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Real-time sampling system

Abstract

Disclosed embodiments include apparatuses, systems, and methods for engaging a stylet within a needle. In an illustrative embodiment, an apparatus includes a stylet configured to be insertable into a lumen of a needle via a proximal port of secured to a needle actuator secured to the needle; and an end cap fixably coupled to the stylet and configured to cover a proximal end of the needle actuator and to be movable relative to the needle actuator to enable an operator to withdraw the stylet from the lumen.

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Background/Summary

PRIORITY CLAIM (1) The present application claims the priority and benefit of U.S. Provisional Patent Applications Ser. Nos. 63/123,571, 63/123,601, 63/123,623, 63/123,641, 63/123,696, and 63/123,731, all of which were filed Dec. 10, 2020, and were entitled “REAL-TIME SAMPLING SYSTEM.”

FIELD

(1) The present disclosure relates to an interface for controlling a device for collecting samples from within a body.

BACKGROUND

(2) The statements in this section merely provide background information related to the present disclosure and may not constitute prior art.

(3) Inserting and manipulating thin, elongated instruments within living bodies or other objects allows for ever-improving types of analysis, diagnosis, and treatment of those bodies or objects with minimally invasive techniques. By way of examples, noninvasive biopsies, endoscopic imaging, and catheterization treatments have enabled evaluation and treatment of numerous internal lesions without invasive surgery.

(4) Correspondingly, elongated instruments also may be used to collect samples from within a body in a relatively noninvasive matter. For example, when a biopsy from a lung is needed to determine whether a detected lesion is cancerous, instead of cutting into the patient's chest to procure a sample, an insertion device such as a bronchoscope may be used to guide one or more elongated instruments to a location near the lesion to procure a sample. However, merely conveying the elongated instruments to the location near the lesion may present only a part of what is needed to sample the lesion itself.

SUMMARY

(5) Disclosed embodiments include apparatuses, systems, and methods for controlling the sampling

of tissue using one or more elongated instrument insertable into a body.

(6) In an illustrative embodiment, an apparatus includes a coupling that is configured to join the control device with a port of an insertion device configured to convey an elongated instrument to a target location. A bushing extends from the coupling and is configured to be inserted within an opening in the port of the insertion device. The elongated instrument is movably extendable through the bushing. A first sealing member is disposed on an outer surface of the bushing and is configured to seal the outer surface of the bushing against an inner surface of the opening in the port. A second sealing member is disposed on an outer surface of the elongated instrument and is configured to movably seal an outer surface of the elongated instrument.

(7) In another illustrative embodiment, a system includes an elongated instrument. A control device is movably couplable with the elongated instrument and is configured to extend and retract the elongated instrument. A coupling is configured to removably secure the control device with an insertion device. The insertion device is configured to convey the elongated instrument to a target location and includes a port to receive the elongated instrument therethrough. A bushing extends from the coupling and is configured to be inserted within an opening in the port of the insertion device with the elongated instrument being movably extendable through the bushing. A first sealing member is disposed on an outer surface of the bushing and is configured to seal the outer surface of the bushing against an inner surface of the opening in the port. A second sealing member is disposed on an outer surface of the elongated instrument and is configured to movably seal an outer surface of the elongated instrument.

(8) In another illustrative embodiment, a method includes presenting a coupling adjacent to an opening in a port of an insertion device where the coupling supports an elongated instrument to be conveyed to a target location by the insertion device. A bushing through which the elongated instrument is inserted movably extends into the opening. An outer surface of the bushing seals against the opening to prevent fluid from passing between an inner surface of the opening and the outer surface of the bushing. An outer surface of the elongated instrument is movably sealed to prevent the fluid from passing between the outer surface of the elongated instrument and the coupling. Fluid is sealably prevented from passing into the coupling around the outer surface of the bushing and around the outer surface of the elongated instrument.

(9) In another illustrative embodiment, an apparatus includes a control device configured to facilitate extension of an elongated instrument to a target location. A port within an end of the control device is configured to compress against sides of the elongated instrument to secure the elongated instrument to move with the control device.

(10) In another illustrative embodiment, a system includes an elongated instrument configured to convey a sampling needle and an imaging probe to a target location. A control device is configured to facilitate extension of an elongated instrument to a target location. A securing mechanism within an end of the control device is configured to compress against sides of the elongated instrument to secure the elongated instrument to move with the control device.

(11) In another illustrative embodiment, a method includes receiving an elongated instrument into an instrument port of a control device configured to facilitate the extension of the elongated instrument to a target location. Sides of the elongated instrument are compressably secured by the control device so that the elongated instrument moves with control device.

(12) In another illustrative embodiment, an apparatus includes a stylet configured to be insertable into a lumen of a needle via a proximal port of secured to a needle actuator secured to the needle. An end cap fixably coupled to the stylet and configured to cover a proximal end of the needle actuator is movable relative to the needle actuator to enable an operator to withdraw the stylet from the lumen.

(13) In another illustrative embodiment, a system includes a needle defining a lumen. A stylet is configured to be insertable into a lumen of a needle via a proximal port of secured to a needle actuator secured to the needle. An end cap fixably coupled to the stylet and configured to cover a

proximal end of the needle actuator is movable relative to the needle actuator to enable an operator to withdraw the stylet from the lumen.

(14) In another illustrative embodiment, a method includes inserting a distal end of stylet into a lumen of a needle secured to a needle actuator. The stylet is inserted into the lumen until an end cap fixably engaged to a proximal end of the stylet covers a proximal end of the needle actuator. The end cap is withdrawn from the proximal end of the needle actuator until the stylet is withdrawn from the lumen. A vacuum source is coupled to the lumen.

(15) In another illustrative embodiment, a system includes a needle defining a lumen. A stylet is configured to be insertable into the lumen of the needle secured to a needle actuator. An end cap is fixably coupled to the stylet. The end cap is configured to be secured to a proximal end of the needle actuator when the stylet is fully inserted within the lumen. The end cap is further configured to cooperate with the proximal end of the needle actuator to prevent the stylet from being dislodged from within the lumen responsive to the needle actuator being manipulated to facilitate extraction of a tissue sample with a distal end of the needle.

(16) In another illustrative embodiment, a method includes inserting a distal end of stylet into a lumen of a needle secured to a needle actuator. The stylet is extended into the lumen until an end cap fixably engaged to a proximal end of the stylet engages a distal end of the needle actuator. The end cap is secured to the proximal end of the needle actuator so that, while the needle actuator is manipulated to facilitate extraction of a tissue sample with a distal end of the needle, the end cap prevents the stylet from being dislodged from within the lumen.

(17) In another illustrative embodiment, an apparatus includes a guide tube defining a lumen through which a needle is extendable. A needle actuator is configured to be fixably coupled to a proximal end of the needle. A first release device is movably coupled to the needle actuator and configured to be engageable to release the needle actuator to move from a retracted position at an end of a guide tube at which a distal end of the needle is retracted within a distal end of a sheath positionable adjacent a tissue to be sampled to a ready position where the distal end of the needle is adjacent the distal end of the sheath. A second release device is movably coupled to the needle actuator and configured to be engageable to release the needle actuator to move from the ready position to a sampling position where the distal end of the needle is advanceable into the tissue to be sampled.

(18) In another illustrative embodiment, a system includes a needle defining a first lumen. A sampling device is configured to be coupled to an insertion device configured to convey the needle to a tissue to be sampled. A guide tube extends from the sampling device and defines a second lumen through which a needle is extendable. A needle actuator is configured to be fixably coupled to a proximal end of the needle. A first release device is movably coupled to the needle actuator and configured to be engageable to release the needle actuator to move from a retracted position at an end of a guide tube at which a distal end of the needle is retracted within a distal end of a sheath insertable via the insertion device and positionable adjacent a tissue to be sampled to a ready position where the distal end of the needle is adjacent the distal end of the sheath. A second release device is movably coupled to the needle actuator and is configured to be engageable to release the needle actuator to move from the ready position to a sampling position where the distal end of the needle is advanceable into the tissue to be sampled.

(19) In another illustrative embodiment, a method includes engaging a first release device to release a needle actuator from a retracted position at an end of a guide tube at which a distal end of a needle is retracted within a distal end of a sheath positionable adjacent a tissue to be sampled. The needle actuator is advanced to a ready position to advance the distal end of the needle adjacent the distal end of the sheath. A second release device is engaged to release the needle actuator from the ready position. The needle actuator is advanced to advance the distal end of the needle into the tissue to be sampled.

(20) In another illustrative embodiment, an apparatus includes a guide tube defining a lumen

configured to slidably convey a needle from a proximal end of the guide tube to a distal end of the guide tube where the proximal end of the guide tube includes an asymmetrical outer cross-section. A needle actuator is configured to be coupled to a proximal end of the needle where the needle actuator includes an asymmetrical distal opening configured to receive the guide tube responsive to the needle actuator being oriented to cause a distal end of the needle to face in a desired direction.

(21) In another illustrative embodiment, a system includes a needle defining a first lumen. A sampling device is configured to be coupled to an insertion device configured to convey the needle to a tissue to be sampled. A guide tube defining a lumen is configured to slidably convey a needle from a proximal end of the guide tube to a distal end of the guide tube, wherein the proximal end of the guide tube includes an asymmetrical outer cross-section. A needle actuator is configured to be coupled to a proximal end of the needle, wherein the needle actuator includes an asymmetrical distal opening configured to receive the guide tube responsive to the needle actuator being oriented to cause a distal end of the needle to face in a desired direction.

(22) In another illustrative embodiment, a method includes inserting a distal end of a needle into a guide tube defining a lumen and configured to convey the distal end of the needle to a tissue to be sampled, where the needle is fixably coupled with a needle actuator. A distal opening in the needle actuator is presented to a proximal end of the guide tube, where the distal opening in the needle actuator is configured to slidably receive the proximal end of the guide tube responsive to the needle actuator being oriented in a desired direction to direct the distal end of the needle to face in a desired direction. The distal opening of the needle actuator is slid over an outer surface of the guide tube when the needle actuator is oriented in the desired direction.

(23) In another illustrative embodiment, an apparatus includes an anti-buckling device including at least one movable support bracket. The at least one bracket includes a generally planar member having an inner orifice and an outer edge configured to movably engage an inner surface of a channel where the planar member is configured to provide lateral support to an elongated instrument chosen from one of a needle and a probe extendable through the inner orifice responsive to the elongated instrument being motivated through the channel by an actuator receivable within the channel. The at least one bracket also includes a positioning member that extends from the planar member where the positioning member is configured to resist twisting of the planar member relative to an axis of the channel and to move relative to a distal end of the actuator so as not to impede movement of the actuator toward a distal end of the channel.

(24) In another illustrative embodiment, a system includes an elongated instrument chosen from one of a needle and a probe. A control device is movably couplable with the elongated instrument and configured to extend and retract the elongated instrument, the control device including an anti-buckling device that includes at least one movable support bracket. The at least bracket includes a generally planar member having an inner orifice and an outer edge configured to movably engage an inner surface of a channel. The planar member is configured to provide lateral support to the elongated instrument extendable through the inner orifice responsive to the elongated instrument being motivated through the channel by an actuator receivable within the channel. The at least one bracket also includes a positioning member that extends from the planar member where the positioning member is configured to resist twisting of the planar member relative to an axis of the channel and to move relative to a distal end of the actuator so as not to impede movement of the actuator toward a distal end of the channel.

(25) In another illustrative embodiment, a method includes engaging an actuator slidably received within a channel where the actuator is configured to be moved from a proximal end of the channel toward a distal end of the channel to advance an elongated instrument chosen from one of a needle and a probe through a distal opening at the distal end of the channel. The elongated instrument is movably supported away from an inner surface of the channel at a point between a distal end of the actuator and a distal end of the channel. At least a portion of the bracket is moved past the distal end of the actuator as the distal end of the actuator is advanced toward the distal end of the channel so

that the portion of the bracket does not impede movement of the distal end of the actuator toward the distal end of the channel.

(26) Further features, advantages, and areas of applicability will become apparent from the description provided herein. It should be understood that the description and specific examples are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

Description

DRAWINGS

(1) The drawings described herein are for illustration purposes only and are not intended to limit the scope of the present disclosure in any way. The components in the figures are not necessarily to scale, with emphasis instead being placed upon illustrating the principles of the disclosed embodiments. In the drawings:

(2) FIG. 1 is a side view of an illustrative sampling system;

(3) FIGS. 2 and 3 is an exploded view of a coupling of the system of FIG. 1;

(4) FIG. 4 is a cutaway view of the coupling of FIGS. 2 and 3;

(5) FIG. 5 is a perspective view of a port for securing an elongated instrument in an actuator of the system of FIG. 1;

(6) FIG. 6 is a cutaway view of the port in the actuator of FIG. 5;

(7) FIGS. 7 and 10 are side views of needle actuators and end caps of the system of FIG. 1;

(8) FIGS. 8 and 9 are cutaway views of the needle actuators and end caps of FIGS. 7 and 10, respectively;

(9) FIGS. 11A, 12A, and 13A are cutaway views of the needle actuator and release mechanism of FIG. 7 configured to control a position of a sampling needle;

(10) FIGS. 11B, 12B, and 13B are side plan views in partial schematic form of a distal end of the sampling needle positioned adjacent to a tissue to be sampled and corresponding to a configuration of the needle actuator and release mechanisms of FIGS. 11A, 12A, and 13A, respectively;

(11) FIG. 14 is a perspective view of the needle actuator of FIG. 7 mounted on a guide tube of the system of FIG. 1;

(12) FIGS. 15A and 15B are schematic diagrams of distal ends of sampling needles having a directional orientation;

(13) FIGS. 16 and 17 are plan views in partial schematic form of asymmetrical openings in a distal end of the needle actuator and guide tubes;

(14) FIGS. 18, 20, and 21 are perspective views in partial cutaway of the system of FIG. 1 showing anti-buckling devices;

(15) FIG. 19 is a side view of a representative anti-buckling device of FIGS. 18, 20, and 21;

(16) FIG. 22 is a flow chart of an illustrative method of coupling the system of FIG. 1 to an insertion device;

(17) FIG. 23 is a flow chart of an illustrative method of securing an elongated instrument within a port of the system of FIG. 1;

(18) FIG. 24 is a flow chart of an illustrative method of securing a stylet within a needle of the system of FIG. 1;

(19) FIG. 25 is a flow chart of an illustrative method of controlling advancement of a needle of the system of FIG. 1;

(20) FIG. 26 is a flow chart of an illustrative method of controlling orientation of a needle actuator of the system of FIG. 1; and

(21) FIG. 27 is a flow chart of an illustrative method of supporting an elongated instrument of the system of FIG. 1.

DETAILED DESCRIPTION

(22) The following description is merely illustrative in nature and is not intended to limit the present disclosure, application, or uses. It will be noted that the first digit of three-digit reference numbers, the first two digits of four-digit reference numbers correspond to the first digit of one-digit figure numbers and the first two-digits of the figure numbers, respectively, in which the element first appears.

(23) The following description explains, by way of illustration only and not of limitation, various embodiments of a control system for sampling tissue using an elongated instrument insertable into a body.

(24) It will be appreciated that various embodiments of the control system described herein may aid in the process of deploying and controlling an elongated instrument. In various embodiments, the elongated instrument may include a sheath that encompasses an imaging probe and a sampling needle. The sheath is insertable into a body to reach a targeted tissue to be sampled. The imaging probe may be used to locate the tissue or a portion of the tissue of interest to be sampled. The sampling needle may be used to procure a sample of that tissue.

(25) In various embodiments, the control system may be coupled with an insertion device, such as an endoscope or a bronchoscope, that includes an insertion conduit insertable into a body via an orifice or other opening. The control system may be coupled directly with the insertion device or coupled to a replaceable valve, such as a biopsy valve coupled with an endoscopic device. The insertion device enables the insertion conduit to be inserted into the body and directed to a desired location within the body. The insertion conduit may be configured to receive an elongated instrument that is extendable through the insertion conduit. The elongated instrument is insertable into the body via the insertion device to procure a tissue sample at the desired location within the body. The elongated instrument may be operably coupled with a control system that enables an operator to manipulate the elongated instrument to procure the tissue sample. An illustrative control system is described below.

(26) Referring to FIG. 1, an illustrative control system **100** operates in conjunction with an insertion device **190** (of which only a portion is shown in FIG. 1) such as an endoscope or a bronchoscope. The endoscopic device may include a replaceable valve, such as a biopsy valve (not shown), through which the elongated instrument **102** may be inserted. As previously described, the insertion device includes an insertion conduit that is insertable into a body via an orifice or other opening (none of which are shown in FIG. 1). The insertion device **190** receives the elongated instrument **102** that may be extended through the insertion conduit to the desired location. As also previously mentioned, in various embodiments, the elongated instrument **102** is a sampling probe that may include an imaging probe and a sampling needle contained within a sheath (none of which is individually shown in FIG. 1). The elongated instrument **102** is insertable via the insertion device **190** to procure a tissue sample at a desired location within a body. The elongated instrument **102** also may include a stylet (not shown in FIG. 1) that may be removably insertable into and/or through the needle, as further described below.

(27) The control system **100** herein described is coupled to the insertion device **190** using a coupling **110** at a distal end **111** of the control system **100**. The elongated instrument **102**, which is manipulated by the control system **100**, extends through the coupling **110** and is inserted into the insertion conduit (not shown) of the insertion device **190**. The elongated instrument **102** may be secured to an actuator **112** that is movably coupled to a housing **114**. The actuator **112** may be moved along the housing **114** between a proximal end **113** and the distal end **111** of the control system **100** (which corresponds with proximal and distal ends of the housing **114**) to extend and retract the elongated instrument **102** relative to the insertion device **190**. Anti-buckling devices (not shown in FIG. 1) may be received within the housing **114** to provide lateral support to the elongated instrument **102** as the actuator **112** motivates the elongated instrument **102** through the housing **114**.

(28) In various embodiments, the sheath of the elongated instrument **102** is fixably secured to the actuator **112** while the imaging probe and the needle are received into the sheath via the actuator **112**. A proximal port **120** is configured to receive and secure the imaging probe. A guide tube **130** is configured to receive and engage a needle actuator **140** to which the sampling needle is secured. The guide tube **130** and the needle actuator **140** may be movably coupled at an orientation interface **150**. The orientation interface **150** is configured to maintain an orientation of the needle actuator **140** relative to the guide tube **130** to control an orientation of the sampling needle, as further described below. The needle actuator **140** may removably receive an end cap **160** that is coupled with the stylet and that may be used to releasably secure the stylet within the sampling needle. The needle actuator also may include a release mechanism **170** that is positively engaged by an operator to permit advancing the sampling needle into a sampling position, as also further described below.

(29) Referring to FIG. 2, a coupling **110** may be used to secure the control system **100** to a port **290** of the insertion device **190**. As previously stated, the insertion device **190** may include a replaceable valve, such as a biopsy valve. In such cases, the coupling **110** may be coupled directly to the biopsy valve joined to the insertion device **190**. In various embodiments, the coupling **110** includes a sealing system **210**, a housing **250**, and a locking mechanism **270**. The components of the coupling **110** are configured to sealably secure the control system **100** to the insertion device **190**.

(30) In various embodiments, the sealing system **210** includes a bushing **212** that extends from the distal end **111** of the control system **100** (FIG. 1). The bushing **212** is configured to be slidably receivable within an opening **292** in a flange at an end of a connector **294** of the port **290**. The bushing **212** is sized to be slidable within the opening **292** and supports a first sealing member **214** and a second sealing member **224**.

(31) In various embodiments the first sealing member **214** may be in the nature of an O-ring that is configured to form a fluid seal between an outer surface **211** of the elongated instrument **102** (which may be the outer surface of a sheath) and an inner surface **216** of the bushing **212**. The first sealing member **214** thus may help prevent fluids from flowing out of the insertion device **190** between the outer surface **211** of the elongated instrument **102** and the bushing **212**. The first sealing member **214** is slidable and movable over the elongated instrument **102** as the elongated instrument **102** is inserted into the port **290**.

(32) The second sealing member **224** is configured to fluidly seal an outer surface **223** of the bushing **212** to the opening **292** of the connector **294** of the insertion instrument **190**. In various embodiments, the second sealing member **224** is a gasket configured to sealably engage the outer surface **223** of the bushing **212** and to sealably engage the opening **292** in the connector **294** of the port **290**. To this end, in various embodiments, the first sealing member **224** includes an angled surface **225** to sealably engage the opening **292**. The second sealing member **224** thus may prevent fluids from flowing out of the insertion device **190** between the opening **292** and the bushing **212**.

(33) In various embodiments, the two sealing members **214** and **224** may replace a single gasket or membrane used to seal the opening **292**. Use of a single gasket or membrane may require the elongated instrument **102** to be forced through a restrictive opening or through a surface of the membrane. As previously mentioned, the elongated instrument **102** may include an imaging probe, a sampling needle, and/or other potentially delicate devices that may be damaged in response to being forced through a restrictive opening or a surface of a membrane. By using a bushing **212** that supports the first sealing member **214** and the second sealing member **224**, a seal between the elongated instrument **102** and the opening **292** may be provided without risk of potential damage to the elongated instrument **102**.

(34) Continuing to refer to FIG. 3, in various embodiments the coupling **110** also includes the housing **250** which is secured to the insertion device **190** by the locking mechanism **270**. The housing **250** includes an outer housing **252** that is configured to cover the connector **294** and/or a base **298** of the connector **290** that extends from the insertion device **190**. The housing **250** also

includes a cowl **260** through which the elongated instrument **102** extends and that may cover and/or help to secure the bushing **212** and the sealing members **214** and **216**. In various embodiments, the cowl **260** assists in holding the first sealing member **214** in place against an end of the connector **290** of the insertion device **190**. The housing **250** also includes a slot **254** configured to receive the locking mechanism **270** that, in various embodiments, is slidably received therethrough.

(35) In various embodiments, the locking mechanism **270** includes a base **272** from which extends a locking member **274** configured to securably engage the connector **294**. Referring to FIGS. 2 and 3, the locking member **274** defines a contoured slot **276** between opposing legs **279**. The contoured slot **276** is configured such that, when the locking mechanism **270** is motivated through the slot **254**, the contoured slot **276** passes over the connector **294** of the port **290** of the insertion device **190**. In various embodiments, the contoured slot **276** includes a wide portion **278** and a narrow portion **280**. The wide portion **278** is configured to be wide enough to pass over the connector **294** and the flange **296**, which is wider than the connector **294**. The narrow portion **280**, however, while wide enough to pass over the connector **294**, is too narrow to pass over the flange **296**. When the locking mechanism **270** is in a secured position, the narrow portion **280** of the contoured slot **276** of the locking member **274** engages the connector **294** behind the flange **296**. The engagement of the locking member **274** with the flange **296** may prevent the coupling **110** from being withdrawn from the insertion device **190** until the locking mechanism **270** is manipulated to slide the narrow portion **280** of the locking member **274** out from behind the flange **296**.

(36) Once the locking mechanism **270** is in the secured position, one or more latches **284**, such as barbed hooks as shown in FIG. 3, engage notches or a similar structure (not shown) in the housing **250** to hold the locking mechanism **270** in place. The one or more latches **284** hold the locking member **274** in place until a removal force is applied to the base **272** to forcibly release the one or more latches **284** to permit the locking mechanism **270** to be at least partially withdrawn from the slot **254** in the housing **250**.

(37) Referring to FIG. 4, in various embodiments the control system **100** is joined with the insertion device **190** by the coupling **110**. The bushing **212** that extends from the control system **100** is inserted into the opening **292** of the port **290** of the insertion device **190**. The first sealing member **214** seals the outside of the elongated instrument **102** against the bushing **212**. In various embodiments, the first sealing member **214** is held in place against the end of the bushing **214** by a fitting **412** coupled with the cowl **260** of the housing **250** through which the elongated instrument **102** extends. The second sealing member **224** seals the outside of the bushing **212** against the opening **292** of the port **290** of the insertion device **190**.

(38) The locking mechanism **270** extends through the slot **254** in the housing **250**. The locking member **274** slides around the connector **294** of the port **290** behind the flange **296** to prevent the control system **110** from being withdrawn from the insertion device **190**. After the control system **110** has been used to collect a sample (not shown), the locking mechanism **270** may be forcibly disengaged to allow the locking mechanism **270** to be at least partially withdrawn from the slot **254** in the housing **250**. When the locking member **274** is moved so that the wide portion **278** (FIG. 3) of the contoured **276** slot passes across the flange **296**, the housing **250** may be moved away from the port **290** to allow the control system **110** to be withdrawn from the insertion device **190**.

(39) Referring to FIG. 5, in various embodiments the actuator **112** includes the proximal port **120** which may be used to securably receive an imaging probe as previously described. The actuator **112** is positioned at a distal end **501** of the housing **114**. The actuator **112** is laterally slidable along the housing **114** to advance the elongated instrument **102** (FIG. 1). As previously described, the elongated instrument **102** may include a sheath (not shown in FIG. 5) that is slidably motivated by the actuator **112**. In various embodiments, as previously described, the sheath may contain an imaging probe and a sampling needle (neither of which is shown in FIG. 5). Both the imaging probe and the sampling needle are securable to the actuator **112** so that, as the actuator **112** is advanced and retracted along the housing **114**, the imaging probe and the needle are advanced with

the sheath. The sampling needle may be separately secured to the actuator **112** and controlled by a needle actuator **140**, as further described below. The imaging probe may be received and secured by the proximal port **120** at a proximal end **530** of the actuator **112**. The proximal port **120** is configured to compress against and thereby compressably grip sides of the imaging probe, as further described below.

(40) The proximal port **120** includes a rotatable cap **550** at a distal end **530** of the actuator **112**. The rotatable cap **550** includes an opening **552** into which the imaging probe is receivable. As further described with reference to FIG. **6**, the imaging probe is gripped by a flexible gasket (not shown in FIG. **5**) that is compressed between the rotatable cap **550** and a body of the actuator **112**.

Compression of the flexible gasket between the rotatable cap **550** and the body of the actuator **112** operate similarly to a Tuohy-Borst adapter, in which a flexible gasket serves as a valve. The flexible gasket includes an opening at its center that may be compressed and thereby deformed so as to close the opening within the flexible gasket. In various embodiments, rotation of the rotatable cap **550** results in compression of the flexible gasket which, in turn, results in the flexible gasket engaging sides of the imaging probe. A rotatable cap of a Tuohy-Borst adapter may be rotated multiple times in order to control a flow of a liquid through the valve. By contrast, in various embodiments, the rotatable cap **550** and the actuator **112** are configured so that only a partial turn of the rotatable cap **550** is used to compressably secure sides of the imaging probe.

(41) In various embodiments, visual and/or tactile confirmation is provided that the imaging probe is secured and, thus, will move with the actuator **112** when it is advanced along the housing. For example, in various embodiments, the rotatable cap **550** and a socket **560** at the distal end **530** of the actuator **112** are shaped to enable the rotatable cap **550** to be received into the socket **560** only when the rotatable cap **550** has been rotated to secure the imaging probe. As shown in FIG. **5**, in various embodiments the rotatable cap **550** includes at least one flattened surface **554** that corresponds to a flattened edge **564** of the socket **560**. In this configuration, when the rotatable cap **550** is rotated to a closed position, the rotatable cap **550** may be slidably received into the socket **560**, thereby providing visual and/or tactile confirmation that the imaging probe has been secured. If the rotatable cap **550** is not rotated to a closed position, the rotatable cap **550** will be blocked from being slidably inserted into the socket **560** because the flattened edge **564** will block non-flattened surfaces of the rotatable cap **550** from being inserted therein.

(42) Referring to FIG. **6**, the flexible gasket **650** is seated in a mounting socket **660** in a body **630** of the actuator **112**. The rotatable cap **550** has an outwardly-threaded surface **652** that is threadably receivable by an inwardly-threaded surface **662** of the socket **560** of the actuator **112**. A distal end **621** of the flexible gasket **650** engages a distal end **661** of the mounting socket **660**. A distal end **653** of the rotatable cap **550** engages a proximal end **623** of the flexible gasket **620**. In response to the rotatable cap **550** being rotated in tightening direction, interaction of the outwardly-threaded surface **652** of the rotatable cap **550** and the inwardly-threaded surface **662** of the socket **660** result in the flexible gasket **620** being compressed between the proximal end **623** of the mounting socket **630** and the distal end **653** of the rotatable cap **550**. Compression of the flexible gasket **620** causes it to compress against an elongated body received therethrough, such as an imaging probe **650**.

(43) As previously described with reference to FIG. **5**, after the rotatable cap **550** has been rotated to compress the flexible gasket **620** to secure the imaging probe **650**, the rotatable cap **550** may be slidably inserted into the socket **560** at the distal end **530** of the actuator **112**. After the sampling operation is completed, the rotatable cap **550** may be slid from the socket **560** and counter-rotated to release the imaging probe **650** from the proximal port **120**. The rotatable cap **550** may be slidable relative to the outwardly-threaded surface **652** to enable the rotatable cap **550** to be slidably received within the socket **560** when the rotatable cap **550** has been rotated to a tightened position and/or slidably withdrawn from the socket **560** when it is desired to loosen the rotatable cap **550**.

(44) Continuing to refer to FIG. **6**, it should be noted that, once inserted through the proximal port **120**, the imaging probe **650** is receivable into a sheath **610** having a proximal end **612** coupled with

the actuator **112**. In various embodiments, the sheath **610** defines a first lumen **614** configured to receive the imaging probe **650** and a second lumen **616** configured to receive a sampling needle **670**. The sampling needle **670**, as further described below, is coupled with and controlled by the needle actuator **140**. The needle actuator **140** is slidably mounted on the guide tube **130** (which is also further described below). In various embodiments, the sampling needle **670** extends from the needle actuator **140** through the guide tube **130** and into the second lumen **616** of the sheath **610**, through which the sampling needle **670** may be extended into a body to collect a sample. The guide tube **130** is also joined with the actuator **112**. Accordingly, when the needle actuator **140** and the imaging probe **650** are secured to the actuator **112**, movement of the actuator **112** advances the sheath **610** as well as the imaging probe **650** and sampling needle **680** contained therein.

(45) Referring to FIG. 7, the sampling needle **670** is secured and controlled by the needle actuator **140**. The needle actuator **140** includes a housing **710** having a distal end **712** that engages the guide tube **130** that extends from the actuator **112**. The needle actuator **140** is movable along the guide tube **130** to enable an operator (not shown) to pierce or otherwise agitate a tissue with a distal end of the sampling needle **670** (FIG. 6) to retrieve a tissue sample (not shown in FIGS. 7-10). In various embodiments, the end cap **160** is removably securable to a proximal end **714** of the housing **710** of the needle actuator **140** to secure a stylet (not shown in FIG. 7), as further described below.

(46) Referring to FIG. 8, in various embodiments a stylet **810** is movably received within the sampling needle **670** and is fixably secured to the end cap **160**. The stylet **810** may serve a range of functions including, by way of illustration and not limitation: sealing an end of the sampling needle **670** until the sampling needle **670** is in position to collect a sample; adding stiffness to the sampling needle **670** to facilitate insertion into tissue; guiding or directing an end of the sampling needle **670**; and/or other functions. Once the sampling needle **670** has been prepared to receive a tissue sample, however, it may be desirable to withdraw the stylet **810** from the sampling needle **670** so that the tissue sample may be drawn into the sampling needle **670**. To facilitate retrieval of the tissue sample, it may be desirable to apply a vacuum source such as a syringe or pump (not shown in FIGS. 7-10) to a proximal end of the sampling needle **670** (via a proximal port, described below) once the stylet **810** is withdrawn from the sampling needle **670**.

(47) As previously described, an operator may move the needle actuator **140** along the guide tube **130** to penetrate or agitate tissue at a distal end (not shown in FIG. 8) of the sampling needle **670**. While the needle actuator **140** is moved, the end cap **160** covers the proximal end of the needle actuator **140**. In addition, while the sampling needle **670** is motivated, it may be desirable to hold the stylet **810** in place so that agitation of the sampling needle **670** does not result in the stylet **810** inadvertently and/or undesirably becoming dislodged and sliding out of the sampling needle **670** before it is desirable to remove the stylet **810**. The end cap **160** may help to prevent the stylet **810** from becoming dislodged.

(48) Continuing to refer to FIG. 8, in various embodiments the stylet **810** is secured in a stylet mount **812** of the end cap **160**. In various embodiments, the stylet **810** and at least a portion of the stylet mount **812** are both receivable within a proximal port **820** at the proximal end **714** of the needle actuator **140**. In various embodiments, an inner surface **814** of the end cap **160** is configured to engage an outer surface **824** of the proximal port **820** of the needle actuator **140** to secure the end cap **160** to the needle actuator **140** and, thus, hold the stylet **810** in place until it is desired to withdraw the stylet **810**.

(49) Referring to FIG. 9, in various embodiments the inner surface **814** of the end cap **160** may include a groove or other recess **916** that is configured to engage a ridge or other projection **926** on the proximal port **820** of the needle actuator **140**. The groove **916** may frictionably engage the ridge **926** so that a degree of force may be required of an operator (not shown) to manually remove the end cap **160** when desired, where the degree of force is greater than an amount of force that may be applied to the stylet in the course of the sampling needle **670** being moved or agitated. In various embodiments, the groove **916** and/or the ridge **926** may have curved or otherwise contoured cross-

sections to facilitate engagement and disengagement of the groove **916** with the edge **926** when the end cap **160** is installed and removed, respectively, from the proximal port **820**.

(50) Referring to FIG. **10**, in various embodiments the inner surface (not shown in FIG. **10**) of the end cap **103** also may include one or more inner-facing threads **1016** (represented by a dotted line) configured to engage one or more outer-facing threads **1026** on the outer surface **824** of the proximal port **820**. The threads **1016** and **1026** enable the end cap **160** to be threadably engaged with the proximal port **820** to alternately secure or remove the end cap **160** by rotating the end cap **160** relative to the housing **710** of the needle actuator **140**. Once the end cap **160** is unsecured from the needle actuator **140**, the stylet **810** may be withdrawn.

(51) Although the examples of FIGS. **8-10** show the end cap **160** engaging the proximal port **820** to secure the end cap **160** to the needle actuator **140**, it will be appreciated that the end cap **160** could engage other parts of the housing **710** of the needle actuator **140** to secure the stylet **810** in place during manipulation of the needle actuator **140**.

(52) Referring to FIG. **11A**, the needle actuator **140** also may include a release mechanism **170** configured to aid an operator (not shown) in selective advancement of the sampling needle **670** using the needle actuator **140**. In various embodiments, the release mechanism **170** includes a first release device **1050** and a second release device **1060**. The first release device **1050** enables an operator to advance the sampling needle **670** from a retracted position within the sheath **610** (FIG. **6**) to a ready position at which the sampling needle is adjacent a distal end of the insertion device (not shown) to prepare for engaging tissue to collect a tissue sample. Engaging the second release device **1060** enables the operator to then advance the sampling needle **670** beyond the distal end of the sheath **610** and the insertion device to penetrate or otherwise engage the tissue to be sampled.

(53) Referring to FIG. **11B**, a distal end **1171** of the sampling needle **670** is in a retracted position removed from a distal end **1111** of the sheath **610**. In various embodiments, a distal end **1181** of the stylet **810** is positioned at the distal end **1171** of the sampling needle **670** to, for example, plug the distal end **1170** of the sampling needle **670** and/or to add stiffness to the sampling needle **670**. The distal end **1111** of the sheath **610** has been positioned near a target location which may include a tissue **1101** to be sampled using the sampling needle **670**.

(54) Referring again to FIG. **11A**, the needle actuator **140** is in a retracted position corresponding to the retracted position of the sampling needle **670** of FIG. **11B**. The release mechanism **170** is configured to prevent the needle actuator **140** from slidably moving relative to the guide tube **130** to move the sampling needle **670** from the retracted position of FIG. **11B** until the first release device **1050** is engaged by the operator.

(55) In various embodiments, the first release device **1050** and the second release device **1060** selectively engage the guide tube **130** to restrict movement of the needle actuator **140** relative to the guide tube **130**. The first release mechanism **1050** includes a first release interlock **1152**. The first release interlock **1152** is slidably received in a first release slot **1153** defined by the housing **710** of the needle actuator **140**. The first release interlock **1152** includes a first interface **1154** that is engageable by an operator (not shown). In various embodiments, the first interface **1154** is in the nature of a button depressible by the operator. The first release interlock **1152** and/or the first release slot **1153** may include a spring **1155** or similar temporarily deformable structure that applies an opposing force to motivate the first release interlock **1152** toward a starting position (as shown in FIG. **11A**) when the operator is not depressing the first release **1154**. The first release interlock **1154** also defines a first channel **1156** through which the guide tube **130** may extend in response to the operator engaging the first interface **1154** to release the first release interlock **1152**.

(56) In various embodiments, the first release interlock **1152** includes a protrusion **1158** that is configured to alternately engage a locking recess **1172** adjacent a proximal end **1177** of the guide tube **130** and a channel **1174** formed in the guide tube **130**. A ramp **1176** in the channel **1174** facilitates guiding the protrusion **1158** back into the locking recess **1172** after the needle actuator **140** has been manipulated to procure a sample and the needle actuator **140** is restored to the starting

position of FIG. 11A.

(57) In the starting position before the first release interlock **1152** is released by an operator's engagement with the first interface **1154**, the protrusion **1158** is received in the locking recess **1172**. The engagement of the protrusion **1158** with the locking recess **1172** prevents the needle actuator **140** from being moved laterally along the guide tube **130**.

(58) In response to the operator depressing the first release **1154**, the first release interlock **1152** may deform the spring **1155** to move the first release interlock **1152** further into the first release slot **1153**, thereby removing the protrusion **1158** from the locking recess **1174**. Removal of the protrusion **1158** from the locking recess **1172** thereby enables the guide tube **130** to slide within the channel **1156** of the first release interlock **1152** and allow the needle actuator **140** to move relative to the guide tube **130** to advance the sampling needle **670**.

(59) Referring to FIG. 12A, the needle actuator **140** is in a ready position corresponding to the ready position of the sampling needle **670** of FIG. 12B. In response to the first release device **1050** being engaged by the operator, the distal end **712** of the needle actuator **140** is advanceable along the guide tube **130** until the guide tube **130** is engaged by the second release device **1060**. It will be appreciated that the protrusion **1158** of the first release interlock **1152** has passed out of the locking notice **1172** of the guide tube **130** and travels within the channel **1174** on the side of the guide tube **130**.

(60) In various embodiments, the second release device **1060** includes a second release interlock **1262**. The second release interlock **1262** is slidably received in a second release slot **1263** defined by the housing **710** of the needle actuator **140**. The second release interlock **1262** includes a second interface **1264** that is engageable by the operator (not shown). In various embodiments, the second interface **1264**, like the first interface **1154** (FIG. 11A), is in the nature of a button depressible by the operator. The second release interlock **1262** and/or the second release slot **1263** may include a spring **1265** or similar temporarily deformable structure that applies an opposing force to motivate the second release interlock **1262** toward a starting position (as shown in FIG. 12A) when the operator is not depressing the second release **1264**. The second release interlock **1262** defines a second channel **1266** through which the guide tube **130** may extend in response to the operator engaging the second interface **1264** to release the second release interlock **1262**.

(61) In various embodiments, the second release interlock **1262** blocks the passage of the distal end **1177** of the guide tube **130** until the second release interlock **1262** is displaced by the operator engaging the second interface **1264**. Engaging or pressing the second interface **1264** moves the second release interlock **1262** further into the second release slot **1263** so that the second release interlock **1262** no longer blocks the distal end **1177** of the guide tube **130**. The guide tube **130** may then pass through the second channel **1266** of the second release interlock **1262**. In various embodiments, as long as the operator continues to engage the second release **1264**, the operator may move the needle actuator **140** along the guide tube **130** to penetrate and/or agitate the tissue **1101** to facilitate retrieval of a tissue sample.

(62) Referring to FIG. 12B, after the first release device **1050** is activated and the needle actuator **140** is advanced along the guide tube **130**, the distal end **1171** of the sampling needle **670** and the distal end **1181** of the stylet **680** move in concert to a ready position adjacent to the distal end **111** of the sheath **610**. With the distal end **1171** of the sampling needle **670** in position at the distal end **1111** of the sheath **610** adjacent to the tissue **1101** to be sampled, the second release device **1060** may be activated to permit the sampling needle **670** to be advanced to sample the tissue **1101**.

(63) Referring to FIG. 13A, the needle actuator **140** is in a sampling position corresponding to the sampling position of the sampling needle **670** of FIG. 13B. With the first release device **1050** and the second release device **1060** having been released, the guide tube **130** is able to pass through the first channel **1156** of the first release interlock **1152** and the second channel **1266** of the second release interlock **1262**. Consequently, the needle actuator **140** may slide along the guide tube **130** to enable the sampling needle **370** to be moved into the tissue **1101** as desired to penetrate and/or

agitate the tissue. The end cap **160** (FIGS. **11A** and **12A**) has been removed to withdraw the stylet **810** from the sampling needle **670**. Accordingly, a vacuum source **1310**, such as a syringe or a pump, may be applied to the proximal port **820** to draw the tissue sample **1301** into the sampling needle **670** to facilitate capture of the tissue sample **1310**.

(64) Referring to FIG. **13B**, after the first release device **1050** and the second release device **1060** have been released, the needle actuator **140** is advanceable into the tissue **1101** to be sampled. The needle actuator **140** may be moved along the guide tube **130** to pierce and/or agitate the tissue **1101** to free a tissue sample **1301**. At this point, the stylet **810** (not shown in FIG. **13B**) may be withdrawn to facilitate receiving the tissue sample **1301** into the distal end **1171** of the sampling needle **670**.

(65) Referring to FIG. **14**, in various embodiments the needle actuator **140** includes an asymmetrical distal opening **1410** configured to receive an asymmetrical guide tube **1430** having an asymmetrical cross-section, as further described below with reference to FIGS. **16** and **17**. In various embodiments, the asymmetrical guide tube **1430** may include one or more protruding structures **1440** that are receivable into a slot **1450** in the asymmetrical distal opening **1410** at the distal end **712** of the needle actuator. The asymmetrical distal opening **1410** may be used to ensure that the needle actuator **140** is rotated to a particular orientation when moved onto the guide tube **130** because the distal end of the sampling needle (not shown in FIG. **14**) may be directed or directable in a particular orientation, as further described below.

(66) Given by way of nonlimiting example and referring to FIG. **15A**, a sampling needle **1570** may have a deflectable distal end **1572**. The deflectable distal end **1572** may conform to a shape of a sheath **1574** when contained therein. However, upon being extended beyond a distal end **1576** of the sheath **1574**, the deflectable distal end **1572** may deflect in a direction **1578**. Accordingly, when the orientation of the deflectable distal end **1572** may be set relative to an orientation of the needle actuator **140**, it may be desirable to orient the needle actuator **140** relative to the guide tube **130** so that, when the deflectable distal end **1572** is extended, the deflectable distal end **1572** deflects in a desired direction.

(67) Given by way of another nonlimiting example and referring to FIG. **15B**, a sampling needle **1571** may have an asymmetrical distal end **1573** having a sampling orifice **1575** on a side **1577** of the asymmetrical distal end **1573**. Accordingly, when the orientation of the deflectable distal end **1573** may be set relative to an orientation of the needle actuator **140**, it may be desirable to orient the needle actuator **140** relative to the guide tube **130** so that the asymmetrical distal end **1573** is presented with the sampling orifice **1575** facing in a desired direction.

(68) Referring to FIG. **16**, in various embodiments the asymmetrical distal opening **1410** at the distal end **712** of the needle actuator **140** is shaped to receive the asymmetrical guide tube **1430**. The asymmetrical distal opening **1410** may have an asymmetrical cross-section that includes, for example, the slot **1450** on a side of the asymmetrical distal opening **1410** to accommodate the protruding structure **1440** on a side of the asymmetrical guide tube **1430**. It will be appreciated that, by virtue of the protruding structure **1440** on the side of the asymmetrical guide tube **1430** and the slot **1450** on the side of asymmetrical distal opening **1410**, the needle actuator **140** may only be moved over the guide tube **130** when the needle actuator **140** is at a predetermined orientation relative to the asymmetrical guide tube **1430**. Thus, when an orientation of the distal end **1571** or **1573** of the sampling needle **1570** and **1572**, respectively, can be established relative to the needle actuator **140**, the orientation of the asymmetrical distal end **1571** or **1573** of the sampling needle **1570** and **1572**, respectively, may be maintained when moving the needle actuator **140** over the asymmetrical guide tube **1430**.

(69) It will be appreciated that, in various embodiments, the asymmetrical distal opening **1410** may have other configurations to receive the asymmetrical guide tube **1430** other than that shown in FIG. **16**. For example and referring to FIG. **17**, in some embodiments an asymmetrical guide tube **1730** may define a channel **1750** to receive a protruding structure **1740** that extends from an

asymmetrical distal opening **1710** at the distal end **712** of the needle actuator **140** (instead of supporting a protruding structure **1440** (FIGS. **14** and **16**)). By comparing FIG. **17** with FIG. **16**, it will be appreciated that protrusions, protruding structures, slots, channels, or other features used in the asymmetrical distal openings or asymmetrical guide tubes may have straight, curved, or angled configurations. Embodiments are not restricted to any particular configuration to orient the needle actuator **140** relative to the guide tube **130**.

(70) Referring to FIG. **18**, in various embodiments the control system **100** includes in the housing one or more anti-buckling devices **1810** and **1812** to support the elongated instrument **102**. When the actuator **112** is moved along the housing **114** from the proximal end **113** toward the distal end **111**, it is possible that the elongated instrument may encounter resistance. For example, if the elongated instrument **102** encounters a crimped, turned, or collapsed portion of an insertion tube (not shown) of the insertion device **190** as it is advanced, advancement of the elongated instrument **102** may be impeded. If the advancement of the elongated instrument **102** is impeded while an operator is motivating the actuator **112** toward the distal end **111**, then the opposing forces on the elongated instrument **102** could buckle the elongated instrument **102** within the housing **114**.

(71) It is desirable to prevent buckling of the elongated instrument **102** to avoid damage that may result from components such as an imaging probe or a sampling needle being bent, broken, or otherwise damaged. Although a telescoping inner housing may be used to support the elongated instrument **102**, lengths of telescoping housing sections potentially could limit advancement of the actuator **112** and, thus, advancement of the elongated instrument **102**. The anti-buckling devices **1810** and **1812** are configured to provide lateral support to the elongated instrument **102** within the housing **114** without impeding advancement of the actuator **112** and the elongated instrument **102**.

(72) Referring to FIG. **19**, in various embodiments an illustrative anti-buckling device **1810** includes a planar member **1920** and a positioning member **1950**. The planar member **1920** includes an inner orifice **1930** and at least one outer edge **1940** configured to movably engage an inner surface **1818** of a channel **1816** defined by the housing **114**. The elongated instrument **102** is received through the inner orifice **1930**. The planar member **1920** is configured to act as a brace by providing structural and lateral support between the inner orifice **1930** and the at least one outer edge **1940**. In other words, if opposing forces were to cause the elongated instrument **102** to flex perpendicularly to its length, then the elongated instrument **102** may be engaged by surfaces of the inner orifice **1930**. Any resulting lateral force is offset by a reaction force of the planar member **1920** between the at least one outer edge **1940** engaging the inner surface **1818** of the channel **1816**, thereby preventing lateral flexure of the elongated instrument **102**.

(73) In various embodiments, the positioning member **1945** is used to maintain orientation of the planar member **1920** in the channel **1816**. The positioning member **1950** may prevent the planar member **1920** from twisting within the channel **1816** in response to lateral force that may be applied by the elongated instrument **102**. In various embodiments, the positioning member **1950** maintains the planar member **1920** in an orientation that is generally perpendicular to the axis **180** of the channel **1816**. In various embodiments, the positioning member **1950** is joined at an end to the planar member **1920** and is generally orthogonal to the planar member **1920**. In use, the positioning member **1950** extends between the inner surface **1818** of the channel **1816** and another body, such as the actuator **112** or another anti-buckling member **1810**, such as anti-buckling member **1812**. With the positioning member **1950** being receivable between the inner surface **1818** of the channel on one side and either the actuator **112** or another anti-buckling member **1812** on the other, the planar member **1950** is prevented from twisting and, thus, is able to prevent the planar member **1920** from twisting within the channel **1816**.

(74) In various embodiments, the positioning member **1950** also supports a linkage **1960** that may engage either the actuator **112** or another anti-buckling member **1812**. As a result, when the actuator **112** is drawn from the distal end **111** of the housing **114** toward the proximal end **113** of the housing, the anti-buckling devices **1810** and **1812** will be drawn back to their original positions

within the housing **114**. In various embodiments, one or more stops **1880** may be disposed along the inner surface **1818** of the housing **114**. The one or more stops **1880** may be configured to engage one or more of the outer edges **1940** of the planar member **1920** to prevent the planar member **1920**—and thus the anti-buckling device **1810** and **1812**—from being collapsed into retraction recesses **1850** and **1852** in or alongside the actuator **112**. As a result, the anti-buckling devices **1810** and **1812** will be in position to support the elongated instrument **102** when the elongated instrument **102** is advanced by the actuator **112**.

(75) Referring back to FIG. **18**, it will be appreciated that the anti-buckling devices **1810** and **1812** may be arranged at angular offsets to each other. In this way, as described further below, the positioning members **1950** of the anti-buckling devices **1810** and **1812** can slide into the opposing retraction recesses **1850** and **1852**, respectively, within or alongside the actuator **112** so as not to impede advancement of the actuator **112** within the channel **1816** defined by the housing **114**. In addition, the inner surface **1818** of the housing **114** may include one or more guides **1885** configured to engage the positioning member **1950** to maintain orientation of the positioning member **1950** of the anti-buckling device **1810** (or the positioning member of the anti-buckling device **1812**) relative to the axis **1801** of the channel **1816**.

(76) Referring to FIG. **20**, in various embodiments the actuator **112** is advanced a distance **2000** toward the distal end **111** of the housing **114**. As the actuator **112** is advanced toward the distal end **111** of the housing **114**, the anti-buckling device **1810** and the anti-buckling **1812** device provide lateral support to the elongated member **102**. At the same time, a positioning member **2050** of the anti-buckling specifically device **1810** passes into the retraction recess **1850** so that the anti-buckling device **1810** does not impede movement of the actuator **112**.

(77) Referring to FIG. **21**, the actuator **112** is further advanced a distance **2100** toward the distal end **111** of the housing **114**. As the actuator **112** is advanced toward the distal end **111** of the housing **114**, the anti-buckling device **1810** and the anti-buckling device **1812** provide lateral support to the elongated member **102**. At the same time, a positioning member **2152** of the anti-buckling device **1812** passes into the retraction recess **1852** so that the anti-buckling device **1812** does not impede movement of the actuator **112**. The anti-buckling devices **1810** and **1812** are offset to one another so that the positioning members **2050** and **2052**, respectively, are received in opposing retraction recesses **1850** and **1852**. Thus, the anti-buckling devices **1810** and **1812** also do not impede each other's movement or the movement of the actuator **112** as the actuator **112** is advanced.

(78) Referring to FIG. **22**, an illustrative method **2200** of coupling a control system to an insertion device is provided. The method **2200** starts at a block **2205**. At a block **2210**, a coupling is presented adjacent to an opening in a port of an insertion device where the coupling supports an elongated instrument to be conveyed to a target location by the insertion apparatus. At a block **2220**, a bushing is inserted into the opening in the insertion device through which the elongated instrument is extendable. At a block **2230**, an outer surface of the bushing is sealed against the opening to prevent fluid from passing between an inner surface of the opening and the outer surface of the bushing. At a block **2240**, an outer surface of the elongated instrument is movably sealed from a body of the coupling to prevent the fluid from passing between the outer surface of the elongated instrument and the coupling so that fluid is sealably prevented from passing into the coupling around the outer surface of the bushing and around the outer surface of the elongated instrument. The method **2200** ends at a block **2245**.

(79) Referring to FIG. **23**, an illustrative method **2300** of securing an elongated instrument into a movable control device is provided. The method **2300** starts at a block **2305**. At a block **2310**, an elongated instrument is received into a port of a control device configured to facilitate the extension of the elongated instrument to a target location. At a block **2320**, sides of the elongated instrument are compressably secured to the control device. The method **2300** ends at a block **2325**.

(80) Referring to FIG. **24**, an illustrative method **2400** of using an end cap to secure a stylet within

a needle is provided. The method **2400** starts at a block **2405**. At a block **2410**, a distal end of stylet is inserted into a lumen of a needle secured to a needle actuator. At a block **2420**, the stylet is extended into the lumen until an end cap fixably engaged to a proximal end of the stylet covers a distal end of the needle actuator. At a block **2430**, the end cap is withdrawn from the proximal end of the needle actuator until the stylet is withdrawn from the lumen. At a block **2440**, a vacuum source is coupled to the lumen. The method **2445** ends at a block **2435**.

(81) Referring to FIG. **25**, an illustrative method **2500** of controlling movement of a needle actuator is provided. The method **2500** starts at a block **2505**. At a block **2510**, a first release device is engaged to release a needle actuator from a retracted position at an end of a guide tube at which a distal end of a needle is retracted within a distal end of a sheath positionable adjacent a tissue to be sampled. At a block **2520**, the needle actuator is advanced to a ready position to advance the distal end of the needle adjacent the distal end of the sheath. At a block **2530**, a second release device is engaged to release the needle actuator from the ready position. At a block **2540**, the needle actuator is advanced to advance the distal end of the needle into the tissue to be sampled. The method **2500** ends at a block **2545**.

(82) Referring to FIG. **26**, an illustrative method **2600** of orienting a needle actuator relative to a control system to orient a distal end of an attached needle is provided. The method **2600** starts at a block **2605**. At a block **2610**, a distal end of a needle is inserted into a guide tube defining a lumen and configured to convey the distal end of the needle to a tissue to be sampled, with the needle being fixably coupled with a needle actuator. At a block **2620**, a distal opening in the needle actuator is presented to a proximal end of the guide tube where the distal opening in the needle actuator is configured to slidably receive the proximal end of the guide tube responsive to the needle actuator being oriented in a desired direction to direct the distal end of the needle to face in a desired direction. At a block **2630**, the distal opening of the needle actuator is slid over an outer surface of the guide tube when the needle actuator is oriented in the desired direction. The method **2600** ends at a block **2535**.

(83) Referring to FIG. **27**, an illustrative method **2700** of preventing buckling of an elongated instrument while the elongated instrument is advanced through a channel is provided. The method **2700** starts at a block **2705**. At a block **2710**, an actuator slidably received within a channel is engaged with the actuator being configured to be moved from a proximal end of the channel toward a distal end of the channel to advance an elongated instrument through a distal opening at the distal end of the channel. At a block **2720**, a planar member is employed to support the elongated instrument away from an inner surface of the channel at a point between a distal end of the actuator and a distal end of the channel. At a block **2730**, a positioning member is employed to prevent the planar member from twisting within the channel. At a block **2740**, at least a portion of the positioning member past is moved past a distal end of the actuator as the distal end of the actuator is advanced toward the distal end of the channel so that the portion of the positioning member does not impede movement of the distal end of the actuator toward the distal end of the channel. The method **2700** ends at a block **2745**.

(84) It will be appreciated that the detailed description set forth above is merely illustrative in nature and variations that do not depart from the gist and/or spirit of the claimed subject matter are intended to be within the scope of the claims. Such variations are not to be regarded as a departure from the spirit and scope of the claimed subject matter.

Claims

1. An apparatus comprising: a stylet configured to be insertable into a lumen of a needle via a proximal port of a needle actuator secured to the needle; and an end cap fixably coupled to the stylet and configured to cover a proximal end of the needle actuator and to be movable relative to the needle actuator to enable an operator to withdraw the stylet from the lumen, the end cap being a

monolithic single piece includes a stylet mount integrally formed and extending distally within a central portion of the end cap, the stylet mount receiving a proximal end of the stylet within a distal opening in the stylet mount.

2. The apparatus of claim 1, wherein the end cap is configured to be secured to the proximal end of the needle actuator.
3. The apparatus of claim 2, wherein the end cap is configured to be secured to the proximal end of the needle actuator when the stylet is fully inserted within the lumen, wherein the end cap being further configured to cooperate with the proximal end of the needle actuator to prevent the stylet from being dislodged from within the lumen responsive to the needle actuator being manipulated to facilitate extraction of a tissue sample with a distal end of the needle.
4. The apparatus of claim 3, wherein the end cap includes an inner surface configured to securably engage an outer surface of the proximal end of the needle actuator.
5. The apparatus of claim 4, wherein the inner surface includes an inwardly-threaded surface configured to threadably engage an outwardly-threaded surface of the outer surface.
6. The apparatus of claim 2, wherein the end cap includes an inner surface configured to securably engage an outer surface of the proximal port.
7. The apparatus of claim 6, wherein the proximal port is coupled to the lumen to enable passage of a fluid through the proximal port and into the lumen.
8. The apparatus of claim 7, wherein when the stylet is withdrawn from the lumen, the proximal port is configured to receive a vacuum source.
9. A system comprising: a needle defining a lumen; a stylet configured to be insertable into a lumen of a needle via a proximal port of a needle actuator secured to the needle; and an end cap fixably coupled to the stylet and configured to cover a proximal end of the needle actuator and to be movable relative to the needle actuator to enable an operator to withdraw the stylet from the lumen, the end cap including a stylet mount extending distally from a proximal end of the end cap to integrally form a central portion of the end cap, the stylet mount receiving a proximal end of the stylet within a distal opening in the stylet mount.
10. The system of claim 9, wherein the end cap is configured to be secured to the proximal end of the needle actuator.
11. The system of claim 10, wherein the end cap is configured to be secured to the proximal end of the needle actuator when the stylet is fully inserted within the lumen, wherein the end cap being further configured to cooperate with the proximal end of the needle actuator to prevent the stylet from being dislodged from within the lumen responsive to the needle actuator being manipulated to facilitate extraction of a tissue sample with a distal end of the needle.
12. The system of claim 11, wherein the end cap includes an inner surface configured to securably engage an outer surface of the proximal end of the needle actuator.
13. The system of claim 12, wherein the inner surface includes an inwardly-threaded surface configured to threadably engage an outwardly-threaded surface of the outer surface.
14. The system of claim 10, wherein the end cap includes an inner surface configured to securably engage an outer surface of the proximal port.
15. The system of claim 9, wherein the proximal port is coupled to the lumen to enable passage of a fluid through the proximal port and into the lumen.
16. The system of claim 15, wherein when the stylet is withdrawn from the lumen, the proximal port is configured to receive a vacuum source configured to create a vacuum within the lumen.
17. A method comprising: inserting a distal end of stylet into a lumen of a needle secured to a needle actuator; extending the stylet into the lumen until an end cap, including a stylet mount portion extending distally from a proximal end of the end cap to integrally form a central portion of the end cap, the stylet mount portion of the end cap fixably receiving a proximal end of the stylet within a distal opening in the stylet mount, covers a proximal end of the needle actuator; withdrawing the end cap from the proximal end of the needle actuator until the stylet is withdrawn

from the lumen; and coupling a vacuum source to the lumen.

18. The method of claim 17, further comprising securing the end cap to the proximal end of the needle actuator when the stylet is extended into the lumen, wherein the securing of the end cap to the proximal end of the needle actuator prevents the stylet from being dislodged from within the lumen responsive to when the needle actuator is moved.

19. The method of claim 18, wherein securing the end cap to the proximal end of the needle actuator includes one of frictionably engaging the end cap with the needle actuator or threadably engaging the end cap with the needle actuator.

20. The method of claim 17, wherein the coupling the vacuum source to the lumen includes coupling the vacuum source to a proximal port fluidly coupled with the lumen of the needle.
