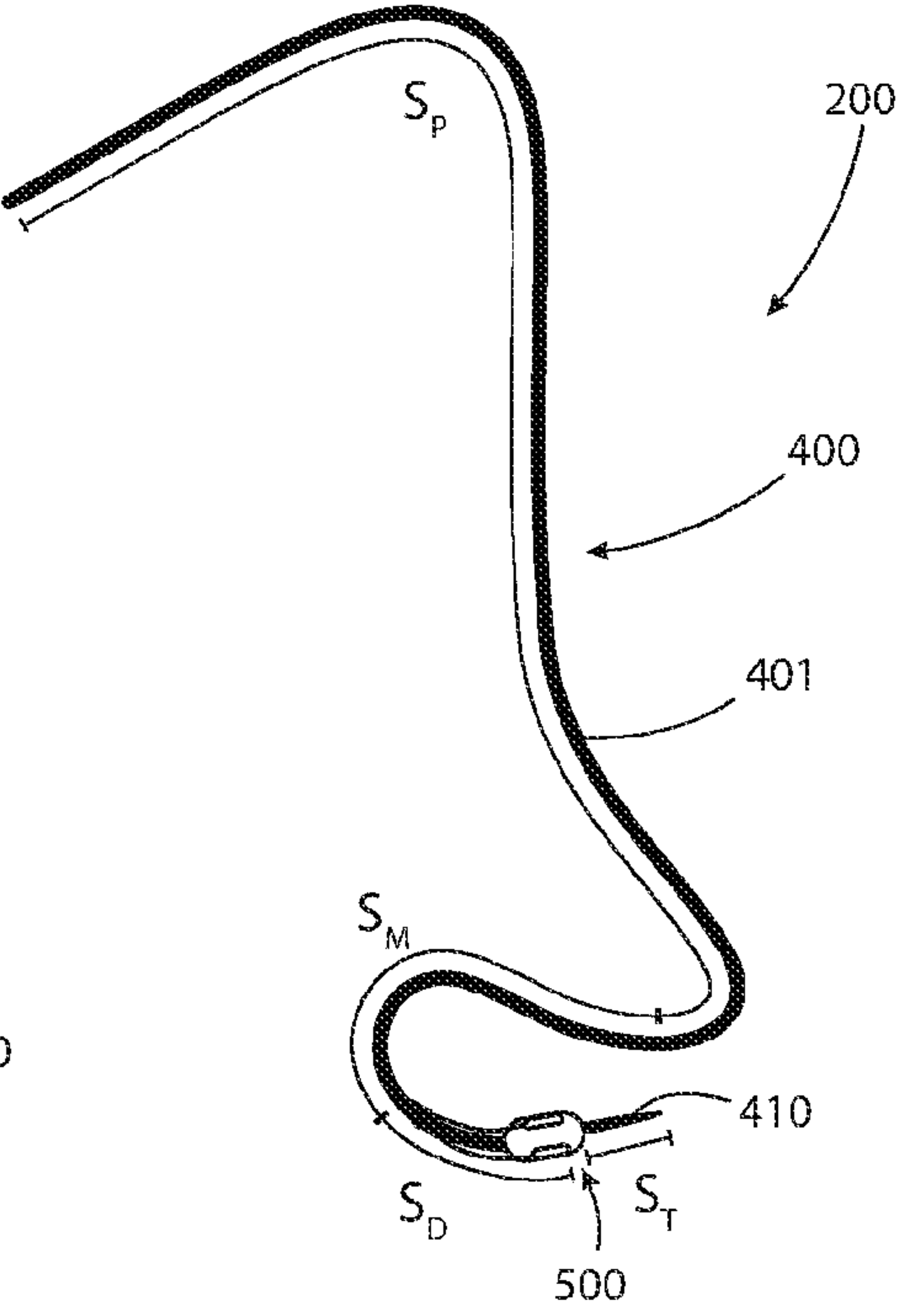


FIG 2B

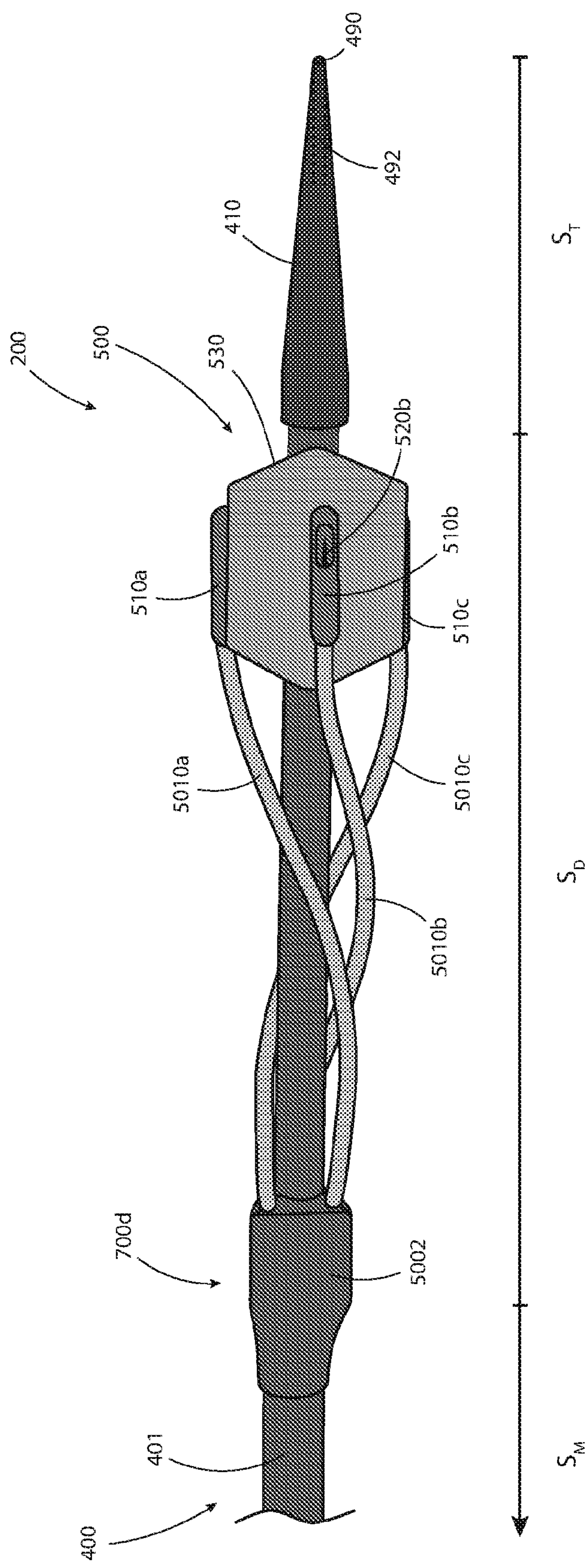


FIG 3A

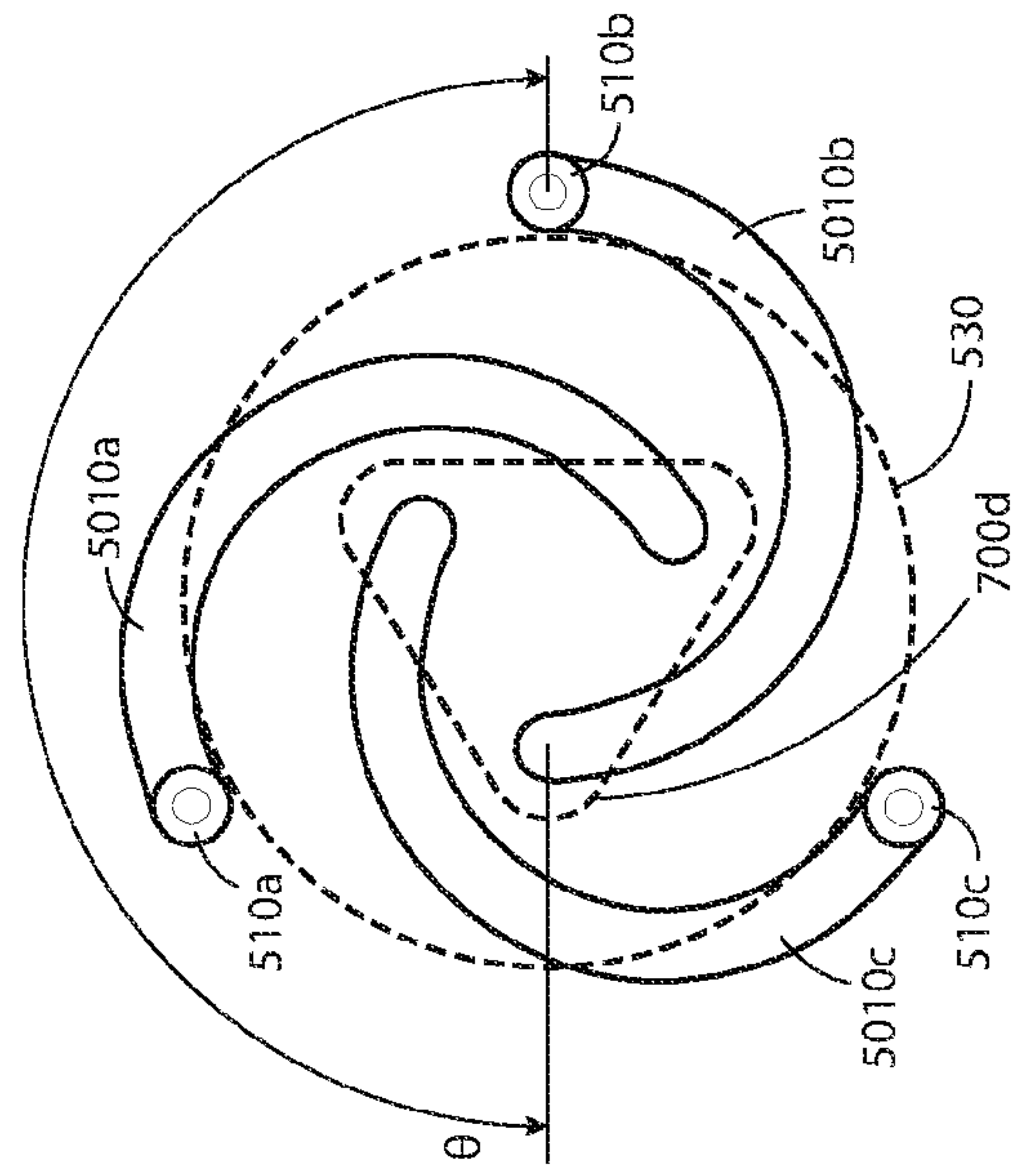


FIG 3B

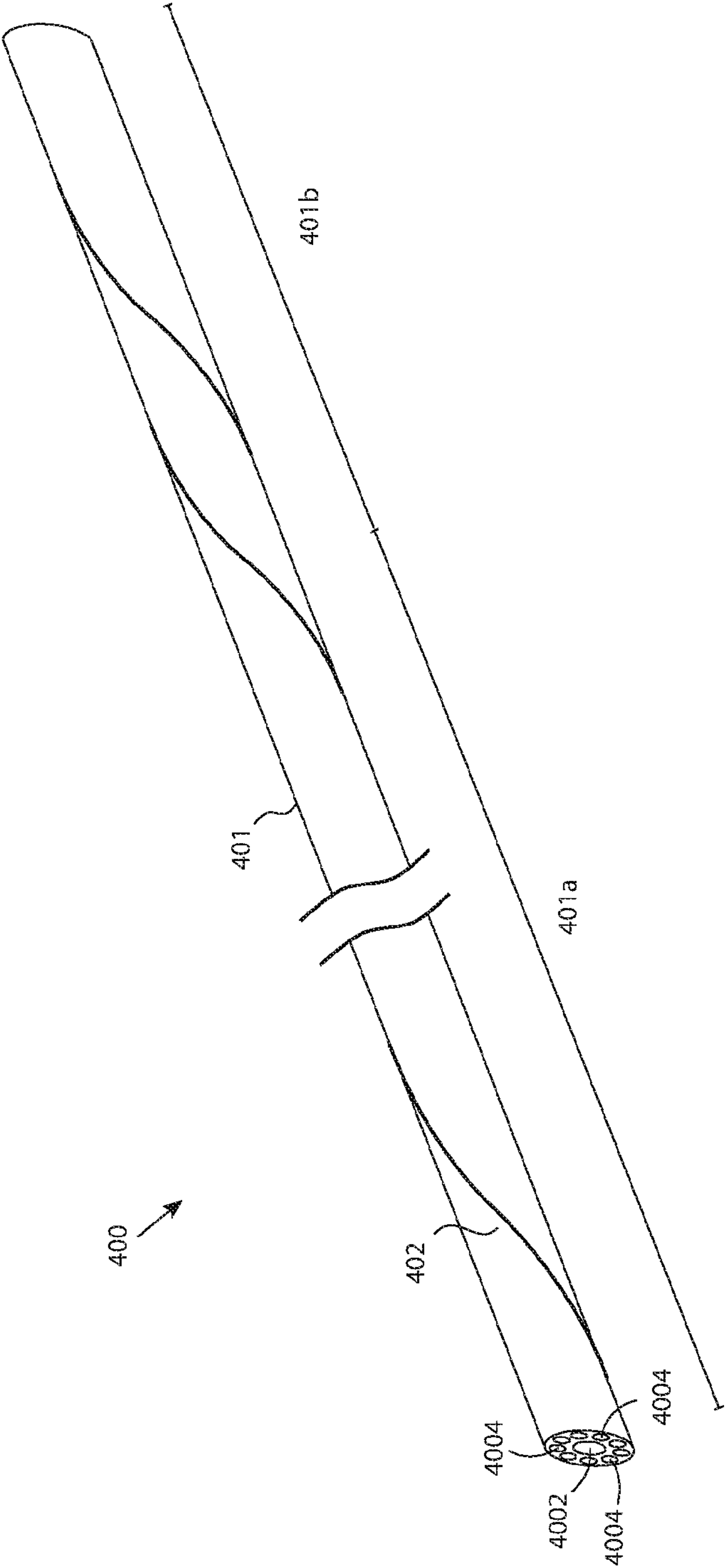


FIG 4

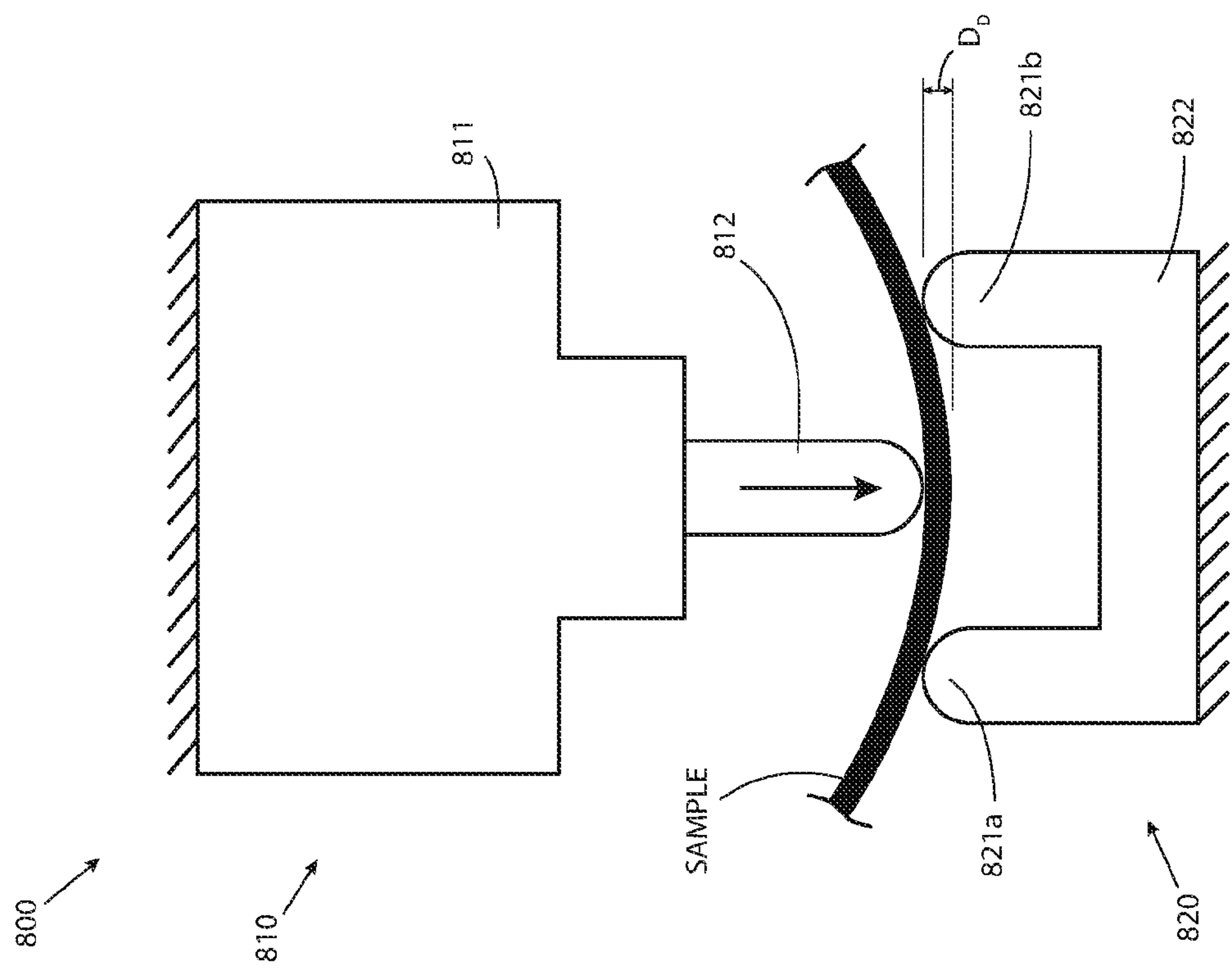


FIG 5A

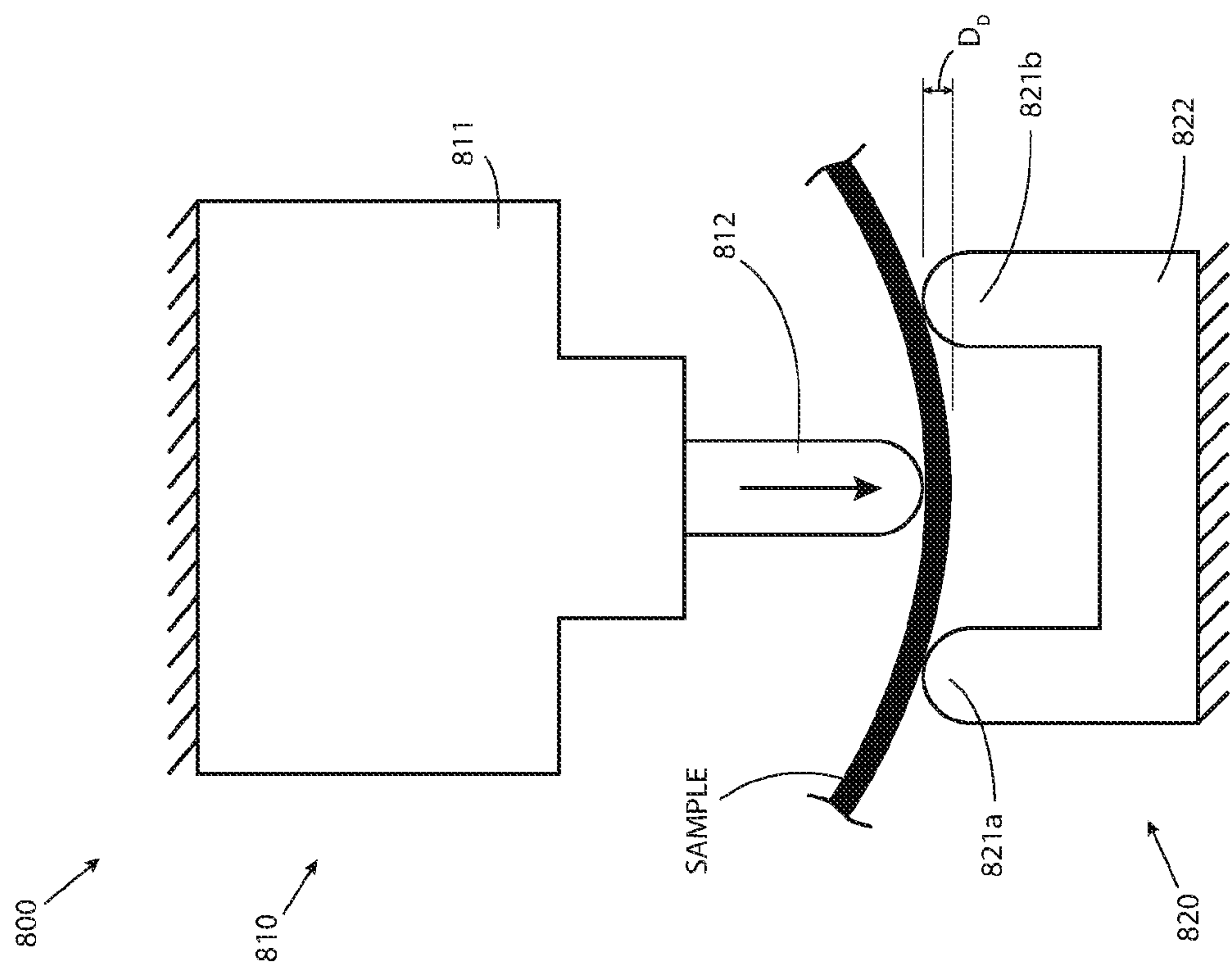


FIG 5B

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 21/13072

A. CLASSIFICATION OF SUBJECT MATTER

IPC - A61B 17/00, A61B 17/29, A61B 17/94, A61B 1/005, A61B 1/012, A61B 1/018 (2021.01)

CPC - A61B 17/29, A61B 2017/00323, A61B 2017/0034, A61B 46/10, A61B 46/13

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)

See Search History document

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

See Search History document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2016/0136393 A1 (Beth Isreal Deaconess Medical Center, Inc.) 19 May 2016 (19.05.2016), entire document	1-4 ----- 5
X --- Y	WO 2019/018362 A1 (Fractyl Laboratories, Inc.) 24 January 2019 (24.01.2019), entire document	27 ----- 5
A	US 2018/0221622 A1 (Fractyl Laboratories, Inc.) 9 August 2018 (09.08.2018), entire document	1-5, 27
A	US 2017/0325666 A1 (Shenyang Shenda Endoscope Co., LTD. et al.) 16 November 2017 (16.11.2017), entire document	1-5, 27

☐ Further documents are listed in the continuation of Box C.☐ 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 application or patent 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

10 March 2021 (10.03.2021)

Date of mailing of the international search report

APR 01 2021

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-8300

Authorized officer

Lee Young

Telephone No. PCT Helpdesk: 571-272-4300

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 21/13072

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

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

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☒ Claims Nos.: 6-26, 28-36
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

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

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

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

Remark on Protest

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