(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
28 January 2016 (28.01.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/014414 A1

(51) International Patent Classification:
A61B 17/22 (2006.01) *A61B 1/307* (2006.01)
A61B 17/221 (2006.01)

(21) International Application Number:
PCT/US2015/041149

(22) International Filing Date:
20 July 2015 (20.07.2015)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/026,916 21 July 2014 (21.07.2014) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

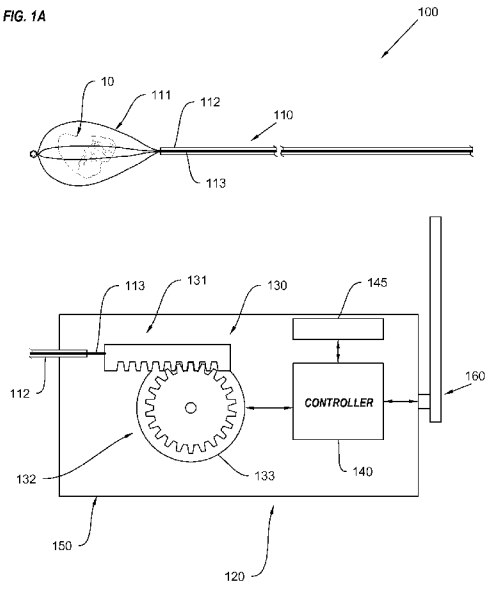
(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

(54) Title: KIDNEY STONE REMOVAL CONTROL DEVICES, SYSTEMS, AND METHODS

FIG. 1A



(57) Abstract: Embodiments described herein are directed to devices, systems, and methods for removing kidney stones. A stone removal system may include a kidney stone removal tool and a removal tool manipulator connected to the kidney stone removal tool. The removal tool manipulator may control capture of a kidney stone by the kidney tone removal tool. Also, a kidney stone removal system according to at least one embodiment may facilitate a single user or operator perform a kidney stone capture and/or removal procedure.

WO 2016/014414 A1

KIDNEY STONE REMOVAL CONTROL DEVICES, SYSTEMS, AND METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Application No. 62/026,916 filed on 21 July 2014, the disclosure of which is incorporated herein in its entirety by this reference.

BACKGROUND

[0002] Urological procedures may involve removal of kidney stones. In some instances, a stone removal tool, such as a stone basket, may be positioned near and/or about the kidney stone and may be manipulated to secure the kidney stone therein. Subsequently, the stone basket may be removed from the kidney together with the kidney stone. Duration and safety of stone removal procedure may vary from one patient to the next and may depend, among other things, on the tools and methods used during the procedure (*e.g.,* stone basket and related tools and methods).

[0003] Accordingly, users and manufacturers of stone removal tools continue to seek improved kidney stone removal tools as well as methods for removing kidney stones.

SUMMARY

[0004] Embodiments described herein are directed to devices, systems, and methods for removing kidney stones. In an embodiment, a kidney stone removal system may include a kidney stone removal tool and a removal tool manipulator connected to the kidney stone removal tool. For instance, the removal tool manipulator may control capture of a kidney stone by the kidney stone removal tool. Also, a kidney stone removal system according to at least one embodiment may facilitate a single user or operator perform a kidney stone capture and/or removal procedure. For example, the kidney stone removal system may allow a single user to position a kidney stone removal tool near and/or about the kidney stone, capture the kidney stone, withdraw the kidney stone removal tool from the kidney, or combinations thereof.

[0005] An embodiment includes a removal tool manipulator system. The removal tool manipulator system includes a removal tool manipulator and an interface device. The removal tool manipulator is configured to manipulate a kidney stone removal tool. More specifically, the removal tool manipulator includes a housing and an actuator assembly secured to the housing and connectable to one or more basket cables of the

kidney stone removal tool. The actuator assembly includes a movable portion configured to move the one or more basket cables relative to the housing along an approximately linear path. The removal tool manipulator also includes a controller operably coupled to the actuator assembly and configured to send one or more actuation signals to the actuator assembly to direct movement of the moveable portion thereof in a first direction or in a second, generally opposite direction, thereby moving the one or more basket cables associated with a kidney stone basket. The interface device includes a user interface configured to receive input from a user. The interface device is operably coupled to the controller and configured to send one or more communication signals to the controller based at least partially on user input received at the user interface. Furthermore, the one or more actuation signals are based at least partially on the one or more communication signals.

[0006] Embodiments also include a kidney stone removal system that includes a kidney stone removal tool and a removal tool manipulator connected to the kidney stone removal tool. The kidney stone removal tool includes a sheath having a proximal end and a distal end and one or more basket cables positioned within the sheath. The kidney stone removal tool also includes a basket positioned near the distal end of the sheath and connected to the one or more basket cables in a manner that movement of the one or more basket cables within the sheath moves the basket relative to the sheath and reconfigures the basket into at least one of deployed configuration, collapsed configuration, or partially collapsed configuration. The removal tool manipulator includes an actuator assembly connected to the one or more basket cables of the kidney stone removal tool and configured to move the one or more basket cables together with the basket relative to the sheath. The removal tool manipulator also includes a controller operably coupled to the actuator assembly and configured to send one or more actuation signals to the actuator assembly to direct movement of the basket cable in a direction of the distal end or in a direction of the proximal end of the sheath.

[0007] At least one embodiment includes a removal tool manipulator system for manipulating a kidney stone removal tool. The removal tool manipulator system includes a removal tool manipulator configured to manipulate the kidney stone removal tool and an interface device. The removal tool manipulator system includes at least one actuator assembly connectable to one or more basket cables of the kidney stone removal tool. The at least one actuator assembly includes one or more movable portions configured to move the one or more basket cables within and relative to a sheath of the kidney stone removal

tool and along an approximately linear path. Moreover, the removal tool manipulator system includes a controller operably coupled to the at least one actuator assembly and configured to send one or more actuation signals to the at least one actuator assembly to direct movement of the one or more moveable portions thereof in a first direction or in a second, generally opposite direction, thereby moving the one or more basket cable of the stone removal tool. The interface device includes a user interface configured to receive input from a user. In particular, the interface device is operably coupled to the controller and configured to send one or more communication signals to the controller based at least partially on user input received at the user interface. The one or more actuation signals are based at least partially on the one or more communication signals.

[0008] Features from any of the disclosed embodiments may be used in combination with one another, without limitation. In addition, other features and advantages of the present disclosure will become apparent to those of ordinary skill in the art through consideration of the following detailed description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] For better understanding, the like elements have been designated by like reference numbers throughout the various accompanying figures. Understanding that these drawings depict only typical embodiments of the disclosure and are not therefore to be considered to be limiting of its scope, the embodiments of the disclosure will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

[0010] **FIG. 1A** is a schematic view of a stone removal system with a basket in a deployed configuration according to an embodiment;

[0011] **FIG. 1B** is a schematic view of the stone removal system of **FIG. 1A** with the basket in an at least partially collapsed configuration according to an embodiment;

[0012] **FIG. 2A** is a schematic view of a stone removal tool according to an embodiment;

[0013] **FIG. 2B** is a schematic view of a stone removal tool according to another embodiment;

[0014] **FIG. 3A** is a schematic illustration of a user interface with an indication of a basket in a deployed configuration according to an embodiment;

[0015] **FIG. 3B** is a schematic illustration of the user interface of **FIG. 3A** with an indication of the basket in a collapsed configuration according to an embodiment;

[0016] **FIG. 3C** is a schematic illustration of the user interface of **FIG. 3A** with an indication of a partially collapsed basket configuration according to an embodiment;

[0017] **FIG. 4A** is an isometric view of an interface device according to an embodiment; and

[0018] **FIB. 4B** is an isometric view of an ureteroscope with an attached interface device according to an embodiment.

DETAILED DESCRIPTION

[0019] Embodiments described herein are directed to devices, systems, and methods for removing kidney stones. In an embodiment, a kidney stone removal system may include a kidney stone removal tool and a removal tool manipulator connected to the kidney stone removal tool. In particular, the removal tool manipulator may control capture of a kidney stone by the kidney stone removal tool. Also, a kidney stone removal system according to at least one embodiment may facilitate a single user or operator perform a kidney stone capture and/or removal procedure. For example, the kidney stone removal system may allow a single user (*e.g.,* a surgeon) to position a kidney stone removal tool near and/or about the kidney stone, capture the kidney stone, withdraw the stone removal tool from the kidney, or combinations thereof.

[0020] For example, the user may control operation of the removal tool manipulator via a user interface. In some embodiments, the user interface may be located or included on an interface device that may be positioned at any suitable location. More specifically, the interface device may be detached from and/or positioned remotely from the removal tool manipulator. For example, the interface device together with the interface may be positioned at a suitable location and/or attached to one or more devices (*e.g.,* such that the user may access the user interface and control the removal tool manipulator and the stone removal tool remotely.

[0021] In some embodiments, the user interface may include a movable indicator, movement of which may direct and/or correspond to movement of the basket of the stone removal tool. For example, a user may move the indicator to produce a corresponding or correlated movement of the basket in the stone removal tool (*e.g.,* thereby manipulating the basket during a stone removal procedure). Moreover, gradual movement of the indicator may produce a corresponding gradual movement of the basket (*e.g.,* the speed of movement of the indicator, which may be moved by the user, may correspond to the speed of movement of the basket at any ratio, such as 1:1, 1:2, 2:1, etc.).

[0022] **FIGS. 1A** and **1B** illustrate a kidney stone removal system 100 according to an embodiment. The stone removal system 100 includes a kidney stone removal tool or kidney stone basket assembly, such as kidney stone removal tool 110, which may be connected to a removal tool manipulator 120 that may control or manipulate the stone removal tool 110. For instance, as described below in further detail, the removal tool manipulator 120 may control deployment of the stone removal tool 110 (*e.g.,* a configuration in which the stone removal tool 110 may grasp or otherwise secure a kidney stone, such as a kidney stone 10).

[0023] Generally, the stone removal tool 110 may be any suitable stone removal tool or basket assembly, which may vary from one embodiment to the next. In some embodiments, the stone removal tool 110 may be BARD DIMENSION™ and may include an articulating stone basket/grasper. For example, the stone removal tool 110 may be fabricated from a superelastic or shape memory alloy, such as a nickel-titanium superelastic or shape memory alloy (*e.g.,* nitinol or other nickel-titanium superelastic or shape memory alloy). It should be appreciated, however, that components and/or elements of the stone removal tool 110 may include and/or may be fabricated from any number of suitable materials.

[0024] Generally, stone removal tool 110 may include a basket 111 that may be manipulated to secure the kidney stone 10, as described below in more detail. In some embodiments, the stone removal tool 110 may include a sheath 112 and a basket cable 113 that may be positioned inside the sheath 112 and connected to or integrated with the basket 111. Moreover, the basket cable 113 may be movable inside the sheath 112, such as to move the basket 111 relative to the sheath 112. For example, the basket 111 may be moved generally in a direction of a distal end of the sheath 112 and may be extended past the distal end of the sheath 112 into the deployed configuration (*e.g.,* such that the basket 111 may capture the kidney stone 10). Conversely, the basket 111 together with the basket cable 113 may be moved in the general direction of a proximal end of the sheath 112 (*e.g.,* such that the basket 111 may be positioned closer to the distal end of the sheath 112 and/or may at least partially enter the sheath 112. For example, as the basket 111 enters the sheath 112, the basket may at least partially collapse or may be reconfigured into a closed or partially closed configuration and/or may secure the kidney stone 10.

[0025] In an embodiment, as shown in **FIG. 1A**, the removal tool manipulator 120 may configure or reconfigure the stone removal tool 110 into a deployed configuration, such as by extending the basket 111 of the stone removal tool 110 out of a

sheath 112, thereby deploying or opening the basket 111. Moreover, the removal tool manipulator 120 may extend the basket 111 out of the sheath 112 to a desired position and/or to a desire opening (*e.g.,* to a desired shaped and/or size of the inner space of the basket 111), such that the internal dimension of the basket 111 may accept or accommodate the kidney stone 10 therein. Accordingly, for instance, when the stone removal tool 110 is in a deployed configuration, a user or operator may position the basket 111 over or about the kidney stone 10.

[0026] In some embodiments, the basket 111 may be connected to or integrated with one or more basket cables, such as basket cable 113 of the stone removal tool 110. The basket cable 113 may move in a distal direction and advance the basket 111 out of the sheath 112 to deploy or open the basket 111 (*e.g.,* when fully extended out of the sheath, the basket 111 may be in a fully open configuration). The basket cable 113 may move in the proximal direction (opposite to the distal direction) and retract the basket 111 into the sheath 112, thereby collapsing or closing the basket 111 (*e.g.,* when the basket 111 is completely inside the sheath 112, the basket may be in a fully collapsed or closed configuration). Moreover, in some instances, before deployment, the basket 111 may be at least partially contained within the sheath 112 and/or may be collapsed, such as to have the same or similar outside dimension (*e.g.,* outside diameter) as the inside dimension (*e.g.,* inside diameter) of the sheath 112. For example, in the collapsed configuration, the basket 111 together with the sheath 112 may be advanced through a urinary canal of a patient and into a kidney containing the kidney stone 10.

[0027] In an embodiment, the removal tool manipulator 120 may move the basket cable 113 in the distal direction to advance the basket 111 out of the sheath 112, thereby configuring or reconfiguring the stone removal tool 110 into the deployed configuration (*e.g.,* at least partially open basket 111 that may accept the kidney stone 10). In an embodiment, the removal tool manipulator 120 may include an actuator assembly 130 that may configure or reconfigure the stone removal tool 110 into deployed configuration and/or into collapsed configuration. For example, the actuator assembly 130 may move the basket cable 113 in the distal direction to advance the basket 111 out of the sheath 112. Generally, the actuator assembly 130 may have any configuration suitable for advancing the basket 111 out of the sheath 112, and such configuration may vary from one embodiment to the next. For example, at least a portion of the actuator assembly 130 may move relative to the sheath 112 in a manner that moves the basket cable 113 and basket 111 in the distal and/or proximal directions.

[0028] Hence, in an embodiment, the actuator assembly 130 may include a movable portion 131 and a stationary portion 132. In particular, the movable portion 131 may move relative to the stationary portion 132 and relative to the sheath 112, while the stationary portion 132 may remain stationary relative to the sheath 112. Furthermore, the basket cable 113 may be connected or attached to the movable portion 131 in a manner that movement of movable portion 131 produces an approximately corresponding movement of the basket cable 113. As such, movement of the movable portion 131 of the actuator assembly 130 may produce relative motion of the basket cable 113 and basket 111.

[0029] Generally, the movable portion 131 may advance or move the basket cable 113 (*e.g.,* the basket cable 113 may be moved generally linearly). In at least one embodiment, the movable portion 131 may be configured to move along an approximately linear path, thereby correspondingly moving the basket cable 113 and the basket 111. In some embodiments, the actuator assembly 130 may include a radial to linear movement converter. For instance, the movement converter (*e.g.,* a gearbox) may convert a radial movement input to a linear movement output. For example, the actuator assembly 130 may have a rack and pinion configuration as illustrated in **FIG. 1A**. In an embodiment, the movable portion 131 may include a rack and the stationary portion 132 may include a pinion engaged with the rack of movable portion 131.

[0030] For example, rotation of the pinion of the stationary portion 132 may move the rack and the movable portion 131 linearly relative to the stationary portion 132. Thus, as described above, movement of the movable portion 131 of the actuator assembly 130 may produce a corresponding movement of the basket cable 113 and basket 111 of the stone removal tool 110 (*e.g.,* in the distal or proximal direction). In an embodiment, the stationary portion 132 may include a motor 133 (*e.g.,* a servomotor) that may produce or generate movement of the movable portion 131. For example, the motor 133 may rotate the pinion of the stationary portion 132, which in turn may produce linear movement of the moveable portion 131.

[0031] In alternative or additional embodiments, the movable portion of the actuator assembly may move radially. For example, the basket cable 113 of the stone removal tool 110 may connect to the radially movable portion of the actuator assembly, such that the basket cable 113 and the basket 111 move generally linearly relative to the sheath 112. In any event, the movable portion of the actuator may move the basket cable 113 together with the basket 111, thereby opening and/or closing the basket 111.

[0032] In an embodiment, the movable portion 131 may be guided (*e.g.,* the movable portion 131 may move in a guide channel) in a manner that may restrict the movable portion 131 to a substantially linear movement relative to the stationary portion 132. While in some embodiments, the actuator assembly 130 may include multiple components or elements, the actuator assembly 130 also may be a single unit or assembly. For instance, the actuator assembly 130 may include a pneumatic or hydraulic cylinder that may move the basket cable 113 and basket 111 in the distal or proximal direction. Examples of additional or alternative suitable actuator assemblies include a screw mechanism that may move the basket cable 113 and basket 111 in the distal and proximal directions. In any event, the actuator assembly 130 may be electrically coupled to a controller 140, which may direct advancement of the movable portion 131 (*e.g.,* based on directions or instructions received from a user).

[0033] In some embodiments, the actuator assembly 130 may be secured to and/or within a housing 150 (*e.g.,* the housing 150 may be configured to secure the actuator assembly 130, the controller 140, and one or more portions of the stone removal tool 110). For instance, the stationary portion 132 of the actuator assembly 130 may be attached or fixedly secured to the housing 150 (*e.g.,* in a manner that the stationary portion 132 exhibits substantially no linear movement relative to the housing 150 during operation of the stone removal system 100). Moreover, in some embodiments, at least some of the stationary portion 132 of the actuator assembly 130 may be integrated with the housing 150.

[0034] In one or more embodiments, the movable portion 131 may be movable (or may be configured to move) relative to the housing 150. As described above, for instance, the movable portion 131 may move generally linearly relative to the stationary portion 132 and relative to the housing 150. Hence, for example, the basket cable 113 may be moved relative to the housing 150 together with the basket 111. Additionally, in some embodiments, the movable portion 131 may be guided to move approximately in a linear manner. For example, the housing 150 may include a guiding mechanism that may be secured to or integrated with the housing 150. The guiding mechanism may at least partially secure and/or guide the movable portion 131 along an approximately linear path.

[0035] As discussed above, when the basket cable 113 moves in the distal direction, the basket 111 may exit the sheath 112 and expand into the deployed or at least partially open configuration. Subsequently, the basket 111 may be placed over the kidney stone 10 (*e.g.,* the kidney stone may be positioned within the interior of the basket 111).

Additionally or alternatively, the basket 111 may expand in a manner that positions the basket 111 over the kidney stone 10. As described below in further detail, the basket 111 may be collapsed or at least partially closed over the kidney stone 10 to secure the kidney stone 10 to the stone removal tool 110.

[0036] In an embodiment, at least a portion of the sheath 112 may be secured to and/or within the housing 150. More specifically, the sheath 112 may be secured to the housing 150 in a manner that allows the basket cable 113 to move relative to the housing 150 and relative to the sheath 112, while the sheath 112 may remain stationary relative to the housing 150. As noted above, in some embodiments, the basket cable 113 may connect to the movable portion 131 such that movement of the movable portion 131 produces a corresponding movement of the basket cable 113, which may be generally linear.

[0037] In at least one embodiment, approximately linear movement of the movable portion 131 relative to the housing 150 may produce an approximately linear movement of the basket cable 113 relative to the housing 150. Thus, relative movement of the movable portion 131 in a first direction may advance the basket 111 into a deployed or at least partially open configuration (shown in **FIG. 1A**). As described below, relative movement of the movable portion 131 in a second direction (*e.g.,* opposite to the first direction) may move the basket 111 in the proximal direction, thereby retracting and/or at least partially collapsing or closing the basket 111.

[0038] In some embodiments, the actuator assembly 130 may be coupled to the controller 140 and may be actuated by one or more commands therefrom. In turn, the user may provide commands to the controller 140 (*e.g.,* from the interface device, described below in more detail), and the controller 140 may translate and/or modify such commands to commands or communications transmitted to the actuator assembly 130. For instance, the controller 140 may be coupled to the interface device that includes a user interface that may send commands from the user to the controller 140. In an embodiment, the user may identify a particular position or configuration of the basket 111 by providing a corresponding indication or selection on the user interface, and such position or configuration of the basket 111 may be communicated to the controller 140. Subsequently, the controller 140 may direct the actuator assembly 130 to position or reposition the basket cable 113, thereby positioning or configuring the basket 111 to the configuration identified by the user at the user interface.

[0039] Commands from the user interface may be transmitted electrically and/or wirelessly to the controller 140. In some embodiments, the controller 140 may include a wireless receiver or transceiver that may wirelessly couple to a device that includes the user interface (*e.g.,* interface device) and receive commands therefrom. For example, the controller 140 may include a Bluetooth chip or chipset that may wirelessly communicate with the interface device and may receive commands therefrom. In an embodiment, the wireless receiver or transceiver may couple to an antenna 160 to provide an adequate range of reception therefor.

[0040] In some embodiments, the removal tool manipulator 120 may include a power source 145, such as a battery (*e.g.,* a rechargeable battery). For example, the power source 145 may be located within and/or secure to the housing 150. Additionally or alternatively, a power source may be located outside of the housing 150 and may electrically and/or wirelessly supply power to the removal tool manipulator 120. More specifically, for example, the power source (*e.g.,* power source 145) may supply power, directly and/or indirectly, to the controller 140, to the actuator assembly 130, to the transceiver (which may be integrated into the controller 140), etc.

[0041] Generally, the controller 140 also may include a processor coupled to a memory (*e.g.,* the memory may include or store instructions for controlling the actuator assembly 130) as well as other elements or components that may receive and/or process instructions or communications from the user interface. The elements or components of the controller 140 may receive communications or communication signal(s) from the interface device and transmit a signal (*e.g.,* actuation signal(s)) to the actuator assembly 130 to move the basket cable 113 and basket 111 in the distal or proximal direction (*e.g.,* by a predetermined amount, to a predetermined location, to a predetermined size of the basket 111 or deployment, etc.). For example, the communication signal(s) may be at least in part based on the input received from the user at the interface device.

[0042] The controller 140 may provide actuation signals to a servomotor of the actuator assembly 130, which may indicate angular rotation of the servomotor for producing a corresponding generally linear displacement of the basket cable 113 and basket 111 as directed by the user (*e.g.,* the actuation signal may include information related to an angle of rotation of the servomotor). For example, the actuation signals may be based at least partially on the communication signals received from the interface device. Hence, in some embodiments, the actuation signals sent from the controller 140

to the actuator assembly 130 may be at least in part based on the user input received at the interface device.

[0043] Accordingly, for example, by manipulating the user interface (*e.g.,* the indicator one the user interface), the user may advance and deploy or open the basket 111 as well as retract and at least partially collapse or close the basket 111 (*e.g.,* to capture the kidney stone 10). **FIG. 1B**, for example, shows the basket 111 in at least a partially retracted and partially collapsed or closed configuration and trapping the kidney stone 10 within the interior space of the basket 111. After the kidney stone 10 is trapped by the basket 111, the stone removal tool 110 together with the kidney stone 10 may be removed from the patient's kidney.

[0044] More specifically, in an embodiment, the controller 140 may direct the actuator assembly 130 to retract the basket cable 113 (*e.g.,* to move the basket cable 113 in the proximal direction), thereby reconfiguring the basket 111 of the stone removal tool 110 into an at least partially collapsed or closed configuration, and thereby securing the kidney stone 10 within the interior space of the basket 111. As noted above, in some embodiments, the movable portion 131 of the actuator assembly 130 may move in the proximal direction (*e.g.,* relative to the stationary portion 132) and may pull the basket cable 113 relative to the sheath 112. In any event, movement of the movable portion 131 of the actuator assembly 130 may at least partially collapse the basket 111 thereby securing the kidney stone 10 inside the interior space thereof.

[0045] As noted above, the particular stone removal tool included in the stone removal system 100 may vary from one embodiment to the next. In at least one embodiment, as shown in **FIG. 2A**, the stone removal tool 110a may be a helical stone removal tool, such as BARD EXPAND™ 212 helical stone basket. It should be appreciated that, in one or more embodiments, the stone removal tool may be interchangeable and/or replaceable. As such, a suitable stone removal tool may be included in the stone removal system and/or connected to or integrated with the removal tool manipulator. Moreover, in some embodiments, the stone removal tool may be disposable, such that the stone removal tool may be discarded after use, and another stone removal tool may be connected to the removal tool manipulator (*e.g.,* the replacement stone removal tool may be the same or similar to the discarded stone removal tool or the replacement stone removal tool may be different from the discarded stone removal tool).

[0046] In some embodiments, the stone removal tool may include multiple basket cables, movement of which may articulate and/or actuate the basket of the stone removal

tool. For example, a stone removal tool 110b, illustrated in **FIG. 2B**, may include multiple basket cables, such as basket cables 113b, 113b', which may move or actuate corresponding portions of the basket 111b. For instance, the first basket cable 113b may move or actuate a first portion 115b of the basket 111b, while a second basket cable 130b' may move or actuate a second portion 116b of the basket 111b.

[0047] Accordingly, in some embodiments, moving the first and second basket cables 113b, 113b' may independently articulate and/or collapse the first and second portions 115b, 116b of the basket 111b. For example, as shown in **FIG. 2B**, positioning the first basket cable 113b proximally relative to the second basket cable 113b' (*e.g.*, moving the first basket cable 113b proximally while maintaining the second basket cable 113b' stationary) may collapse the first portion 115b of the basket 111b more than the second portion 116b thereof. In any event, evenly or unevenly collapsing the basket 111b may capture a kidney stone 10b therein.

[0048] Correspondingly, in some instances, the removal tool manipulator may include multiple actuator assemblies with corresponding moveable portions and/or a single actuator assembly with multiple movable portions. For example, the movable portions of the actuator assembly (or assemblies) may connect to the corresponding basket cables, such as the first and second basket cables 113b, 113b'. Moreover, in some embodiments, the removal tool manipulator may independently actuate or move the basket cables 113b, 113b'. Hence, in at least one embodiment, the removal tool manipulator may include multiple movable portions and/or multiple actuator assemblies connected to corresponding basket cables, such as the basket cables 113b, 113b' of the stone removal tool 110b. Also, the controller of the removal tool manipulator may independently control or actuate multiple actuator assemblies and/or movable portions of one or more actuator assemblies to produce independent movement of the basket cables 113b, 113b'.

[0049] As described above, the removal tool manipulator may receive commands or communication signals from an interface device and, in response to and/or based at least partially on the communication signals, the removal tool manipulator may manipulate the stone removal device in a manner that deploys the stone removal device and/or grasps a kidney stone (*e.g.*, by manipulating basket cables of the stone removal tool). **FIGS. 3A-3C** illustrate a user interface 200, which may be configured to receive input from a user and/or may allow a user to provide input to an interface device that may transmit or communicate such input to a removal tool manipulator. More specifically, in

some embodiments, the user interface 200 may include a movable indicator 210 that may be manipulated by the user to input a desired configuration for the stone removal tool.

[0050] In one or more embodiments, the movable indicator 210 may slide along an approximately linear path between first and second ends of the path. Particularly, the first end of the path (as shown in **FIG. 3A**) may correspond with an indication or request for an open basket (*e.g.,* the deployed configuration of the stone removal tool (*e.g.,* as shown in **FIG. 1A**), and the second end of the path (as shown in **FIG. 3B**) may correspond with a closed basket (*e.g.,* collapsed configuration of the basket. In some embodiments, positions of the movable indicator 210 along the path between the first and second points (as shown in **FIG. 3C**) may correspond to a state of the basket that is between the deployed and collapsed configurations thereof (*e.g.,* corresponding to a request for partially collapsed basket, such as shown **FIG. 1B**).

[0051] In some embodiments, as mentioned above, the stone removal may include multiple basket cables that control movement and/or deployment of the basket. In an embodiment, the user interface may include a single indicator that may be manipulated and/or modified by the user to indicate a requested positioned and/or size of the basket to the controller (*e.g.,* the controller may determine the amount of movement for each of the multiple basket cables and corresponding movement of the movable portions of actuator assembly (or assemblies) based on the indication from a single indicator on the user interface (*e.g.,* from movement of the movable indicator 210). Alternatively, the user interface may include multiple indicators (*e.g.,* movable indicators), some or each of which may receive input from the user for movement of one or more corresponding basket cables. For example, the user may indicate a specific movement or change or position for each of the multiple basket cable in the stone removal tool (*e.g.,* the interface device may receive multiple inputs from the user, which correspond to movement of specific basket cables, and may send one or more communication signals to the controller of the removal tool manipulator, which may include information related to movement of such basket cables). The controller, in turn, may generate corresponding actuation signal(s) for the movable portions of the actuator assembly (or assemblies) to move the basket cable based at least partially on the communication signals received from the interface device.

[0052] As noted above, the controller of the removal tool manipulator may translate or correlate the communications or input received at an interface device (*e.g.,* from an interface device that includes the user interface 200), which may correspond to

the indication received from the user positioning the movable indicator 210 along the path. More specifically, for example, when the movable indicator 210 is positioned in a manner that indicates closure or collapse of the basket, the controller may provide a corresponding signal to the actuator assembly to collapse the basket. Conversely, when the movable indicator 210 is positioned in a manner that indicates opening or deployment of the basket, the controller may provide a corresponding signal to the actuator assembly to open or deploy the basket. The controller also may provide signals to the actuator assembly, which may correspond with a particular position of the movable indicator 210 that indicate a particular state of the basket between the deployed and collapsed configurations thereof.

[0053] It should be appreciated that the user interface may be embodied in any number of different interface devices and/or components. For instance, a user interface may be provided by a slidable or rotatable potentiometer or rheostat that may indicate or read a particular position of physically movable indicator along a path. Additionally or alternatively, the user interface may be a virtual interface provided on a display of a computing device, such as a computer, a tablet, smart phone, watch, PDA, and the like. In any event, the user interface may allow the user to input or provide information about the desired positioning or configuration of the basket, which may be configured into such desired position and configuration by the removal tool manipulator.

[0054] Furthermore, readings of the position of the movable indicator may be communicated or transmitted to the controller of the removal tool manipulator as communication signals. Also, as noted above, transmission of the communication signals to the controller may be wireless. Alternatively or additionally, an interface device that includes the user interface may be hardwired to the controller. Hence, in at least one embodiment, communication of readings of the movable indicator may be over a wire or cable (*e.g.*, electrically conductive cable, optical fiber, etc.).

[0055] In at least one embodiment, as shown in **FIGS. 4A-4B**, the device including the user interface may be attached to an ureteroscope. For example, an interface device 220 may include a strap 221 that may secure the interface device 220 to an ureteroscope 230. The interface device 220 may be secured at any desired location along the ureteroscope 230. Furthermore, the interface device 220 may be oriented at any desired orientation on the ureteroscope 230. In other words, the interface device 220 may be positioned and oriented on the ureteroscope 230 in a manner that facilitates operation or use of the user interface by the user, while using the ureteroscope 230. In addition, the

user may have access to the user interface while inserting and positioning the stone removal tool. Accordingly, a single user may insert, position, and manipulate the stone removal tool (*e.g.,* deploy the basket and capture the kidney stone thereby). For example, the user's index finger may operate the interface device 220, while the user's thumb may control the ureteroscope 230.

[0056] Also, in some embodiments, the user may view the basket of the stone removal tool during the procedure via the ureteroscope 230. Moreover, the user may configure the stone removal tool into a deployed configuration while viewing the basket. Similarly, the user may reconfigure the stone removal tool in to at least partially collapsed configuration, to capture a kidney stone, while viewing the capture. Accordingly, in some embodiments, the user may maintain view of the procedure to assure that the kidney stone is captured within the internal space of the basket).

[0057] While various aspects and embodiments have been disclosed herein, other aspects and embodiments are contemplated. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting.

CLAIMS

What is claimed is:

1. A removal tool manipulator system, comprising:

a removal tool manipulator configured to manipulate a kidney stone removal tool, the removal tool manipulator including:

a housing;

an actuator assembly secured to the housing and connectable to one or more basket cables of the kidney stone removal tool, the actuator assembly including a movable portion configured to move the one or more basket cables relative to the housing along an approximately linear path; and

a controller operably coupled to the actuator assembly and configured to send one or more actuation signals to the actuator assembly to direct movement of the moveable portion thereof in a first direction or in a second, generally opposite direction, thereby moving the one or more basket cables associated with a kidney stone basket; and

an interface device including a user interface configured to receive input from a user, the interface device being operably coupled to the controller and configured to send one or more communication signals to the controller based at least partially on user input received at the user interface, wherein the one or more actuation signals are based at least partially on the one or more communication signals.

2. The removal tool manipulator system of claim 1, wherein the movable portion of the actuator assembly is configured to move generally linearly.

3. The removal tool manipulator system of claim 1, wherein the actuator assembly includes a servomotor or a step motor coupled to the controller.

4. The removal tool manipulator system of claim 3, wherein the one or more actuation signals from the controller include information related to angle of rotation of the servomotor or step motor.

5. The removal tool manipulator system of claim 1, wherein movement of the one or more basket cables reconfigures a basket of the kidney stone removal tool into at least one of collapsed configuration, deployed configuration, or partially collapsed configuration.

6. The removal tool manipulator system of claim 5, wherein the one or more communication signals include an indication to reconfigure the kidney stone basket into

at least one of collapsed configuration, deployed configuration, or partially collapsed configuration.

7. The removal tool manipulator system of claim 6, wherein the controller is configured to correlate the one or more communication signals with a position of the movable portion of the actuator assembly.

8. The removal tool manipulator system of claim 5, wherein the user interface includes an indicator movable between a first position indicating a request to open the kidney stone basket of the kidney stone removal tool and a second position indicating a request to close the kidney stone basket of the kidney stone removal tool.

9. The removal tool manipulator system of claim 8, wherein the indicator is movable generally linearly.

10. The removal tool manipulator system of claim 8, wherein the interface device is configured to generate the one or more communication signals at least partially based on a change in position of the movable indicator.

11. The removal tool manipulator system of claim 1, wherein the actuator assembly is at least partially positioned inside the housing.

12. The removal tool manipulator system of claim 1, wherein the housing is configured to secure the sheath of the kidney stone removal tool.

13. A kidney stone removal system, comprising:

a kidney stone removal tool including:

a sheath having a proximal end and a distal end;

one or more basket cables positioned within the sheath;

a basket positioned near the distal end of the sheath and connected to the one or more basket cables in a manner that movement of the one or more basket cables within the sheath moves the basket relative to the sheath and reconfigures the basket into at least one of deployed configuration, collapsed configuration, or partially collapsed configuration; and

a removal tool manipulator connected to the kidney stone removal tool, the removal tool manipulator including:

an actuator assembly connected to the one or more basket cables of the kidney stone removal tool and configured to move the one or more basket cables together with the basket relative to the sheath;

a controller operably coupled to the actuator assembly and configured to send one or more actuation signals to the actuator assembly to direct movement of

the one or more basket cables in a direction of the distal end or in a direction of the proximal end of the sheath.

14. The kidney stone removal system of claim 13, further comprising an interface device electrically or wirelessly coupled to the controller and configured to send one or more communication signals to the controller based at least partially on an input from a user.

15. The kidney stone removal system of claim 14, wherein the interface device includes a user interface configured to receive input from the user.

16. The kidney stone removal system of claim 15, wherein the user interface device includes a movable indicator, and movement of the moveable indicator is correlated to movement of the basket cable.

17. The kidney stone removal system of claim 14, wherein the one or more communication signals sent from the interface device to the controller indicate a request for a collapsed configuration of the basket, deployed configuration of the basket, or partially collapsed basket.

18. The kidney stone removal system of claim 14, further comprising an ureteroscope having the interface device is attached thereto.

19. The kidney stone removal system of claim 13, wherein the removal tool manipulator includes a housing, and the sheath of the kidney stone removal tool is secured to the housing.

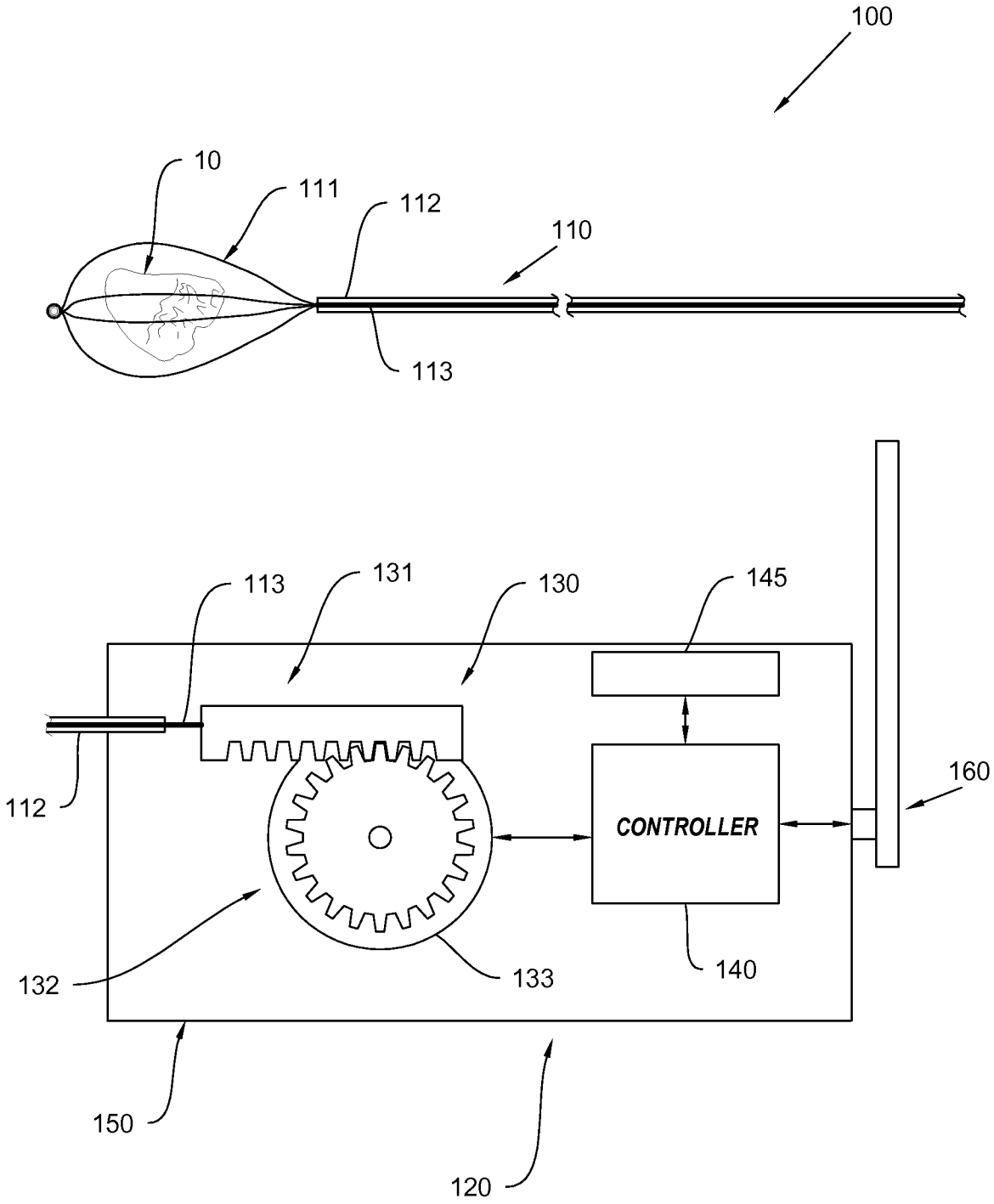
20. A removal tool manipulator system for manipulating a kidney stone removal tool, the removal tool manipulator system comprising:

a removal tool manipulator configured to manipulate the kidney stone removal tool, the removal tool manipulator including:

at least one actuator assembly connectable to one or more basket cables of the kidney stone removal tool, the at least one actuator assembly including one or more movable portions configured to move the one or more basket cables within and relative to a sheath of the kidney stone removal tool and along an approximately linear path; and

a controller operably coupled to the at least one actuator assembly and configured to send one or more actuation signals to the at least one actuator assembly to direct movement of the one or more moveable portions thereof in a first direction or in a second, generally opposite direction, thereby moving the one or more basket cables of the kidney stone removal tool; and

an interface device including a user interface configured to receive input from a user, the interface device being operably coupled to the controller and configured to send one or more communication signals to the controller based at least partially on user input received at the user interface, wherein the one or more actuation signals are based at least partially on the one or more communication signals.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CONTROLLER
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FIG. 1A

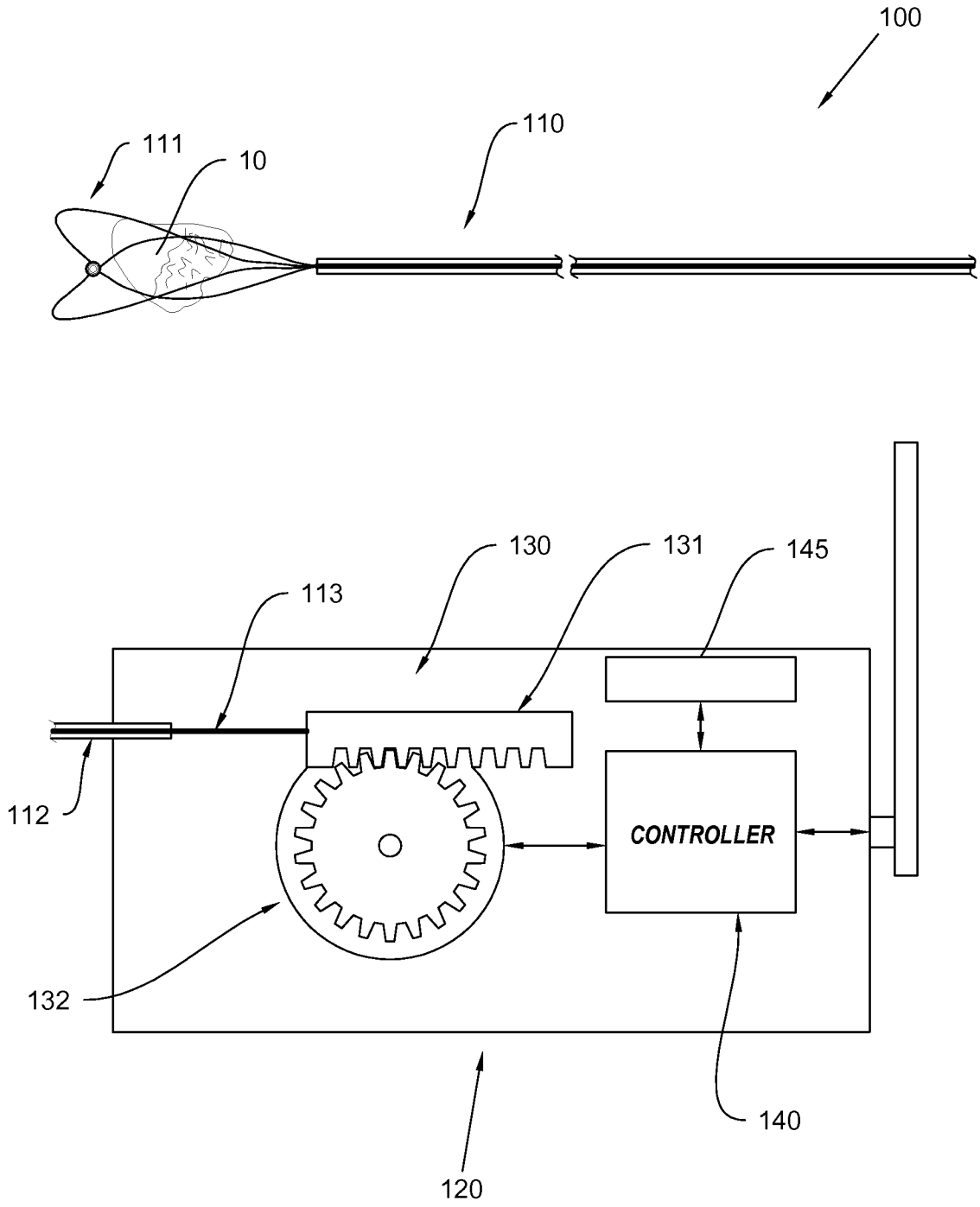

FIG. 1B

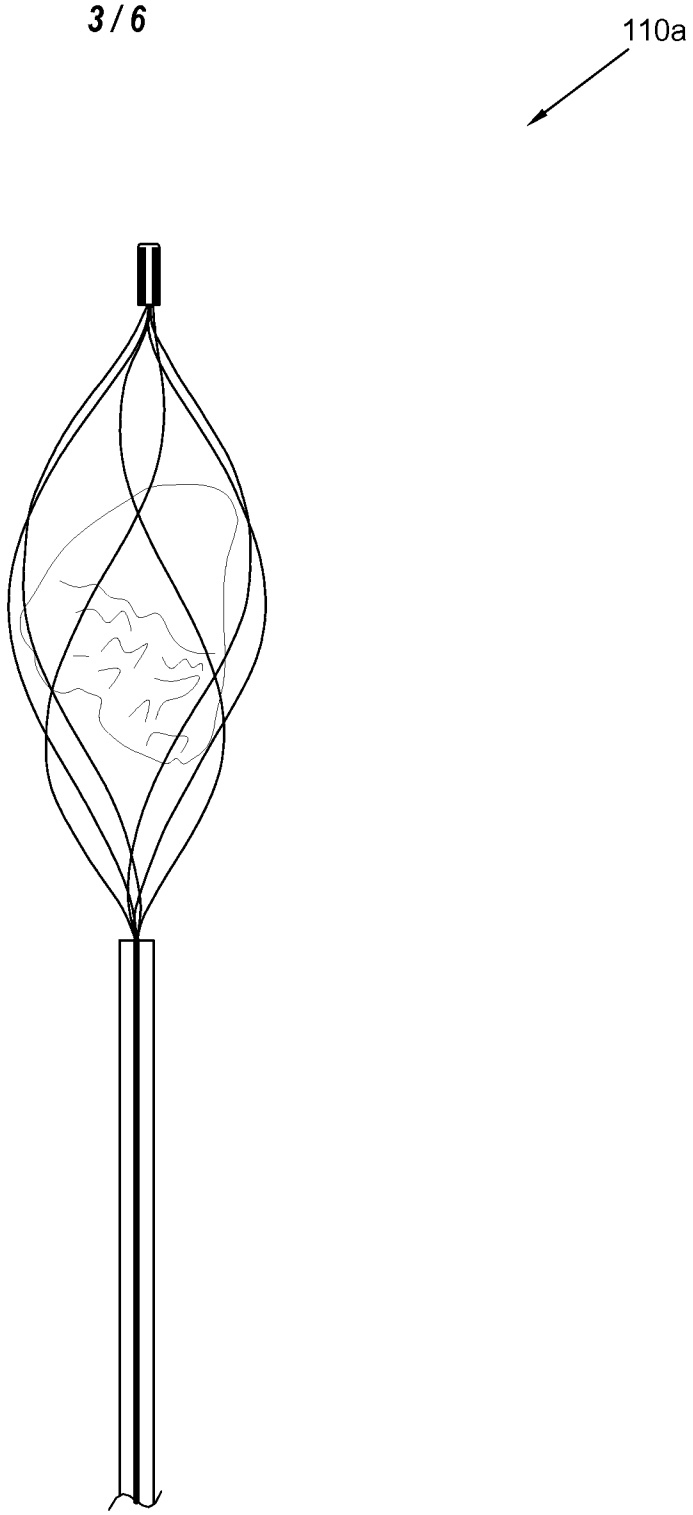

FIG. 2A

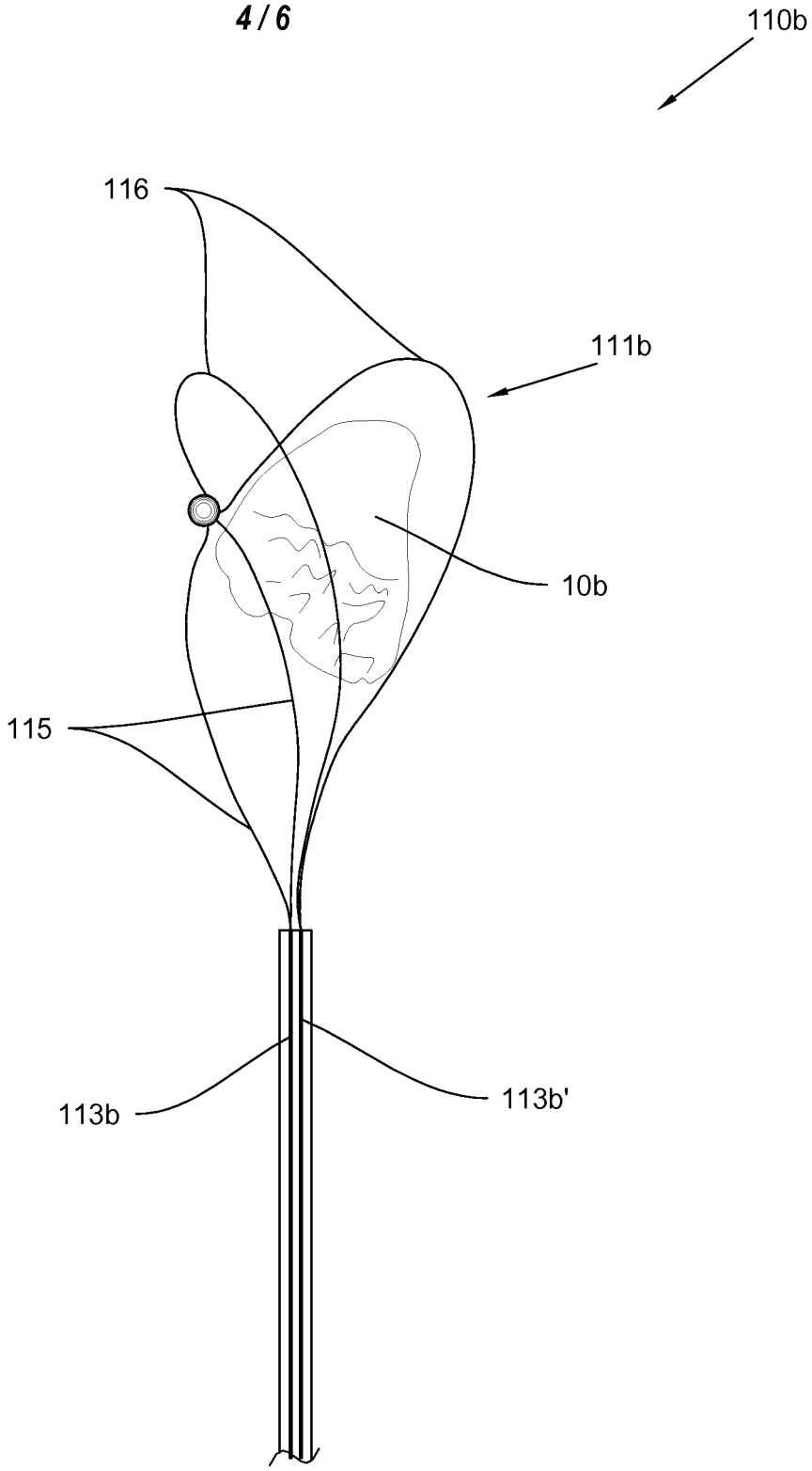

FIG. 2B

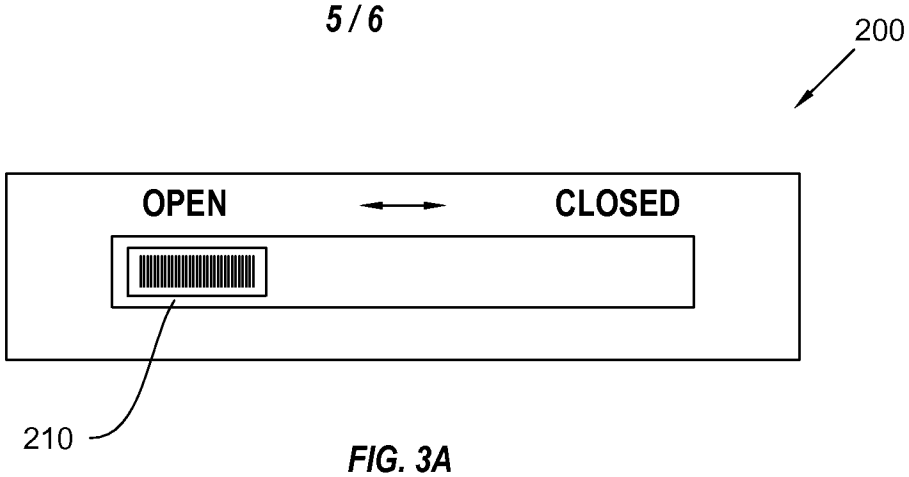

FIG. 3A

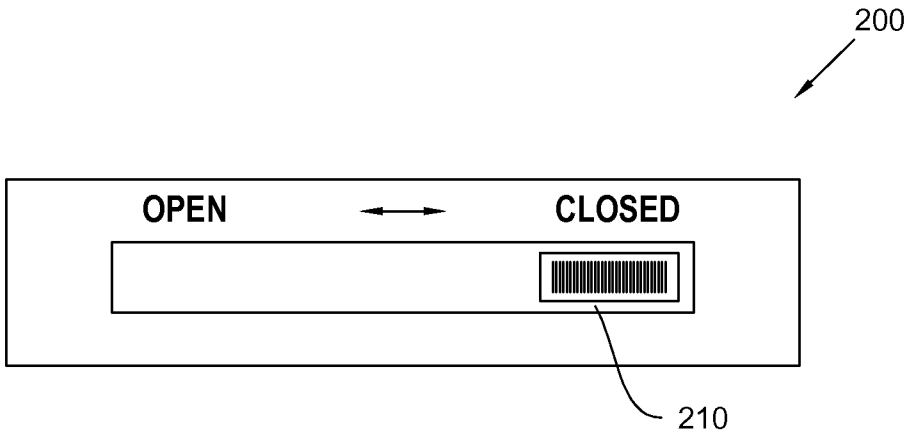

FIG. 3B

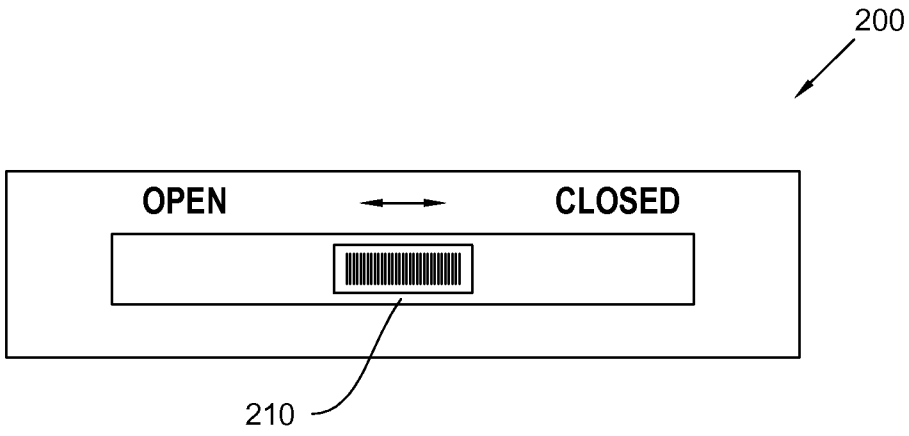

FIG. 3C

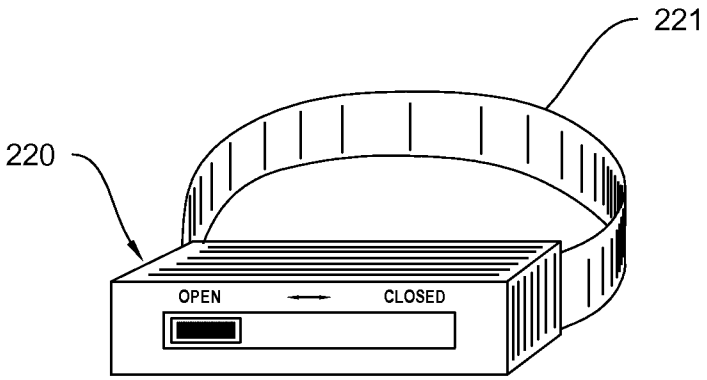

FIG. 4A

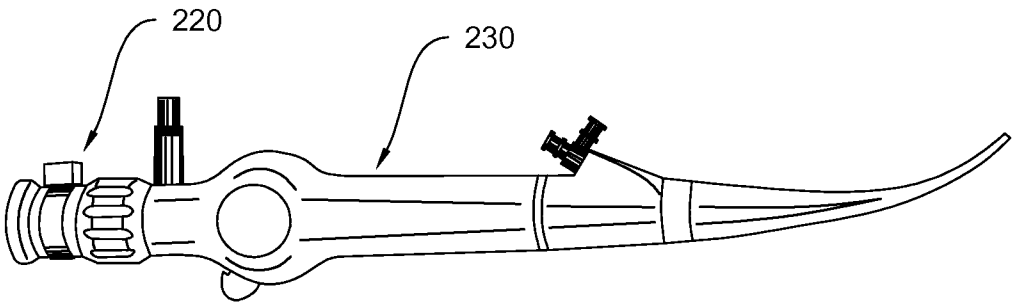

FIG. 4B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US15/41149

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - A61B 17/22, 17/221, 1/307 (2015.01)
CPC - A61B 17/22, 17/221, 1/307
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)
IPC(8): A61B 17/22, 17/221, 1/307 (2015.01)
CPC: A61B 17/22, 17/221, 2017/2212, 2017/2215, 2017/2217, 1/307

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatSeer (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, INPADOC Data); Google/Google Scholar; IP.com; PubMed/MEDLINE: kidney*, gall*, stone*, calculus*, extract*, remov*, manipulat*, control*.

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 2011/0015648 A1 (ALVAREZ, JB et al.) January 20, 2011; abstract; figures 6G-6N; paragraphs [0004], [0032], [0034], [0038]	1-2, 5-7, 11-15, 17-20 — 3-4, 8-10, 16
Y	US 2004/0179332 A1 (SMITH, SF et al.) September 16, 2004; abstract; paragraphs [0014], [0026], [0072	8-10, 16
Y	US 6,473,116 B1 (TAKAHASHI, T) October 29, 2002; abstract; column 5, lines 54-55	3-4

☐ 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
"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	Date of mailing of the international search report
29 September 2015 (29.09.2015)	23 OCT 2015
Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774